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By

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Abstract

Experimental methods have been widely used to elicit consumer preferences. However, the estimates are challenged because the existing literature indicates that individuals overstate their economic valuation in hypothetical settings, thus giving rise to the so-called "hypothetical bias." Although many studies seek to experimentally test which factors emphasize or ameliorate the hypothetical bias, no studies analyze its theoretical foundations. In this paper, we provide a theoretical model to demonstrate the underlying causes of hypothetical bias. Our results also help to explain experimental regularities, such as that hypothetical bias increases in a commodity's income elasticity of demand, and that the hypothetical bias for public goods is larger than for private goods.

Keywords: Experiments; Hypothetical Bias; Income Elasticity; Private and Public Goods; Willingness to Pay.

JEL classification: C9, D01, D10

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1 Introduction

Field and laboratory experiments in the last decades have sought to elicit consumers' willingness to pay for various goods, both private and public in nature, including environmental services and other nonmarket goods. However, many studies have shown the presence of what is often referred to as *hypothetical bias* (HB): subjects reporting a higher willingness-to-pay in the "hypothetical" threatment of the experiment (when they do not have to pay for the good the monetary amount they report) than in the "real" treatment (in which subjects have to actually pay for the good the amount they report). For instance, in a recent survey of the literature, Harrison and Rutström (2008) find a positive bias in 34 of 39 studies, with the median HB being 67%. Similarly, List and Gallet (2001) examine a large set of experimental articles, concluding that, while the experimental methodology and the type of goods considered largely varies across studies, a positive HB still arises in 27 of 29 articles. Given the broad range of studies finding a positive bias, several scholars, such as Unnevehr et al. (2010) emphasize that there are still open questions about the HB and how to explain this gap. Similarly, Carson (2012) points out that, while contingent valuation is preferable than other methods in consumer choice studies, it can only remain a valuable tool if we discern why HB emerges, and why it varies so significantly across different types of goods. Finally, many researchers note that, due the lack of a theory about the causes of HB, our ability to identify which factors are responsible for the bias is rather limited; see Carson et al. (1996), Harrison (1996), and Murphy et al. (2005). A better understanding of the HB is, hence, necessary and timely.

In this study, we present an individual decision-making model which helps explain different experimental regularities: (1) our theoretical results show that the HB is positive under relatively general conditions (and it only becomes zero under very special conditions); (2) the HB is larger for those goods with a high income elasticity (luxury goods); and (3) the HB is larger for public than private goods. In particular, our study helps rationalize a surprising experimental result: the recurrent observation that consumer's HB increases when they are asked to reveal their willingness to pay for goods that can be regarded as luxuries, while it decreases when the good is a necessity. We demonstrate that the HB can be mathematically expressed as a function of the income elasticity of demand, along other parameters. Thus, our results provide a theoretical explanation as to why the HB varies across different goods, being especially large in commodities regarded as luxuries. Finally, we apply our model to a context in which individuals can acquire units of a private and public good, and find the HB for each type of good. Interestingly, our results help explain under which conditions the HB for public goods is larger than for private goods, a recurrent observation in experimental studies.

The following subsection elaborates on the experimental studies that, mostly during the last two decades, identified the presence of HB in many goods, ranking the reported HBs and the good used in each experiment. We then present a tractable model that explains the connection between HB and income elasticity of demand. Section 3 applies our model to settings in which subjects' utility function is quasilinear, Stone-Geary (thus considering the Cobb-Douglas type as a special case), and the generalized Constant Elasticity of Substitution function (which embodies the standard CES as a special case). These examples help us offer testable predictions from our model that future researchers can use to investigate to which extent our model predicts subjects' behavior in controlled experiments, and in which cases it differs. Finally, section 4 considers a setting with both private and public goods, and how the HB varies across these types of goods.

1.1 Related literature

Real versus Hypothetical payments. Recent experiments required participants to make real purchases according to their stated willingness-to-pay.[1] However, several researchers argue that based solely on what can be inferred from the data, the willingness-to-pay in hypothetical treatments could accurately describe subjects' valuation of the good they face in the experiment, while the willingness-to-pay reported in the real treatment could misstate the participants' actual preferences for the object; see Harrison (1996). To overcome this problem, some experiments included both hypothetical and real payment scenarios. For example, Lusk and Schroeder (2004) compared hypothetical and actual payments in a study of consumer demand for quality-differentiated beef. They conclude that average willingness-to-pay for steaks in the hypothetical setting was about 1.2 times that in the non-hypothetical setting. As we describe below, the presence of a positive HB in experiments with several types of goods, and its significant variation from one good to another, has remained a puzzle among experimentalists in the last decades.

Introducing cheap-talk. In order to remove HB, some studies have included a previous cheap-talk stage in which subjects are allowed to talk about the characteristics of the object before the beginning of the experiment. In particular, they demonstrate that the HB can be reduced to a significant extent; see Cummings and Taylor (1999). However, List (2001) took the cheap talk design to a well-functioning marketplace to conduct an auction for sports cards. In this context, he found that, while cheap talk mitigates HB for certain consumers, HB is essentially unaffected for bidders with experience in the market.[2]

Luxury goods. Each of the above papers measured HB for a single good. However, List and Gallet (2001) and Murphy et al. (2005) estimate the factors that influence HB in a set of 29 previous studies. While existing studies do not include income elasticity as an explanatory variable of HB variations, Table 1 reports the HB in a sample of studies, showing that HB is larger for luxury goods (e.g., fine chocolates sold for \$15 a piece) than for necessities (bread, sold at \$1.1), i.e., HB increases with the good's income elasticity of demand. Our model provides a theoretical explanation for such a significant variation in the observed HB between different types of goods.

[1] Becker–DeGroot–Marschak (BDM) auctions have become the most popular method for revealing participants real willingness-to-pay (e.g., Davis and Holt, 1993; Shogren et al., 2001).

[2] Similarly, Blumenschein et al. (2008) show that introducing cheap talk does not reduce HB (they consider, in particular, an experiment on a diabetes management program).

Study	*Commodity*	*Hypothetical Bias*
Ginon et al., 2011	Bread	10%
Lusk and Schroeder, 2004	Beef	20%
Cummings, Harrison and Rutström, 1995	Juicers	63%
Cummings, Harrison and Rutström, 1995	Calculator	63%
Neill et al., 1994	Paintings	190%
Cummings, Harrison and Rutström, 1995	Chocolates	773%

Table 1. A sample of studies on Hypothetical Bias for private goods.

Public goods. Finally, List and Gallet (2001) and Murphy et al. (2005) use metadata to show that HB in the studies of public goods is higher than in the articles analyzing private goods. Table 2 summarizes some studies on HB for public goods. In the last section of our paper, we examine under which conditions HB is positive for public goods, which occurs when the public good enters linearly in the subject's utility function while the private good enters non-linearly. If, in contrast, all goods enter non-linearly, we show that the HB is positive for both public and private goods. Thus, our results indicate that, for HB to emerge in both types of goods, individual preferences cannot be quasilinear but, instead, exhibit non-linearities in both goods.

Study	*Commodity*	*Price*	*Hypothetical Bias*
Bohm, 1972	TV program	\$1.6	100%
Brown et al., 1996	Road paving	\$19.0	311%
Seip and Strand, 1995	Protection of nature	\$36.2	1,917%

Table 2. A sample of studies on Hypothetical Bias for public goods.

2 Model

Consider a consumer with utility function $u(x, y)$, which is continuous and non-decreasing, and is strictly quasiconcave in both x and y. The consumer faces a price p for good x, while the price of all other goods (embodied in the composite commodity y) is normalized to \$1, i.e., the numeraire. We are interested in the hypothetical bias that emerges in his willingness to pay for good x in experimental contexts. In this setting, we distinguish two types of wealth: the real wealth level, w, which he considers when being on the experimental treatment in which he must really pay for good x; and his wealth in the hypothetical treatment, w_H, at which he does not have to pay for good x. In addition, we assume that $w_H \geq w$, which gives rise to a larger demand for the good when the subject plays in the hypothetical than in the real treatment, i.e., his Walrasian demand satisfies $x(p, w_H) \geq x(p, w)$. Since the hypothetical bias (HB) measures the difference in his willingness to pay for the good, we first obtain the inverse of the above Walrasian demands, i.e., $x^{-1}(p, w_H) \equiv p(x, w_H)$ and $x^{-1}(p, w) \equiv p(x, w)$, and then define the HB as

$$HB(\varepsilon) \equiv p(x, w_H) - p(x, w)$$

When $w_H - w$ is sufficiently small, the HB can be defined as

$$HB(\varepsilon) \equiv \frac{\partial p(x, w)}{\partial w}$$

While the hypothetical bias can arise from different reasons, it has been suggested that it could emerge from consumers' uncertainty about the utility level that the good will provide. However, most of the products used in experiments are relatively homogeneous and well-known by participants, thus reducing the potential of uncertainty to explain the observed HB. More importantly, the experimental evidence summarized in subsection 1.1 suggests that the HB is larger for luxury goods, which indicates that the primitive reason giving rise to the HB must be connected with income elasticity, as we next describe. Let us first define income elasticity in terms of the inverse demand function $p(x, w)$, as follows $\varepsilon_{w,p} = \frac{\partial p(x,w)}{\partial w} \frac{w}{p(x,w)}$. Using this expression we can now represent the HB in the more compact coefficient described in Proposition 1 (all proofs are relegated to the appendix).

Proposition 1. *The hypothetical bias (HB) can be expressed as* $HB(\varepsilon) = \varepsilon_{w,p} \frac{\theta_x}{x(p,w)}$, *where* $\theta_x \equiv \frac{p(x,w) \cdot x}{w}$ *represents the budget share that the consumer spends on good* x.

Thus, the experimentally observed HB should: (1) increase in the income elasticity of the good presented to the subject, $\varepsilon_{w,p}$, i.e., becoming particularly large for luxury goods where $\varepsilon_{w,p} > 1$, as suggested in several experimental settings; and (2) in the consumer's budget share on this good, θ_x. For the case in which consumers demand only one unit of the good being analyzed (as it is the case in many experimental treatments where subjects are asked to reveal their willingness-to-pay for a single unit of the good), $x(p, w) = 1$, the expression of the HB becomes $\varepsilon_{w,p} \cdot \theta_x$. Hence, for a given HB, e.g., 0.2 as reported for beef by Lusk and Schroeder (2004), we can describe the $(\theta_x, \varepsilon_{w,p})-$pairs that yield such an HB with the function $\theta_x = \frac{0.2}{\varepsilon_{w,p}}$; as depicted in the level set of figure 1. Intuitively, for the HB coefficient to remain constant as the good becomes more luxurious (larger income elasticity), the subject's budget share θ_x must decrease. Otherwise, the HB unambiguously increases, graphically represented by $(\theta_x, \varepsilon_{w,p})-$pairs to the northeast of level set $HB(\varepsilon) = 0.2$.

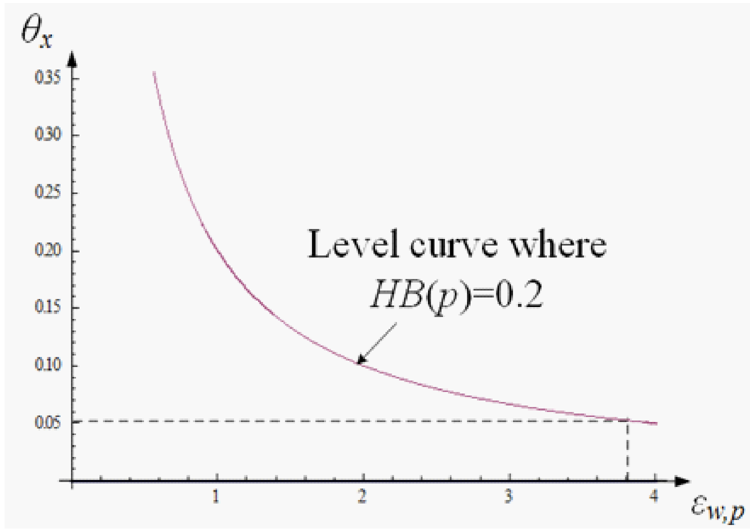

Figure 1. Level curve of $(\theta_x, \varepsilon_{w,p})-$pairs yielding $HB(\varepsilon) = 0.2$.

Since the HB coefficient depends on the income elasticity of demand, quasilinearity in the utility function $u(x, y)$ can play a critical role in the emergence of HB. In particular, consider $u(x, y) = v(f(x), g(y))$, where $v' > 0$, $f' > 0$ and $g' > 0$ (positive marginal utilities), but f'' can be zero if good x enters linearly or $f'' < 0$ if it enters non-linearly. A similar argument applies to good y and g''. The next proposition evaluates the HB coefficient in each of these cases.

Proposition 2. *If the utility function is quasilinear with respect to good x (good y), i.e., $f'' < 0$ and $g'' = 0$ ($f'' = 0$ and $g'' < 0$, respectively), then income effects for this good are absent, $\varepsilon_{w,p} = 0$, ultimately implying a null HB coefficient. However, if both goods enter non-linearly, i.e., $f'', g'' < 0$, income effects are present for both goods, i.e., $\varepsilon_{w,p} > 0$, and their HB is positive. Finally, if both goods enter linearly, $f'', g'' = 0$, income effects (and HB) are only positive for the good/s consumed in positive amounts.*

Hence, a utility function such as $u(x, y) = ax^{\alpha} + by^{\beta}$, where $\alpha, \beta \leq 1$ will exhibit a positive HB in both goods as long as $\alpha, \beta \neq 1$. If, in contrast, the utility function is quasilinear in good x, i.e., $\alpha \neq 1$ but $\beta = 1$, then HB is zero for this good, but positive for good y.[3] Finally, if the utility function is linear in both goods, $\alpha, \beta = 1$ (as in the case of perfect substitutes), then income effects arise for the good being consumed in positive amounts (the good with the highest marginal utility per dollar, e.g., good x if $\frac{a}{p} > b$), thus yielding a positive HB; whereas the income effect (and HB) for the good not consumed is zero.[4]

[3] An alternative quasilinear functional form often used in applications is $u(x, y) = a \ln x + by$. We explore this utility function in the numerical simulations in the next section.

[4] If the marginal utility per dollar coincides across goods, $\frac{a}{p} = b$, a continuum of utility maximizing bundles arises. In this context, if the consumer chooses a bundle with strictly positive amounts of both goods, a marginal increase in income would yield positive income effects for both goods and, as a consequence, a positive HB. For this reason,

Our results therefore suggest that experimental subjects, which recurrently exhibit positive HBs, must have a utility function that is either: (1) non-linear in both goods; or (2) quasilinear in good y (i.e., good y enters non-linearly while good x enters linearly); or (3) a linear utility function (thus regarding goods as perfect substitutes) but only consume good x, i.e., $x > 0$ and $y = 0$. Since good y embodies all goods different from x, the third option (where $y > 0$) seems unrealistic. More experimental studies are, however, needed in order to disentangle whether HB arises because consumer preferences fit the non-linearity in (1) or the quasilinearity in (2).

3 Application to different utility functions

Example 1: *Stone-Geary utility function.* Let us first consider that the consumer's utility function is given by

$$u(x, y) = (x - a)^{\alpha}(y - b)^{\beta}$$

where $\alpha, \beta > 0$, and $a, b > 0$ denote the minimal amounts of goods x and y that the consumer needs to survive. For simplicity, we assume that these minimal amounts are not extremely high, i.e., $a, b < w$. In this setting, the Walrasian demand becomes $x(p, w) = \frac{\alpha\beta p+\alpha(w-d)}{(\alpha+\beta)p}$, thus implying that the inverse demand function is $p(x, w) = \frac{\alpha(w-b)}{(\alpha+\beta)x-\beta\alpha}$. As a consequence, income elasticity is $\varepsilon_{w,p} = \frac{w}{w-b}$, which becomes 1 when the above parameters satisfy $a = b = 0$, as in the case of Cobb-Douglas utility function. Therefore, the HB coefficient in this context is

$$HB(\varepsilon) = \frac{w}{w-b}\frac{\theta_x}{x(p, w)} = \frac{p}{w-b}$$

where $\theta_x = \frac{p\frac{\alpha\beta p+\alpha(w-d)}{(\alpha+\beta)p}}{w} = \frac{\alpha\beta p+\alpha(w-d)}{(\alpha+\beta)w}$ represents the budget share of good x. Hence, the HB increases in the price of good x, and in the minimal amount that the consumer needs of all other goods, b. Intuitively, when the consumer needs more units of good y to survive, his consumption of good x is low in relative terms. Hence, a marginal change in income yields a large increase in the demand of good x, which ultimately increases the HB coefficient. Figure 2 depicts $HB(\varepsilon)$ for a value of $b = 1$.

Proposition 1 states that income effects are positive for the good consumed in positive amounts (in the case of corner solutions), or the goods consumed in positive amounts (in the case of an strictly interior solution).

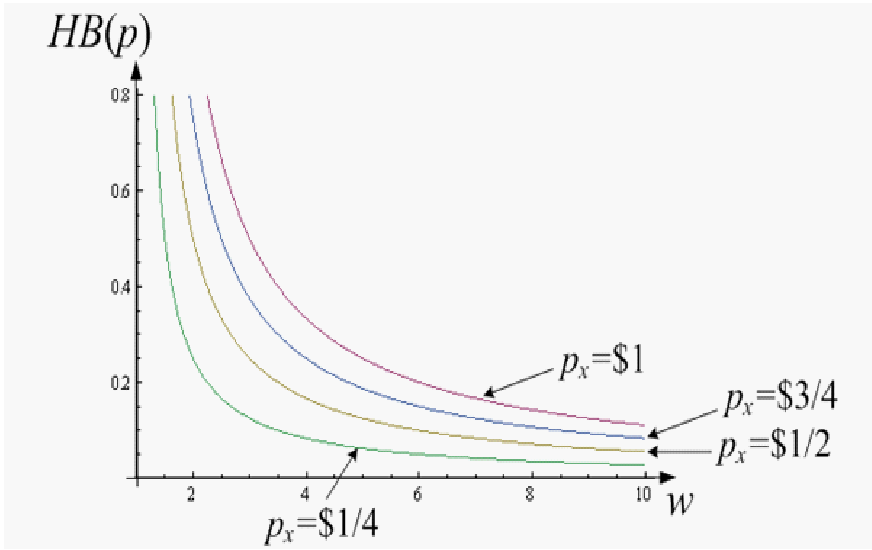

Figure 2. $HB(\varepsilon)$ for a Stone-Geary utility function, where $b = 1$.

Importantly, our above discussion embodies the Cobb-Douglas utility function as a special case, namely, when $a = b = 0$. In this case, the HB decreases to $\frac{p}{w}$. Graphically, all the HB curves depicted in figure 2 (where $b = 1$) would experience a downward shift.

Example 2: *Quasilinear utility function.* Let us now consider that the consumer's utility function is given by

$$u(x, y) = a \cdot x + b \cdot \ln y$$

In this setting, the Walrasian demand becomes $x(p, w) = \frac{a \cdot w - b \cdot p}{a \cdot p}$, thus implying that the inverse demand function is $p(x, w) = \frac{a \cdot w}{b + ax}$. As a consequence, income elasticity is $\varepsilon_{w,p} = 1$, ultimately yielding an HB of

$$HB(\varepsilon) = 1 \frac{\theta_x}{x(p, w)} = \frac{p}{w}$$

where $\theta_x = \frac{p \cdot \frac{aw - bp}{ap}}{w}$. Hence, similarly as for the Stone-Geary and Cobb-Douglas utility functions considered above, the HB increases in the price of good x, but decreases in the individual's wealth level; as depicted in figure 3.

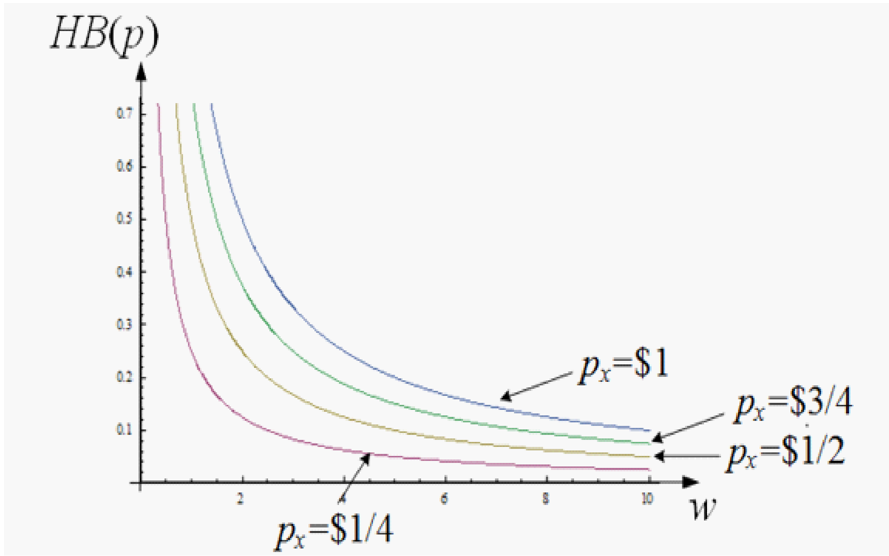

Figure 3. $HB(\varepsilon)$ for quasilinear utility.

Example 3: *Generalized CES utility function.* Let us now consider a generalized CES utility function

$$u(x, y) = \left[(x + b)^{\delta} + y^{\delta}\right]^{\frac{1}{\delta}}$$

where parameter b captures whether good x is a luxury relative to the composite good y, which occurs when $b < 0$, or if instead good y is a luxury, i.e., when $b > 0$. Note that in the special case in which $b = 0$ the above utility function coincides with a standard CES utility function. In addition, parameter δ satisfies $0 \neq \delta \leq 1$. As it is well known if, besides $b = 0$, parameter $\delta \to 0$ $u(x, y)$ represents a Cobb-Douglas utility function; if $\delta = 1$, it represents preferences for substitutes (linear utility function); while if $\delta \to -\infty$, it represents preferences for complements (Leontieff utility function). In this context, the HB becomes

$$HB(\varepsilon) = \frac{p}{w} \cdot \frac{\left[(b + x)^2 + 4wx\right]^{1/2} - (b + x)}{\left[(b + x)^2 + 4wx\right]^{1/2}}$$

(See appendix 1 for more details about the Walrasian demand under the generalized CES utility function, and its associated income elasticity.) The left-hand panel of figure 4 illustrates that HB is increasing in prices and decreasing in wealth, similarly as for previous utility functions.[5] The right-hand panel of the figure, however, examines a new dimension that the previous functional forms could not capture: the degree to which good x is considered a luxury or a necessity (embodied in parameter b). In particular, when the good is a luxury ($b < 0$), the curve representing the

[5] For simplicity, the figure assumes $b = 2$, but similar results arise for other values of parameter b.

HB coefficient shifts upwards, indicating that experimental subjects fall more prey of the HB. In contrast, when the good is a necessity ($b > 0$), the HB coefficient decreases, ultimately reflecting that HB is likely small in experimental settings.[6]

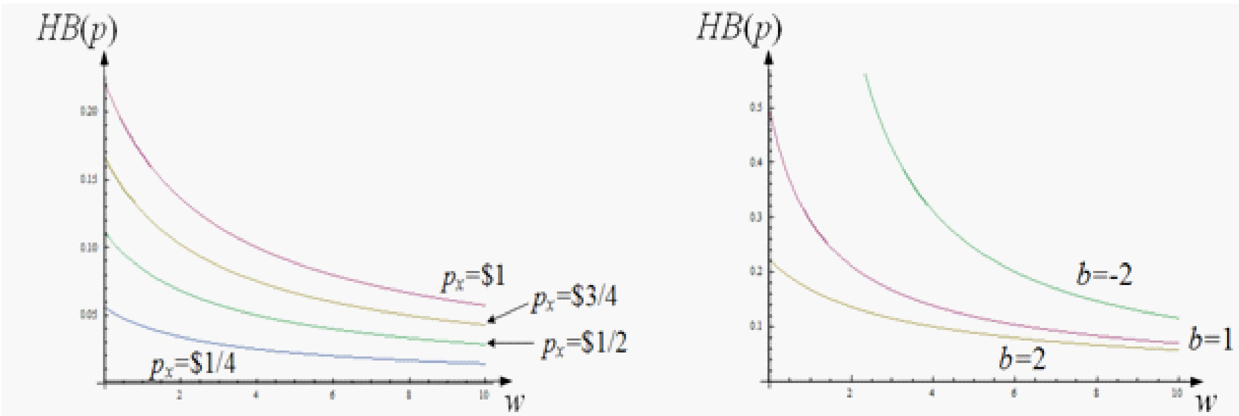

Figure 4. $HB(\varepsilon)$ for the generalized CES utility function.

Finally, note that in the special case in which $b = 0$, the above utility function becomes the standard CES utility function, and the HB coefficient simplifies to

$$HB(\varepsilon) = \frac{p}{w} \cdot \left(1 - \frac{x^{1/2}}{(4w + x)^{1/2}}\right).$$

In the case in which the consumer only purchases one unit of the item, $x = 1$, the HB coefficient reduces to $\frac{p}{w} \cdot \left(1 - \frac{1}{(4w+1)^{1/2}}\right)$. As for previous utility functions, the HB increases in the price of good x, but decreases in income, w.[7]

4 Private versus Public Goods

As described in the Introduction, List and Gallet (2001) and Murphy et al. (2005) demonstrate that HB exists for both public and private goods, with the bias being higher for public goods. In order to show that our model can also account for this experimental observation, let us next evaluate the HB for an economy with 2 consumers $i = \{A, B\}$, one private good x, and one public good G. Denote the price of private good by $p_x > 0$, while that of the public good is $p_y > 0$. The income of both individuals is w, and their utility function is

$$u(x^i, Y) = v\left(f(x^i), g(Y)\right).$$

[6] For simplicity, the right-hand panel of figure 4 considers a price $p = 1$, but similar results emerge for other price levels.

[7] In addition, it is easy to show that $HB(p)$ decreases in the purchases of good x.

where $Y \equiv y^i + y^j$ denotes aggregate contributions to the public good for every individual $i \neq j$. Similarly as in section 3, let us consider that $v' > 0$, and that the marginal utility of the private and public good are positive, i.e., $f' > 0$ and $g' > 0$ respectively. In addition, we allow for these goods to enter nonlinearly, i.e., $f'', g'' \leq 0$. Specifically, if the utility function is quasilinear with respect to the private (public) good, $f'' < 0$ and $g'' = 0$ ($f'' = 0$ and $g'' < 0$, respectively). If, instead, both goods enter non-linearly (linearly), $f'' < 0$ and $g'' < 0$ ($f'' = g'' = 0$, respectively). In this setting, we next use the results from Proposition 2 to the context of private and public goods.

Corollary 1. *If the utility function is quasilinear with respect to the private (public) good then its HB coefficient is zero, while that of the public good (private good, respectively) is positive. If the utility function is non-linear in both the private and public good, then the HB of both goods is positive. If both goods enter linearly, only the good consumed in positive amounts has a positive HB coefficient.*

Our results hence suggest that, for quasilinear utility functions such as $u(x^i, Y) = ax^i + bg(Y)$, where $g(Y)$ is nonlinear in the total donations to the public good, the HB coefficient of the public (private) good should be null (positive, respectively). In contrast, utility functions such as $u(x^i, Y) = f(x^i) + bY$, where $f(x^i)$ is nonlinear in the private good, yield a positive HB for the public good but a null HB for the private good. When both goods enter nonlinearly, such as in $u(x^i, Y) = \log x^i + \log Y$, Corollary 1 demonstrates that the HB is positive for both types of goods. This result goes in line with recurrent experimental observations whereby HB arises for both public and private goods, thus suggesting that individual preferences rarely fit the quasilinear description and, instead, exhibit non-linearities in both goods. In order to examine under which conditions the public good produces the largest HB, the next example considers the functional form $u(x^i, Y) = a \log x^i + b \log Y$.

Example 4. *Public goods.* Consider an individual decision maker with utility function $u(x^i, Y) = a \log x^i + b \log Y$. In this setting, it is straightforward to find the demand function for the public good, $y^i(p, w) = \frac{w}{3p_y}$, and for the private good, $x^i(p_x, w) = \frac{w - p_y y^i}{p_x} = \frac{2w}{3p_x}$. (See appendix 2 for more details.) Solving for p_y and p_x in order to obtain the inverse demand functions, and using the definition $HB(\varepsilon) = \varepsilon_{w,p} \frac{\theta_x}{x(p,w)}$, we obtain an HB coefficient for the public and private good of

$$HB_y(\varepsilon) = \frac{p_y}{w} \quad \text{and} \quad HB_x(\varepsilon) = \frac{p_x}{w}$$

where $HB_y(\varepsilon) > HB_x(\varepsilon)$ if and only if prices satisfy $p_y > p_x$. While there are no studies measuring the HB of private and public goods for the same group of experimental subjects, articles using metadata of experiments involving both private and public goods, such as List and Gallet (2001) and Murphy et al. (2005), conclude that experimentalists generally assume a more expensive price for the public than the private good, i.e., $p_y > p_x$, and that the HB is higher for public goods, a result and assumption that goes in line with our findings. Importantly, our results are robust to other non-linear functional specifications, such as the Cobb-Douglas utility function $u(x^i, Y) = a \left(x^i\right)^\alpha Y^\beta$.

5 Conclusions and further research

Our paper, hence, provides a theoretical foundation for three repeatedly observed results in experiments on market and nonmarket valuation: (1) positive HBs, which arise under most experimental methodologies and types of goods; (2) a larger HB for luxury goods than for goods regarded as necessities; and (3) a larger HB for public than private goods. Interestingly, our theoretical results offer several unexplored experimental tests. First, while studies abound on the presence of HB, to our knowledge all experimental articles measure subjects' valuation focusing on a single good; thus not providing a direct comparison of how HB varies as different goods are presented to the same individuals. Second, our results provide at least two testable implications that should hold regardless of the underlying preference relation of the subjects participating in the experiment: (1) HB increases in the income elasticity of the good; and (2) it also increases in the budget share of that good. Nonetheless, when we examine quasilinearity and nonlinearity in subjects' utility function our results are relatively flexible, which ultimately allow for tests that identify which is the utility function that best fits subjects' behavior in controlled experiments.

6 Appendix

6.1 *Proof of Proposition 1*

Using $HB(\varepsilon) = \frac{\partial p(x,w)}{\partial w}$, we can rewrite $\varepsilon_{w,p} = \frac{\partial p(x,w)}{\partial w}\frac{w}{p(x,w)}$ as

$$\varepsilon_{w,p} = HB(\varepsilon)\frac{w}{p(x,w)}$$

Solving for $HB(\varepsilon)$ we obtain,

$$HB(\varepsilon) = \varepsilon_{w,p}\frac{p(x,w)}{w}$$

Finally, we can multiply and divide by $x(p,w)$ on the right-hand side of the equality, to obtain

$$HB(\varepsilon) = \varepsilon_{w,p}\frac{\theta_x}{x(p,w)}$$

where $\theta_x \equiv \frac{p(x,w)\cdot x}{w}$ represents the budget share that the consumer spends on good x. ■

6.2 *Proof of Proposition 2*

Case 1. The utility maximization problem of individual i is that of selecting his consumption of good x and y to solve:

$$\max_{x,y} v(f(x), g(y))$$

$$\text{subject to } px + y = w.$$

Since $y = w - px$, the above problem can be more compactly expressed as

$$\max_{x} v(f(x), g(w - px))$$

Taking first order condition with respect to x yields

$$v'f' + v'g'(-p) \leq 0$$

which in the case of interior solutions reduces to $f' = pg'$. When the utility function is quasilinear with respect to good x, i.e., $f'' < 0$ and $g'' = 0$, f' is decreasing in x while pg' is constant. On one hand, the left-hand side of the first-order condition $f' = pg'$ does not depend on income, w, since it originates from $\frac{\partial v}{\partial f}\frac{\partial f(x)}{\partial x}$ where w is absent. Similarly, the right-hand side, pg', does not depend on w either since $g''(w - px) = 0$. As a consequence, the solution of first-order condition $f' = pg'$, i.e., the Walrasian demand for good x, is independent of income. Therefore, $\frac{\partial x(p,w)}{\partial w} = 0$, ultimately implying that income-elasticity of demand is null, and that the HB is also null.

Case 2. A similar argument applies to the case in which the utility function is quasilinear with respect to good y, i.e., $f'' = 0$ and $g'' < 0$, whereby we can solve for x in the budget constraint, $x = \frac{w-y}{p}$, in order to express the utility function in terms of good y alone.

Case 3. In the case in which both goods enter non-linearly, i.e., $f'' < 0$ and $g'' < 0$, the above first-order condition $f' = pg'$ depends on income, w. In particular, while f' is independent of income, pg' is a function of on w since $g'' < 0$, e.g., if $g(w - px) = (w - px)^{1/2}$, then $g' = \frac{1}{2}(w - px)^{-1/2}$. In particular, since w enters positively into $g(\cdot)$, an increase in w produces a shift in the g' function, ultimately increasing the Walrasian demand for good x In this setting, income-elasticity of demand is thus positive, and HB is also positive.

Case 4. Finally, when both goods enter linearly, i.e., $f'' = g'' = 0$, both the left- and right-hand side of first-order condition $f' = pg'$ is constant in x. In this context, the consumer only demands positive amounts of good x, which occurs when $f' > pg'$; or of good y otherwise. Since an increase in income does not alter the sign of this inequality (given that both f' and pg' are independent on income), a marginal increase in w is entirely spent in the good whose demand was originally positive. Only for this good are wealth effects positive, and its associated HB positive. ■

6.3 *Appendix 1 - Generalized CES utility function*

In this context, the Walrasian demand of good x is

$$x(p, w) = \frac{w - b\sqrt{p}}{\sqrt{p} + p}$$

In this setting, we can only find the expression of the inverse demand function $p(x, w)$ for specific values of r. In particular, if $r = \frac{1}{2}$, then $p(x, w) = \frac{\left[(b+x)^2+4wx\right]^{1/2}+(b+x)}{\left[(b+x)^2+4wx\right]^{1/2}}$, which yields an income elasticity of $\varepsilon_{w,p} = \frac{\left[(b+x)^2+4wx\right]^{1/2}-(b+x)}{\left[(b+x)^2+4wx\right]^{1/2}}$. Thus, the budget share is $\theta_x = \frac{px(p,w)}{w} = \frac{p\left(w-b\sqrt{p}\right)}{\left(\sqrt{p}+p\right)w}$. As a consequence, the HB is

$$HB(\varepsilon) = \varepsilon_{w,p}\frac{\theta_x}{x(p,w)} = \frac{p}{w}\cdot\frac{\left[(b+x)^2+4wx\right]^{1/2}-(b+x)}{\left[(b+x)^2+4wx\right]^{1/2}}$$

6.4 *Appendix 2 - Public good contributions*

In order to find the Walrasian demand for the public and private good, let us first identify each individual's best response function. The utility maximization problem of individual i is that of selecting his consumption of private good, x, and his contribution to the public good, y^i, to solve:

$$\max_{x,y^i} \; a\log x^i + b\log G$$

$$\text{subject to } \; p_x x^i + p_y y^i = w, \quad \text{and } y^i + y^j = G$$

Since $x^i = \frac{w-p_y y^i}{p_x}$, the above problem can be more compactly expressed as

$$\max_{y^i} \; a\log\left(\frac{w-p_y y^i}{p_x}\right) + b\log(y^i + y^j)$$

taking first order condition with respect to y^i yields

$$\frac{b}{y^i+y^j} + \frac{ap}{p_y y^i - w} = 0$$

and solving for y^i we obtain a best response function of

$$y^i(y^j) = \frac{bw}{(a+b)p_y} - \frac{a}{a+b}y^j$$

By symmetry, the best response function of individual j is

$$y^j(y^i) = \frac{bw}{(a+b)p_y} - \frac{a}{a+b}y^i$$

Simultaneously solving for y^i and y^j, we find the demand function for the public good, $y^i(p,w) = \frac{bw}{(2a+b)p_y}$, and for the private good, $x^i(p_x,w) = \frac{w-p_y y^i}{p_x} = \frac{2aw}{(2a+b)p_x}$. Solving for p^y in $y^i(p,w)$, yields the inverse demand function for the public good $p_y(y^i,w) = \frac{bw}{(2a+b)y^i}$. This inverse demand entails an income elasticity of $\varepsilon_{w,p} = 1$. Hence, using the definition $HB(\varepsilon) = \varepsilon_{w,p}\frac{\theta_x}{x(p,w)}$, we obtain an HB coefficient for the public good of

$$HB_y(\varepsilon) = \frac{p_y}{w}$$

Solving for p_x in $x^i(p_x,w) = \frac{2aw}{(2a+b)p_x}$ entails an inverse demand for the private good of $p_x(x,w) = \frac{2aw}{(2a+b)x}$. Hence, the income elasticity of this good also becomes $\varepsilon_{w,p} = 1$ for the private good. As a consequence, the HB for the private good is

$$HB_x(\varepsilon) = \frac{p_x}{w}$$

Finally, comparing both biases, we obtain that $HB_y(\varepsilon) > HB_x(\varepsilon)$ if and only if prices satisfy $p_y > p_x$. ■

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