The Ordinary Price of Zero

by
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Abstract

Classical demand theory can accurately predict consumer behavior when a good is free. We aim to demonstrate that the economic model presented in the 2007 paper “Zero as a special price: the true value of free products” is incapable of predicting consumer behavior when presented with a price of zero because the model lacks a budget constraint. Simply, including a budget constraint accounts for the observed behavior and there is no need to invoke “affect” to explain the discrepancy. This is demonstrated using mathematical programming and the well-known Cobb-Douglas functional form which shows that heavy consumption of a free good is a rational and predictable behavior.

Table of Contents

Figures

Tables

1. Introduction

Economists model behavior by assuming that consumers and firms maximize an objective function. To be specific, consumers maximize utility subject to a budget constraint. This has been a standard part of the discipline for decades. Mas-Colell, Winston, and Green deemed this “the utility maximization problem” (50) and went on to say that it is a part of “the underlying assumption common to nearly all economic models" (314). Henceforth, we will call this model, which is a standard part of classical demand theory, the Standard Economic Model (SEM) of consumer behavior. It is common for economics textbooks to present this model using a Cobb-Douglas functional form (Nicholson).

In a 2007 paper titled, “Zero as a special price: The true value of free products” Shampanier, Mazar, and Ariely (hereafter SMA) put forth the claim, supported by experimental evidence, that the SEM does not accurately predict consumer behavior when consumers are given the option to choose a free good. In other words, zero is a special price and the SEM model does not hold as a general theory of consumer behavior. Upon further examination of SMA’s work, we conclude that SMA model did not properly test the SEM and instead created an alternative model (hereafter referred to as the SMA model). The SMA model, and their experiments, failed to account for the consumer budget constraint, leading them to conclude that when a good is free consumers overvalue the good and make irrational decisions. We demonstrate, using a Cobb-Douglas utility function and mathematical programming, that SMA’s observed behavior is entirely consistent with the SEM. In other words, even when prices go to zero, consumers respond in a predictably rational manner.

2. Literature Review

"Zero as a Special Price" has been cited on many occasions. Many of these papers seem to take the claims asserted by SMA at face value. For example, Jeffery T. Denning cites SMA's work in his paper "College on the Cheap: Consequences of Community College Tuition Reductions" published in the *American Economic Journal: Economic Policy*. Denning takes the SMA economic model at face value with no analysis and asserts that:

> Shifting pricing to "free college" might have different effects than reducing tuition by 50 percent. This might happen for behavioral reasons around a price of zero or for messaging reasons about the promise of free college. (Denning 185)

Authors Nicole Koschate-Fischer and Katharina Wullner also cite SMA in their paper "New Developments in Behavioral Pricing Research" published in the Journal of Business Economics. They write,

> The zero-price effect implies an overreaction to free products, which means that consumers preferably choose a product offered for free over a priced alternative although the priced alternative actually is considered more attractive in terms of quality. According to Shampanier et al. (2007), affective processes are most likely to account for this effect. (Koschate-Fishcher)

The authors go on to refer to the "Zero-Price Effect" as new, stating it "challenge[s] the traditional view of consumers' response to price information" (Koschare-Fishcher). This paper will demonstrate that this is not a new effect and that economists have been well aware of this behavior for decades.

The previously mentioned examples are just two incidents of authors citing SMA's work without challenging the claim or performing their own tests. According to Google Scholar, the original SMA paper has been cited more than 700 times, infiltrating academic journals of many kinds. Another work titled *When Retailing and Las Vegas Meet: Probabilistic Free Price Promotions* published in the *Management Science Vol. 63 Issue 1* journal also cites SMA's work without offering any further testing or criticism. The authors of this paper are the same authors of *Zero as a Special Price: The True Value of Free Products,* Nina Mazar, Kristina Shampanier, and Dan Ariely. In this new work, they write,

> Shampanier et al. (2007) found that people experienced significantly more positive effects when facing a free offer (the price equals $0) compared with other price offers (e.g., the price equals $0.01 or $0.02), and this disproportionately positive effect led to a larger demand for zero-priced products than what standard cost-benefit analysis would have predicted. (Mazar 252)

Not only did they cite their previous work without offering any retest, but the actual claim from the original paper has also been altered. Here, the claim is that consumers reacted irrationally according to cost-benefit analysis, not the "standard" economic model. This demonstrates the inconsistency of the argument presented in the original paper. It is important to note that in the original SMA paper the authors used quotation marks around the word standard, and did not cite any sources, thus indicating that the SMA was a new model of consumer behavior and not the SEM.

The influence of the original SMA paper can be felt even outside of academia. Articles like one from *Business Insider* titled “12 Ways that People Behave Irrationally.” *Business Insider* cites Dan Ariely many times in this article breaking down consumers' “irrational” behavior. The *American Psychological Association* also published an article detailing co-author Ariely’s work: “Totally Irrational: Psychologist and behavioral economist Dan Ariely explores the forces that shape our most perplexing decisions.” The author of this article, Kristen Weir, interviews Ariely about his research and his work in the fields of psychology and behavioral economics. Before transcribing the interview, she writes, “Ariely is also known for his frequent public presentations and TED talks, and his advice column for *The Wall Street Journal* — all projects undertaken with the goal of helping people do things a little bit better, one decision at a time.” This statement highlights the influence this study has had on society, even outside of academic studies.

3. Hypothesis

The SEM can accurately predict consumer behavior when goods are free, which demonstrates that zero is an ordinary price. This behavior is predictable and rational. When consumers are given the option to choose between a free good and paying for another good, the consumer will rationally choose the free good–even without evidence of a utility boost, called affect, when a good is free.

4. **Background**

The SMA model is an original model developed to describe "how consumers behave in a situation in which they must choose between two products at certain prices (or buy nothing)" (Shampanier et al. 744). The SMA model is specified as follows. The consumer can choose one unit of a good out of a set of goods and will only choose a good if the value (v) of the good is greater than the price (p). In other words, the consumer will only choose the i'th good if:

$$v_i - p_i > 0$$

When faced with more than one good, the consumer will choose the good that maximizes the difference between value and price.

$$argmax(v_i - p_i, 0)$$

The consumer is subject to the constraint that they may choose no more than one unit of a good.

$$\sum_{i=1}^{I} q_i \leq 1$$

Here, q_i is the quantity of the i'th good.

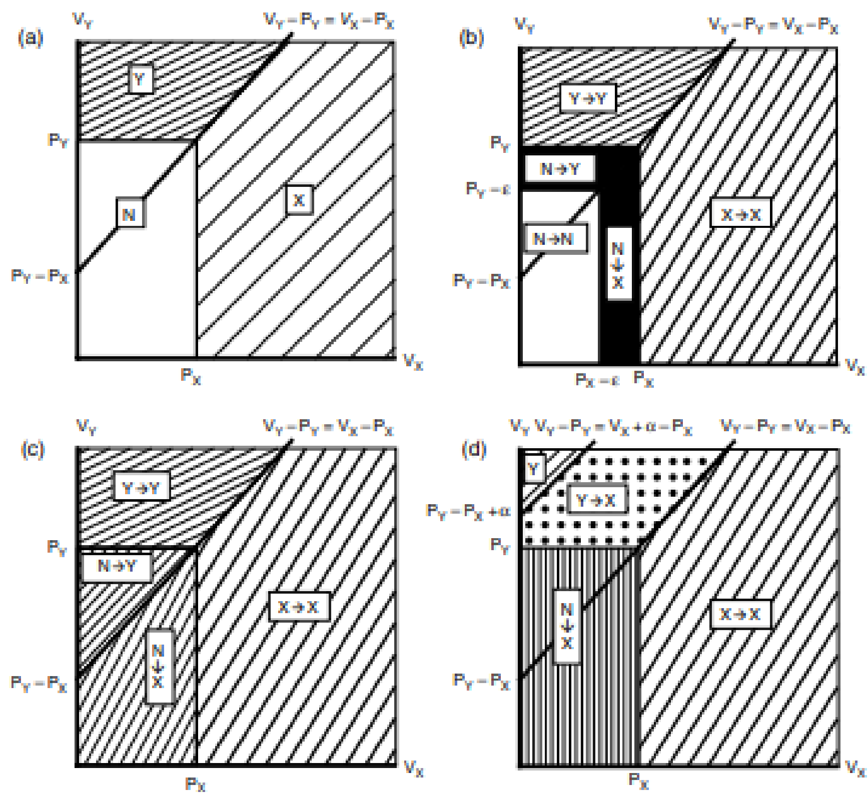
Before moving forward, it is important to correct SMA's terminology. The term "value" is more commonly known as willingness to pay (WTP), which is the highest price a consumer is willing to pay for a good. WTP is the perceived value a consumer gives to a good. This is the breaking point at which a consumer decides a good is "too expensive" to purchase. The difference between the willingness to pay and the price of a good is called consumer surplus. In the SMA model the consumer chooses one unit of the good that maximizes consumer surplus.

When using an economic experiment to test a theory, it is important to pay attention to the environment, institution, and behavior (Smith). SMA creates an environment via their experimental marketplace. However, the environment includes consumers who have a budget constraint that is not present in their model. Because the SMA model does not account for a budget constraint, the test environment is inconsistent with the theory being tested. The institution (in this case, SMA), limits the quantity to one. This may be a reasonable restriction for a big-ticket item like a car or a house, but they are inconsistent for inexpensive times such as the candy used the SMA experiments. These inconsistencies limit the predictive power of the SMA model and explain why observed consumer behavior when presented with a price of zero appears irrational.

SMA credits “affect”, among other psychological mechanisms, as the force causing irrational consumer behavior. “Affect” allegedly causes consumers to purchase more of the free good because, “Options with no downside (no cost) invoke a more positive affective response; to the extent that consumers use this affective reaction as a decision-making cue, they opt for the free option” (Shampanier et al. 751). Simply, “affect” is a boost in the value that the consumer receives from the free good, meaning a consumer is willing to pay more for a good because it is free. This explanation should be rejected outright as it is completely absurd to claim that WTP goes up when the price goes down. The claim violates the definition of WTP, and the law of demand does a much better job of explaining this phenomenon; when prices fall consumption increases. It is more rational to conclude that an infinitely small price should stimulate an infinitely large demand. In their model SMA accounts for "affect" by inserting the term α into their formulation, where α is some positive number if the price is zero, and α is zero otherwise. The alleged impact of "affect" can be seen in Figure 1 which shows SMA's graphical analysis of their model.

Figure 1 shows four panels developed by SMA, each of which demonstrate the behavior predicted by the SMA model. "Panel A presents the demand distribution when prices are [P_x, P_y]" (Shampanier et al. 745). Consumers purchasing in the "X" zone or "Y" zone are choosing to purchase one unit of Product X or Product Y. Consumers purchasing in the "N" zone are choosing to purchase no goods. They assert that if the prices of both goods fall by the same amount (no matter the amount) that ratio of X to Y will not change, as shown in panel B, and panel C takes this claim to the extreme case where ethe price of good X is zero. It is important to note that SMA deem this the standard model. They go on to note:

Figure 1 **Segments of Customers Who Choose Options X, Y, and N as Prices Go Down from $[P_X, P_Y]$ to $[P_X - \varepsilon, P_Y - \varepsilon]$, as Predicted by the Standard Economic Model with Linear Utilities and the Zero-Price Model**



Notes. Panel A presents the demand distribution when prices are $[P_X, P_Y]$.

Panel B presents the changes in segments of customers choosing options X, Y, and N when prices are reduced from $[P_X, P_Y]$ to $[P_X - \varepsilon, P_Y - \varepsilon]$.

Panel C presents the changes in segments of customers choosing options X, Y, and N when prices are reduced from $[P_X, P_Y]$ to $[0, P_Y - P_X]$ under the assumptions of the standard model.

Panel D presents the same changes under the assumptions of the zero price model.

Figure 1: SMA Model Prediction (Shampanier et al. 745)

Comparing the two sets of formulas (or inspecting Figure 1b), we note that consumers who originally choose X keep choosing X, and consumers who originally choose Y keep choosing Y. Thus, according to this model, there should be no switching from one product to another. The only two possible changes in demand are that some consumers who originally buy nothing switch to either X (those with $VX - PX > VY - PY$ and $PX - \varepsilon <$

VX < PX) or Y (those with VY − PY > VX − PX and PY − ε < VY < PY). (Shampanier et al. 744)

In other words, the SMA model specifically forbids substitution effects because consumers cannot switch between goods in this model. To clarify, as the prices change by a specific ratio, demand for the goods will change by the same ratio, despite the benefits of each good remaining the same.

In contrast, consumer choice theory asserts that individuals maximize their utility subject to a budget constraint. Utility is defined as "the way in which individuals rank alternative bundles of commodities" (Nicholson). The assumption of non-satiation assumes that any consumer will maximize their consumption within a given set of constraints in order to receive maximum utility from that consumption. In other words, a consumer will consume until they are receiving no more additional joy (or utility) from the goods. This theory, along with the SEM, has been the standard for at least a century, dating back to Alfred Marshal. The first Nobel Prize in economics was award to Ragner Frisch for his work on utility theory (Arrow). The basic formulation for the SEM can be found in numerus textbooks (e.g. Nicholson; Mas-Colell, Winston, and Green). With this model, consumers are presumed to solve the following optimization problem.

$$\max \mathrm{U} = U(q)$$

$$ST\colon \sum_{i=1}^{I} p_i q_i \leq B$$

Where *U(q)* is a utility function, p_i is the price of good *i*, q_i is the quantity of good *i*, and *B* is income or wealth. In a model with one good, consumers will optimize by consuming until the price is equal to the marginal utility. The solution to the optimization problem, with two goods is:

$$\frac{p_1}{p_2} = \frac{MU_1}{MU_2}$$

In other words, the consumer will choose a consumption bundle such that the ratio of the marginal utilities will be equal to the price ratio. Figure 2 shows a graphic representation of this solution. Any point beneath the budget constraint (*B*) can be purchased, when the budget constraint is tangent to the indifference curve (*U*) the consumer maximizes utility. We can see in the diagram the choice set (q_1, q_2) that maximizes utility.

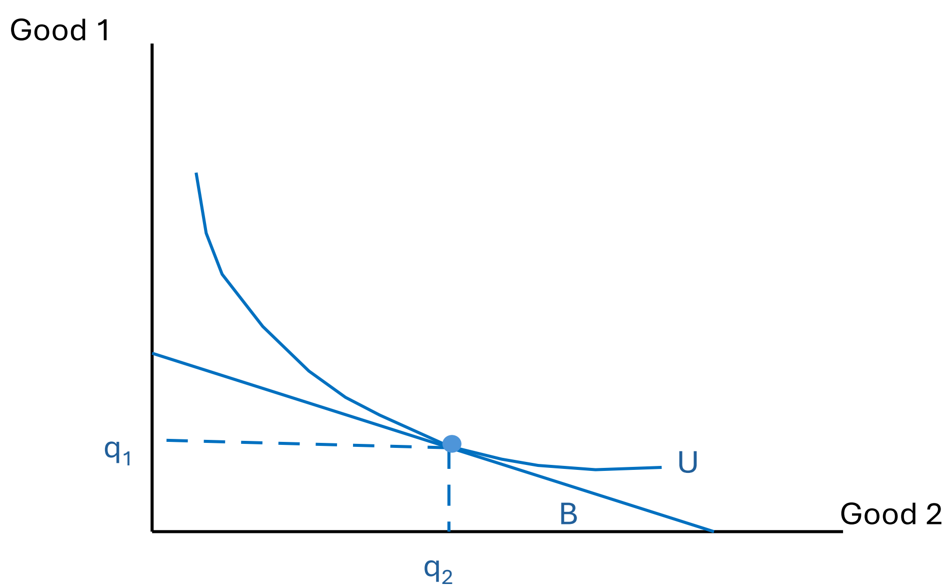


Figure 2: Utility Maximization with a budget constraint.

The ratio of the marginal utilities is known as The Marginal Rate of Substitution (MRS) between the two goods. At the optimum the MRS is equal to the price ratio:

$$\frac{Px}{Py} = -\frac{dy}{dx}\Big|_{U\,=\,\text{Constant}} = \text{MRS (of } X \text{ for } Y\text{), or}$$

$$\text{Slope of the Budget Constraint} = -\frac{Px}{Py} = \text{Slope of the Indifference Curve}$$

5. Mathematical Programming Simulations

This paper simulates consumer responses to prices via mathematical programming using the Solver in MS Excel (Tohamy). Mathematical Programming is a set of procedures, typically concerning problems of optimization. The procedures account for a vector of "decision variables" and the "objective function." Bruce McCarl writes in his paper "Applied Mathematical Programming Using Algebraic Systems," "One must define a) decision variables; b) constraints; c) the objective function; d) linkages between variables and constraints that reflects complementary, supplementary and competitive relationships among variables; and e) consistent data" (McCarl 1-4).

In this context, the constraints are the bounds within which an individual may consume and will take two forms, budget constraints and quantity constraints. The objective functions will be based upon either the SMA model or the SEM using a Cobb-Douglas functional form. We will also impose an integer constraint; the simulated consumers will not be able to consume fractions of a good. Following SMA's lead the two goods in question will be a high-quality candy (Q_1) such as a Lindt Truffle or a Ferrero Rocher and the second good will be a low-quality candy (Q_2) such as a Hershey's Kiss. In this research we present two different constraints: quantity and budget. The quantity constraint limits the number of candies purchased by a consumer. In the SMA model, the quantity constraint is one.

The first simulation is intended to replicate the theoretical model describe by SMA and is specified as:

$$argmax: \ (WTP_1 - p_1, WTP_2 - p_2, 0)$$

$$ST: \ q_1 + q_2 \leq 1$$

For the simulations the WTP for "low quality" candy was held constant at \$0.05, candy prices were held constant at \$0.26 for the "high quality" candy and \$0.01 for the "low quality" candy. The WTP for "high quality" candy was varied to represent different types of consumers. Results, found in Table 1, show that this formulation is consistent with the SMA model predictions. Consumers will self-select into two different categories, each type selecting the candy that maximizes the consumer surplus from consuming one piece of candy.

Cost Condition		
WTP1	Q1	Q2
0	0	1
0.05	0	1
0.1	0	1
0.2	0	1
0.3	1	0
0.5	1	0
0.8	1	0
1	1	0

Table 1: SMA Model Results, Cost Condition.

Mathematical programming results match the SMA predictions under the SMA restrictions, The consumer switches to the high-quality candy when:

$$WTP_1 - p_1 \geq WTP_2 - p_2$$

This corresponds to the dividing line in Panel A and Panel B of Figure 1.

Table 2 shows the results for the free condition, where the prices have dropped to \$0.25 and \$0.00. Results are consistent with the claims made by SMA. The switching point does not change and thus the ratio of candy consumption does not change when the price of both goods changes by the same amount, again replicating the SMA model.

Free Condition		
WTP1	Q1	Q2
0	0	1
0.05	0	1
0.1	0	1
0.2	0	1
0.3	1	0
0.5	1	0
0.8	1	0
1	1	0

Table 1: SMA Model Results, Free Condition.

However, if you modify the SMA model by eliminating the quantity constraint and replacing it with a \$1.00 budget constraint the results change. The optimization problem is now:

$$MAX\colon\ (WTP_1 - p_1, WTP_2 - p_2, 0)$$

$$ST\colon\ q_1 p_1 + q_2 p_1 \leq \$1$$

Table 3 shows that when the budget constraint is in place the consumer will purchase more candy and will still switch when:

$$WTP_1 - p_1 \geq WTP_2 - p_2$$

Cost Condition		
WTP1	Q1	Q2
0.05	0	100
0.1	0	100
0.2	0	100
0.3	0	100
0.4	3	0
0.8	3	0
1	3	0

Table 2: SMA Model with Budget Constraint, Cost Condition.

In the free condition the consumer now faces a non-binding budget constraint when

$$WTP_1 - p_1 \leq WTP_2 - p_2$$

And will thus consume an infinite amount of "low quality" candy. This resulted in errors in the MS Excel solver routine since the optimization problem is unbounded. In order to facilitate a solution one can pick an arbitrary, and completely unrealistic, quantity constraint such as 1,000. The mathematical programming model is now

$$MAX\colon\ (WTP_1 - p_1, WTP_2 - p_2, 0)$$

$$ST\colon\ q_1 + q_2 \leq 1{,}000$$

$$q_1 p_1 + q_2 p_1 \leq \$1$$

Comparing the results to Table 4 to Figure 1 there are two important facts: 1) The quantity constraint drives the results in the original SMA model and 2) Consumers that get more consumer surplus from the "low quality" candy will consume a massive quantity of that candy if it is free.

Free Condition		
WTP1	Q1	Q2
0.05	0	1000
0.1	0	1000
0.2	0	1000
0.3	0	1000
0.4	4	0
0.8	4	0
1	4	0

Table 3: SMA Model with budget constraint, free condition.

SMA's experimental results are more in line with these simulated results. There is no need to go back to the model and add "affect," as is done in Panel D of Figure 1, in order to explain consumer behavior. All that is required is the inclusion of a budget constraint and we instantly see that when prices go to zero there is a dramatic increase in consumption.

Finally, we present results from the SEM using a Cobb-Douglas functional form:

$$MAX\colon\ U = q_1^a q_2^b$$

$$ST\colon\ q_1 p_1 + q_2 p_1 \leq \$1$$

In this case instead of varying the willingness to pay we adjusted the relative marginal utilities of the two goods by adjusting the exponent on q_1 (a). As can be seen in Table 5 the quantity chosen by the consumer is a function of the relative marginal utilities of the two goods. As a increases the consumer gradually substitutes away from the q_2 and into q_1.

Cost Condition		
a	Q1	Q2
0.1	1	7
0.2	1	7
0.3	1	7
0.4	1	7
0.5	2	4
0.6	2	4
0.7	3	2
0.8	3	2
0.9	3	2

Table 4: SEM, Cost Condition.

Before presenting the final set of results, when the price of q_2 is set to zero, it is important to note the central claim made by SMA: if the price of two goods changes by the exact same amount, then the consumption ratio between those two goods will not change. Review Table 1 and Table 2–the consumption pattern does not change. However, in the experiments conducted by SMA, this did not hold true when one of the prices was set to zero. SMA then asserts that the SEM cannot account for this discrepancy. This paper has demonstrated that the consumer choice model derived by SMA is not the same consumer choice model used by economists, the SEM. Table 6, in fact, shows that the SEM predicts that consumers will choose an infinite amount of a good if that good is free. In other words, when prices approach zero consumers behave as predicted by the standard model and zero is not special.

Free Condition		
a	Q1	Q2
0.1	4	Infinity
0.2	4	Infinity
0.3	4	Infinity
0.4	4	Infinity
0.5	4	Infinity
0.6	4	Infinity
0.7	4	Infinity
0.8	4	Infinity
0.9	4	Infinity

Table 5: SEM, Free Condition.

Perhaps more interesting, when good 2 is free, consumers spend all their budget on good 1. Consumption of both goods increases when the less desirable good is free. This is not a new or exciting result and is driven by a well-known and predictable process. Consider Figure 2, which shows what happens when the prices of both goods drop, with the price of good 2 falling to zero.

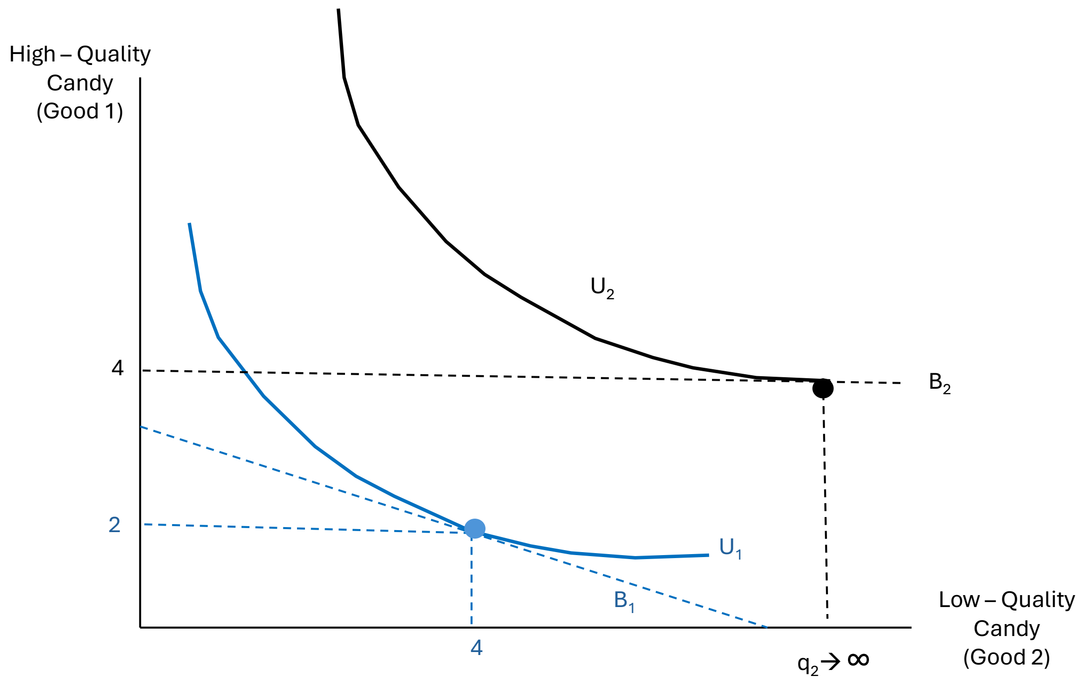


Figure 3: Utility maximization when a good is free.

The budget constraint moved from B_1 to B_2, pivoting out until it became flat, and then shifted upward to account for the drop in the price of the high-quality candy. This graphical analysis shows that when the price is zero the optimization is unbounded. The consumer can afford a literal infinite quantity of good 2. Since the standard model assumes that the consumer will exhaust his or her budget constraint, all income is spent on good 1. If you have ever "filled up on bread" at a restaurant you have exhibited this predictably rational behavior. Notice that, compared to Figure 1, Figure 3 looks quite different because Figure 3 shows the quantities purchased. Figure 1 only shows the distribution of WTP when the consumer chooses Q_1 (*X*), Q_2 (*Y*), or nothing (*N*). This difference accounts for the obvious discrepancies.

6. Discussion

As a final thought, consider that economists have long known how “free” impacts decision making. Consider the Tragedy of the Commons (ToC) which dates back to the work of William Forster Lloyd in 1833. Although the ToC focuses on production, rather than consumption, it provides an excellent analogy and historical evidence that economists fully understand behavior when $p = 0$. The ToC asserts that the price of using the commons is zero, hence, the marginal cost of using the commons is also zero. When maximizing profit, Marginal Revenue is set equal to Marginal Cost, so even if the use of the commons provides zero revenue, it is still profit maximizing behavior to use the commons. The use of the commons leads to what, on the surface, appears to be irrational behavior. The commons become overused, and the resource becomes depleted. However, it is rational because it follows the predictions of the profit maximization model. Consumer behavior when consuming free candy is no different.

This behavior, and the discrepancy in the SMA model, can be further understood by examining the Slutsky decomposition, which can be found in numerous economics textbooks (i.e. Nicholson; Mas-Colell, Whinston, and Green), which shows that a change in demand can be broken down into two effects, the income effect, and the substitution effect.

$$\frac{\partial x_1(p,w)}{\partial p_2} = \frac{\partial h_1(p,w)}{\partial p_2} - \frac{\partial x_1(p,w)}{\partial w} x_1(p,w)$$

Where $x_1(p,w)$ is the Marshallian demand and $h_1(p,w)$is the Hicksian demand (i.e. the compensated demand), p represents prices and w represents wealth (i.e. the income or budget). The first term on the right-hand side represents the substitution effect as it shows the change in consumption of good one as the price of good two changes. The second term on the right-hand side shows how consumption of a good changes as income changes, the income effect. In other words, the demand for a good will change when the price of a related good changes (the substitution effect) and then, because a change in price will impact the budget constraint, the consumer will act as if their income changed, as shown in Figure 3. In this case, we can see that making the low-quality candy free creates a situation where the optimization problem is unbounded; the consumer can (and does) choose a near infinite quantity of the low-quality candy *plus* the consumer now has ample room in the budget to purchase a higher quantity of the high-quality candy. Again, this is a normal and rational consumer behavior as predicted by the SEM–there is nothing special about zero and this is not a new effect. There is no "affect" that boosts utility, instead consumers feel as if they received a raise as the lower price gives them, in effect, more wealth.

7. Limitations

This research conducts tests using mathematical programming in place of an experimental marketplace. While mathematical programming is widely recognized as a reliable research method, there are some aspects of consumer decision making that cannot fully be accounted for. SMA conducted their experiment using an experimental marketplace in which consumers were faced with the same conditions and restraints. We intend to design and test a more robust version of this marketplace in the future.

8. Conclusion

This research aims to understand consumer behavior when presented with a prize of zero, or a free good. The SMA Model is not, as the authors claim, the standard economic model. It is, however, a new model derived independently by SMA. The key feature is the lack of a budget constraint, which is the feature that derives the model's predictions. The real-world consumers studied by SMA operated with a budget constraint, hence the model's failed predictions. SMA incorrectly labels their model as the standard model. Thus, the authors incorrectly conclude that decades of classical demand theory are incorrect. The SEM, or Cobb Douglass functional form, accurately predicts behavior when the price of one good is zero. If the behavior is predictable, it is not irrational.

The research is significant as it helps to apply a long-time model of economics to a newer branch of the field. The field of Behavioral Economics, while valid, is still establishing roots and forming a solid foundation. By applying these tried-and-true economic concepts, the field will move in the correct direction of understanding consumer behavior more thoroughly.

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