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Price as an Indicator of Quality: Implications for Utility and Demand Functions

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Abstract

Consumers often infer quality information from prices and rely on their reference prices. This paper incorporates both behavioral regularities into the classic utility function. The analytical investigation reveals five qualitatively different types of consumers, three of which are relatively new to modeling literature. The authors test the model's theoretical insights using a new experimental method, random allocation of scarce inventories (RASI), which is designed to align people's incentives, such that they state their true rank order preferences. The results support the existence of five different types of consumers; the authors discuss the managerial implications for pricing strategies.

Keywords: Price and quality; Utility functions; Incentive alignment; Analysis

Introduction

Contrary to classic economic theory, consumers do not always buy the lowest priced product in a category, even when the products are otherwise similar.[3] One behavioral explanation, supported by empirical evidence (Leavett 1954; Lichtenstein and Burton 1989; Monroe and Krishnan 1985; Rao 1984, 1993; Rao and Monroe 1988; Schindler 1991; Stiving 2000), suggests that consumers infer information (e.g., quality) from price. As a result, price appears to play two opposite roles—allocative and informational—in consumers' purchasing decisions (Rao and Sattler 2000; also see Gabor and Granger 1966). On the one hand, higher price decreases consumer utility, because they must pay more for the product. On the other hand, higher price may induce higher quality perceptions, which increase utility (Monroe and Krishnan 1985). Intuitively, this complex relationship may lead to a nonmonotonous (individual) utility function over price, which then should create an (aggregate) demand function that is not necessarily downward sloped, as assumed ubiquitously in literature and practice.[4]

Understanding the shape of the demand function is fundamental to managerial decisions, because an incorrect assumption about its shape leads to suboptimal decisions. In addition, a firm may suffer if it assumes a single type of demand function when several types actually mark different consumers. Ignoring such consumer demand heterogeneity will deprive the firm of opportunities to optimize its marketing mix and compete effectively with other firms in the market. Despite anecdotal evidence of more complicated demand functions, the classic

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[3] This complex relationship should be evident to anyone who has looked for a book from an online bookstore. Consider a recent search for *Ender's Game* by Orson Scott Card as an example: Amazon.com carried the book new for $6.99 but also offered used copies from 47 affiliated sites, varying in price from $2.98 to $6.99; new copies from 19 affiliated sites, varying in price from $3.91 to $6.99; and collectible copies, including a first edition, from three sites, varying in price from $5.15 to $6.95. There seems to be little or no difference among the options except for price, and Amazon guarantees the reliability of all sites. The mere existence of such a variety of prices implies that at least some people have more complicated utility functions.

[4] Following convention, we define a utility function as one person's preferences for a given product according to some of its characteristics (e.g., price); the demand function is the number of units of a product that a market will demand (purchase) at a given price level.

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downward-sloping assumption predominates in both research and practice (cf. Stiving 2000, who assumes a kinked demand curve). This predominance may persist because no alternative shapes have been proposed for demand functions or tested in rigorous research. We attempt to fill this important research gap by making four key contributions.

First, we develop a parsimonious, analytically tractable, behavior-based analytical model to serve as a descriptive theory of consumers' utility functions. Instead of studying demand directly, we focus on the consumer's utility functions and make inferences about demand, based on the aggregation of the utility functions. The proposed model builds on classic utility theory, augmented with two well-documented behavioral regularities (BRs): (1) consumers infer quality information from a product's price and (2) consumers have a reference price for a given product. This new formulation captures two opposing effects of price, product heterogeneity in terms of both value and the information content of price, and consumer heterogeneity in terms of the degree to which they attend to the information content of price and their reference price for the product category. By developing a model based on behavioral regularities, we offer an alternative formulation of consumers' responses to prices, which analytical modelers may use to specify a model that is more realistic than the standard downward-sloping demand curve.

Second, our model is more realistic in that it is more useful; it explicitly identifies five types (four main types and one subtype) of consumers for a given product, each with a qualitatively different utility function. Two types are well known in prior literature, namely, those who follow a classic downward-sloping curve and those who prefer a medium price overall. Both utility function types previously have been identified empirically (Ofir 2004; Rao and Sieben 1992; see also, for a much different context, Suri and Monroe 2003), and models exist to represent each, though perhaps not at the same time. However, three additional types remain relatively novel, if not completely unknown, particularly in modeling literature. The third type refers to a strictly upward-sloping utility function; these consumers prefer a medium price when the inflection point for the utility function is not within the range of extant price points. The fourth and fifth types begin with a downward-sloping segment, shift to an upward-sloping segment, and end with another downward segment (graphically, they look like inverted Ns). The two utility functions differ only with regard to whether the consumers' most preferred price is 0 or not. For modeling purposes, once empirically verified, our model offers a technique that captures various different types of utility functions.

Third, we propose a new experimental procedure that enables researchers and practitioners to obtain an incentive-compatible preference rank order of alternatives, which in turn provides a means to test various shapes of functions empirically. The use of an incentive-compatible experimental procedure is important; existing literature demonstrates that subjects' stated preferences differ systematically from their revealed preferences and are poor predictors of their actual behavior (Ding 2007; Ding, Grewal, and Liechty 2005; Ding, Park, and Bradlow 2009). The proposed procedure, which we designate the random allocation of scarce inventories (RASI), allocates a limited number of alternatives to a large set of consumers on the basis of their stated preference rank order, such that each consumer has some probability of receiving any product in the category. As a result, it fully motivates consumers to provide a truthful ranking of their preference structure. This new experimental procedure also may be valuable in contexts other than measuring utility functions; for example, a researcher could use it to elicit a consumer's ranked consideration set.

Fourth, we provide strong empirical evidence that the vast majority of consumers can be captured by the five types of utility functions identified in our model. Using our proposed experimental procedure, we conduct an experiment with six different types of food in the context of purchasing a lunch combination. Respondents receive money, which they may use to buy (or not buy) real foods and then consume them. The results from the experiment demonstrate: (1) the existence of all five shapes of utility functions; (2) the relative infrequency of the downward-sloping utility function; (3) the relative preponderance of the utility function that prefers a medium price; (4) individuals exhibiting different utility function have statistically significantly different levels of product involvement for the product categories such that the less uncertain the customer is, the more concerned with price as a sacrifice he or she also is; and (5) utility functions that behave substantially differently from the simple downward slope assumption common in literature and practice. Together, these results provide strong support for the usefulness of our model and for the empirical validity of its theoretical insights.

The rest of this article is organized as follows: In the next section, we discuss the theoretical model and illustrate some key insights. Then, we describe an experiment designed to test our key theoretical insight, namely, the existence of four different types of consumers and the complexity of the demand function. We conclude and point to several research directions in the last section.

Theoretical model

We develop a parsimonious model that mathematically incorporates price-oriented behavioral regularities (BRs) into a classic utility theory model. Our purpose is not to study the scenario in which price serves as credible signal (Bagwell and Riordan 1991; Shoemaker et al. 2003; Stiving 2000) but rather to investigate the scenario in which price could be considered "cheap talk" (i.e., sellers may choose a price without incurring other costs). Our research also differs from existing literature that makes the firm the target of analysis and assumes consumers' demand function (e.g., Stiving 2000); instead, we investigate how consumers react to different prices and identify different utility functions. Our objective therefore is to investigate the impact of BRs on the characteristics of the utility function, as well as its ramifications for demand functions. We first develop our proposed model by augmenting classic utility theory with two relevant and well-documented BRs; afterward, we investigate the theoretical properties of the new utility func-

Table 1
Notation and key terms.

Notation	Meaning
BR	Behavioral regularity
Utility function	Individual's utility as a function of relevant variables, such as price
Demand function	The units of a product that a market will demand (purchase) at a given price level
$u_i^j(q_i^j, p^j)$	Utility function for individual i of product *j* with a given perceived quality q_i^j, unit is dollar
$v_i^j(q_i^j)$	Value function for individual i of product *j* with a given perceived quality q_i^j, equals the utility $u_i^j(q_i^j, p^j)$ excluding the cost of acquiring the product p^j, unit is dollar
V^j	Maximum $v_i^j(q_i^j)$, when product *j* has infinitely high quality q_i^j, unit is dollar
q_i^j	The perceived quality of product *j* by individual *i*, and $q_i^j \geq 0$
p^j	Price of product *j*
p_i^{j*}	Price of product *j* that will give individual i maximum utility
α_i^j	Quality coefficient, extent to which individual *i*'s value is determined by q_i^j, and $\alpha_i^j \geq 0$
β_i^j	Information coefficient, extent to which individual i interprets quality information from p^j, and $\beta_i^j \geq 0$ (0 if the individual disregards quality information from p^j)
γ_i^j	Individual *i*'s reference price for product *j*

tions. We define our model parameters and key notations in Table 1.

Model development

We specify a person's utility function in our specific context (focus on quality and price) according to classic economic literature. We then augment the utility function with two key relevant BR.[5] Following extant literature (Mas-Colell, Whinston, and Green 1995), we assume a quasilinear utility function for a given person:

$$u_i^j(q_i^j, p^j) = v_i^j(q_i^j) - p^j. \quad (1)$$

By convention (Tirole 1988), the value function increases at a decreasing rate over the product's quality and has an upper bound:

$$\frac{\partial v_i^j(q_i^j)}{\partial q_i^j} > 0, \qquad \frac{\partial^2 v_i^j(q_i^j)}{\partial q_i^{j2}} < 0, \qquad \lim_{q_i^j \to \infty} v_i^j(q_i^j) = V^j. \quad (2)$$

This assumption appears intuitive; rational consumers should desire higher quality products. However, as a product gets better, consumers may be less likely to detect improvement or find value in that improvement. Therefore, the existence of an upper bound is an intuitively appealing assumption. No matter how good a product is, its utility must be bound by the nature of the product category, so the utility of a 27-in. television, no matter how high its quality, is limited by its purpose, as an apparatus for viewing video material on a 27-in. screen.

To facilitate our theoretical investigation, we propose the following specific functional form that satisfies these assumptions:

$$v_i^j(q_i^j) = \frac{q_i^j}{\alpha_i^j + q_i^j} V^j, \quad (3)$$

where the individual-specific quality coefficient (α_i^j) captures the sensitivity of a consumer's value to quality, as this could be seen more clearly by reformulating Eq. (3) as $v_i^j(q_i^j) = ((q_i^j/\alpha_i^j)/(1 + (q_i^j/\alpha_i^j)))V^j$. That is, α_i^j is essentially a coefficient for quality in the value function. For the same quality, a person with higher α_i^j derives less value than an otherwise identical consumer with lower α_i^j. Substituting Eq. (3) into Eq. (1), we obtain the utility function according to standard economic assumptions:

$$u_i^j(q_i^j, p^j) = \frac{q_i^j}{\alpha_i^j + q_i^j} V^j - p^j. \quad (4)$$

This utility function decreases monotonically over price. In a market populated by such consumers, the demand function for the product reveals a standard downward-sloping curve, as widely used in research and practice. If we incorporate the BRs related to price as a quality signal though, does the utility formulation change? If so, what are the ramifications for the demand function?

Economists generally treat price information that is costless to send as cheap talk and assume that rational decision makers will not incorporate such information (for other situations in which price conveys information, see Bagwell and Riordan 1991; Stiving 2000). However, marketing literature consistently demonstrates that consumers take price as an indication of real product quality and thus utility, even if the information is costless to send (e.g., Leavett 1954; Monroe and Krishnan 1985; Rao and Sattler 2000). Furthermore, consumers usually rely on reference prices for their decision making (cf. Kahneman and Tversky 1979). Therefore, we formally establish these two BRs and propose specific formulations to integrate them into the standard utility function (Eq. (4)).

BR 1. Consumers infer quality information from a product's price (even if it is cheap talk).

Beginning with Leavett's (1954) seminal work, consumer behavior researchers have devoted considerable attention to whether consumers perceive that price carries information about product quality within the rubric of the price–quality relationship. Although the results have not been univocal, integrative reviews (e.g., Monroe and Krishnan 1985) indicate that most research find that consumers perceive price and quality as posi-

[5] In our analytical model, we examine the case of a purchase of a single item, which is realistic for many retailers. However, the participants in the empirical study do not fit this special case. If the insights from the special case receive support in a realistic empirical environment, we have strong support for the generalizability of our analytical model results.

tively related. Thus, we assume[6]:

$$\frac{\partial q_i^j}{\partial p^j} > 0, \quad \frac{\partial^2 q_i^j}{\partial p^{j^2}} \geq 0. \tag{5}$$

BR 2. Consumers make decisions based on their reference prices for a given product.

Abundant literature documents this powerful phenomenon, including Swalm (1966), who studies managers' decision utilities for decisions that represent losses compared with those that entail gains. Swalm (1966) finds that for most managers, the response function in the loss domain is considerably different (i.e., much steeper) than the response function in the gain domain, which implies that the zero point acts as a reference or inflection point. Kahneman and Tversky (1979) employ the notion of a reference point in utility functions in their prospect theory, a descriptive model of preference. Their approach has been adopted by many consumer researchers (e.g., Hardie, Johnson, and Fader 1993; Puto 1987; Winer 1986). Putler (1992) also develops an analytical model that explicitly incorporates reference price into existing economic models, with the objective of studying the effect of this BR on traditional theory and its implications for marketing practice. We extend this research stream. To facilitate further theoretical investigations, we specify a formulation to capture the two BRs and Eq. (5)[7]:

$$q_i^j = e^{\beta_i^j (p^j - \gamma_i^j)}. \tag{6}$$

Although we assume one specific functional form, we design the empirical study to test the robustness of the finding from the analytical model, which invariably employs some restrictive assumptions. This method represents a well-established tradition for testing the robustness of theoretical insights, and it differs from the alternative approach in which we might establish robustness by relaxing the assumptions using analytical analysis or simulations.

We allow for consumer heterogeneity in this formulation by using an individual-specific reference price (γ_i^j) and an individual-specific information coefficient (β_i^j). Many authors reveal that consumers differ in how they modify their perceptions of the quality of a product according to a given price. This sensitivity results from various factors, including whether the consumers possess a price–quality schema (Peterson and Wilson 1985; Rao and Monroe 1988), the perceived risk of the purchase (Lambert 1970; Monroe and Krishnan 1985), and the frequency of purchase (Lichtenstein and Burton 1989). The values of $\beta_i^j (\geq 0)$ indicate how much weight a consumer places on the quality information derived from the price. For example, if the actual price is \$10 higher than the consumer's reference price, the perceived quality of the product is higher for a person with higher β_i^j than for a person with lower β_i^j. Finally, we substitute Eq. (6) into Eq. (4) and obtain the BR-augmented utility function:

$$u_i^j(q_i^j(p^j), p^j) = \frac{e^{\beta_i^j (p^j - \gamma_i^j)}}{\alpha_i^j + e^{\beta_i^j (p^j - \gamma_i^j)}} V^j - p^j \tag{7}$$

Theoretical insights

The standard utility function indicates that a person will prefer a product for free rather than one that costs money, but this new utility function likely will tell a more complicated story. We therefore investigate first the conditions in which consumers no longer prefer free products; that is, what is the price that induces maximum utility for an individual consumer? The second theoretical property we investigate is the shape of the utility function (first- and second-order behavior of the utility with regard to price), which enables us to understand the qualitatively different patterns of utilities. Finally, we investigate the implications of this augmented utility function for purchase decisions and its ramifications on the demand function.

When presented with similar products for different prices, a consumer with the BR-augmented utility function should identify a product with a price level that conveys sufficient quality without being excessively expensive. In other words, he or she identifies the price that will maximize utility (to economize on notation, we use $u_i^j(p^j)$ instead of $u_i^j(q_i^j(p^j), p^j)$) and purchases that product, as long as the utility is greater than 0 (individual rationality):

$$\max_{p^j} u_i^j(p^j), \tag{8}$$

and

$$\text{s.t.} \quad u_i^j(p_i^{j*}) \geq 0, \tag{9}$$

where p_i^{j*} is the price of product j that generates the maximum utility for consumer i. Thus,

Theorem 1. A consumer prefers a free product unless his or her information coefficient (β_i^j) is above a threshold and quality coefficient (α_i^j) is of intermediate value, in which case the most preferred price is

$$p_i^{j*} = \gamma_i^j - \frac{1}{\beta_i^j} \ln\left(\frac{V^j\beta_i^j - 2 - \sqrt{V^j\beta_i^j(V^j\beta_i^j - 4)}}{2\alpha_i^j}\right). \tag{10}$$

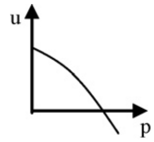
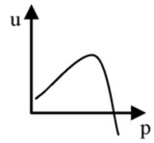
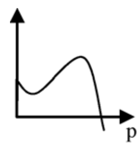
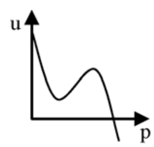
Proof. See Appendix A.

The specific regions of the information coefficient (β_i^j) and quality coefficient (α_i^j), where an interior p_i^{j*} exists, appear in Appendix A. Theorem 1 identifies the conditions in which an interior price is optimal for a given consumer and shows that

[6] The relationship may be S-shaped rather than convex, which would capture a ceiling effect. The concavity (Eq. (2)) we assume regarding utility as a function of quality should alleviate this concern.

[7] In some situations, the price for a product may be presented to consumers in multiple components (e.g., dealer cost plus dealer markup on a car), and consumers may pay attention only to prices associated with those components that have quality implications. To capture this situation, we simply introduce a parameter $\delta^j \in [0, 1]$, where $q_i^j = e^{\beta_i^j (\delta^j p^j - \gamma_i^j)}$.

Table 2
Five theoretical consumer types.

Type	Graphic Representation	Shape Characteristics	Optimal Price	Consumers Belonging to Each Type
T1. Bargain hunter		Decreasing; concave	0	$\beta_i^j \le 4/V^j$ or $\beta_i^j > 4/V^j$ and $\alpha_i^j \in (0, \alpha_{i1}^j]$
T2 and T2t. Quality conscious		Increasing then decreasing; concave	Interior	$\beta_i^j > 4/V^j$ and $\alpha_i^j \in (\alpha_{i1}^j, \alpha_{i2}^j]$
T3. Quality conscious unless dirt cheap		Decreasing then increasing then decreasing; convex then concave	Interior	$\beta_i^j > 4/V^j$ and $\alpha_i^j \in (\alpha_{i2}^j, \alpha_{i3}^j]$
T4. Bargain hunter unless quality is high enough		Decreasing then increasing then decreasing; convex then concave	0	$\beta_i^j > 4/V^j$ and $\alpha_i^j \in (\alpha_{i3}^j, \infty)$

consumers do not prefer a free product only when they are sufficiently sensitive to price information for a given product and neither completely discount quality nor blindly thrilled with any quality level. When consumers do not infer much quality information from the price (very small β_i^j), the BR-augmented utility function reduces into the standard utility function. As a result, these consumers prefer the free product. However, not everyone who values quality information derived from the price has an interior p_i^{j*}. A consumer who does not care about quality (large α_i^j) will not buy a product with a higher price, even if he or she believes the price carries significant quality information. Consumers also will not purchase a higher priced product if they value even the baseline quality (small α_i^j), because they already are happy with the quality the free product offers.

The value of this interior p_i^{j*} clearly depends on many different factors (see Appendix A), characterizing both the consumer and the product. For different consumers, this price increases as (1) their reference price increases, (2) their utility becomes less responsive to quality, or (3) they grow more sensitive to the price–quality relationship when their utility is highly responsive to quality and less sensitive when their utility is not highly responsive to quality. Across different products, this price increases with the maximum value of the product.

Theorem 1 provides specific predictions about the utility-maximization price for a given consumer and a given product. As a more qualitative yet powerful result, Theorem 2 pertains to whether individual consumers deviate from the downward-sloping assumption of the classic demand function in any systematic ways.

Theorem 2. Consumers can be divided into four different types on the basis of the shape of their utility function, as summarized in Table 2.

Proof. See Appendix A.

Theorem 2 specifies five different utility functions characterized by qualitatively different shapes, which offers some interesting dynamics. The T1 utility functions describe a consumer who infers no (or very little) quality information from price or is easily pleased with even low quality and therefore prefers a product more when it is less expensive. This consumer is the analogue to the downward-sloping utility function from micro-economic literature. The T2 utility functions represent people who infer significant quality information from price and whose valuation is reasonably sensitive to quality. If they value quality, their utility depends on both price aspects, and they consider price in accordance with the methods outlined in perceived value literature (Monroe and Krishnan 1985; Zeithaml 1988). A higher priced item increases utility by (implicitly) providing a signal of better quality and decreases utility by requiring a higher price paid. The utility derived from consuming a product should be limited by an upper bound, whereas the disutility (higher price to pay) is not bounded. Conceivably, the disutility should overpower the positive utility at some price level, as price increases, so the consumer prefers a higher priced item only up to this point, then prefers a lower priced item. The utility functions thus take an inverted U shape. The T2t utility functions are upward sloping; they may be considered best as T2 utility functions in which the inflection point has not been reached, though they are interesting substantively.

The T3 and T4 utility functions take an inverted N shape to depict consumers who are quite sensitive about quality information derived from the price but whose valuations of a product are less sensitive to quality. For example, a consumer might discount any price below his or her reference price as noninformative but treat prices above this reference price as informative (i.e., conveying information about quality). In this case, this consumer sees only the disutility of price up to a certain threshold (similar to T1), then experiences both quality and disutility after the threshold (similar to T2). As a result, the demand curve shows a downward-sloping preference segment (T1), followed by an inverted U shape (T2). In short, this utility function consists of slopes with three different signs: downward, upward, and downward again. The difference between T3and T4 reflects where the consumer's unique most preferred price is located.

Because the T3 and T4 utility functions are the most difficult to envision, we consider an extended example: An undergraduate student, with little or no previous experience in selecting places to stay, is considering staying in an independently owned Bed and Breakfast (B&B) for her spring break vacation at a resort destination that she has never visited and for which she finds it impossible to find quality information about the local, independently owned B&B's on the internet. In general, few consumers would be willing to pay a price below some number, say $30 per room per night, which is unrealistically low for a room in a B&B at a spring break destination, so it does not convey much useful information about quality. However, if she has to stay in a B&B in that price range, the consumer probably would prefer a price of nearly $0 to a price of $30, because all prices in this range suggest poor quality. However, in the $30–$90 price range, which reflects a more reasonable range for a B&B room, the same consumer might, up to some price point, prefer a higher priced room, in the belief that the higher price signals a higher quality room. In this range, the utility function therefore is upward sloping. Finally, if the price increases above $90, the student's preference likely would shift back to a lower rather than a higher priced B&B room, with the belief that the quality represented by the lower priced (in the region above $90) room will be sufficient and the incremental increase in quality associated with the higher priced room does not justify the increased price.

To provide an intuitive example of these types and highlight the difference between the standard utility function and the BR-augmented utility function, we graph the utility function of an individual consumer ($\alpha = 5$, $\beta = 0.1$, $\gamma = 15$) for a certain product ($V = 70$) in Fig. 1. In one case, the price contains quality information, whereas in the other, it does not (equivalent to setting $\beta = 0$). A dramatic difference emerges in the utility function when the price does or does not provide quality information.

Finally, we investigate some implications of this augmented utility function on purchase decisions and its ramifications for the demand function. It is important to understand the optimal price and the shape of a consumer's utility function after incorporating quality information from price, but this understanding does not speak directly to a marketer interested in aggregate market behavior, who instead asks, for example, "How many people will buy my product if I price it at a certain level?" In other words, marketers need answers to questions about the demand function, given the BR-augmented utility function. We therefore state our main insight as Corollary 1:

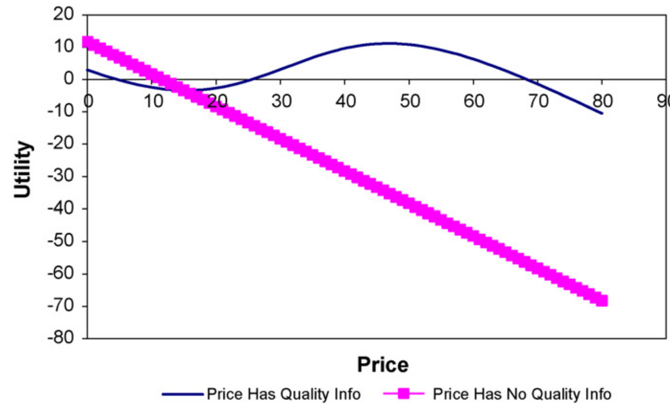


Fig. 1. Utility function with or without inferring quality information from price.

Corollary 1. The five types of consumers purchase products at different price levels, as summarized in Table 3.

Proof. See Appendix A.

In a standard utility framework (Eq. (4)), a consumer's utility monotonically decreases over price, so he or she purchases a product if it is priced below a threshold and does not purchase above that level. For each consumer, a manager therefore observes a particular purchase pattern as the price increases. In the first pattern, the person never buys anything (NP), such as when someone has a negative utility for owning a product. The second pattern dictates that the consumer buys (P) the product if the price is low but not if the price is high (P → NP).

Corollary 1 predicts two new patterns as well. In the NP → P → NP pattern, consumers only purchase the product when it is priced at a reasonable level; they do not purchase at very low prices, because they believe such products offer inferior quality and are not worth the money. Neither will they purchase a product at a very high price, because the added quality cannot justify the additional price premium. According to the second pattern, P → NP → P → NP, a consumer will buy the product at a very low price ("bargain basement") but will not buy it if the price increases yet fails to indicate significant quality. However, the consumer then will buy the product at an even higher price, because such a price indicates the product to be of better quality and thus worth the money. Eventually however, price grows too

Table 3
Purchase patterns of the four theoretical consumer types.

Type	Patterns of purchase (P) or not purchase (NP) as price for a product increases			
	NP	P → NP	NP → P → NP	P → NP → P → NP
T1		√		
T2	√	√	√	
T2t		√		
T3	√	√	√	√
T4	√	√		√

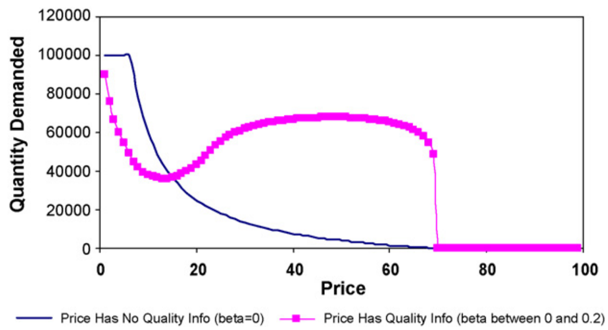


Fig. 2. Demand function for a hypothetical market.

high for the consumer, and the consumer will not purchase, even if the price signals very high quality.

In Table 3, we show explicitly, for each consumer type (T1, T2, T2t, T3, and T4), which of the four purchasing patterns can be observed empirically. Each consumer type exhibits a specific subset of the purchasing patterns, such that the specific pattern observed for a given consumer depends on the absolute values of the utility function of this consumer, as in the graphs in Table 2. Use T2 as an example: If the utility curve is completely below the *x*-axis, it exhibits pattern NP; if only the middle section of the utility curve is above the *x*-axis, it exhibits pattern NP → P → NP; and finally, if the utility curve is above the *x*-axis at price = 0, it exhibits the pattern P → NP.

The four different purchasing patterns and the unique combination of different patterns for each consumer type imply that the behavior of the demand function is intricate. Furthermore, this behavior depends on the composition of consumers in the market and their purchasing patterns. As an illustration of how the demand function becomes more complex as a result of the BR-augmented utility function, we conduct a simple simulation in which we examine a market for a certain product ($V = 70$), for which consumers all have the same reference price ($\gamma = 15$) but differ in their quality and information coefficients. We assume quality coefficients are uniformly distributed from 0 to 10 ($\alpha \in [0,10]$), and information coefficients are uniformly distributed from 0 to 0.2 ($\beta \in [0,0.2]$). We simulate the utility function for 100,000 consumers and then examine each purchasing decision at a given price (i.e., purchase if the consumer's utility is positive at that price, no purchase otherwise). The decisions of the 100,000 consumers at every price level (from 0 to 100), in aggregate, appear in Fig. 2. For comparison, we also simulate demand based on the standard utility function (treating all information coefficients as 0). As expected, the standard utility function formulation leads to a classic downward-sloping demand function, whereas the demand function based on the BR-augmented utility function is much more complicated. Demand first decreases as price increases, similar to a standard demand curve. After passing a certain price threshold, demand increases as the price further increases, before eventually decreasing to 0.

Because this simulation involves persons with different utility functions, the results should not relate directly to any particular type, even if the shape is analogous to that of T3 and T4. Nevertheless, we can offer some observations about this specific simulation market. First, the maximum market size occurs when a product charges a price around 50. Second, the driver in the standard demand curve entails consumers who leave the market when the price increases beyond their reservation prices. In our model, increased price has two effects: It makes the product less attractive because of the disutility of paying more (as in the standard model), and it makes the product more attractive because it indicates higher quality (which increases the reservation price). Depending on a person's specific utility function, he or she may move in and out of the market as the price increases (Corollary 1) because of the trade-off between these two competing effects. The standard economic model instead establishes a fixed reservation price for each person (though the actual reservation price differs across consumers), below which he will buy and above which he will not. In our framework, consumers of type T2, T3, and T4 utility have no such fixed reservation price (Corollary 1 and Table 3). This complexity drives the shape we observe in Fig. 2.

Note that we ask how consumers might respond to a product priced at a certain level when no other information is available (except reference price). In the real world though, other moderating factors, such as dynamic competition,[8] have an effect, as we note in our discussion of some further research issues.

Hypothesis development: who is likely to exhibit a specific utility function?

Our model predicts a more diverse set of utility functions than extant modeling literature assumes. From both theoretical and managerial perspectives, it appears interesting and relevant to understand the profile of consumers who are likely to exhibit a specific utility function type. Such knowledge would allow managers to act accordingly in real life. Therefore, we take the analytical insights into each utility type and relate them to extant managerial literature, then develop hypotheses regarding specific profiles that might be associated with each type.

We identified consumer's involvement in the product category[9] as a major construct in the managerial and consumer behavior literature (for a review, see Monroe and Krishnan 1985). As we noted previously, the basic premise of our model is the trade-off between the cost role of price, or what Rao (1984) calls the allocative role and Monroe and Krishnan (1985) call the sacrifice aspect, and the quality role of price, which Rao (1984) calls the informative role. Lichtenstein, Bloch, and Black (1988) demonstrate that involvement relates positively to price–quality inferences and negatively to price consciousness, or the degree to which the respondent focuses on price. Suri and Monroe (2003), considering how time constraints may influence con-

[8] In the current formulation, competition is implicitly modeled as a contributing factor to the reference price a consumer has formed.

[9] Other dimensions in a consumer's profile also may indicate the consumer's utility type. Among others, the consumer's category knowledge may affect utility type. Interestingly it also may be that category knowledge and involvement, our focus, are correlated. However, we focus our theorization on involvement based on the literature in this area, but note that we make a ceteris paribus argument for involvement and are not suggesting that other dimensions do not affect utility type.

sumer responses to price, find that the motivation to process information (similar to involvement) has similar effects. We use these findings to propose a link between each specific utility function type (very hard to observe) and involvement in a product category (easier to observe/measure). Such a relationship could give managers a means to infer consumers' utility function type on the basis of their involvement and thereby adopt relevant pricing strategies.

Consider the downward-sloping utility function (T1), which implies relatively high attention to the sacrifice aspect and relatively low or no attention to the informational aspect of price—in short, high price consciousness and low price–quality inferences according to Lichtenstein and colleagues' (1988) framework. Respondents evincing this utility function should have low involvement with the product category in question. Thus, we hypothesize:

H1. Downward-sloping utility functions are associated with a low level of product category involvement.

Conversely, the upward-sloping utility function (T2t) implies relatively high attention to the informational aspect and relatively low attention to the sacrifice aspect of price, which corresponds to the low price consciousness and high price–quality inferences in Lichtenstein and colleagues' (1988) framework. Respondents that represent this utility function should exhibit high involvement with the product category in question.

H2. Upward-sloping utility functions are associated with a high level of product category involvement.

Thus, we arrive at the utility functions with interior preference maxima: the ideal point utility function with one internal maximum (T2 with the downward-sloping section within the range of observation) and the two utility functions that begin with a downward-sloping section, followed by an upward-sloping section, and ending with an additional downward slope (T3 and T4, or the inverted-N utility functions). Recall that the only difference between T3 and T4 is whether the maximum utility is associated with the lowest priced member of the class or with an interior maximum. Such utility functions involve trade-offs between the sacrifice and the informational aspects of price, which suggests a relatively moderate level of price consciousness, price–quality inferences, or both. According to Lichtenstein et al. (1988), respondents with these utility functions should exhibit moderate product involvement with a product category in question, compared with those in the downward- and upward-sloping utility functions.

H3. Ideal point and inverted-N utility functions are associated with a moderate level of product category involvement.

We cannot explicitly hypothesize the potential differences between these two types of utility functions.

Experiment

To verify whether the theoretical insights are real rather than simply mathematical artifacts, we conduct an experiment with two main purposes. First, we test our model's key insight of four qualitatively different utility functions (Theorem 2), with overall demand functions more complex than a simple downward-sloping curve (Corollary 1 and its implications). Second, we explicitly test our hypotheses and thus examine the nature of the individual differences across the four utility functions.

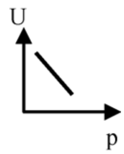
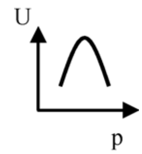
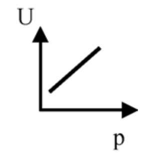
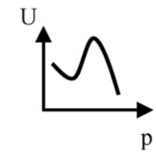
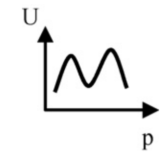
General design and procedure

We recruited subjects from among students of a major U.S. university. Fifty-nine students participated and received a $7 endowment (part of which they used to purchase food), as well as the food items they chose according to their stated preferences. The students were randomly assigned to a treatment group, one of which received no price–quality information and another that heard the statement, "The higher priced variety has better quality." The purpose of using these two treatments is to examine whether inferences of quality from price is embedded or must be prompted. We provide the complete experimental instructions in Appendix B.

Subjects considered six types of food: vegetable eggroll, hot and sour soup, egg drop soup, cheese pizza, veggie pizza, and pepperoni pizza. For each type of food, five varieties, whose only difference known to the subjects was price, were available. The eggrolls and soups were made for this experiment by a popular local Chinese restaurant; the pizzas were ordered from a single, local Pizza Hut restaurant with specific instructions regarding the different types. We used the same restaurant to produce each food in a given category to ensure that respondents could not use the store name as a quality cue. Each subject ranked his or her preference for the five varieties of each food type, as well as his or her preference for the option of not purchasing. (Appendix B contains the price variations for each food type.) Two of the lowest price variations are quite inexpensive but realistic for our subject pool, in that undergraduate students often find very low prices, such as 10¢ wings or 25¢ pizza slices. Furthermore, all subjects knew the identities of the restaurants that provided the food, which ensured they would consider the quality of the food at least acceptable to some consumers.

We designed a truth-telling procedure to elicit their preference rank order, which we call RASI (Random Allocation of Scarce Inventories). This RASI procedure allows each subject to receive any food choice offered according to his or her stated preference ranking, through a random drawing combined with limited availability of the food items of each variety. Thus, it is incentive compatible for subjects to think carefully about and provide their true preferences for each food type. The use of an incentive-compatible experimental procedure is critical, because recent literature on preference measurement methods demonstrates that subjects' stated preferences differ systematically from their revealed preferences and provide poor predictions of their actual behavior (Ding 2007; Ding et al. 2005, 2009). If we simply ask them to state their preference, without any consequences for their answers, the subjects likely will not think very carefully about their choices. Because inferring quality from

Table 4
Empirical preference types.

Empirical preference type	E1	E2	E3	E4	E5
Corresponding theoretical type	T1	T2	T2t	T3 and T4	Not predicted
Graphic representation					

price requires cognitive effort, respondents might not work to identify their exact preference order if there were no penalty for stating an inaccurate rank order.

Specifically, RASI involves three steps:

1. Provide a limited quantity (units) for each food item, such that the total number of units for all varieties equals the total number of subjects. For example, in the veggie eggroll category in a session with 30 subjects, we supply five units of each of the five eggroll options (e.g., 5 Type C eggrolls priced at \$0.75, 5 Type D eggrolls priced at \$1.20, and so on), plus five incidences of no purchase. Therefore, five subjects can purchase each of the five varieties of veggie eggrolls, and five subjects will not purchase any eggrolls, for a total of 30 subjects.
2. Randomly determine the order in which subjects' preferences are fulfilled. For a session with 30 subjects, put 30 pieces of paper, labeled 1–30, into an envelope. Each subject then randomly draws a piece of paper from the envelope and is assigned the specific number on that piece of paper as his or her selection rank.
3. Fulfill each subject's preference, starting with the subject assigned the lowest number (highest rank), until all subjects' preferences are fulfilled. Each subject receives his or her preferred item if it is available. Thus, we give each subject his or her most preferred item, unless that item has been taken already by previous (higher-ranked) subjects, in which case the subject receives his or her second most preferred item, unless it has been exhausted as well. We continue down the subject's preference order until we find an available item. To return to our veggie eggroll example, assume we are fulfilling the preferences of the subject who drew the 23rd rank. Because 22 subjects have already chosen, there must be eight items left in the veggie eggroll category. Suppose they are as follows: 1 A, 0 Bs, 0 Cs, 4 Ds, 2 Es, and 1 F, where F is the no-purchase option. Subject 23 expresses the following preference: C > B > A > E > D > F. Because we cannot fulfill the first (C) or second (B) preference, we move to the third preference (A) and fulfill it, then subtract 1 A from our inventory, which leaves 0 As. Following this step, subject 24 receives his or her most preferred option from among the remaining inventory of 0 As, 0 Bs, 0 Cs, 4 Ds, 2 Es, and 1 F. This process continues until we fill all 30 subjects' preferences

The implications of this design are that each subject may receive any item from any of the choice sets, but they are more likely to receive those items for which they indicate a higher preference. We explained both the process and its implications carefully to subjects, so they were motivated to tell the truth about their preference structure. The instructions for the procedure appear in Appendix B. After subjects received the food according to their preferences and the random draw, they also retained any cash that remained from their original endowment.

Measure

Our hypotheses suggest that a consumer's involvement with a particular product drives the various types of utility functions. To determine product involvement in an unobtrusive way, we asked respondents three relatively innocuous questions about each category to measure their involvement with it. These questions, which were the only ones we asked, followed in order: "Do you like the food?" "How much experience do you have with the food?" and "How important is the food to you?" These three questions capture the basic nature of involvement, attractiveness, experience, and importance relatively unobtrusively, which is important for a task in which each respondent considers six product categories. When we combine the three measures, the resulting involvement scale reaches a coefficient alpha of .92; the three measures behave similarly and should be combined in our measure.

Observed utility functions

Recall that there are five possible patterns of utility functions, which we examine empirically. We summarize in Table 4 the possible empirical observations of different shapes of preferences and their relationships with the theoretical types (T1–T4).

Type E1: Always prefers a lower price, everything else being equal, consistent with the classic utility function, or the T1 utility function predicted by the model.

Type E2: Prefers an interior price, such that the curve is first upward and then downward, equivalent to the T2 utility function.

Type E3: Always prefers a higher priced item, which is the T2t utility function, for which the price used is not high enough to capture the downward-sloping segment of the utility.

Table 5
Existence of different price preference types.

Empirical preference type	E1	E2	E3	E4	E5	Total
Veggie eggroll	19	31	4	3	2	59
Hotsour soup	34	16	6	1	1	58
Eggdrop soup	29	19	5	3	3	59
Cheese pizza	8	32	9	8	2	59
Veggie pizza	19	24	9	5	1	58
Pepperoni pizza	16	31	8	4	0	59
Total	125 (35.5 percent)	153 (43.5 percent)	41 (11.6 percent)	24 (6.8 percent)	9 (1.7 percent)	352

Type E4: Begins with a downward-sloping section, followed by an upward-sloping section, and then concluding with a downward-sloping section, which are the T3 and T4 utility functions predicted by the model.
Type E5: Has a more complicated preference structure not explained by the other types.

We summarize the prevalence of the various price preference patterns in Table 5.[10] In two cases, the subjects did not provide full rankings for a food item; as a result, we have 352 observations instead of the theoretical total of 354.

The results indicate that consumers have much more complicated utility functions than that assumed by standard economic theories. If we use veggie pizza as an example, only 19 (of 58) subjects' utilities decrease as the price of veggie pizza increases (E1). More commonly (24 of 58), their utilities first increase and then decrease (E2), and an additional nine subjects' utilities increase as the price increases over the entire range of price tested (E3). Thus, the subjects clearly treat the price as an indicator of quality. As predicted by theory, five subjects exhibit the more complicated, inverted-N utility function (E4).

At the aggregate level, our primary expectation receives support. Complicated price preference patterns (E2, E3, and E4) exist and are in the majority; together, they account for 218(=153 + 41 + 24) (62 percent) responses, whereas E1 represents only 125 (36 percent) responses. The difference is statistically significant ($Z = 6.90$, $p < .0001$). The E5 responses, which are not explained by our four types of utility functions, are rare; the percentages are not statistically significantly different from 0 in the experiment ($Z = .459$, NS). This strong evidence implies that participants were not responding randomly to the stimuli in the experiment, which provides important support for the existence of different types of utility functions.

Hypothesis tests

To test our hypotheses, we ran a one-way ANOVA with the utility function types that we have predicted (E1–E4) as the independent variables and the involvement scale as the dependent variable. The model is statistically significant ($F_{3,327} = 48.48$, $p < .0001$, $R^2 = .31$), which indicates that there are significant differences in the means across the different utility functions. In Table 6, we include the mean responses for all five utility function types; not all subjects provided responses to the three questions. Means with different superscripts are statistically significantly different at the .05 level.

The results support all three hypotheses. That is, subjects with E1 utility functions (downward sloping) rate their involvement as statistically significantly lower than subjects with the other three kinds of functions, in support of H1. Subjects with the E3 utility function (upward sloping) rate their involvement as statistically significantly higher than subjects in the other three types of functions, in support of H2. Finally, subjects with the E2 and E4 utility functions do not rate their involvement differently from each other and fall in the middle, between the E1 and E3 utility functions, in support of H3. These results therefore offer support for our claim of a trade-off between price as information and price as allocation or sacrifice. They also suggest that the classic economic model, with its downward-sloping demand curve, may be more applicable when subjects are not very interested in or inexperienced with the product category.

Aggregated demand functions for the six product categories

The key implication of the existence of these complicated utility functions is that they prompt different purchasing patterns (Corollary 1), which in turn create complex demand functions. We demonstrate this pattern using a simulation (Fig. 2); we now examine whether the data from this experiment support this implication. Because each subject is incentive-aligned to rank the six food options in the order of their preferences, we obtain the demand function by identifying the food varieties that each subject ranks above the no-purchase option, then sum these

Table 6
Least squares mean responses to involvement scale across utility function types.

Empirical preference type	E1	E2	E3	E4	E5[a]
Number of responses	119	147	41	24	9
Mean involvement[b]	6.50[A]	12.60[B]	14.68[C]	12.17[B]	11.00

[a] This utility function type was not predicted. In addition, its N is not statistically significantly different from 0. Hence, it is not included in the ANOVA.
[b] Means with different superscripts are statistically significantly different from each other at the $p < .05$ level.

[10] The results from the two treatment (cuing vs. non-cuing of the price–quality relationship) are surprisingly similar, and the difference is not statistically significant. We speculate that this behavioral interpretation of price information for quality is built into each consumer's preference and does not need to be externally prompted. We thus combine the subjects from the two treatments for this analysis.

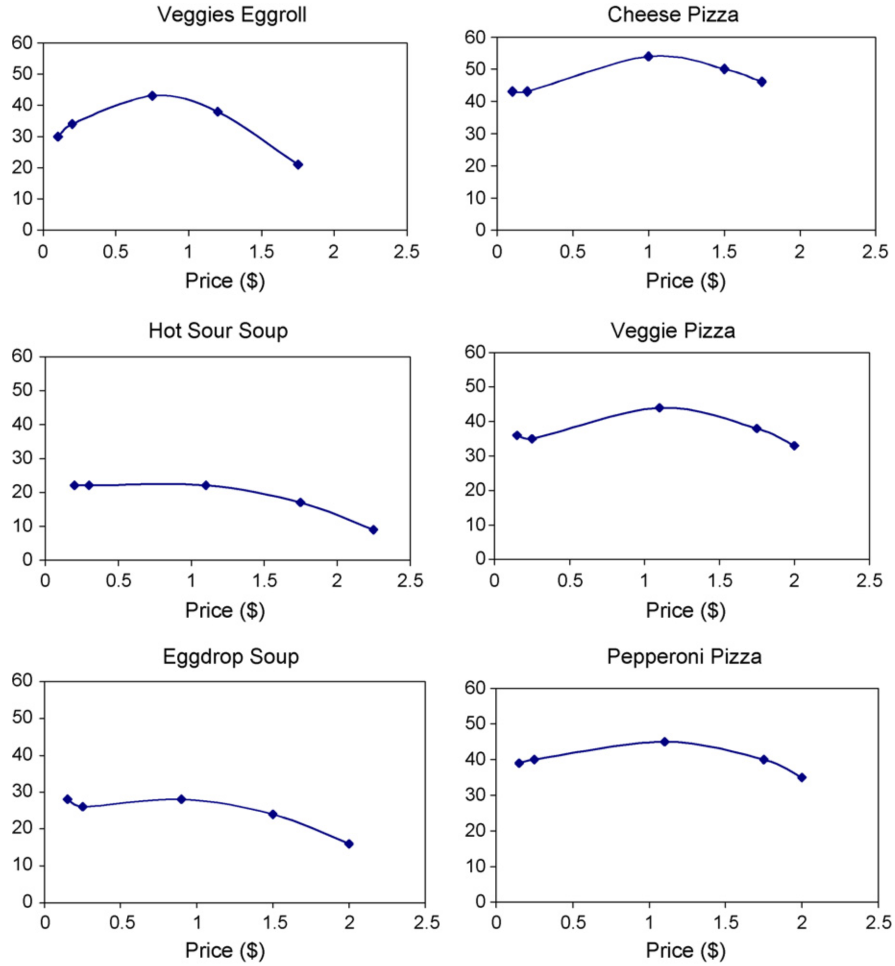


Fig. 3. Demand and price.

numbers for each food variety across all subjects. We report the results in Fig. 3.

None of the six food categories exhibits a standard downward-sloping demand curve. Veggie pizza, for example, exhibits an inverted-N demand curve, such that demand f is 36 at the lowest price point ($0.15), then decreases to 35 as the price increases to $0.25. However, demand jumps to 44 when the price increases further to $1.10, then gradually decreases to 38 and 33 as the price increases to $1.75 and $2.00, respectively. A manager or researcher who relied on the classic downward-sloping demand function would clearly have misjudged this market and obtained suboptimal results.

To provide a more concrete picture of how much money managers might be leaving on the table by ignoring the quality aspect of price, we calculate the revenue for each food category at each price level and plot them separately in Fig. 4. The difference in revenue is dramatic when the price takes different levels.

For example, veggie pizza earns the lowest revenue ($5) when priced at the lowest level ($0.15) and the highest revenue ($67) at the second highest level ($1.75). Furthermore, the price that generates the highest demand is not necessarily the price that generates the highest revenue (or, assuming the costs are similar, profit). For example, the price that generates the highest demand for veggie pizza is the third level ($1.10), but the price that generates the highest revenue is a more expensive version ($1.75), and even the highest price level ($2.00) leads to greater revenue than the $1.10 level, despite its much smaller demand. This observation confirms the intuition that the optimal pricing strategy does not always equate to demand maximization.

Summary and discussion

We propose a new, behavioral-based, analytical model that incorporates two well-accepted behavioral regularities into a classic utility function: Consumers infer quality from price and make judgments relative to a reference price. The resulting model yields some important results with regard to how a consumer's utility changes as price changes. Five different types of utility functions emerge empirically, one of which (T1) is the standard utility function and another (T2) that reflects the ideal point utility function. The other three utility functions (T2t, T3, and T4) are relatively new. A new incentive-compatible experimental procedure (RASI) tests the key model insights and examines what leads to these different utility functions. We find strong empirical evidence for the existence of all five types, though the standard utility function is a distinct minority. We also find evidence that there are very few (statistically equivalent to 0) other categories of utility functions, which supports the validity

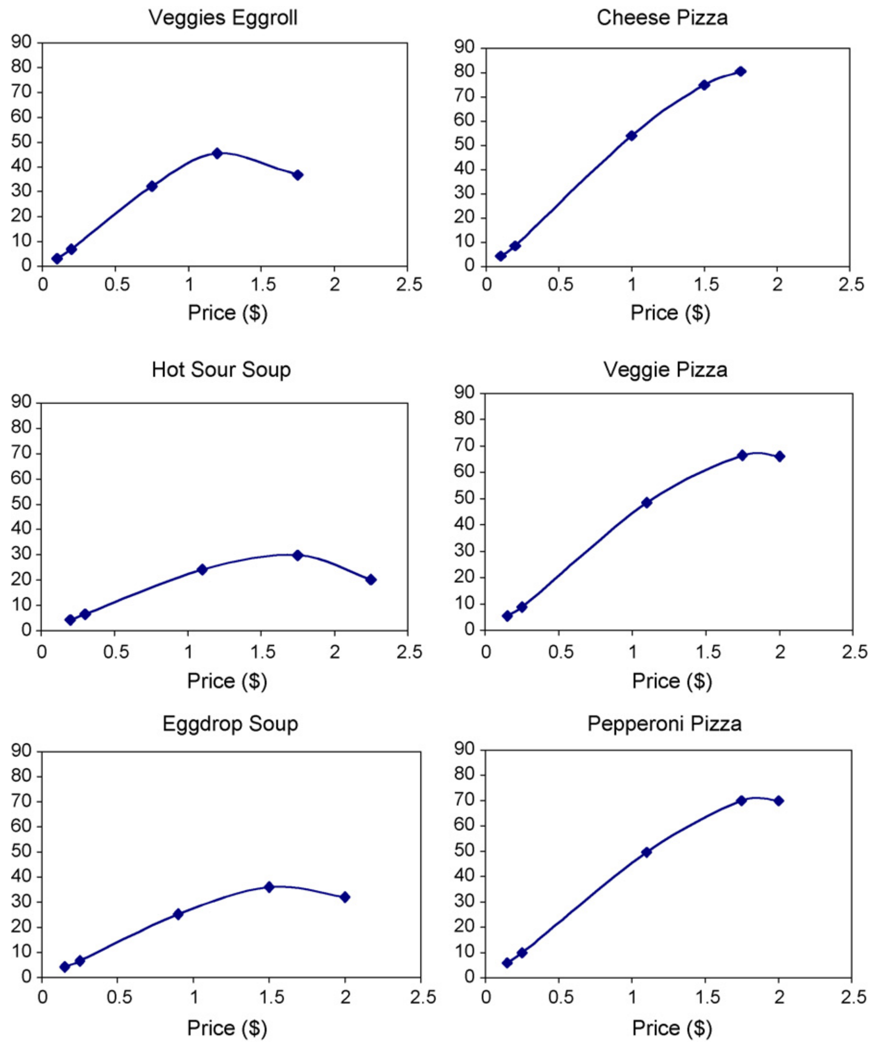


Fig. 4. Revenue and price.

of our model. Membership in categories is associated with the consumers' degree of involvement with that category, such that more involvement correlates with more attention to the information value of price and less attention to the sacrifice aspect of price. We also discover that the standard downward-sloping utility functions (T1) are associated with product categories that consumers find uninteresting. Finally, we document, in line with our predictions, much more complex demand functions than the simple downward-sloping function used so frequently in extant literature and practice.

We therefore speculate about the applicability of the downward-sloping demand curve. Classic economic theory is based on one or both of the following conditions: (1) There is no uncertainty about the quality of a product; (2) there is uncertainty about the quality of a product but consumers treat price differences as cheap talk (which they may be) and disregard the information they convey. Yet the conditions in which the downward-sloping demand curve offers a good approximation appear to represent relatively few product categories. Durable goods, such as televisions, are unlikely to reflect these conditions, and even in repeatedly purchased goods categories, such as detergent, subtle differences across brands can be hard to verify, such that quality uncertainty never gets completely removed from actual repeated usage. In extreme cases, consumers may remain skeptical about the quality of two otherwise identical products. In the pharmaceutical industry, for example, a branded drug and its generic equivalent are certified to be equivalent by the Food and Drug Administration, yet many consumers continue to believe there is a difference in quality. Not only is quality uncertainty (real or perceived) almost ubiquitous, but consumers also commonly correlate price with the inherent quality of a product. We speculate that this correlation may hint at a "false extrapolation." That is, a consumer may observe that prices in a product category for which he can verify quality after the purchase correlate positively with product quality. In his next purchase choice, this consumer applies the same correlation to other categories. Models such as ours offer more appropriate representations of consumer preferences and thereby add to understanding of consumer responses to pricing, as well as suggest better guidelines for firm pricing decisions.

This research represents a first step in integrating behavioral regularities into classic utility in the pricing domain, and we note several important future research directions. On the theoretical side, we provide a parsimonious, rigorous, informative model that analytical researchers might use to examine consumer responses to price in a more realistic and more complete fashion. This model also might be extended in three ways. First, additional behavioral regularities could be incorporated, such as a reflexive shape around the reference point (Kahneman and Tversky 1979). Second, alternative functional forms might test the robustness of our results from a different angle. We conjecture the results, however, should be similar to our findings, because our key insights (Theorem 2 and Corollary 1) receive strong support from the realistic experiment. Third, we study how consumers respond to price when there is no other information available (except those enough to construct the reference price); it would be interesting to consider the effect of dynamic competition in this context.

On the empirical side, though our experiments provide strong support for the existence of five types of utility functions, it would be beneficial to test the existence of these utility functions further, perhaps using secondary data. Existing literature captures heterogeneity by allowing for different price sensitivities; assuming a four- or five-segment market (in which each segment corresponds to one utility function shape) might further improve model fit and forecasting ability.

Acknowledgments

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Appendix A. Proofs for Theorems 1 and 2, Corollary 1

We first state and prove two lemmas, followed by proof for Theorems 1 and 2, and Corollary 1. For ease of exposition, we drop the subscript i (individual) and superscript j (product) in the proof.

Lemma 1. If we consider the utility function defined in Eq. (7), it can be shown that

if $\beta < 4/V$, there is no stationary point, and $\partial u/\partial p < 0$;
if $\beta = 4/V$, there is one stationary point, $p_1 = (\beta\gamma + \ln(\alpha))/\beta$, and $\partial u/\partial p \leq 0$;
if $\beta > 4/V$, there are two stationary points:

$$p_1 = \left(\frac{\beta\gamma - \ln((-2 + V\beta - \sqrt{V\beta(V\beta - 4)})/2\alpha)}{\beta}\right),$$

$$p_2 = \left(\frac{\beta\gamma - \ln((-2 + V\beta - \sqrt{V\beta(V\beta - 4)})/2\alpha)}{\beta}\right),$$

$\partial u/\partial p > 0$ when $p \in (p_2, p_1)$, and $\partial u/\partial p < 0$ when $p \in (0, p_2) \cup (p_1, \infty)$.

Proof.

$$\frac{\partial u}{\partial p} = \frac{\alpha\beta e^{-\beta(p-r)}}{(1 + \alpha e^{-\beta(p-r)})^2} V - 1.$$

FOC becomes:

$$\frac{\alpha\beta Y}{(1 + \alpha Y)^2} V - 1 = 0,$$

where $Y = e^{-\beta(p-\gamma)}$.

Solve for Y:

$$Y_1 = \frac{-2 + V\beta - \sqrt{V\beta(V\beta - 4)}}{2\alpha},$$

$$Y_2 = \frac{-2 + V\beta + \sqrt{V\beta(V\beta - 4)}}{2\alpha}.$$

Substituted back to the expression of Y, we obtain:

$$p_1 = \frac{\beta\gamma - \ln((-2 + V\beta - \sqrt{V\beta(V\beta - 4)})/2\alpha)}{\beta} \quad \text{and}$$

$$p_2 = \frac{\beta\gamma - \ln((-2 + V\beta + \sqrt{V\beta(V\beta - 4)})/2\alpha)}{\beta}.$$

For the solution(s) to exist, we need to have

$$V\beta(V\beta - 4) \geq 0 \quad \text{and} \quad \frac{-2 + V\beta - \sqrt{V\beta(V\beta - 4)}}{2\alpha} > 0.$$

Solve these two inequalities to obtain the following:

If $\beta < 4/V$, there is no feasible solution (stationary point), substitute the inequality back

$$\frac{\partial u}{\partial p} = \frac{V\alpha\beta e^{-\beta(p-r)} - (1 + \alpha e^{-\beta(p-r)})^2}{(1 + \alpha e^{-\beta(p-r)})^2}$$
$$< \frac{4\alpha e^{-\beta(p-r)} - (1 + \alpha e^{-\beta(p-r)})^2}{(1 + \alpha e^{-\beta(p-r)})^2}$$
$$= \frac{-(1 - \alpha e^{-\beta(p-r)})^2}{(1 + \alpha e^{-\beta(p-r)})^2} < 0.$$

If $\beta = 4/V$, there is one solution (stationary point), and $p_1 = p_2 = (\beta\gamma + \ln(\alpha))/\beta$, similarly substitute the inequality back, $\partial u/\partial p \leq 0$.
If $\beta > 4/V$, other solutions are feasible (two stationary points), and similarly substitute the inequality back, $\partial u/\partial p > 0$ when $p \in (p_2, p_1)$ and $\partial u/\partial p < 0$ when $p \in (0, p_2) \cup (p_1, \infty)$.□

Lemma 2. If we consider the utility function as defined in Eq. (7), it can be shown that

if $\alpha \leq e^{-\beta\gamma}$, then $\partial^2 u/\partial p^2 \leq 0$ for all $p^j \in [0, \infty)$ (concave for all feasible prices greater than 0);
if $\alpha > e^{-\beta\gamma}$, then $\partial^2 u/\partial p^2 > 0$ if $p \in [0, ((\ln\alpha + \beta\gamma)/\beta))$ (convex) and $\partial^2 u/\partial p^2 \leq 0$ if $p \in [((\ln\alpha + \beta\gamma)/\beta), \infty)$ (concave).

Proof. The SOC is

$$\frac{\partial^2 u}{\partial p^2} = \frac{V\alpha\beta^2 e^{-\beta(p-r)}(\alpha e^{-\beta(p-r)}-1)}{(1+\alpha e^{-\beta(p-r)})^3},$$

and we know $(1+\alpha e^{-\beta(p-r)})>0$ and $V\alpha\beta^2 e^{-\beta(p-r)}>0$.

Thus, the sign of SOC only depends on $(\alpha e^{-\beta(p-r)}-1)$.

It can be shown that

if $p<(\ln\alpha+\beta\gamma)/\beta$, then $(\alpha e^{-\beta(p-r)}-1)>0 \rightarrow \partial^2 u/\partial p^2>0$ (convex);
if $p>(\ln\alpha+\beta\gamma)/\beta$, then $(\alpha e^{-\beta(p-r)}-1)<0 \rightarrow \partial^2 u/\partial p^2<0$ (concave); and
if $p=(\ln\alpha+\beta\gamma)/\beta$, then $(\alpha e^{-\beta(p-r)}-1)=0 \rightarrow \partial^2 u/\partial p^2=0$ (monotonic).

The monotonic situation can be absorbed in the concave or convex condition and will not be discussed independently.

Note that if $(\ln\alpha+\beta\gamma)/\beta\leq 0$, the price will always be higher than the threshold, and the function will be concave for any price (larger than 0); thus, Lemma 2 holds.□

Proof of Theorem 1. Based on Lemmas 1 and 2, we can construct six cases (3 from Lemma 1 × 2 from Lemma 2) to facilitate the identification of the utility-maximizing price. We discuss each case in detail and demonstrate how various optimal prices are obtained:

If $\beta\leq 4/V$, according to Lemma 1, $\partial u/\partial p\leq 0$. Thus, the optimal price is $p^*=0$.
If $\beta>4/V$ and $\alpha\leq e^{-\beta\gamma}$, then the utility function has two extreme points and is concave $\partial^2 u/\partial p^2\leq 0$ for all $p\in[0,\infty)$ (concave for all feasible p that is greater than 0).

In this case, it is straightforward that $p^*=p_1$ only when $p_1>0$. Because

$$p_1 = \frac{\beta\gamma - \ln((-2+V\beta-\sqrt{V\beta(V\beta-4)})/2\alpha)}{\beta}$$

the condition is simply

$$\beta\gamma - \ln\left(\frac{-2+V\beta-\sqrt{V\beta(V\beta-4)}}{2\alpha}\right) > 0 \Leftrightarrow \alpha > \frac{-2+V\beta-\sqrt{V\beta(V\beta-4)}}{2}e^{-\beta\gamma}$$

and it can be shown that

$$\frac{-2+V\beta-\sqrt{V\beta(V\beta-4)}}{2}e^{-\beta\gamma} < e^{-\beta\gamma}.$$

As a result,

If $\beta>4/V$ and $\alpha\leq((-2+V\beta-\sqrt{V\beta(V\beta-4)})/2)e^{-\beta\gamma}$, then $p^*=0$.
If $\beta>4/V$ and $((-2+V\beta-\sqrt{V\beta(V\beta-4)})/2)e^{-\beta\gamma}<\alpha\leq e^{-\beta\gamma}$, then $p^*=p_1$.
If $\beta>4/V$ and $\alpha>e^{-\beta\gamma}$, then the utility function has two extreme points and $\partial^2 u/\partial p^2>0$ if $p\in[0,(\ln\alpha+\beta\gamma)/\beta)$ (convex) and $\partial^2 u/\partial p^2\leq 0$ if $p\in[((\ln\alpha+\beta\gamma)/\beta),\infty)$ (concave).

In this case, we must compare the utilities at $p=0$ and p_1. Since $p_1>0$ in this condition, it is straightforward that

$$p^* = p_1 \quad \text{if } u(p=0) < u(p=p_1) \text{ and}$$
$$p^* = 0 \quad \text{if } u(p=0) \geq u(p=p_1).$$

Substitute into the utility function and we obtain

$$u(p=0) = \frac{1}{1+\alpha e^{\beta r}}V$$

$$u(p=p_1) = \frac{V\beta-2\beta\gamma+\sqrt{V\beta(V\beta-4)}+2\ln((-2+V\beta-\sqrt{V\beta(V\beta-4)})/2\alpha)}{2\beta},$$

with $\Delta=u(p=0)-u(p=p_1)$ and

$$\frac{\partial\Delta}{\partial\alpha} = \frac{2\alpha e^{\beta\gamma} - V\alpha\beta e^{\beta\gamma} + \alpha^2 e^{2\beta\gamma}+1}{\alpha\beta+2\alpha^2\beta e^{\beta\gamma}+\alpha^3\beta e^{2\beta\gamma}}.$$

It can be shown that

$$\frac{\partial\Delta}{\partial\alpha} > 0 \quad \text{when } \alpha\in(0,\alpha_1)\cup(\alpha_2,\infty) \text{ and}$$
$$\frac{\partial\Delta}{\partial\alpha} < 0 \quad \text{when } \alpha\in(\alpha_1,\alpha_2),$$

where

$$\alpha_1 = \frac{-2+V\beta-\sqrt{V\beta(V\beta-4)}}{2}e^{-\beta\gamma} \quad \text{and}$$
$$\alpha_2 = \frac{-2+V\beta+\sqrt{V\beta(V\beta-4)}}{2}e^{-\beta\gamma}.$$

Again, it can be shown that

$$\alpha_1 = \frac{-2+V\beta-\sqrt{V\beta(V\beta-4)}}{2}e^{-\beta\gamma} < e^{-\beta\gamma} < \frac{-2+V\beta+\sqrt{V\beta(V\beta-4)}}{2}e^{-\beta\gamma} = \alpha_2.$$

Given the behavior of $\partial\Delta/\partial\alpha$, we know that Δ will decrease between $e^{-\beta\gamma}$ and α_2 and increase after α_2. Therefore, Δ is positive for any α greater than a certain threshold, α_3, where $\alpha_3>\alpha_2$.

It is straightforward to examine the behavior of the nonzero optimal price as a function of other variables:

$$\frac{\partial p^*}{\partial\gamma} = 1 > 0 \quad \text{and} \quad \frac{\partial p^*}{\partial\alpha} = \frac{1}{\alpha\beta} > 0,$$

$$\frac{\partial p^*}{\partial\beta} = \frac{1}{\beta^2\sqrt{V\beta(V\beta-4)}}\left(V\beta+\sqrt{V\beta(V\beta-4)}\ln\frac{-2+V\beta-\sqrt{V\beta(V\beta-4)}}{2\alpha}\right).$$

To find the sign, we must check the sign for

$$V\beta+\sqrt{V\beta(V\beta-4)}\ln\frac{-2+V\beta-\sqrt{V\beta(V\beta-4)}}{2\alpha}.$$

Solve it for α and we obtain

$$\frac{\partial p^*}{\partial\beta} > 0 \text{ if } \alpha<\alpha'; \quad \frac{\partial p^*}{\partial\beta} < 0 \text{ if } \alpha>\alpha'; \quad \frac{\partial p^*}{\partial\beta} = 0 \text{ if } \alpha=\alpha',$$

where

$$\alpha' = \frac{-2+V\beta-\sqrt{V\beta(V\beta-4)}}{2}e^{V\beta/\sqrt{V\beta(V\beta-4)}},$$

$$\frac{\partial p^*}{\partial V} = \frac{1}{4}\left(\frac{-2+V\beta-\sqrt{V\beta(V\beta-4)}}{\sqrt{V\beta(V\beta-4)}}\right) \times (V\beta+\sqrt{V\beta(V\beta-4)}-2) > 0. \quad \square$$

Proof of Theorem 2. This table follows from Lemmas 1 and 2 and the intermediate results for deducing Theorem 1. Each row represents a specific shape of the utility–price curve for all prices greater than 0.

Proof of Corollary 1. The various outcomes in each row are obtained by moving the x-axis along the y-axis and examining the regions that are either higher or lower than the 0 utility.

Appendix B. Experimental instrument

This appendix contains the instructions for the experiment. Complete instructions are attached below for treatment 2 (sensitized). The instrument for treatment 1 is exactly the same except we omit the bolded sentence "The higher priced variety has better quality" in the instrument.

General instructions

This is a marketing experiment designed to understand consumers' purchasing behavior. In this experiment, you will be given \$7 to purchase one veggie eggroll, one pint of soup (either hot and sour soup or eggdrop soup), and one slice of pizza (cheese, or veggie, or pepperoni pizza). There are five different varieties in each food type (e.g., eggdrop soup), and you need to tell us your exact preference of these varieties within each food type. At the end of the experiment, you will receive food based on your stated preference, availability of the food, and a random mechanism (see *how do we determine which type of food you will receive*?), plus any cash balance left. The experiment is designed such that it is in your best interest to tell us your true preference. *How will you get paid* (*cash and food*)?

- If the outcome (see next section on *how do we determine which type of food you will receive*?) is to purchase no food for all types (eggroll, soup, and pizza), you will receive \$7.
- In all other cases, you will receive the \$7 cash minus the cost of the food, plus, of course, the food you have selected.
    - For example, if you receive one veggie eggroll at \$0.75, no soup, and one slice of cheese pizza at \$0.50, you will receive \$5.75 (7.00–0.75–0.50) in addition to the veggie eggroll and cheese pizza.

How do we determine which type of food you will receive?

Once we have received your response, we will try to fulfill your desire based on your stated preference order, availability of the food, and a random mechanism.

Food availability

Assuming there is a total of 72 subjects. One possible scenario could be:.

Veggie eggroll:	12 for each of 5 varieties, plus 12 no purchase (total 72)
Hot and sour soup:	6 pints for each of 5 varieties, plus 6 no purchase (total 36)
Eggdrop soup:	6 pints for each of 5 varieties, plus 6 no purchase (total 36)
Cheese pizza:	4 slices for each of 5 varieties, plus 4 no purchase (total 24)
Veggie pizza:	4 slices for each of 5 varieties, plus 4 no purchase (total 24)
Pepperoni pizza:	4 slices for each of 5 varieties, plus 4 no purchase (total 24)

Random mechanism

There are two random events in the experiment. First, we randomly decide whose demand will be fulfilled first. Second, we randomly decide, for each subject, what type of soup and what type of pizza s/he will receive. Assuming we have 72 subjects in the experiment. The first random mechanism is achieved by using an envelope that contains 72 pieces of paper (labeled from 1 to 72). For each subject, we will randomly draw a piece of paper from the envelope. The number on the paper will then be assigned to the subject. Please note the paper, once drawn, will not be put back into the envelope and everybody will get a unique number between 1 and 72. The second random mechanism is achieved similarly. We will have two pieces of paper labeled Hot Sour Soup and Eggdrop Soup, and we will randomly select a piece of paper for a subject to determine the type of soup to offer. For Pizza, we have three pieces of paper (Cheese, Veggie, and Pepperoni) and one will be randomly selected for each subject.

Fulfillment

We will determine what kind of food a subject will receive by fulfilling the preferences of subjects one at a time, starting with the subject with the smallest number (1), then 2, until we fulfill all subjects (72). For each subject, we will fulfill his/her preference subject to the availability of the preferred items at the time. In other words, we will try to give each subject his/her most preferred item unless all have been taken by subjects ranked higher (smaller number), in which case we will try to give him/her his/her second most preferred item unless it has also been exhausted. We will go down his/her preference order until we find an item for this subject.

An example for eggroll

Let's look at one example. Suppose we are in the process of fulfilling subject #61's desire after fulfilling subjects #1-60's desire. Out second random mechanism has decided that #61 will receive Veggie eggroll, Eggdrop Soup, and Cheese pizza. There are 12 items left for the veggie eggroll—1 A, 0 B, 0 C, 5 Ds, 4 Es, and 2 Fs, and suppose subject #61 has the following preference for the veggie eggroll: C > B > A > E > D > F. We will first try to fulfill his first preference, C, but we cannot as it is no longer available. We will then try to fulfill his second preference, B, but again it is no longer available. So we moved to the third preference A, and we could fulfill it as we still have 1 A left. As the result, subject #61 will receive A. Furthermore, the items that will be available to the next subject (#62) are 0 A, 0 B, 0 C, 5 Ds, 4 Es, and 2 Fs. Subject #61's Eggdrop Soup and Cheese Pizza will be determined in the same manner. We move to fulfill subject #62's desire after we finish with #61. This process continues until all 72 subjects' desires have been fulfilled. *Now please tell us your preferences for the food*:

We will show you THREE types of Chinese foods and THREE types of pizza in this survey, with SIX different choices within each type (labeled A, B, C, D, E, and F) that you can make. The higher priced variety has better quality.

Subjects then complete the ranking for six types of food, and respond to the three questions (like experience, and importance) for each type of food.

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