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CONSUMER BEHAVIOR AND BELATED INFORMATION: THE CASE OF UNCERTAIN TASTES

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ABSTRACT

This paper analyzes optimal search and consumption strategies for consumers with respect to goods for which *tastes* are unknown prior to actual consumption of the good. The form of an optimal strategy is characterized and certain comparative statics results derived. Of particular interest is the possibility that an increase in search costs might actually increase pre-initial purchase search.

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1. INTRODUCTION

The notion that consumer behavior varies systematically across markets as a function of the informational characteristics of goods has a long history. Melvin Copeland, writing in the Harvard Business Review in 1923, divided goods into three classes, shopping goods, convenience goods and specialty goods.[1] The first contemporary economist to exploit the implications of informational differences between goods was Nelson (1970). Nelson drew a distinction between goods for which the consumer can judge the potential stream of utility yielded by purchasing and consuming the good prior to actual consumption (search goods) and those goods for which such judgments require actual consumption (experience goods). A third class of goods was added to these two by Darby and Karni (1973). They defined a credence good as one for which the stream of utility associated with purchase and consumption cannot be known with certainty even after the good has been consumed. Many "services" such as those provided by doctors or mechanics are said to fall in this category. Prescription drugs, perhaps, do also.

The original papers analyzing the implications of the distinction between search, experience and credence goods relied on relatively simple models and focused on market structure effects. In a later paper, Nelson (1974) also used his categorization to develop a theory of advertising. Somewhat more sophisticated models of consumer behavior related to search and experience goods can be found in Wilde (1980, 1981), Hey and McKenna (1981) and Lippman and McCall (1981).

The purpose of this paper is to introduce yet another class of goods, to analyze consumer behavior with respect to these goods, and thus highlight the importance of distinguishing between them and search, experience or credence goods. For want of a letter name, I will call the new class innovative goods. The essential feature of an innovative good is that the consumer does not know his or her own tastes with respect to the good before consuming it. "Quality" (that is, unobservable nonprice attributes) may or may not be observable before purchase and consumption. Once the good has been consumed, quality may still be an issue, but generally there will be no question about tastes. Thus innovative goods may have search, experience or credence features; i.e., this new class of goods is distinct from those identified to date in the economics literature since all presume tastes are known, but it is more in the nature of a generalization of existing classes than an "intermediate" subset.

The class of innovative goods is extremely broad and important. Consider, for example, motorcycles. Most people don't really know if they will like riding motorcycles before they purchase their first one. After doing so, one of two events typically occurs, either the consumer is scared witless and sells the motorcycle immediately or he or she falls in love with motorcycles and buys a bigger one at the first opportunity. Backpacking gear is another example. Outdoor equipment stores usually have noteboards covered with private ads listing both new and used equipment for sale. The new items are typically advertised by people who have discovered they hate staggering around the hills in heavy boots with everything they need to survive for a week strapped to their back, the used items are typically advertised by people who love doing this and desire to "upgrade" their gear. Other examples are musical instruments, ski gear and, perhaps, the services of psychologists.

The unique feature of an innovative good is that available sources of information about it (e.g., word of mouth, consumer magazines, advertising, or even personal introspection) are inadequate to eliminate a consumer's uncertainty about the degree to which he or she will want to continue consuming the good after an initial trial. To some degree this problem exists for any good which is unfamiliar to a consumer. In particular, new products will generally qualify as innovative goods since by definition no consumer has ever had any experience with them.[2] For new products, the source of information most consumers use for reducing uncertainty about their potential preferences for untried products, recommendations by acquaintances

with similar tastes to their own on related products, is unavailable.

The point of this discussion is that innovative goods constitute a large and significant class. Furthermore, they come in two types; goods which already exist but may be new to individual consumers, and goods which are new to all consumers. While the analysis of both is of interest to economists because of its implications for market structure, advertising, and the like, it should also be of interest to marketing specialists since their primary concerns include designing strategies for attracting new customers, both to existing products and new products. The formal model developed in this paper will focus on an individual consumer so the distinction between products which are new to all consumers and those which are new to an individual consumer will not matter in what follows. However, the implications of the model may be sensitive to this distinction so it is important to be aware of it.

The simplest model possible which captures the essence of innovative goods is one in which there is no quality variation — goods are homogeneous. Thus, as a first step, this paper will consider innovative "search" goods. Given a nondegenerate distribution of prices, positive search costs, and a discount factor strictly less than one, the consumer faces two interconnected problems; (1) how much should he or she search prior to buying a good, consuming it and thus discovering his or her true tastes, and (2) once tastes are known, should he or she stop consuming the good altogether, continue to repurchase the good consumed on the initial trial, or search more for a lower price? Once nonprice attributes are introduced, there is an additional problem of determining desired quality.[3]

However, as already noted, this paper will ignore the quality issue. Section 2 will set up the formal model when goods are homogeneous. Section 3 will analyze the model under the assumption that the consumer's tastes are such that he or she will never desire to stop consuming the good altogether once his or her tastes are known. This simple case illustrates well the striking difference between innovative goods and existing categorizations of goods based on their informational properties. When the consumer's uncertain tastes are such that he or she will always want to continue consuming the good once those tastes are known, it will be shown that the optimal search and consumption strategy is based on a scalar, p^*, and a function, $r(x)$, where x is a measure of tastes, such that the consumer will search prior to observing the true value of the taste parameter until a price less than or equal to p^* is observed. Once such a price is found, the good will be purchased at that price, consumed, and the true value of x observed. At this point the consumer will renew search if x turns out to be less than or equal to $r(x)$, seeking only a lower price since goods are homogeneous. Otherwise he or she will continue to purchase the initially consumed good. While it will always be the case that $r(x)$ increases when search costs increase, the striking result derived in Section 3 is that the sign of dp^*/dc is ambiguous. In other words, an increase in

search costs will always make the consumer <u>less</u> likely to renew search (and <u>less</u> likely to hold out for a low price if search is renewed) once tastes are known, but one cannot rule out the possibility of <u>more</u> search prior to the initial purchase of the good. This is an unintuitive result, and one which never occurs for search/experience goods (Wilde, 1980, Section 4). In fact, it appears that no other existing search model yields such a possibility.

Section 4 will add the possibility that the consumer may wish to cease consuming the good once his or her tastes are known. This additional option will not significantly effect the qualitative features of the simpler model considered in Section 3. In particular, the possibility that an increase in search costs will increase search prior to initial purchase will still exist. However, Section 4 does show that an increase in the value of the no-consumption option will increase p^*, implying that pre-initial purchase search falls. In other words, the larger is the difference between the expected utility of consuming the innovative good and not consuming it, the more intense is price search.

Section 5 will conclude the paper by discussing the implications of the analysis and the effects of modifying various assumptions. It will also outline a strategy for future research.

2. THE GENERAL MODEL FOR INNOVATIVE SEARCH GOODS.

The formal model of optimal consumer behavior with respect to innovative goods developed in this section is structurally similar to the analysis of search/experience goods developed in Wilde (1980). Suppose initially that goods last for one period. Ultimately one would like to allow for variable durability in order to investigate the sensitivity of the consumer's optimal strategy to increases in the lifetime of the good (Wilde, 1980, Section 5), but a one-period model simplifies the analysis since there is no issue of disposal value in cases where the consumer desires not to continue consumption once tastes are known.[4] Let the distribution of prices be F(p) where $f(p) = F'(p)$ is the density function associated with F.

Assumption 1: $f(p) > 0$ for all $p \geq 0$.

Assumption 1 is made without loss of generality. Undoubtedly prices are bounded below 0 and cannot be arbitrarily large, but assuming such only introduces excess notation and specious realism.

Regarding preferences, let the consumer have an indirect utility function over price which is parameterized by some taste parameter x. That is, preferences are summarized by $V(p;x)$ where the following holds.

Assumption 2: For all $p \geq 0$ and all x:

(i) $\partial V/\partial p \equiv V_p < 0$,

(ii) $\partial V/\partial x \equiv V_x > 0$,

(iii) $\partial^2 V/\partial p \partial x \equiv V_{px} = V_{xp} = \partial^2 V/\partial x \partial p > 0$.

Indirect utility is decreasing in price and increasing in the taste parameter. The crucial, and strongest assumption is that the cross partial of the indirect utility function with respect to these two

variables is positive. This means that a higher value of the taste parameter decreases the marginal disutility of paying higher prices. In other words, the taste parameter, in some sense, measures the intensity of the consumer's preference for the good — the more the consumer prefers the good, the less he or she is concerned with marginal increases in the price of the good (for any given price). The implications of assuming this cross partial is negative will be discussed in Section 5.

Let the distribution of the taste parameter be G(x) where $g(x) = G'(x)$ is its associated density function.

Assumption 3: $g(x) > 0$ for all $x \in \mathbb{R}$.

Assumption 3 can easily be relaxed. Again, like Assumption 1, it is made primarily for analytical and notational convenience.

Assumption 4: The cost of observing prices is a constant, c, measured in the same units as V, where $c \geq 0$. Price observations are independent draws from F.

Assumption 5: Search activity is timeless. The discount rate on consumption is β, where $0 < \beta < 1$. The horizen is infinite.

Assumption 4 is standard. Assumption 5 is strong but important for conceptual reasons as well as analytical tractability. There are two kinds of costs associated with consuming a good when tastes are uncertain; the first is the opportunity cost of consuming a good when tastes are potentially of low intensity, thus foregoing alternative uses of income. The second is the postponement of the latter into the future (in this model, one period). Search is herein assumed to be timeless — as many observations of price as the consumer desires can be obtained (at cost c per observation) at the beginning of any period (see footnote 4 and text supra; Wilde, 1980, p. 1267) — in order to avoid confounding these two effects. As a formal matter, this assumption could easily be relaxed.[5]

Assumption 6: The utility to the consumer of not consuming the good at all is U per period.

If the expected discounted utility of an optimal search and consumption strategy is less than $U/(1-\beta)$, the consumer will never buy the good at all. If the good is purchased, the consumer will subsequently compare, once his or her tastes are known, the discounted utility of repurchasing the good at the original price forever with the expected discounted utility of renewing search or the utility of discontinuing consumption (the latter yielding U per period). Let the expected discounted utility of an optimal search strategy once tastes are known be denoted W(x). Let the expected discounted utility of an optimal search and consumption strategy, prior to observing tastes, given a current observation of price p be denoted z(p), and let the expected value of z(p) with respect to the price distribution F be denoted Z. Then

$$z(p) - c + \max\{Z, B(p)\}, \tag{1}$$

where B(p) is the expected discounted utility of buying the good at price p and proceeding optimally thereafter.[6] Under Assumptions 1-6, B(p) is defined by

$$B(p) = \int_{-\infty}^{\infty} V(p;x)dG(x) + \beta E_x \max\{U/(1-\beta),\ W(x), V(p;x)/(1-\beta)\}. \tag{2}$$

The logic of (2) is as follows. The cost of observing p is c (measured in "utils"). If the consumer buys the good at price p, the expected value of V(p,x) with respect to x is received in the current period (recall search is assumed to be timeless). At the beginning of the next period the consumer has three options; cease consumption and receive $U/(1-\beta)$, renew search and receive W(x), or repurchase the good at price p forever and receive $V(p;x)/(1-\beta)$. The latter two options are evaluated as expectations over x, however, at least as viewed before any consumption has taken place, since tastes are not known ex ante.[7]

Equations (1) and (2) define the basic functional equation for consumer behavior with respect to innovative goods. This functional equation is structurally similar to the one associated with a generalized search/experience goods model (see Wilde, 1980, equations (3) and (8), pages 1269-70), but, as will become evident below, it has quite different properties.

3. THE MODEL WHEN CONTINUED CONSUMPTION IS CERTAIN; $W(x) \geq U/(1-\beta)$ FOR ALL x

This section analyzes the model developed in Section 2 when the consumer's utility function is such that consumption of the good ultimately is never an issue; i.e., under the following assumption.

<u>Assumption 7</u>: $W(x) \geq U/(1-\beta)$ for all x.

Assumption 7 rules out the option of no repurchase after observing the taste parameter — all values of x yield an expected discounted utility of renewed search which exceeds the utility of not consuming the good at all. This assumption will be relaxed in Section 4. For now, however, it implies that once tastes are known the consumer's decision reduces to comparing $W(x)$ to $V(p;x)/(1-\beta)$, where p is the price paid for the initially purchased good.[8]

3a: <u>The Search-Again Versus Repurchase Decision</u>

Suppose the consumer has made an initial purchase at price p and observed a taste parameter of x. Define

$$R(p) = \{x \mid V(p;x)/(1-\beta) \geq W(x)\} \tag{3}$$

and

$$S(p) = \{x \mid V(p;x)/(1-\beta) < W(x)\}.^{9} \tag{4}$$

The set $R(p)$ gives all values of x for which repurchase is optimal given p; $S(p)$ gives all values of x for which renewed search is optimal given p. Clearly these sets are disjoint and exhaust all

possible values of x. Using these definitions (and Assumption 7), equation (2) can be written as

$$B(p) = \int_{-\infty}^{\infty} V(p;x)dG(x) + \beta\{\int_{R(p)} [V(p;x)/(1-\beta)]dG(x) + \int_{S(p)} W(x)dG(x)\}. \tag{5}$$

In order to analyze the basic functional equation (1), using (5) instead of (2), it is first necessary to characterize $R(p)$ and $S(p)$. With this in mind, consider $W(x)$.

Let $W(p;x)$ be the expected discounted utility of an optimal search strategy when the taste parameter is known to be x, given a current price observation of p. Then

$$W(p;x) = -c + \max\{W(x), V(p;x)/(1-\beta)\}. \tag{6}$$

Once again, (6) incorporates the notion that search is timeless.[10]

By definition, $W(x)$ is the expected discounted utility of an optimal search strategy once tastes are known to be x. Hence,

$$W(x) \equiv \int_{0}^{\infty} W(p;x)dF(p). \tag{7}$$

But, following the logic of the basic search model for homogeneous goods, one can define $r(x)$ via

$$W(x) \equiv V[r(x);x]/(1-\beta). \tag{8}$$

Since $W(x)$ is independent of p and $V_p < 0$, the definition of $r(x)$ given in (8) implies

$$W(p;x) = \begin{cases} -c + [V(p;x)/(1-\beta)] & \text{if } p \leq r(x) \\ -c + W(x) & \text{if } p > r(x).^{11} \end{cases} \qquad (9)$$

Taking the expectation of (6) with respect to F, using (9), gives

$$W(x) = -c + \int_0^{r(x)} [V(p;x)/(1-\beta)]dF(p) + \int_{r(x)}^{\infty} W(x)dF(p). \qquad (10)$$

Equations (8) and (10) together imply r(x) is defined by

$$c(1-\beta) = \int_0^{r(x)} \{V(p;x) - V[r(x);x]\}dF(p). \qquad (11)$$

Equation (11) is the standard rule for defining a reservation price when indirect utility is nonlinear in price, search is timeless, and the future utility of consumption is discounted at rate β over an infinite horizen.

Lemma 1: Assumptions 1-7 imply that the unique optimal ex post search strategy is characterized by a reservation price, r(x), such that W(p,x) is given by (9), where r(x) is defined by (11). Moreover, $dr(x)/dx > 0$ and $r(x) > 0$ iff $c > 0$ and x is finite, and $r(x) = 0$ iff $c = 0$.

Proof: That r(x) is uniquely defined by (11) is trivial, (9) holds by definition, and differentiating (11) totally with respect to r and x gives

$$0 = \int_0^{r(x)} \{V_x(p;x) - V_x[r(x);x]\}dF(p) \cdot dx - \int_0^{r(x)} V_p[r(x);x]dF(p) \cdot dr.$$

Hence

$$\frac{dr(x)}{dx} = \int_0^{r(x)} \{V_x(p;x) - V_x[r(x);x]\}dF(p) / \int_0^{r(x)} V_p[r(x);x]dF(p). \qquad (12)$$

Assumption 2 implies $V_x(p;x) - V_x[r(x);x] < 0$ for $p < r(x) < \infty$ and $V_p[r(x);x] < 0$. Clearly, (11) implies $r(x) > 0$ iff $c > 0$ and $r(x) = 0$ iff $c = 0$. Hence $dr(x)/dx > 0$ iff $c > 0$. Q.E.D.

Clearly the crucial assumption in Lemma 1 is $V_{xp} > 0$. If $V_{xp} < 0$ then $dr(x)/dx < 0$ for $c > 0$. The model has been developed assuming $V_{xp} > 0$ since this implies that an increase in the intensity of tastes (as measured by x) is associated with a higher reservation price; i.e., the consumer is willing to pay higher prices for the good when the taste parameter increases, a result which accords nicely with the interpretation of x as a measure of the "intensity" of preferences. Figure 1 illustrates r(x) as a function of x.

In order to characterize R(p) and S(p), define h(x;p) as

$$h(x;p) = [V(p;x)/(1-\beta)] - W(x). \qquad (13)$$

Then (3) and (4) become

$$R(p) = \{x | h(x;p) \geq 0\} \qquad (14)$$

and

$$S(p) = \{x | h(x;p) < 0\}. \qquad (15)$$

From (8), however, (13) can be written as

$$h(x;p) = \{V(p;x) - V[r(x),x]\}/(1 - \beta). \quad (16)$$

The repurchase and search sets, R(p) and S(p) respectively, will have a structure which depends on the "zeros" of h. To analyze these points it is necessary to establish properties of h, a process which requires the following assumption and lemma.

Assumption 8: $\lim_{x \to \infty} V_{xp}(p,x) > 0$ for all $p \geq 0$.

Lemma 2: Given Assumptions 1-5 and 8,

(i) $r^{-1}(p)$ exists for all $p > \bar{p}$,

(ii) $dr^{-1}(p)/dp > 0$ for all $p > \bar{p}$,

(iii) $\partial h(x,p)/\partial p < 0$ for all x and $p > \bar{p}$,

where $\bar{p}$ is given by $\bar{p} = \lim_{x \to \infty} r(x)$.

Proof: Suppose r(x) is finite as $x \to \infty$. Then from (12),

$$\lim_{x \to \infty} \frac{dr(x)}{dx} = 0 \text{ if and only if } \int_0^{r(\infty)} \{V_x(p,\infty) - V_x[r(\infty),\infty]\} dF(p) = 0,$$

where $r(\infty) = \lim_{x \to \infty} r(x)$ is finite and $V_x(1,\infty) = \lim_{x \to \infty} V_x(1,x)$ for any $q \geq 0$. Since r(x) is finite, however, this means

$$\lim_{x \to \infty} \frac{dr(x)}{dx} = 0 \text{ if and only if } \lim_{x \to \infty} V_{xp}(p,x) = 0,$$

a contradiction to Assumption 8. Hence since $dr(x)/dx > 0$ for all $x < \infty$,

$$\lim_{x \to \infty} r(x) = \infty.$$

Thus $r^{-1}(p)$ exists for all $p > \bar{p}$, $dr^{-1}(p)/dp > 0$ since $dr(x)/d(x) > 0$, and $\partial h(x,p)/\partial p < 0$ for all x and all $p > \bar{p}$ from (16). Q.E.D.

Assumption 8 is really a technical convenience. If it does not hold, r(x) may converge to some finite value, say $\bar{r}(x)$, as x goes to infinity. In this case $r^{-1}(p)$ is only well-defined for $\bar{p} < p < \bar{r}(x)$ and one must constantly allow for this in the formal analysis of the optimal search and consumption strategy. No analogue to Assumption 8 can eliminate this problem for low prices however unless c = 0, in which case r(x) = 0 for all x. To ease the notational burden, it is therefore useful to define $r^{-1}(p) = -\infty$ for $p \leq \bar{p}$.

Theorem 1: Given Assumptions 1-5 and 8,

$$S(p) = (-\infty, r^{-1}(p)],$$

where r(x) is uniquely defined for all x by (11).

Proof: It is clear from (16) that $x = r^{-1}(p)$ solves $h(x;p) = 0$ when $r^{-1}(p)$ exists. This is the case for $p > \bar{p}$ (see Figure 1). If $p \leq \bar{p}$, then $r^{-1}(p) = -\infty$ so S(p) is empty in this case. Furthermore, if $p > \bar{p}$,

$$\partial h(x,p)/\partial x = \{V_x(p,x) - V_p[r(x),x][dr(x)/dx] - V_x[r(x),x]\}/(1 - \beta). \quad (17)$$

But from (12),

$$dr(x)/dx = \int_0^{r(x)} \{V_x(q,x) - V_x[r(x),x]\}dF(q)/V_p[r(x),x]F[r(x)],$$

where q is an arbitrary variable of integration. Hence (17) becomes

$$\partial h(x,p)/\partial x = \{V_x(p,x) - F[r(x)]^{-1} \int_0^{r(x)} [V_x(q;x) - V_x(r(x),x)]dF(q)$$

$$- V_x[r(x),x]\}/(1 - \beta)$$

$$= \int_0^{r(x)} [V_x(p;x) - V_x(q,x)]dF(q)/(1 - \beta)F[r(x)]. \qquad (18)$$

Hence

$$\partial h[r^{-1}(p),p]/\partial x = \int_0^p \{V_x[p,r^{-1}(p)] - V_x[q,r^{-1}(p)]\}dF(q)/(1 - \beta)F(p). \qquad (19)$$

Equation (19) is positive since $V_{xp} > 0$. Thus each h(x,p) curve cuts the x axis at $x = r^{-1}(p)$ with positive slope. Furthermore, every x has such a curve passing through it. Since $\partial h(x,p)/\partial p < 0$ no point can have more than one curve passing through it, so $x = r^{-1}(p)$ must be a unique solution to $h(x,p) = 0$. Q.E.D.

<u>Remark 1</u>: Theorem 1 should come as no surprise. Once the consumer has purchased a good at price p and consumed it, the taste parameter is known and the current price observation is p. At this point the consumer is in a standard sequential search environment. The known price p is compared to the reservation price r(x). If it exceeds r(x) search is initiated, otherwise the good priced at p is repurchased.

But $p \geq r(x)$ is equivalent to $r^{-1}(p) \geq x$. Hence $S(p) = [-\infty, r^{-1}(p)]$.

3b. <u>The Initial Purchase Decision</u>

Given Theorem 1, B(p) can be written, from (5), as

$$B(p) = \int_{-\infty}^{\infty} V(p;x)dG(x) + \beta\int_{-\infty}^{r^{-1}(p)} W(x)dG(x) + \beta\int_{r^{-1}(p)}^{\infty} [V(p;x)/(1 - \beta)]dG(x). \qquad (20)$$

Using (20) in (1), it is now possible to analyze the consumer's behavior prior to purchasing and consuming a good; i.e., before the taste parameter is known.

<u>Lemma 3</u>: Under Assumptions 1-8, $dB(p)/dp < 0$ for all $p \geq 0$.

<u>Proof</u>: From (20),

$$B'(p) = \int_{-\infty}^{\infty} V_p(p,x)dG(x) + \beta g[r^{-1}(p)][dr^{-1}(p)/dp]\{W[r^{-1}(p)]$$

$$- [V(p,r^{-1}(p))/(1 - \beta)]\} + [\beta/(1 - \beta)] \int_{r^{-1}(p)}^{\infty} V_p(p,x)dG(x). \qquad (21)$$

But (8) implies

$$W[r^{-1}(p)] = V[p,r^{-1}(p)]/(1 - \beta),$$

so the second term in (21) is zero. Hence

$$B'(p) = \int_{-\infty}^{\infty} V_p(p,x)dG(x) + [\beta/(1 - \beta)] \int_{r^{-1}(p)}^{\infty} V_p(p,x)dG(x). \qquad (22)$$

Clearly (22) is negative since $V_p < 0$. Q.E.D.[12]

Since Z equals the expected value of z(p) with respect to F, it can be treated as a constant. With $B'(p) < 0$, this means that the equation

$$Z = B(p) \tag{23}$$

will have a unique solution, p*, unless $B(p) > Z$ for all $p \geq 0$ or $B(p) < Z$ for all $p \geq 0$. In the former case define $p^* = \infty$ and in the latter case define $p^* = 0$. Then

$$z(p) = \begin{cases} -c + B(p) & \text{if } p \leq p^* \\ -c + Z & \text{if } p > p^*.^{13} \end{cases} \tag{24}$$

Hence p* is a "reservation price" for pre-initial purchase search.[14] Summarizing this discussion gives another basic result.

<u>Theorem 2</u>: Under Assumptions 1-8, there exists a unique price, p*, such that z(p) is characterized by (24). Furthermore, p* is defined by

$$c = \int_0^{p^*} [B(p) - B(p^*)]dF(p), \tag{25}$$

which implies $p^* > 0$ iff $c > 0$ and $p^* = 0$ iff $c = 0$.

<u>Proof</u>: Taking the expectation of z(p) with respect to p, using (24), gives

$$Z = -c + \int_0^{p^*} B(p)dF(p) + \int_{p^*}^{\infty} ZdF(p). \tag{26}$$

But $Z = B(p^*)$ by definition of p*. Hence (26) can be written as (25). Given Assumption 6, $p^* = 0$ iff $c = 0$ and $p^* > 0$ iff $c > 0$. Q.E.D.

<u>Remark 2</u>: The consumer's optimal search and consumption strategy with respect to innovative goods is fully characterized by p* and r(x). Issues related to the existence of solutions to the two functional equations, (1) and (6), have been sidestepped by using constructive techniques. More general approaches to the existence problem in search models are well-known so will not be discussed in this paper.

3c. <u>The Effects of Increased Search Costs</u>

The optimal search and consumption strategy for innovative goods when $W(x) \geq U/(1 - \beta)$ for all x has rough similarities to that for search/experience goods. The striking difference between these models becomes obvious, however, when one considers the effects of increases in search costs.

<u>Theorem 3</u>: Given Assumptions 1-5, $dr(x)/dc > 0$. Given Assumptions 1-8, dp^*/dc is ambiguous. In particular,

$$\frac{dp^*}{dc} = [B'(p^*)F(p^*)]^{-1}\{\beta \int_0^{p^*}\int_{r^{-1}(p)}^{r^{-1}(p^*)} F[r(x)]^{-1}dG(x)dF(p) - 1\}.$$

However, there exists $\hat{\beta}$, where $0 < \hat{\beta} \leq 1$, such that $\beta < \hat{\beta}$ implies $dp^*/dc > 0$ if $c > 0$. Moreover, if $c = 0$, $dp^*/dc = 0$.

<u>Proof</u>: Totally differentiating (25) gives

$$\frac{dp^*}{dc} = [B'(p^*)F(p^*)]^{-1}\{\int_0^{p^*}[\frac{\partial B(p)}{\partial c} - \frac{\partial B(p^*)}{\partial c}]dF(p) - 1\}. \qquad (27)$$

Lemma 3 asserts that $B'(p^*) = \partial B(p^*)/\partial p < 0$. Hence the sign of dp^*/dc depends on the bracketed term in (27). However, differentiating (20) gives

$$\frac{\partial B(p)}{\partial c} = \beta\{W[r^{-1}(p)] - [V(p;r^{-1}(p))/(1-\beta)]\}[dr^{-1}(p)/dp]g[r^{-1}(p)]$$

$$+ \beta\int_0^{r^{-1}(p)}[\partial W(x)/\partial c]dG(x), \qquad (28)$$

As in Lemma 3, (8) implies the term in brackets in (28) is zero. Hence

$$\frac{\partial B(p)}{\partial c} = \beta\int_{-\infty}^{r^{-1}(p)}[\partial W(x)/\partial c]dG(x). \qquad (29)$$

Differentiating (8) next gives

$$\frac{\partial W(x)}{\partial c} = V_p[r(x),x][dr(x)/dc]/(1-\beta). \qquad (30)$$

Finally, totally differentiating (11) and rearranging terms gives

$$\frac{dr(x)}{dc} = -(1-\beta)/F[r(x)]V_p[r(x),x]. \qquad (31)$$

Substituting (31) into (30) gives

$$\frac{\partial W(x)}{\partial c} = -F[r(x)]^{-1}, \qquad (32)$$

which implies (29) can be written as

$$\frac{\partial B(p)}{\partial c} = -\beta\int_{-\infty}^{r^{-1}(p)}F[r(x)]^{-1}dG(x). \qquad (33)$$

Similarly,

$$\frac{\partial B(p^*)}{\partial c} = -\beta\int_{-\infty}^{r^{-1}(p^*)}F[r(x)]^{-1}dG(x). \qquad (34)$$

The only difference between (33) and (34) is the upper limit of integration. But the range of integration in (27) is $[0,p^*]$. Hence in (33), $p \le p^*$ and $r^{-1}(p) \le r^{-1}(p^*)$, where the strict inequality holds for $p < p^*$. Thus if $c > 0$,

$$\frac{\partial B(p)}{\partial c} - \frac{\partial B(p^*)}{\partial c} = \beta\int_{r^{-1}(p)}^{r^{-1}(p^*)}F[r(x)]^{-1}dG(x) > 0. \qquad (35)$$

Substituting (33) in (27) gives the expression for dp^*/dc stated in the theorem. It is clear from (31) that $dr(x)/dc > 0$. Furthermore, $B'(p^*) < 0$ by Lemma 3. Thus the sign of dp^*/dc depends (in reverse fashion) on the sign of

$$\beta\int_0^{p^*}\int_{r^{-1}(p)}^{r^{-1}(p^*)}F[r(x)]^{-1}dG(x)dF(p) - 1. \qquad (36)$$

The first term in (36) is positive since $r^{-1}(p^*) \ge r^{-1}(p)$ for $p \le p^*$ (with strict inequality if $p < p^*$) and $p^* > 0$ whenever $c > 0$ by Theorem 2. Moreover, $F[r(x)]^{-1} > 1$ for all x since $r(x) > 0$ for all x when $c > 0$ by Lemma 1. Thus it is quite possible for (36) to be positive, in which case dp^*/dc is negative. Clearly, though, if β is small enough, less than $\hat{\beta}$, say, (36) will necessarily be negative and $dp^*/dc > 0$. Of course, $\hat{\beta} = 1$ is also a possibility. When $c = 0$, $p^* = 0$, though, as does $r(x)$. Hence $dp^*/dc = 0$ in this case. Q.E.D.

Remark 3: Theorem 3 yields the somewhat counterintuitive result that p^* might be decreasing in c even though, as usual, $r(x)$ is always increasing in c. If p^* is decreasing in c this means the consumer searches more when search costs rise (in terms of the expected number of observations needed to find an acceptable price prior to initial purchase of the good). This is most likely when p^* is high and $r(x)$ is low; that is, when the consumer engages in relatively little search prior to an initial purchase of the good and expects a relatively high percentage of possible values of the taste parameter to be such that renewing search once the good has been consumed will be optimal. In this case the consumer is spending relatively little on search prior to initial purchase of the good but often finds more search to be desirable later. But an increase in search costs effects the consumer both before the initial purchase and after. In the situation just described, the costs associated with the latter increase so much when search costs rise that the consumer chooses to search more intensely prior to the initial purchase, presumably in the hope of finding a lower price and thus reducing the likelihood of having to bear the increased search costs associated with renewing search once tastes are known. Effects on post-initial purchase search costs, of course, matter less as β falls. For β small enough (that is, when the future matters relatively little) they will be dominated by the direct, pre-purchase effects and p^* will rise as c rises.

Remark 4: Another way of seeing how raising p^* in response to an increase in c might be desirable is illustrated in Figure 2. Let p^* be the original pre-initial purchase reservation price and $r(x)$ the original post-initial purchase reservation price function. Suppose c increases. Let $\hat{r}(x)$ be the new post-initial purchase reservation price function. Necessarily, $\hat{r}(x)$ is everwhere greater than $r(x)$. Before the increase in c, taste parameters less than or equal to $r^{-1}(p^*)$ would induce renewed search. If p^* remained constant when c rose, only values of x less than or equal to $\hat{r}^{-1}(p^*)$ would induce such behavior. Since $\hat{r}(x) > r(x)$ for all x, $\hat{r}^{-1}(p) < r^{-1}(p)$. This means less post-initial purchase search would be expected. But this implies the consumer is more likely to repurchse the good forever at the initial purchase price. Hence more search prior to the initial purchase may be desirable as it will increase the chance of finding a lower price, thus avoiding the increased search cost associated with renewing search.

Remark 5: When $dp^*/dc < 0$, the counter-intuitive case, the consumer expects to sample more firms prior to making an initial purchase, but $dr^{-1}(p^*)/dc < 0$ in this case as well so that less post-initial purchase search is also expected, both because fewer values of x will induce renewed search and because lower initial purchase prices are to be expected. This can be seen in Figure 2 where an increase in $r(x)$ to $\hat{r}(x)$ and a decrease in p^* to $\hat{p}^*$ necessarily implies that $\hat{r}^{-1}(\hat{p}^*)$ is less than $r^{-1}(p^*)$. The situation is less clear when $dp^*/dc > 0$. Figures 3a and 3b illustrate two possibilities. In Figure 3a, p^* rises more slowly than $r(x)$ as c increases so that $r^{-1}(p^*)$ falls. Thus fewer price observations are expected prior to the initial purchase, search is less likely to be renewed once tastes are known, and will involve fewer expected observations before an ultimatly acceptable price if found — all this even though the initial purchase price is on average higher. In Figure 3b, p^* rises faster than $r(x)$ as c increases so that $r^{-1}(p^*)$ rises. In this case both p^* and $r(x)$ increase with increases in c, but the consumer expects to renew search more often once tastes are known, even though it is more costly and will involve fewer expected observations before an ultimately acceptable price is found — on average, the expected amount of post-initial purchase search, viewed at the start of the process (i.e., before any consumption has taken place), might well increase as search costs rise. Thus when $dp^*/dc < 0$, there is an unambiguous shift from post-initial purchase search to pre-initial purchase search. When $dp^*/dc > 0$, the relative investment in pre- versus post-initial purchase search is ambiguous.

To summarize Remarks 3, 4, and 5, three situations are possible, illustrated in Figures 2, 3a, and 3b. In the first an increase in search costs shifts search away from post-initial purchase toward pre-initial purchase; in the second search is reduced for both, the relative effect being ambiguous; and in the third search is shifted from pre-initial purchase to post-initial purchase.

3d. <u>An Example</u>

As might be expected, constructing examples for this problem is tedious. I have not yet found one for which $dp^*/dc < 0$. However, consider the following:

$$V(p,x) = x - (m \log p)/x,$$

$$f(p) = 1/m \text{ for } p \in [0,m],$$

$$g(x) = 2x/n^2 \text{ for } x \in [0,n] \text{ and } n > \beta.$$

Then

$$r(x) = xc(1 - \beta)$$

and

$$W(x) = [1/(1 - \beta)][x - (m \log xc(1 - \beta))/x].$$

Hence

$$p^* = cn^2(1 - \beta)/2(n - \beta),$$

so that $dr(x)/dc > 0$ and $dp^*/dc > 0$.

4. THE MODEL WHEN NO CONSUMPTION IS AN OPTION

Much of the analysis needed to characterize the consumer's optimal search and consumption strategy when he or she has the option of not consuming the good at all once tastes are known has already been done. The comparison between $W(x)$ and $V(p,x)/(1-\beta)$ in this case is identical to Section 3, the only new element is that when no consumption is an option, obtaining $\bar{U}/(1-\beta)$ might dominate both of these values.

More specifically, when Assumption 6 is dropped the functional equation for the model is again given by (1) and (2). Although $W(x)$ and $V(p,x)/(1-\beta)$ are the same as in Section 3, it will now be necessary to consider them separately rather than focusing on their difference; i.e., $h(x,p)$ must be decomposed.

<u>Lemma 4</u>: Assumptions 2 and 5 imply $V(p,x)/(1-\beta)$ is monotonically increasing in x. In addition, Assumption 1–6 and 8 imply it has a unique intersection with $W(x)$ at $x = r^{-1}(p)$ such that

$$W(x) \gtrless V(p;x)/(1-\beta) \quad \text{as} \quad x \lessgtr r^{-1}(p).$$

<u>Proof</u>: This result follows directly from Assumption 2 and the proof of Theorem 1. Q.E.D.

The relationship between $V(x,p)/(1-\beta)$ and $W(x)$ is illustrated in Figure 4. Figure 4 also suggests the importance of the level of expected utility achieved at $r^{-1}(p)$. Denote this value by $u(p)$; i.e., set

$$W[r^{-1}(p)] \equiv u(p) \equiv V[p,r^{-1}(p)]/(1-\beta). \tag{37}$$

If $\bar{U}/(1-\beta) \geq u(p)$, $W(x)$ is irrelevant — it will always be the case

that $\max\{\bar{U}/(1-\beta), V(p,x)/(1-\beta)\} \geq W(x)$. On the other hand, if $\bar{U}/(1-\beta) < u(p)$, then all three post-initial purchase options are possible, depending on the observed value of the taste parameter. Of course, whether $W(x)$ matters will depend on the initial purchase price since $V(p,x)/(1-\beta)$, and hence $u(p)$, depends on p. But $V(p,x)/(1-\beta)$ is decreasing in p and $r^{-1}(p)$ is increasing in p (see Lemma 2) so that $u(p)$ is increasing in p. This fact yields the following Lemma, which can be stated without proof.

<u>Lemma 5</u>: Assumptions 1–6 and 8 imply there exists a unique price, p_c, such that

$$u(p_c) = \bar{U}/(1-\beta).$$

Furthermore,

$$u(p) \gtrless \bar{U}/(1-\beta) \quad \text{as} \quad p \gtrless p_c.$$

Lemma 5 establishes the existence of a unique price, p_c, such that an initial purchase price less than or equal to p_c implies renewing search after observing x will never be optimal. If the initial purchase price exceeds p_c, then low values of x will imply that no further consumption is optimal, intermediate values of x will imply that renewing search is optimal, and high values of x will imply that consuming the initially purchased good forever is optimal.

More formally, Lemma 5 implies that if $p > p_c$, then

$$B(p) = \int_{-\infty}^{\infty} V(p,x)dG(x) + \beta E_x \max\{\bar{U}/(1-\beta), V(p,x)/(1-\beta), W(x)\}, \tag{38}$$

and if $p \leq p_c$, then

$$B(p) = \int_{-\infty}^{\infty} V(p,x)dG(x) + \beta E_x \max\{U/(1-\beta), V(p,x)/(1-\beta)\}. \qquad (39)$$

4a. <u>The Case in which $p > p_c$</u>.

Consider first (38). By definition, $u(p_c) = U/(1-\beta)$. But (37) implies

$$W[r^{-1}(p_c)] = U/(1-\beta). \qquad (40)$$

In other words, $W(x)$ always intersects the $U/(1-\beta)$ line at $r^{-1}(p_c)$. This makes sense since neither $W(x)$ nor $U/(1-\beta)$ depends on p. If $p = p_c$, then $V(p,x)/(1-\beta)$ passes through this same point with slope greater than $W'[r^{-1}(p_c)]$. If $p > p_c$, then $V(p,x)/(1-\beta)$ cuts $W(x)$ to the right of this point (see Lemma 4) and if $p < p_c$ then $V(p,x)/U - \beta)$ cuts $W(x)$ to the left of this point. Thus if $x < r^{-1}(p_c)$, $U/(1-\beta)$ dominates in (38), if $r^{-1}(p_c) \leq x \leq r^{-1}(p)$, $W(x)$ dominates in (38), and if $x > r^{-1}(p)$, $V(p,x)/(1-\beta)$ dominates in (38). This is illustrated in Figure 5 and summarized in the following lemma.

<u>Lemma 6</u>. Under Assumptions 1-6 and 8, there exists a function, $r(x)$, defined by (11), and a unique price, p_c, defined in Lemma 5, such that for $p > p_c$,

$$\max\{U/(1-\beta), V(p,x)/(1-\beta), W(x)\} = \begin{cases} U/(1-\beta) & \text{if } x < r^{-1}(p_c) \\ W(x) & \text{if } r^{-1}(p_c) \leq x \leq r^{-1}(p) \\ V(p,x)/(1-\beta) & \text{if } r^{-1}(p) < x. \end{cases} \qquad (41)$$

In this case $(p > p_c)$,

$$B(p) = \int_{-\infty}^{\infty} V(p,x)dG(x) + \beta \int_{-\infty}^{r^{-1}(p_c)} [U/(1-\beta)]dG(x)$$

$$+ \beta\int_{r^{-1}(p_c)}^{r^{-1}(p)} W(x)dG(x) + \beta\int_{r^{-1}(p)}^{\infty} [V(p,x)/(1-\beta)]dG(x). \qquad (42)$$

4b. <u>The Case in which $p \leq p_c$</u>.

Consider next (39). In this case $W(x)$ is irrelevant and the optimal policy reduces to comparing $U/(1-\beta)$ to $V(p,x)/(1-\beta)$, or since $0 < \beta < 1$, to comparing U to $V(p,x)$. This is a simple exercise which yields the analogue to Lemma 6.

<u>Lemma 7</u>: Under Assumptions 1-6 and 8, there exists a function, $\sigma(p)$, such that for $p \leq p_c$,

$$\max\{U/(1-\beta), V(p,x)/(1-\beta)\} = \begin{cases} U/(1-\beta) & \text{if } x < \sigma(p) \\ V(p,x)/(1-\beta) & \text{if } x \geq \sigma(p). \end{cases} \qquad (43)$$

In this case $(p \leq p_c)$,

$$B(p) = \int_{-\infty}^{\infty} V(p,x)dG(x) + \beta\int_{-\infty}^{\sigma(p)} [U/(1-\beta)]dG(x)$$

$$+ \beta\int_{\sigma(p)}^{\infty} [V(p,x)/(1-\beta)]dG(x). \qquad (44)$$

<u>Proof</u>: The critical value of x is given by

$$V[p,\sigma(p)] = U. \tag{45}$$

Since $V_p < 0$ and $V_x > 0$, $\sigma(p)$ is well-defined. Furthermore, $V_x > 0$ also implies that $U > V(p,x)$ for $x < \sigma(p)$ and $U < V(p,x)$ for $x > \sigma(p)$. Q.E.D.

Remark 6: As $p \to p_c$, equations (42) and (44) yield the same value for B(p). Hence B(p) is continuous for all $p \geq 0$. Moreover, it will be shown below that it is also differentiable at $p = p_c$. The latter is merely a curiosity, while the former is crucial since it implies that p* is still defined uniquely by $Z = B(p^*)$.

4c. Optimal Preinitial-Purchase Search.

Lemmas 6 and 7, and Remark 6 characterize B(p) fully. The fact that it is continuous means that the form of optimal pre-initial purchase search can be analyzed using the same techniques as those employed in Section 3. Initially, the logic used to prove Lemma 3 (essentially an envelope-type theorem), yields the following.

Lemma 8: Under Assumptions 1-6 and 8, for $p \leq p_c$,

$$B'(p) = \int_{-\infty}^{\infty} V_p(p,x)dG(x) + \beta\int_{\sigma(p)}^{\infty} [V_p(p,x)/(1-\beta)]dG(x), \tag{46}$$

and for $p > p_c$,

$$B'(p) = \int_{-\infty}^{\infty} V_p(p,x)dG(x) + \beta \int_{r^{-1}(p)}^{\infty} [V_p(p,x)/(1-\beta)]dG(x). \tag{47}$$

Hence $B'(p) < 0$ for all $p \geq 0$. Furthermore, B(p) is differentiable at $p = p_c$.

Proof: Equations (46) and (47) follow directly from (44) and (42), respectively. That B(p) is differentiable at p_c follows from noting that $\sigma(p_c) = r^{-1}(p_c)$. Q.E.D.

Given Lemma 8, the analogue to Theorem 2 is immediate.

Theorem 4: Under Assumptions 1-6 and 8, there exists a unique price, p*, such that

$$z(p) = -c + \max\{Z,B(p)\} = \begin{cases} -c + B(p) & \text{if } p \leq p^* \\ -c + Z & \text{if } p > p^*, \end{cases} \tag{48}$$

where $Z = E_p z(p)$, B(p) is given in (42) and (44), and p* is defined by

$$c = \int_0^{p^*} [B(p) - B(p^*)]dF(p). \tag{49}$$

Furthermore, $p^* > 0$ iff $c > 0$ and $p^* = 0$ iff $c = 0$.

As should be evident by now, the addition of a no-repurchase option does little to effect the qualitative features of the model, at least from a formal point of view. In its absence the consumer must decide between renewing search and repurchasing the initially purchased good once tastes are known. For x low enough (less than $r^{-1}(p)$) the latter will dominate the former. As x increases two things happen: first, the expected discounted utility of an optimal ex post search strategy increases (renewed search is more attractive in absolute terms), but, second, repurchase is still even more attractive relative to renewed search (eventually dominating it for x large enough). It is the first effect which is crucial to the analysis of a no-repurchase option — it implies that the latter simply protects the consumer against low outcomes of x. However, if $p^* \leq p_c$, then all acceptable initial purchase prices will yield post-initial purchase situations in which the need to renew search is eliminated altogether by the no-repurchase option. If $p^* > p_c$, then for some acceptable initial purchase prices (those between p_c and p^*), the need to renew search once tastes are known is a possibility (i.e., for x between $r^{-1}(p_c)$ and $r^{-1}(p)$).

<u>Remark 7</u>: One basic issue in models of belated information concerns the trade-off between investments in information acquisition before and after initial consumption takes place. In the context of innovative goods, it is important to understand how the presence of a no-repurchase option effects this trade-off.[15] It would appear from the above discussion that it mitigates more against post-initial purchase search that pre-initial purchase search, but a definite judgment in this matter must await the comparative statics derived next.

4d. <u>The Effects of Increases in c and U</u>.

Consider first the effects of increases in c. This analysis follows much like that in Section 3c. In particular, similar arguments yield the following result.

<u>Theorem 5</u>: Given Assumptions 1-5, $dr(x)/dc > 0$. Furthermore, Assumptions 1-6 and 8 imply that if $p^* \leq p_c$ then

$$\frac{dp^*}{dc} = -[B'(p^*)F(p^*)]^{-1} > 0, \tag{50}$$

but if $p^* > p_c$, however, dp^*/dc is ambiguous since in this case

$$\frac{dp^*}{dc} = [B'(p^*)F(p^*)]^{-1}\{\beta\int_{p_c}^{p^*}\int_{r^{-1}(p)}^{r^{-1}(p^*)} F[r(x)]^{-1}dG(x)dF(p) - 1\}. \tag{51}$$

Thus, when $p^* > p_c$, there exists $\hat{\beta}$, where $0 < \hat{\beta} \leq 1$, such that $\beta < \hat{\beta}$ implies $dp^*/dc > 0$ if $c > 0$. If $c = 0$, then $dp^*/dc = 0$.

<u>Proof</u>: That $dr(x)/dc > 0$ is immediate from Section 3 since $r(x)$ is independent of U. Moreover, differentiating (40) once again gives the general form

$$\frac{dp^*}{dc} = [B'(p^*)F(p^*)]^{-1}\{\int_0^{p^*}[\frac{\partial B(p)}{\partial c} - \frac{\partial B(p^*)}{\partial c}]dF(p - 1\}.$$

Now consider $\partial B(p)/\partial c$. When $p \leq p_c$, $B(p)$ is given in (44) and is clearly independent of c. Hence equation (50) holds since $p^* \leq p_c$ = implies $p \leq p_c$. When $p^* > p_c$, there exists acceptable pre-initial purchase prices such that $p > p_c$. For these,

$$\frac{\partial B(p)}{\partial c} = -\beta\int_{r^{-1}(p_c)}^{r^{-1}(p)}[\partial W(x)/\partial c]dG(x). \tag{52}$$

The only difference between (52) and (29) is that the no-repurchase option truncates the integral at $r^{-1}(p_c)$. Thus for $p^* \geq p > p_c$,

$$\frac{\partial B(p)}{\partial c} - \frac{\partial B(p^*)}{\partial c} = \beta \int_{r^{-1}(p_c)}^{r^{-1}(p^*)} F[r(x)]^{-1}G(x) - \beta \int_{r^{-1}(p_c)}^{r^{-1}(p)} F[r(x)]^{-1}G(x)$$

$$= \beta \int_{r^{-1}(p)}^{r^{-1}(p^*)} F[r(x)]^{-1}dG(x). \qquad (53)$$

For $p^* > p > p_c$, (53) must be positive since $r^{-1}(p) < r^{-1}(p^*)$ on this range. Hence for $p^* > p_c$, dp^*/dc has a form identical to that given in Theorem 3 except that prices are integrated over $[p_c, p^*]$ in this case since the integrand is zero for $p \leq p^*$. Q.E.D.

<u>Remark 8</u>: The introduction of the no-repurchase option has no effect on post-initial purchase search, viewed <u>ex post</u> of the realization of the taste parameter. However, it does effect the qualitative relationship between p^* and c. In particular, for low values of p^* (less than p_c), dp^*/dc will always be positive. Furthermore, for higher values of p^* (greater than p_c), dp^*/dc would appear to be increasing in U; that is, the role of U seems to be to increase dp^*/dc so that increases in search costs will lead to <u>relatively</u> less pre-initial purchase search when $W(x) < U$ for some x compared to the situation in which $W(x) \geq U$ for all x. However, this argument is incomplete since it turns out that both p^* and, by Lemma 2, $r^{-1}(p^*)$ are increasing in U, so that dp^*/dc as given in Theorem 5 may not always be less than dp^*/dc as given in Theorem 3.

The speculations of Remark 8 can be made more rigorous by considering formally the effects of increases in U.

<u>Theorem 6</u>: Given Assumptions 1-6 and 8, $dr(x)/dU = 0$. In addition, for all $p^* \geq 0$,

$$\frac{dp^*}{dU} = \beta\int_0^{p^*} \{G[\sigma(p)] - G[\sigma(p^*)]\}dF(p)/(1-\beta)B'(p^*)F(p^*) > 0. \qquad (54)$$

<u>Proof</u>: Differentiating (49),

$$\frac{dp^*}{dU} = [B'(p^*)F(p^*)]^{-1} \int_0^{p^*} [\frac{\partial B(p)}{\partial U} - \frac{\partial B(p^*)}{\partial U}]dF(p). \qquad (55)$$

For $p \leq p_c$, equation (44) gives

$$\frac{\partial B(p)}{\partial U} = \beta G[\sigma(p)]/(1-\beta).$$

But $\sigma'(p) > 0$ so (54) is positive. For $p > p_c$, equation (42) gives

$$\frac{\partial B(p)}{\partial U} = \beta G[r^{-1}(p_c)]/(1-\beta).$$

But $r^{-1}(p_c)$ is independent of p so

$$\frac{\partial B(p)}{\partial U} - \frac{\partial B(p^*)}{\partial U} = 0 \qquad \text{for } p^* \geq p > p_c.$$

Hence (54) holds for all p^*. Q.E.D.

<u>Remark 9</u>: The greater is the value of no-repurchase, the less the consumer searches before making an initial purchase. Thus, on average, the initial purchase will be made at a higher price. If p^*

is still less than p_c after the increase in U, the latter effect can never induce the consumer to renew search once the taste parameter is known, it only implies that no-repurchase will dominate repurchase at the initial price more often. However, if p* exceeds p_c after the increase in U, renewed search becomes a viable option in some cases. No-repurchase will be optimal more often (always), but now renewed search will dominate continued repurchase at the initial price for some prices and some taste parameters. Thus post-initial purchase search may or may not increase, on average (as viewed *ex ante*) with increases in U. The likelihood of continued repurchase at the initial price will always decrease though.

5. SUMMARY, CONCLUSIONS, AND SUGGESTION FOR FUTURE RESEARCH

For the general model of consumer behavior with respect to innovative goods, as developed in Section 4 of this paper, an optimal search and consumption policy is characterized by two scalars, p* and p_c, and by two functions, r(x) and σ(p), such that in the pre-initial purchase phase,

$$p \leq p^* \Rightarrow \text{buy the good at price } p \text{ and observe } x\text{; and}$$
$$p > p^* \Rightarrow \text{search again,}$$

and in the post-initial purchase phase, if p_0 is the price of the initially purchased good, then

$$p_0 \leq p_c \Rightarrow \begin{cases} \text{cease consumption altogether if } x < \sigma(p_0)\text{, or} \\ \text{consume the initially purchased good forever if } x \geq \sigma(p_0)\text{,} \end{cases}$$

and

$$p_0 > p_c \Rightarrow \begin{cases} \text{cease consumption altogether if } x < r^{-1}(p_c)\text{,} \\ \text{renew search for a lower price if } r^{-1}(p_c) \leq x \leq r^{-1}(p_0)\text{, or} \\ \text{consume the initially purchased good forever if } r^{-1}(p_0) < x. \end{cases}$$

This policy was established under fairly weak assumptions, the strongest being that $V_{xp} > 0$. This assumption, however, seems to be the natural way to introduce a taste parameter into the indirect utility function since it is equivalent, under the other assumptions of the model, to dr(x)/dx > 0 (see Lemma 1), where r(x) is the reservation price for a standard sequential search problem when the taste parameter is known to be x. Hence when $V_{px} > 0$, an increase in the value of the taste parameter induces the consumer to search less intensely for low prices if his or her tastes were known with certainty. If V_{px} were assumed to be negative, then the proof of Lemma 1, in particular equation (12), would imply that dr(x)/dx < 0 — the consumer would set a lower reservation price and search more intensely as his or her intensity of preference increased, as measured by increases in x. This is a peculiar situation, however, since the good in question is homogeneous — quality is not an issue in this paper.

On the other hand, casual introspection might cause one to argue that an increase in the consumer's intensity of preference *should* lead to *more* search, not *less*, but this argument is based on the presumption that quality varies — to the extent that most consumers search more intensely for goods they desire more intensely, it is likely to be because their concern for quality increases as their intensity of preference increases, not because they become more concerned about price. In fact, price is unlikely to be a major issue for a consumer who desires some good intensely — such a consumer would be willing to pay whatever is necessary (within some appropriate bounds — i.e., up to $r(x)$) to get the good as long as it meets some minimum quality standard. The latter, however, is not an issue in this model.

This paper has explored the basic structure of the optimal search and consumption strategy for innovative goods. In addition, two further questions were addressed: (1) how do the various parameters, in particular c and U, effect the "critical" prices which characterize the consumer's optimal search and consumption policy, and (2) how do these parameters effect the trade-off between pre-initial purchase search and post-initial purchase search behavior?

Regarding question (1) and post-initial purchase behavior, an increase in search costs will increase $r^{-1}(p_c)$ and decrease $r^{-1}(p)$ (the latter for <u>all</u> $p \geq 0$). Hence for any given initial purchase price, p_0, the expected amount of post-initial purchase search will remain at zero (if $p_0 \leq p_c$) or fall (if $p_0 > p_c$). Increases in the utility of no consumption will increase $\sigma(p)$ and $r^{-1}(p_c)$ but have no effect on $r^{-1}(p_0)$. Hence when the utility of no consumption increases, the consumer is more likely to forego consumption

altogether after observing his or her tastes, either by repurchasing the initially consumed good less often (if $p_0 \leq p_c$) or by renewing search less often (if $p_0 > p_c$).

The effects of increases in c and U on pre-initial purchase behavior are less straightforward. While p^* is always increasing in U -- a rise in the utility of foregoing consumption altogether will induce <u>less</u> pre-initial purhcase search (on average), an increase in c has ambiguous effects — in particular, an increase in search costs can lead to more pre-initial purchase search (on average).

Regarding question (2), one must consider the combined effects of changes in c and U on pre- and post-initial purchase behavior. For example, when U increases, p^* will rise, implying less pre-initial purchase search. For any given initial purchase price, p_0, post-initial purchase search will fall as well. But now higher values of p_0 are possible. As p_0 increases, $\sigma(p_0)$ will increase as will $r^{-1}(p_0)$. The former has no effect on post-initial purchase search but the latter implies that the higher initial purchase prices will be associated with more post-initial purchase search. Whether the average amount of post-initial purchase search increases when U increases is thus unknown. However, since pre-initial purchase search always falls, one could predict with some confidence that the relative distribution of search effort will shift toward post-initial purchase search as the utility of foregoing consumption altogether increases.

Increases in search costs have even more ambiguous effects on the relative distribution of search effort than increases in the utility of nonconsumption. In particular, as c increases, p* might rise or fall. For any given initial purchase price, p_0, $r^{-1}(p_c)$ will rise and $r^{-1}(p_0)$ will fall as c increases. Thus post-initial purchase search will decrease on average for any given p_0 (or stay constant at zero when $p_0 < p_c$). If p* rises (the standard case), then pre-initial search will on average fall. But, again, this means that initial purchase prices on average rise. Since $r^{-1}(p_0)$ is increasing in p, the latter effect implies more post-initial price search. Thus if an increase in search costs reduces pre-initial purchase search, it will also have ambiguous effects on post-initial purchase search.

If p* falls when c rises, then the expected amount of pre-initial purchase search will increase, $r^{-1}(p_0)$ will on average fall since p_0 will on average fall, and the direct effect of the increase in c on post-initial purchase search; which is to decrease it, will be reinforced. Thus if an increase in search costs increases pre-initial purchase search, it will also decrease post-initial purchase search and cause an unambiguous shift from the latter to the former.

Since "new" products, in general, fall into the class of innovative goods, one might well be interested in strategies that would induce consumers to at least "try" the new product as this is prerequisite to establishing a "loyal" set of consumers. To the extent that word-of-mouth information flows increase sales, such strategies become especially crucial. At the same time, it would be of little use to get consumers to try a new product once if most of them only discover that they don't like it; not only will "repeat"

sales be lost, but other consumers may be induced to never even try the product, despite the fact that tastes may be heterogeneous. Only slightly less desirable (from the firm's point of view) is a situation in which the consumer tries a given firm's product, decides to continue consumption, but fails to repeat purchase in favor of renewing search for a lower price.

Inducing initial purchases is to some extent out of the control of an individual firm; although advertising that shifts G(x) outward or decreases the consumer's perception of U might be of use in this regard. Given that $Z \geq U/(1 - \beta)$, so that the consumer is <u>willing</u> to "try" the good, the only strategy which can increase the likelihood that a consumer tries a given firm's product, is to lower price. Situations which lead to repeat purchases are characterized by $p_0 \leq p_c$ and $x \geq \sigma(p_0)$, or $p_0 > p_c$ and $x > r^{-1}(p_0)$, where p_0 is the initial purchase price. At the level of generality of this model, it is hard to predict the effects of changes in F or G on these parameters. The only variables, besides β, which can be analyzed are c and U. Lowering search costs, say by "educating" consumers about the properties of the good generally (i.e., providing information which informs the consumers about <u>all</u> firm's goods) will have no effect if $p_0 \leq p_c$ but will decrease the likelihood of a repeat purchase if $p_0 > p_c$. This strategy seems unwise. Lowering U by convincing the consumer that "substitutes" are inadequate, etc., will have no effect if $p_0 > p_c$ but will increase repeat purchases when $p_0 \leq p_c$. This seems helpful, but a fall in U will also decrease p*, so that this strategy can hurt high-priced firms.

Of course these conclusions are all based on a model of homogeneous goods. "Quality" is no less important for innovative goods than noninnovative goods. Moreover, quality could be of the "search" variety or the "experience" variety (Wilde, 1980). Introducing quality to the model developed in this paper is clearly an important extension. Other extensions are somewhat more pedestrian. Introducing durability (goods with lifetimes longer than one period) is an example. Once goods last for more than a single period, a number of issues arise. For example, one could allow for the existence of secondary markets (Hey and McKenna, 1981) or analyze the effects of changes in durability on the optimal search and consumption strategy (Wilde, 1980, Section 5). Finally, the model might have interesting applications to the labor market since a significant amount of "job-shopping" might well be an attempt by workers to find a job they "like."

FOOTNOTES

1. Copeland defined convenience goods as "those customarily purchased at easily accessible stores," shopping goods as "those for which the consumer desires to compare prices, quality and style at the time of purchase," and specialty goods as "those which have some particular attraction for the consumer, other than price, which induces him to put forth special effort to visit the store in which they are sold, and to make the purchase without shopping." While Copeland's analysis is remarkably sophisticated for its time (50 years ago!), it's major weakness is that it taxonomizes goods primarily on the basis of consumer behavior (whether or not shopping takes place). Modern approaches deduce consumer behavior from more basic informational properties of goods.

2. "New" goods generally fall within some existing product class. Consumers might have some familiarity with the class but won't necessarily know their tastes with respect to the new good since by definition it must have some unique features. The more familiar a consumer is with a product class, the less uncertain he or she is likely to be with respect to the potential utility associated with any new good introduced to that class (see Hirschman, 1980, p. 288).

3. "New" goods (i.e., innovations with a well-defined, existing product class) are often introduced initially by a single firm. However, different retail outlets may still charge different prices for the good so the assumption of homogeneity is not unreasonable. In the case where the model represents a consumer who is unfamiliar with an entire existing product class, the assumption of homogeneity is primarily one of convenience — it represents a useful first step in the analysis of consumer behavior under uncertain tastes.

4. See Hey and McKenna (1981) for a formal analysis of such a possibility in the context of a search/experience goods model.

5. For "new" goods, as defined in footnote 3, Assumption 5 is not entirely innocuous. In fact, some authors have proposed that consumer "innovativeness" be defined as "the degree to which an individual is relatively earlier in adopting an innovation than other members of his social system," (Rogers and Shoemaker, 1971, p. 27). Economic analysis of the adoption of new innovations has also focused on the timing issue, generally from the point of view of firms (e.g., Reinganum, 1981; Balcer and Lippman, 1982; Jensen, 1982).

6. Equation (1) assumes no recall. As is well-known in the search literature, under the assumptions of this model this is equivalent to allowing recall. Since the consumer is allowed to repurchase the initially purchased good once tastes are known, the latter is the more appropriate assumption with respect to search activity. However, as noted, the implicit assumption of no recall with respect to search activity yields equivalent results to recall, and it eases the notational burden considerably.

7. Equation (2) ignores any repurchase costs over and above p. See Wilde (1980) for an example of their effect on the search/experience goods model.

8. It will be implicitly assumed throughout the remainder of the paper that $Z > U$; i.e., the consumer actually finds trial consumption of the innovative good preferable to no consumption of the innovative good.

9. Indifference between repurchase and renewed search is assumed to be resolved by repurchase. This choise is arbitrary but innocuous.

10. Timeless search is a less restrictive assumption for search activity after the taste parameter is known than before it is known since the crucial thing from the firm's perspective is initial adoption of the good. To the extent that repeat purchases are important, the distinction between <u>ex ante</u> discounting and <u>ex post</u> discounting would be captured by letting c, or possibly even β, be lower for <u>ex post</u> search than <u>ex ante</u> search.

11. Here indifference is between purchase at $r(x)$ and renewed search is assumed to be resolved in favor of purchase. again, this choice is arbitrary but innocuous — see footnote 9.

12. Note that when $p \le \bar{p}$, then by definition, $r^{-1}(p) = -\infty$. Hence

$$B'(p) = \int_{-\infty}^{\infty} V_p(p,x)dG(x) < 0.$$

13. Once again, indifference is assumed to be resolved in favor of no search in (24) — see footnotes 9 and 11.

14. Under standard usage, a "reservation price" is defined as the unique price such that price observations less than or equal to the reservation price terminate search while price observations greater than the reservation price result in continued search — see Wilde (1980, p. 1270 and footnote 7) and, especially, Rothschild (1974, p. 701) for further discussions of reservation prices so defined and their importance.

15. See Wilde (1981, Section IV) and Lippman and McCall (1979) for a further discussion of this issue in the context of formal search/experience goods models.

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FIGURE 1

FORM OF r(x) WHEN $V_{xp} > 0$

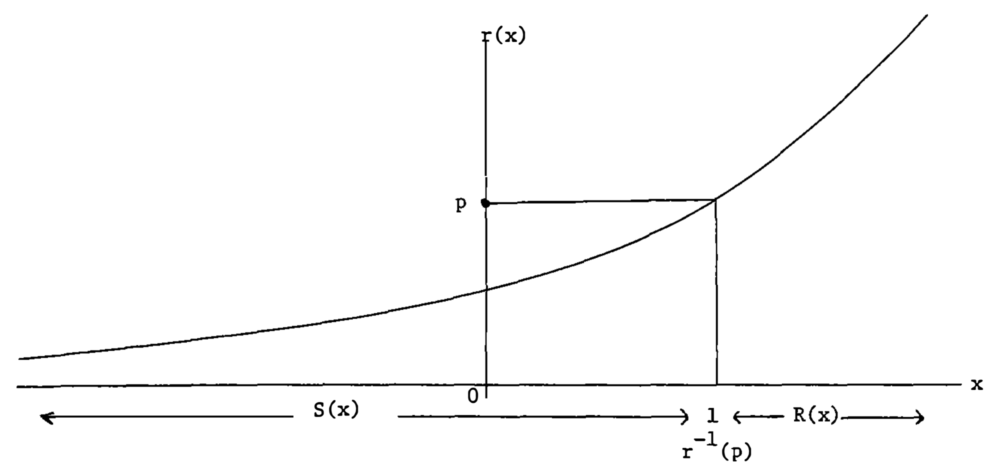


FIGURE 2

EFFECTS OF INCREASES IN SEARCH COSTS (p* CONSTANT ON FALLING).
HERE (p*,r(x)) IS THE LOW SEARCH COST OUTCOME AND
($\hat{p}$*,$\hat{r}$(x)) IS THE HIGH SEARCH COST OUTCOME.

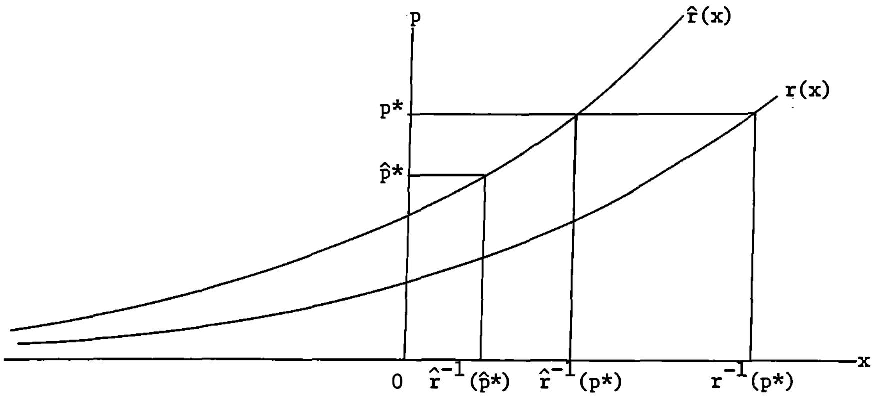
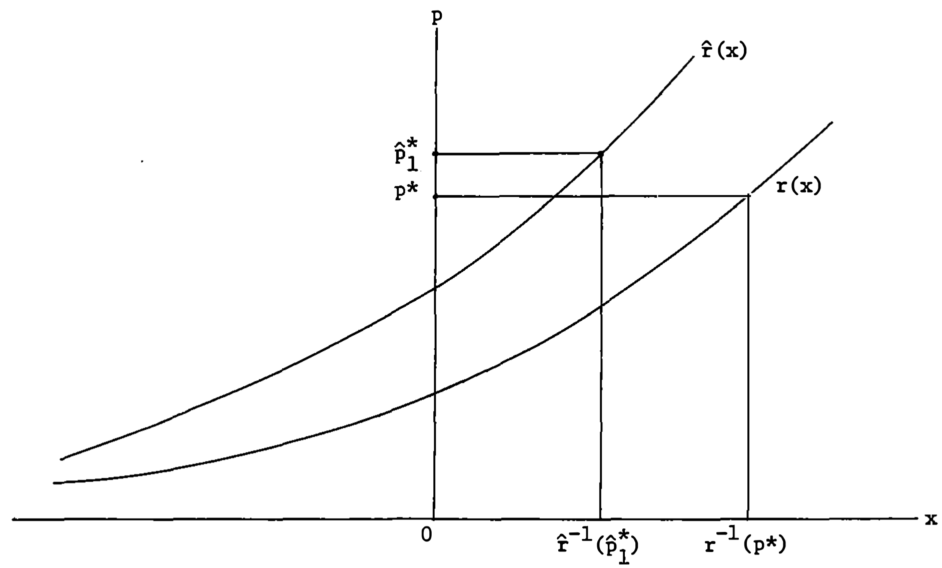


FIGURE 3a

$dr^{-1}(p^*)/dc < 0$



FIBURE 3b

$dr^{-1}(p*)/dc > 0$

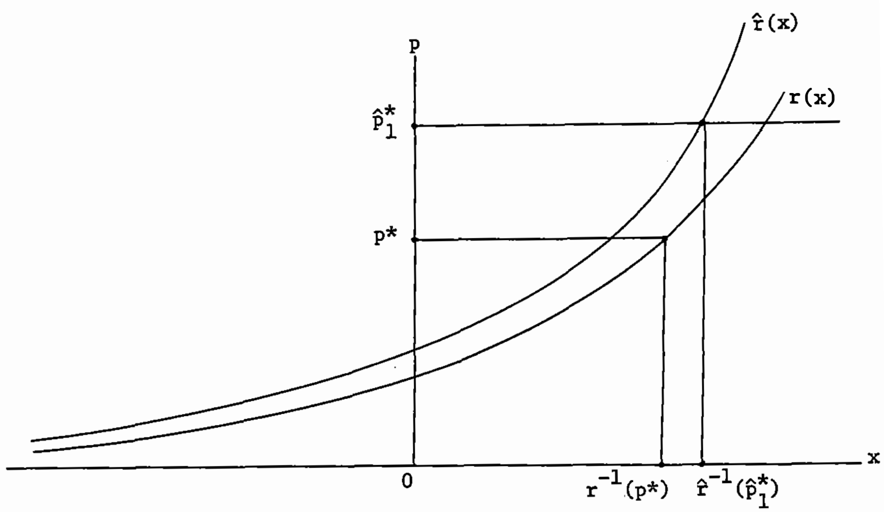


FIGURE 4

$V(p,x)/(1-\beta)$, $W(x)$, AND THE DEFINITION OF $u(p)$

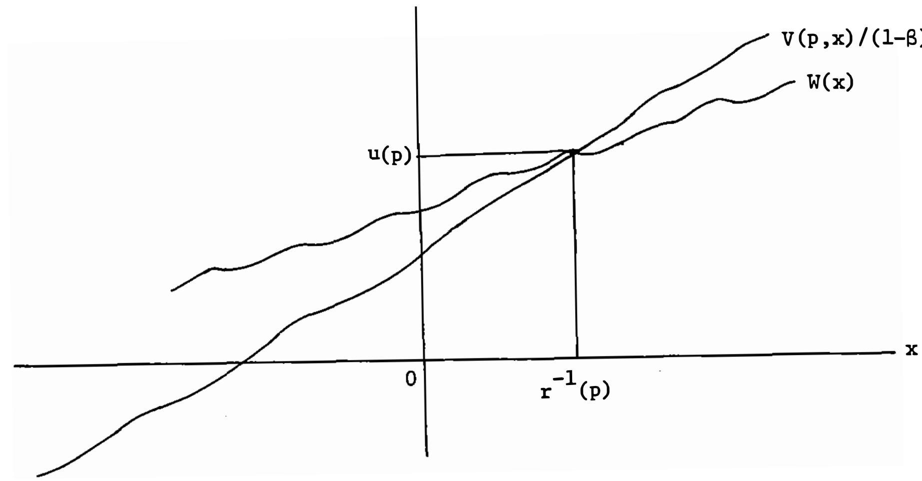


FIGURE 5

THE CASE IN WHICH $p > p_c$