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Testing A Signaling Theory of Advertising

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Testing A Signaling Theory of Advertising

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TESTING A SIGNALLING THEORY OF ADVERTISING
by
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TESTING A SIGNALLING THEORY OF ADVERTISING

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ABSTRACT. The signalling theory of advertising predicts that levels of dissipative advertising may be used by a firm to signal to consumers the quality level of its products. This paper develops such a theory within a durable goods framework. It is shown that, subject to refinements of beliefs, the model predicts a strong positive rank order correlation between firm type and the level of dissipative advertising it conducts. Data on the levels of television and total media advertising as well as quality ratings for different model automobiles sold in Canada over the period (1980-1988) are used to test this result using nonparametric procedures.

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SECTION 1: Introduction.

A 1989 advertisement for the Cutlass Supreme features William Shatner (of Star Trek fame) and his daughter being "beamed" into the Cutlass. The two complement the product in general terms and then the viewer is treated to the car being driven off into space. What does this advertisement tell the viewer? Some authors have suggested that ads of this nature are used by firms to signal (or to inform indirectly) viewers as to the quality of the product. This paper examines the plausibility of such suggestions.

Advertising in the industrial organization literature may be placed into three general categories:

1. (directly) informative
2. persuasive
3. signalling.

This paper focuses on the third category. We argue that a signalling theory of advertising leads naturally to tests based on the rank order correlation between advertising expenditures and product quality.

Signalling, is related to the second category in that both forms are dissipative. That is, neither signalling nor persuasive advertising need directly increase the market demand for the advertised product. Indeed the advertising characterized as signalling need be neither persuasive nor directly informative. The firm signals so as to inform consumers about characteristics (namely quality) of its product when such information cannot otherwise be directly conveyed at a reasonable cost. The simple facts that dissipative advertising yields less net benefit to a lower quality firm, and that firms can commit to advertising expenditures are enough to ensure that it can be used to signal quality.

The hypothesis that dissipative advertising may be used to signal quality was first proposed by Nelson (1974). Milgrom and Roberts (1986) formalized Nelson's argument. Their model allows a firm two signalling tools, price and dissipative advertising; this results in a general but rather confusing analysis of the choice of signalling variables and clouds

the relationship between advertising and firm/product quality¹. It is worthwhile to note that the Milgrom and Roberts predictions are conformable to the tests which develop to examine the predictions of our model.

In the following section we develop a model in which only dissipative advertising may be used as a signal of quality. The model's main purpose is to illustrate the relationship between a firm's quality and chosen level of dissipative advertising in a durable goods market². The model is tested using retail data from the Canadian automotive industry. While authors have cited automobile advertising as an example of signalling quality the models they use do not encompass durable goods markets. We introduce a noisy "word of mouth" communication between generations of consumers to motivate signalling in the context of a durable goods model. In Section 3 we conduct an equilibrium analysis of the signalling model. It is shown that, subject to standard belief refinements, signalling equilibrium is a Riley equilibrium. This equilibrium yields a strong prediction of positive rank order correlation between advertising and firm quality.

The results of Section 3 are common to most signalling models and lead naturally to nonparametric rank based tests of theory. In Section 4 we outline how these tests are calculated and how they should be applied to the model, we also discuss the data used for testing. The tests we propose are general, that is they do not impose unnecessary parametric restrictions on the underlying belief structure of the agents. The testing procedures may be easily adapted to examine the predictions of other signalling models. In Section 5 we discuss how the tests were implemented and the results of these tests. Section 6 concludes.

SECTION 2: The Model.

The model developed below illustrates the optimal signalling behavior of a durable goods firm. The analysis of the model provides a justification for the properties of the profit functions used in the equilibrium analysis

¹Firm and product quality will be used interchangeably throughout this paper.

²The model is easily adapted to encompass a nondurable stochastic quality goods market with repeat purchase

conducted in section 3.

Before we develop the model it should be noted that the only advertising available to the firm is purely dissipative. Thus, in place of advertising throughout this paper one may read purely dissipative advertising³.

Consider a firm which is developing a new product. The new product can be one of two possible types (quality levels). Ex ante (before purchase) consumers cannot observe the quality of the product, but do hold ex ante (prior) beliefs as to its quality. Advertising may be used to signal quality because i) the firm, via contracts etc. can credibly commit to a level of advertising expenditure (eg contracts with the media), and ii) a firm of higher quality finds advertising more beneficial than a firm of lower quality due to a larger customer base after the initial period. This condition is analogous to the single crossing of indifference curves in the Spence (1973) job market signalling model.

The advertising signalling model readers will be most familiar with is Milgrom and Roberts (1986), here after M&R. The model developed here is motivated in part by M&R. There are three major differences however: i) the choice of a product's price does not influence consumers beliefs about the quality of the product⁴, ii) a new pool of consumers is born each period and individuals in the pool live for two periods, and iii) we introduce a "word-of-mouth" communication mechanism between old customers of period $i-1$ and young *potential* customers of period i ⁵.

The first difference is added for clarity. In the automobile market, dealerships have the flexibility to change the price they charge in order to

³ Incorporating an optimal level of informative advertising will not alter the qualitative predictions of the model.

⁴ We provide justification for this assumption, within the context of our model, below. It is worth noting however that Hertzendorf (1990) has shown that within a signalling model in which consumers do not observe all dissipative advertising (signal loss) that price loses its strength as a signal. That is, he shows firms must always pool on price; they then use advertising to signal.

⁵ A consumer is a potential customer once he becomes aware of the product's existence, he becomes a customer upon purchasing the product.

maximize profits given the demand they face. We often see automobile dealers offering substantial price discounts, along with factory incentives when the demand they face is lower than expected. The manufacturer, on the other hand, decides on the level of dissipative advertising, but he rarely sets the observable retail price of the product. We sometimes observe the manufacturer's suggested retail price, which arguably may be a signal. However, it is at best a weak one as there is no commitment involved in announcing such a price.

The assumption that a new pool of consumers arrives each period is added to capture the fact that we wish to examine the model within a durable goods (automobile) industry framework. This assumption rules out the repeat purchase effect which is crucial to M&R.

The third difference is added to capture the fact that, although firms which produce durable goods may not face the same pool of potential customers each period, knowledge of product quality will rise over time. This mechanism results in an effect analogous to M&R's repeat purchase effect. Communication is noisy in the model. We show that the results of the generic signalling model with refinements hold in our model even when quality is not fully revealed via the "word-of-mouth" mechanism. We now develop the economy in detail.

As in M&R, quality is characterized as the probability that a randomly selected consumer finds the product satisfactory. Consumers know only that the product is one of 2 quality levels, $0 < q_1 < q_2 < 1$.

The players of the game are characterized as follows. The firm's type chosen by nature is given by $q \in \{q_1, q_2\}$. A firm of type q produces a product of quality q . Consumers are born in each period and live for two periods. They are uniformly distributed according to their valuation of the product on $[0, R_{i+1}]$, with total mass M_{i+1} . We use the $i+1$ subscript because consumers born in period i make their purchase decisions in period $i+1$. In the first period of life a consumer seeks information about the quality of the product the firm is producing. In the second period of life a consumer decides whether or not to purchase the firm's product. A consumer makes a purchase decision based on the maximization of his expected utility. A consumer with

valuation r receives utility $r(q + \theta_{i+1}) - p$, where p is the price of the product and θ_{i+1} denotes a quality shock in period $i+1$, for concreteness we assume $\theta_{i+1} \sim \text{IID}(0, \sigma^2)$ ⁶. A consumer receives zero utility if he does not purchase the product.

The firm's profit function for any period after period zero is given by $(p_i - c_q) x_i - A_{i-1}$; where p_i is the unit price of the product, c_q is the constant cost of producing a unit of the good, q is the quality of the firm, x_i gives the product demand and A_{i-1} details dissipative advertising expenditures. For clarity i subscripts will be deleted in the remainder of the paper.

The game is modeled as a three period, three stage game. Generalizations to an infinite horizon overlapping generations game are straightforward. Reference to Table 1 should help the reader in understanding the timing of the game.

In period 0 Nature reveals to the firm its type and therefore quality of the product it may produce. The firm then chooses its optimal level of period 0 dissipative advertising. Consumers born in period 0 observe this level of advertising and form beliefs about the firm's quality based on this advertising. In period 1, consumers born in period 0 decide whether to purchase the product. Given its demand function the firm chooses its period 1 price to maximize the expected present discounted value of all future profits given its expected future demands. Also in period 1, another group of consumers are born. These consumers become aware of the firm's product only if they receive a report $\tilde{q} = (q + \theta)$ about the product from the firm's customers (the old, born in period 0)⁷. These young customers use the report \tilde{q} to update their initial beliefs about the firm's quality according to Bayes' Rule⁸. This assumption precludes the use of dissipative advertising to signal quality

⁶ Distributional assumptions about θ are unimportant. We need only ensure that the distribution of $q + \theta$ follows the monotone likelihood ratio condition (see Laffont (1989) pp.185-186).

⁷ This assumption captures the idea that wider product proliferation will lead to wider product recognition

⁸ In this sense we are following Telser (1964), J.P.E. p. 555.

beyond the initial period. The effect we are trying to capture is that initially the information set available to consumers is limited, thus they may rely heavily on the firm's actions. After the initial period, however, product reviews and past consumers may be consulted thus consumers are less reliant on firm actions.

In period 2. the -now old- consumers born in period 1 decide whether or not to purchase the firm's product, provided they are aware of its existence. Based on the demand function so generated the firm chooses its second period price to maximize its second period profits.

Table 1. Timing of the Game

	PERIOD 0.	PERIOD 1.	PERIOD 2.
FIRM	ENGAGES IN DISSIPATIVE ADV.	CHOOSSES P1 TO MAX FUTURE PROFITS	CHOOSSES P2 TO MAX PERIOD 2 PROFITS
CONSUMERS BORN IN 0	YOUNG VIEW ADV. UPDATE BELIEFS	OLD MAKE PURCHASE DEC. IF BUY TELL YOUNG	
CONSUMERS BORN IN 1		YOUNG COMMUNICATE AT RANDOM WITH OLD UPDATE BELIEFS	OLD MAKE PURCHASE DEC.

It should be apparent that most of the action in the model is contained in the demand functions. We now develop them in detail, following standard practice by adding the restriction that the final equilibria be unaffected by the sequential elimination of dominated strategies from the normal form of the game.

The assumed continuum of consumers implies that as long as individual purchases are not observable it is a dominant strategy for each individual to act as a price taker in any period. Thus the marginal consumer in period 1 (found by equating price to expected utility) is defined by the valuation r^* where

$$p_1 = \int_{\Theta} [\rho_2(q_2 + \theta)r^* + \rho_1(q_1 + \theta)r^*] f(\theta) d\theta$$

and ρ_1 , and ρ_2 denote a consumer's (ex post) beliefs that the firm is of type 1 or type 2 respectively ($\rho_1 + \rho_2 = 1$). If we define $Q(\rho_2, \rho_1) = \rho_2 q_2 + \rho_1 q_1 = Q(\rho)$ to be the expected quality of the firm, then $r^* = \frac{p_1}{Q(\rho)}$, $\rho = \rho(A_0)$, where consumer beliefs about the values of ρ are conditioned on the observed period 0 advertising level⁹. Thus period 1 demand is given by

$$M_1 \left\{ \frac{R_1 - [p_1/Q(\rho)]}{R_1} \right\} \text{ where } \rho = \rho(A_0), [p_1/Q(\rho)] \leq R_1 \quad (1)$$

In the second stage a new pool of consumers is born, they have mass M_2 and valuations on $[0, R_2]$. These consumers become aware of the product only if they obtain a report from an individual who consumed the product in period 1. We assume the probability that a period 2 consumer meets a period 1 customer is directly proportional to the fraction of people who made initial period 0 purchases. Under these assumptions the customer base for the firm in period 2 is given by

$$\left[\frac{R_1 - [p_1/Q(\rho)]}{R_1} \right] M_2 = \hat{M}_2. \quad (2)$$

The old customers provide a noisy report about the products performance ($\tilde{q} = q + \theta_1$), to the young they chance to meet. The young use this report \tilde{q} to update their beliefs about product quality¹⁰. The updating process is relatively simple. Understanding of the process is improved by reference to Figure 0. This illustrates, for a given quality report \tilde{q} , the relationship between the conditional probabilities that the product was produced by a firm of type 1, or type 2.

[Figure 0 here]

⁹This characterization of the marginal consumer depends on the assumption that θ has a zero mean. All results will hold if this assumption is dropped, the assumption is made to avoid unnecessary complication of notation.

¹⁰In the context of a nondurable stochastic quality goods market assume that individuals use \tilde{q} to update their own beliefs about a products quality each period.

Given our distributional assumptions on θ_1 , the probability that \tilde{q} was observed conditional on the firm being of type 2 is given by $f_2(\tilde{q})$ ¹¹, that is

$$f_2(\tilde{q}) = \Pr(\tilde{q} \mid q = q_2). \quad (3)$$

Similarly the probability \tilde{q} was observed conditional on the firm being of type 1 is given by

$$f_1(\tilde{q}) = \Pr(\tilde{q} \mid q = q_1). \quad (4)$$

Let $\hat{\rho}_1$ be the updated belief of second period potential consumers that the product is of quality level q_1 , so let $\hat{\rho}_2 = 1 - \hat{\rho}_1$. Invoking Bayes' Rule posterior beliefs will be given by

$$\hat{\rho}_1 = \frac{\rho_1^0 f_1(\tilde{q})}{\rho_1^0 f_1(\tilde{q}) + \rho_2^0 f_2(\tilde{q})}.$$

and

$$\hat{\rho}_2 = \frac{\rho_2^0 f_2(\tilde{q})}{\rho_1^0 f_1(\tilde{q}) + \rho_2^0 f_2(\tilde{q})}.$$

Where ρ_i^0 represents the prior belief that the firm is of type i .

We denote the updated quality belief of the period 2 potential consumer by $E_q = \hat{\rho}_1 q_1 + \hat{\rho}_2 q_2$. Assuming that $f(q)$ obeys the monotone likelihood ratio property we obtain the following result¹².

RESULT 0. The higher is the reported quality of the product the higher is the expected quality of the product. ($\partial E_q / \partial \tilde{q} > 0$).

This fact ensures that the expected benefit to a higher quality firm from an enlarged second period customer base exceeds the expected benefit to a lower quality firm.

The marginal consumer in the second period is given by r^* where

¹¹This is an ex post probability, the ex ante probability that \tilde{q} will be observed is of course zero for any value q .

¹²Proofs of results 0 to 3 are given in appendix A.

$$p_2 = \int_{\Theta} [\hat{\rho}_2(q_2+\theta)r^* + \hat{\rho}_1(q_1+\theta)r^*] f(\theta) d\theta$$

Thus $r^* = \frac{P_2}{E_q}$, where E_q is as defined above. The second period demand function faced by a type q firm is then

$$\hat{M}_2 \left(\frac{R_2 - p_2/E_q}{R_2} \right). \quad (7)$$

The "word-of-mouth" communication mechanism is designed to capture the effect that a large customer base in the introductory period will increase the potential customer base in future periods. This may result simply because the more the product is seen by the general public the higher will be the product awareness. This effect links the first and subsequent periods and makes initial period advertising (even dissipative) worthwhile.

Having obtained the demand functions we can now solve the game for the firm's optimal choices of p_1 , p_2 and A_0 . The type q firm's objective function is

$$\begin{aligned} \varphi(p_1, p_2, A_1, A_2) = & (p_1 - c_q) M_1 \left[\frac{R_1 - \{p_1/Q(\rho)\}}{R_1} \right] - A_0 + \\ & \delta \left\{ (p_2 - c_q) \hat{M}_2 \left[\frac{R_2 - \{p_2/\int_{\Theta} E_q(q)f(\theta)d\theta\}}{R_2} \right] \right\} \end{aligned} \quad (8)$$

One should note that we have replaced E_q by $E_q(q)$ in (8). This is done to emphasize the fact that the distribution of \tilde{q} for a type q_1 firm is different from that of a type q_2 firm. The difference can easily be seen by examining the values of $\hat{\rho}_1$ for types q_1 and q_2 :

$$\hat{\rho}_1:q_1 = \frac{\rho_1^0 f_1(q_1+\tilde{\theta})}{\rho_1^0 f_1(q_1+\tilde{\theta}) + \rho_2^0 f_2(\tilde{q}_1+\tilde{\theta})} \quad \text{and} \quad \rho_1:q_2 = \frac{\rho_1^0 f_1(q_2+\tilde{\theta})}{\rho_1^0 f_1(q_2+\tilde{\theta}) + \rho_2^0 f_2(q_2+\tilde{\theta})}$$

We define $E_q(q)$ as $(\hat{\rho}_1:q)q_1 + (\hat{\rho}_2:q)q_2$. One can show (see Appendix A) that $\int_{\Theta} E_{q_1}(q_1)f(\theta)d\theta < \int_{\Theta} E_{q_2}(q_2)f(\theta)d\theta$. This ensures that the type q_2 firm will expect a larger consumer base than a type q_1 firm. Denote $\int_{\Theta} E_q(q)f(\theta)d\theta$ by E_q^q , we may rewrite the objective function of firm 1 as

$$\varphi(p_1, p_2, A_1, A_2) = (p_1 - c_q) M_1 \left[\frac{R_1 - \{p_1/Q(\rho)\}}{R_1} \right] - A_0$$

$$\delta \left\{ (p_2 - c_q) \hat{M}_2 \left[\frac{R_2 - \{p_2/E_q^q\}}{R_2} \right] \right\} \quad (9)$$

Solving the game recursively, a type q firm chooses second period price in order to maximize second period profits. The firm recognizes that noisy signals \tilde{q} have been reported and therefore that potential period 2 customers hold beliefs given by $\hat{\rho}_1$ and $\hat{\rho}_2$. The type q firm's problem is given by

$$\max_{p_2} \pi_2 = (p_2 - c_q) \hat{M}_2 \left[\frac{R_2 - p_2/E_q(q)}{R_2} \right] \quad (10)$$

Solving for p_2 and substituting back into the maximization problem we obtain

$$\pi_2 = 1/4 \left[\frac{E_q(q) R_2^2 - 2R_2 c_q + c_q^2/E_q(q)}{R_2} \right] \hat{M}_2.$$

RESULT 1. Period 2 profits increase as potential second period customer base rises.

RESULT 2. For sufficiently large R_2 , the better the quality of the firm the higher will be period 2 profits¹³.

Working back a period, the type q firm chooses period 1 price in order to maximize the expected discounted value of all future profits. It takes period 0 advertising levels as given. This advertising, in turn has been observed by period 1 potential customers who form beliefs ρ . The type q

¹³This result simply states that if costs rise with quality there must be sufficient numbers of high valuation individuals to make high quality products profitable.

firm's problem is

$$\max_{p_1} (p_1 - c_q) M_1 \left[\frac{R_1 - p_1/Q(\rho)}{R_1} \right] + \delta \left\{ \frac{1}{4} \left[\frac{E_q(q)R_2^2 - 2R_2c_q + c_q^2/E_q(q)}{R_2} \right] \hat{M}_2 \right\}. \quad (11)$$

It is straight forward but tedious to show that the optimal choice of p_1 is given by

$$p_1 = 1/2 \left[Q(\rho)R_1 + c_q - \delta M_2 K / 2M_1 R_2 \right] \quad (12)$$

where $K = E_q(q)R_2^2 - 2R_2c_q + c_q^2/E_q(q)$.

Using this result, one can show the following.

RESULT 3. For sufficiently large M_1 , as perceived quality $Q(\rho)$ rises (a) p_1 rises but, (b) not enough to decrease the initial customer base.

Result 3 implies that period 1 profits rise as perceived quality rises. It also implies that the higher is the firm's perceived quality the larger will be its base of potential second period customers.

Taken together results 1 and 3 imply that a firm of any type prefers, ceteris paribus, to be perceived to be of high quality. The only internally consistent way of achieving the perception of high quality is to engage in dissipative advertising which reduces profits. The firm thus determines its optimal level of advertising subject to this constraint.

At the first stage, the firm chooses its level of dissipative advertising, knowing that individuals update their beliefs via Bayes' Rule "along the equilibrium path". The firm's problem is thus to choose A_0^* such that

$$A_0^* = \operatorname{argmax}_{A_0} (p_1(E_q(q), Q(\rho[A_0])) - c_q) M_1 \left[\frac{R_1 - p_1(E_q(q), Q(\rho[A_0]))/Q(\rho)}{R_1} \right] + \delta \left\{ \frac{1}{4} \left[\frac{E_q(q)R_2^2 - 2R_2c_q + c_q^2/E_q(q)}{R_2} \right] \left[\frac{R_1 - p_1(E_q(q), Q(\rho[A_0]))/Q(\rho)}{R_1} \right] \right\} - A_0 \quad (13)$$

where p_1 in its reduced form is given by $p_1(E_q(q), Q(\rho[A_0]))$.

The choice a type q firm makes concerning the level of A_0 will depend on the beliefs ρ . As with any signalling model beliefs "off the equilibrium path" are, without refinement, arbitrary. Consequently there are an infinite number of advertising levels which, given particular beliefs, could be equilibrium values of A_0^* . To motivate the equilibrium analysis which will be conducted in the next section consider the following profit function for a type q firm which is believed to be type q' .

$$\pi(q, q') = V(q, q') - A_0 = (p_1(E_q(q), q') - c_q) M_1 \left[\frac{R_1 - p_1(E_q(q), q')/q'}{R_1} \right] +$$

$$\delta^{1/4} \left\{ \left[\frac{E_q(q)R_2^2 - 2R_2c_q + c_q^2/E_q(q)}{R_2} \right] M_2 \left[\frac{R_1 - p_1(E_q(q), q')/Q(\rho)}{R_1} \right] \right\} - A_0. \quad (14)$$

where $V(q, q')$ denotes the firm's reduced form revenue function.

Result 2 stated that second period profits increase with the true quality of the firm. It is not necessarily the case that period 1 profits increase with true quality. High quality firms may sacrifice period 1 profits in order to increase the second period consumer base from which they obtain a greater benefit than do lower quality firms. However the second (and in an extended model future) period effect must dominate in equilibrium so that total profits must rise with true quality.

RESULT 4. In equilibrium profits (*ceteris paribus*) must be at least as high for a firm of high quality as for a low quality firm.

If result 4 did not hold, that is if a firm of lower quality obtained higher profits than a firm of higher quality then the higher quality firm could (costlessly) mimic the lower quality firm and obtain equal profits¹⁴ ■

Given results 1 to 4 two obvious relationships follow. A firm which is believed to be of higher type will obtain higher profits (*ceteris paribus*) than one believed to be of lower type. In addition, a firm which is of

¹⁴This assumption may not be true in all industries but is a suitable one for the automotive industry.

higher type will (ceteris paribus) always earn profits at least as high as a firm which is known to be a lower quality type. Also a higher quality firm will benefit more from being perceived high than will a low quality firm due to the second period effect). The only interesting case is when higher quality firms earn strictly greater profits. The function (14) in (V, A_0) space will have the form shown in Figure 1. Given these relationships we may discuss the types of signalling equilibria which exist in the model.

[Figure 1 here]

SECTION 3: Equilibrium Analysis.

In this section we analyze the equilibria which may result in the model outlined in Section 2. We find that the imposition of standard belief refinements on the equilibria of the model results in a testable prediction of positive rank order correlation between agent type and the strength of signal. The model given above easily generalizes to n types. Thus we allow a firm to be any one of n different quality types $q_1 < q_2 < \dots < q_n$.

We first define an equilibrium for the model. The existence of separating and pooling equilibria is then examined. This examination is conducted by refining the set of possible equilibria by successive application of the "sequential elimination of dominated strategies" and the Intuitive Criterion of Cho and Kreps (1987) (here after C&K). We establish that, subject to these refinements, a Riley equilibrium is the only type of equilibrium which survives.

Since p_1 and p_2 are ultimately functions of initial period advertising in the model, we define a strategy for the firm as a function $F(q): [q_1, q_2, \dots, q_n] \rightarrow A_0$, which translates the actual quality of the firm into a nonnegative level of period 0 advertising. Since we have assumed that each consumer purchases one unit of the good if his subjective valuation exceeds the market price, only beliefs of such consumers are relevant. Beliefs are defined by ρ_i , the probability that the firm is of type i . Let us, without loss of generality, characterize consumers in each period by their expectations of the quality of the firm. First period consumers' expectations of firm quality are given by $Q(\rho(A_0)) \equiv Q(A_0) : \mathbb{R}^+ \rightarrow [0, q_n]$ and

second period consumers' expectations are given by $E(\tilde{q}) : \mathbb{R}^+ \rightarrow [0, q_n]$. Since \tilde{q} is not a strategic variable we will not be too concerned with it in what follows. We write the profits of the firm as $V(q, Q(A_0)) - A_0$. Given this notation we are now ready to define the equilibrium concept.

Definition A Perfect Bayesian Equilibrium for this model is a strategy $F(q)$ for the firm and a system of beliefs $Q(A_0)$ and $E(\tilde{q})$ for period 1 and 2 customers respectively such that

- 1) $F(q)$ maximizes $V(q, Q(A_0)) - A_0$ given beliefs $Q(A_0), E(\tilde{q})$
- 2) $Q(A_0)$ and $E(\tilde{q})$ are computed using Bayes' Rule along the equilibrium path¹⁵
- 3) A_0 is nonnegative.

All equilibria we examine are Perfect Bayesian (PB). We now discuss the existence of PB separating and PB pooling equilibria. The "Perfect Bayesian" prefix will be dropped but should always be understood.

In a separating equilibrium a firm's optimal advertising level varies with its type given the system of beliefs.

PROPOSITION 1. There exists a separating equilibrium if and only if the following conditions hold for equilibrium advertising levels $A_0^* \in [0, \infty)$ and $q \in \{q_1, \dots, q_n\}$

1. For a type q_i firm $A_{0,1}^* = 0$
2. A_0^* for any two successive types $q_i > q_j$ must satisfy
 - i) $V(q_i, q_i) - A_{0,i}^* \geq V(q_i, q_j) - A_{0,j}^*$
 - ii) $V(q_j, q_j) - A_{0,j}^* \geq V(q_j, q_i) - A_{0,i}^*$

where $A_{0,i}^*$ is the equilibrium level of period 0 advertising chosen by a type q_i firm.

If beliefs are such that $Q(A_{0,i}^*) = q_i$ and $Q(A_0) = q_i, A_0 \neq A_{0,i}^*$ for all $A_0 \in [0, \infty)$, then no type has incentive to deviate from its equilibrium strategies: $F(q_i) = A_{0,i}^*$ for all i and $Q(A_{0,i}^*)$ will trivially satisfy Bayes' Rule. This demonstrates sufficiency. If condition 2i is not satisfied then any high type has an incentive to defect to a lower advertising level (and

¹⁵ Note $E(\tilde{q})$ satisfies Bayes' Rule by definition.

vice-versa if condition 2ii does not hold), and separation is not obtained. Of course condition 1 simply states that in a separating equilibrium the firm of lowest type is known to be low and therefore has no incentive to engage in purely dissipative advertising. Thus the conditions of proposition 1 are both necessary and sufficient■

Condition 2ii will never hold strictly if the set of separating equilibria are subjected to the sequential elimination of dominated strategies, since it would require that a lower type (q_j) would mimic a high type, even if (by choosing $A_{0,1}^*$) it received lower profits than $V(q_j, q_j) - A_{0,j}^*$. Hence applying the sequential elimination of dominated strategies to the set of separating equilibria, one can prune the set of equilibrium advertising levels to that shown in Figure 2.

[Figure 2 here]

In a pooling equilibrium two or more firm types optimize by choosing the same level of advertising. Consumers posterior beliefs as to firm type will not be updated to certainty since observation of the chosen level of advertising is not fully informative about type. When beliefs are subject to refinement we will see that the pooling equilibria in our model will fail to hold (a standard result). There is a condition however, which if met may allow for the possibility of pooling, subject to the constraint that no firm may play a dominated strategy out of equilibrium. This result is included in a note in Appendix B for completeness.

PROPOSITION 2. No pooling equilibria may exist in the model when beliefs are subject to the Intuitive Criterion of C&K.

The reader is encouraged to consult C&K for a formal analysis of their Intuitive Criterion. The criterion may be summarized as follows. Fix a pooling equilibrium in which two or more types send the message A_p^* to maximize profits. Beliefs are subject to the following refinement; $Q(a_p^*) = q_1$ if and only if the type q_1 player would prefer to send the message a_p^* to A_p^* ; if by doing so the receiver will believe the signal was sent by q_1 , and if no other type in the pool would prefer to send message a_p^* to A_p^* no matter how the signal is interpreted. Then A_p^* is overturned as an equilibrium.

In our model this criterion is used in the following manner (see Figure 3). Fix A_p^* as a pooling equilibrium between any two successive types q_i and q_j ¹⁶. Now examine the "off-the-equilibrium-path" signal \bar{A} which generates the following two inequalities.

$$V(q_i, q_i) - \bar{A} > V(q_i, q_{p,i,j}) - A_p^*$$

$$V(q_j, q_i) - \bar{A} < \bar{V}(q_j, q_{p,i,j}) - A_p^*$$

Let S denote the set of all \bar{A} which satisfy the above inequalities.

[Figure 3 here]

That is if the type q_i firm is believed to be of type q_i , if \bar{A} is observed out of equilibrium it would strictly prefer to send \bar{A} to the equilibrium signal A_p^* . Also no matter how consumers interpret \bar{A} (we examine the best possible case for the type q_j firm ie. $Q(\bar{A}) \rightarrow q_i$) the type q_j would strictly prefer to send the equilibrium signal A_p^* . Because of the functional form of each of the V 's such an \bar{A} will always exist for any given pooling equilibrium A_p^* ¹⁷. Therefore upon observing \bar{A} out of equilibrium, the Intuitive Criterion places the following restriction on the beliefs of consumers: $Q(\bar{A}) = q_i$. Since for A_p^* to survive as a pooling equilibrium it must be the case that upon observation of \bar{A} , the beliefs of potential customers $Q(\bar{A})$ are updated to a level of quality q such that $V(q_i, q) - \bar{A} < V(q_i, q_{p,i,j}) - A_p^*$ then subject to the refinements placed on "off-the-equilibrium-path" beliefs imposed by the Intuitive Criterion A_p^* must fail as a pooling equilibrium ■

PROPOSITION 3. Successive application of the sequential elimination of dominated strategies along with the Intuitive Criterion limits the set of possible equilibria to separating equilibria of the Riley type (defined below), Which exhibit strong rank order correlation.

¹⁶If more than two types pool, successive application of the following procedure leads to the desired result.

¹⁷That is such an \bar{A} always exists if $V(q_i, q_i) - V(q_i, q_p) > V(q_j, q_i) - V(q_j, q_p)$. This implies that $V(q_i, q_i) - V(q_j, q_i) > V(q_i, q_p) - V(q_j, q_p)$, which must be the case since the higher type always benefits more from a larger second period customer base.

Between any two successive types the continuum of pooling equilibria defined by each type choosing the same A_0 may be narrowed to $A_0 = A_{0,j}^*$ via the sequential elimination of dominated strategies. By then imposing the Intuitive Criterion we rule out $A_{0,j}^*$ as a pooling equilibrium since under this criterion beliefs must be such that a q_i type firm would defect to some $\bar{A} \in S$. Thus we now consider the existence of separating equilibria.

Define the set R as all A_0 which satisfy $V(q_j, q_i) - A_0 > V(q_j, q_j) - A_{0,j}^*$, and R^* as $R - [0, A_{0,j}^*]$. Also define the set Q as all A_0 which satisfy $V(q_j, q_i) - A_0 < V(q_j, q_j) - A_{0,j}^*$. Then between any two successive types ($q_i > q_j$) it will be optimal for a type q_j firm to mimic a type q_i firm for all $A_{0,i} \in R^*$. Thus in a separating equilibrium the firm of type q_i must choose $A_{0,i} \in Q$. By then subjecting the set Q to the elimination of dominated strategies we can reduce the set to $A_{0,i} = A_{0,i}^*$, where $A_{0,i}^*$ is the minimum element of Q . Since all values of $A \in Q$ are strictly greater than those contained in R^* the rank order correlation result is obtained ■

This equilibrium may be generated within the model via the following optimization problem

- 1) the firm of lowest type chooses $A_0 = 0$.
- 2) for each successive type pair q_i, q_j ($q_i > q_j$) firm of type q_i solves the problem

$$\begin{aligned} \text{Max}_{A_{0,i}} \quad & V(q_i, q_i) - A_{0,i} \\ \text{subject to} \quad & V(q_j, q_j) - A_{0,j}^* > V(q_j, q_i) - A_{0,i} \end{aligned}$$

- 3) for all i $Q(A_{0,i}) = q_i$.

The equilibrium resulting from the above optimizing conditions is referred to as a Riley equilibrium. It satisfies the existence conditions for a separating equilibrium given in Proposition 1. An equilibrium of this type is shown for the three firm case in Figure 4. This equilibrium predicts a strong positive rank order correlation between agent type (quality) and the strength of the signal (period 0 expenditure on dissipative advertising). The Riley equilibrium for this model reflects exactly the hypothesis of Nelson (1974).

[Figure 4 here]

SECTION 4: Tests and Data.

4.1 Tests

The result of the generic signalling model with suitable refinements does not necessarily predict a linear relationship between type and signal strength. For this reason a simple linear regression between the two variables should not be used to test signalling theory. Some authors have used Box-Cox regressions to test signalling theory in an attempt to let the data choose a functional form. The tests proposed here are much more general and allow for testing of the model without imposing unnecessary parametric restrictions on the underlying belief structure of the agents.

Since the model developed in sections 2 and 3 predicts strong positive rank order correlation between product quality and the level of dissipative advertising conducted for that product, we propose to examine this prediction using Kendall's Distribution-Free Test for Independence which is based on Kendall's tau. Kendall's tau calculates an estimate of the rank correlation between two variables. This test examines the hypothesis that X,Y variables of a bivariate population are independent, the test is designed to detect a class of alternatives associated with either positive or negative values of tau¹⁸. This test and the testing procedures outlined in the next section may be may be used in the manner presented here to test the predictions of a wide variety of signalling models.

4.1 Kendall's Tau and Kendall's Distribution Free Test for Independence

¹⁸There are distributions (see Heoffding 1948) for which tau is equal to zero and the null hypothesis of independence is false. To check the results of our tests and to check for this possibility in particular we also calculated the Heoffding Distribution-Free test for Independence which does not suffer from this deficiency. The Heoffding test although based on ranks is not however based on rank correlation, for this reason and because the results of this test did not differ significantly from those obtained using Kendall's test we do not report the results of these test in the tables.

The advantage of Kendall's tau is that its distribution approaches the normal distribution quite rapidly. Thus the normal approximation is better for this statistic than for others of its type such as Spearman's rho.

The statistic is calculated in the following manner: Assume the data consists of a bivariate random sample (X, Y) , of size n . Define two observation pairs as concordant if both members of one observation are larger than their respective members of the other observation pair, for example $(1.3, 2.3), (1.6, 2.7)$. Let N_c denote the number of concordant pairs out of the total $\binom{n}{2} = n(n-1)/2$ possible pairs. Let N_d denote the remaining pairs. Kendall's tau is calculated as $\tau = [N_c - N_d] / \{n(n-1)/2\}$. The hypotheses one may test with this statistic take the following form.

A: two tailed test

H_0 : the X_i and Y_i are mutually independent

H_1 : either (a) there is a tendency for the larger values of X to be paired with the larger values of Y or (b) there is a tendency for the larger values of X to be paired with the smaller values of Y .

B: one tailed test for positive correlation

H_0 : the X_i and Y_i are mutually independent

H_1 : (a) above.

C: one tailed test for negative correlation

H_0 : the X_i and Y_i are mutually independent

H_1 : (b) above.

We are interested in a hypothesis of the form B. Tables are printed for the quantiles of τ .

However a test based simply on $N_c - N_d$, Kendall's Distribution-free test for Independence has wider usage. To illustrate how the construction of this test statistic is based upon the null hypothesis define the Kendall coefficient τ by $\tau = 2 P\{(X_i - X_j)(Y_i - Y_j) > 0\} - 1$. We wish to test the hypothesis that the X and Y random variables are independent (which implies that $\tau = 0$), formally, $H_0: P(X \leq a \text{ and } Y \leq b) = P(X \leq a)P(Y \leq b)$ for all a, b .

The statistic used to test this hypothesis is K where K is defined in the following way

1. for $1 \leq i \leq j \leq n$ calculate $\zeta(X_i, X_j, Y_i, Y_j)$

$$\text{where } \zeta(a, b, c, d) = \begin{cases} 1 & \text{if } (a-c)(b-d) > 0 \\ -1 & \text{if } (a-c)(b-d) < 0 \end{cases}$$

2. Set $K = \sum_{1 \leq i \leq j \leq n} \zeta(X_i, X_j, Y_i, Y_j)$

3. for a one sided test of the null hypothesis of the null versus say $\tau > 0$, the test at the α level of significance would be

$$\text{reject } H_0 \text{ if } K \geq k(\alpha, n)$$

$$\text{accept } H_0 \text{ if } K < k(\alpha, n)$$

where the constant $k(\alpha, n)$ satisfies $P_0[K \geq k(\alpha, n)] = \alpha$. $K = N_c - N_d$.

The large sample approximation of the Kendall K statistic is given by

$$KL \frac{K - E_0(K)}{[\text{var}_0(K)]^{1/2}} = \frac{K}{[n(n-1)(2n+5)/18]^{1/2}}$$

When H_0 is true the test statistic KL has an asymptotic $N(0,1)$ distribution.

The Normal Theory Approximation to the finite sample test would be

$$\text{reject } H_0 \text{ if } KL \geq z(\alpha)$$

$$\text{accept } H_0 \text{ if } KL < z(\alpha)^{19}.$$

4.2 Data

We test the theory using data on advertising expenditures and quality ratings for all high volume North American and Japanese automobiles produced and sold in the Canadian market during the 1980-89 period. In addition some popular European models sold in Canada are included.

In testing the theory we use two measures of advertising obtained from issues of the Annual Summary of Advertising Expenditures published by Media Measurement Services (MMS). The first, television advertising expenditures per model, was chosen because it is generally agreed that this type of

¹⁹ If there are ties among the X or among the Y observations the forms of the Kendall and Heoffding statistics are more complicated however they are easily programmed. The forms of these statistics with ties are given in Hollander and Wolfe (1973).

advertisement (at least concerning the automotive industry) provide little or no direct informational content. It is worth noting here that in all forms of media advertising expenditures devoted to cash back and/or low financing offers as well as dealership promotion are classified separately from advertising devoted to a particular automotive model.

The television advertising expenditures include expenditures on network, selective and spot advertising. All Canadian national and regional networks and affiliates as well as larger independent stations are monitored. Dollar amounts are calculated via program format billings and/or actual billing statements provided by the stations airing the ads.

Total advertising expenditures from all forms of media for each model are also used for comparison purposes. These total expenditure figures include television advertising expenditures, as described above, as well as advertising expenditures in 97 Canadian daily newspapers, 128 Canadian magazines, 9 Canadian trade publications and expenditures from out-of-home media (ie. billboards). The billing information for these publications is readily available and volume discounts offered by all media sources are taken into account.

The expenditures obtained from MMS are recorded for each model but are for the calendar and not model year. There are a few cases within a calendar year in which different years of the same model were distinguished (e.g. expenditures on the 1982 and 83 Buick Skyhawk for the 1982 calendar year). In almost all such cases it was found that less than 10 percent of total expenditures (either on television or overall) were allocated for the automobile whose model and calendar year corresponded. Thus the expenditure data after being deflated according to the procedure outlined in appendix D was adjusted according to this crude method to obtain an estimate of the expenditure on each model automobile based on 1981 advertising dollars²⁰.

The measure of product quality used to test the theory was obtained from

²⁰Several other splits were tried, including assuming that 20 and 30 percent of expenditures in the calendar year being devoted to that model year automobile. There was no significant change in the results.

annual issues of the Canadian Automobile Association's (CAA's) Autopinion. Each year the CAA asks its members to answer a questionnaire in which they evaluate their automobile (see appendix C). In an attempt to assess the overall quality of the automobile in question we used the percentage of positive responses to the following survey question. "If you were given the opportunity to go back in time to the date at which you bought your car would you buy the same car again?"²¹ More specifically we used the percentage of positive responses of those which had owned the model for approximately a 2 year period. Thus the 1983 Autopinion data was used to evaluate the quality of 1981 model year automobiles etc.

The data we have collected fits our theory well. We use responses two years after purchase to get an accurate measure of the *true* quality q of the automobiles' as opposed to \tilde{q} the report communicated soon after purchase. If we used responses of owners of automobiles more than two years old we heighten the possibility that the respondents may not be the original purchasers and thus may not know the full history of the automobile.

For the test results described below the automobiles were placed in one of six broad classifications. The placements were based upon size as well as as the automobiles' relative base prices. Placement according to these two criteria avoided the obvious problems of placing the Ford Tempo in the same category with a BMW 325e. Although cost was of concern in determining placement, the categories may be generally thought of as:

²¹I thank Paul Anglin for pointing out that this measure may be written as $\text{Prob} \{r(q+\theta) - p_i > 0 \mid rE(q) + rE(\theta) - p_i \geq 0, r \geq r_i\}$ for each product i . In a separating equilibrium consumers who purchase relatively higher quality products will require a relatively larger negative shock to induce a 'NO' response. Thus this measure is perfectly correlated with firm type. It is worth noting that this measure is often what is meant by quality in the literature (see Schmalensee 1982).

- 1) sub-compact (SC)
- 2) compact (CO)
- 3) mid sized (MD)
- 4) luxury (LX)
- 5) sport (SP)
- 6) truck (TR)

The data allow for a very general test of the theory. In addition, to our knowledge there exists no data set which allows the testing of signalling theory at such a micro level. We believe a thorough examination of this data set will provide important insights into advertising theory in general.

Section 5. Testing procedures and Results

5.1 Procedures

Because the nonparametric tests outlined above involve only 2 variables we control for fixed effects with strategic grouping of data, a procedure standard in experimental design. We attempt to control for the following effects; i) differing markets faced by differing product groups, ii) "new models" as opposed to cosmetically changed products, and iii) brand loyalty and/or uncertainty over rivals type.

Controlling for these effects leads to several separate tests of the theory²². To control for i), we group the data into the categories given in the previous section. We also test the theory without grouping (ALL) for comparison. This grouping procedure controls for many of the problems which could arise in the data set we use. The quality ratings are from survey data. In determining if they would repurchase their vehicle, the respondents would naturally judge the performance of their automobile relative to its purchase price. The data is grouped to account for the fact that an individual who purchases a low cost automobile will have different expectations on the product's performance from an individual who purchases a luxury automobile.

²²The "theory" refers to the results of the signalling literature which incorporates belief refinements.

These prior expectations are important in determining if firms will attempt to separate or pool, although equilibrium refinements rule out the possibility of such pooling²³.

Since our theory deals with new products we conduct tests of the theory under both strict and lax definitions of new product. For the latter we run our tests over the whole data set arguing that since the expenditures collected are for each model year they are technically always expenditures on new products, with older products defining the used car market, which is not of concern to us. It may be argued however that from year to year most automobiles undergo only cosmetic changes and therefore strictly speaking are not new. To control for this fact we also narrow the data set to automobiles which had not been produced in the previous model year and automobiles which have been advertised as "all new"/"re-engineered"²⁴. We refer to these automobiles as "new models". This restriction narrows our data set considerably. Our nonparametric tests, however, have exact finite sample distributions in addition to rapid convergence properties which allow for valid small sample inference.

To further focus on the signalling effect as an introductory affect we test for signalling evidence using data on the difference between advertising expenditure at product introduction and two years after introduction. Again the data set used consists only of models satisfying our strict definition of new. In conducting such tests we are attempting to control for the fact that we see advertising long after product introduction and it may thus be the increase over and above normal advertising expenditures which signals quality.

The third effect we control for is brand loyalty. Signalling models have yet to reach a level of sophistication which would allow for existence of more than one signalling agent. This does not mean that the theory cannot be tested on data from a non-monopolistic industry, in fact in testing the theory it is crucial that observation of products of differing qualities is possible. Signalling models indeed attempt to explain intra-industry differences.

²³See Note in Appendix B.

²⁴This classification was determined by observing magazine advertisements from several magazines published between 1980-1988.

However it could be argued that in applying the theory to a multi-firm industry we make the implicit assumption that firms know the relative quality of their products and this may not be the case²⁵. Within the corporation however product quality will certainly be known, since brand loyalty is also a characteristic of the market we look for evidence of signalling within the corporation in addition to within product classification. We group the data by corporation using four classifications A, B, and C for the three large American corporations and D for all foreign corporations (ninety percent of the data in this classification are on products produced by Japanese corporations).

In addition to these strategic groupings we run all tests using two definitions of dissipative advertising. Total media expenditures, that is expenditures on each model year automobile from all media sources discussed above, and television expenditures for each of these products. This allows us to determine if television advertising, generally agreed to be the most dissipative form of advertising, fits signalling theory better than media advertising in general.

5.2 Results

Before examining the results of our tests it is useful to discuss trends in the data (see table A1). Quality ratings appear to be what one would expect, namely as one moves from subcompact to luxury the mean quality level rises. Also later year automobiles on average receive higher quality ratings. This presumably reflects innovation and the fact that product quality has become an increasingly important factor in the purchase decision and the industry has responded. There is considerable quality variation in the data although the ratings are less volatile for later year automobiles.

Turning to an examination of expenditures on television and total media advertising, observe that, on average more money is spent on lower quality automobiles. This indicates that the theory is likely to be rejected when tests are run over the entire data set. Expenditure variability is high in all

²⁵ Note that the assumption is not be unrealistic since corporations face each other in the product market repeatedly and are certainly capable of observing their competitor's product quality, at least with a lag.

categories. One will notice that we have dropped the (TR) classification for new automobiles. This was due to lack of data.

Tables A2 and A3 give results for the tests of the theory with grouping according to product classification. Almost all rank order correlation estimates are negative. A comparison of rank correlation estimates between these two tables does indicate a trend in the direction of positive rank correlation when tests are run using television advertising expenditures. However the tests fail to reject the null hypothesis of independence.

Results of our tests of the theory using our strict definition of new cars are given in tables A4 and A5. Again we find little support for the theory. No test can reject a null hypothesis of independence between the level of advertising (using either measure) and product quality.

Tables A6 and A7 examine tests under the hypothesis that it is the increased expenditure at product introduction above normal expenditure levels which signals product quality. An examination of table A6 indicates little support for this hypothesis. We find in all categories, except MD, that there are more discordant than concordant pairs and in no case may we reject the null hypothesis of independence. We find several positive estimates of τ when television expenditures are used, we find a significant positive estimate for the SC grouping.

From the tests discussed thus far we conclude that at the market level there is little support for signalling theory in this industry. Even in the cases where estimates of rank correlation are positive they are not significantly different from zero, statistically or in order of magnitude.

We now turn our focus inward and test for evidence of signalling within the firm. Although our theory deals with one firm producing one product it is easily generalized to a multiproduct firm, yielding the same incentives to pool and separate. By looking within the firm we can eliminate the possible problems of firms not knowing their relative product quality alluded to above.

Table B1 gives some relevant statistics on the data as classified by

corporation. For each corporation the quality ratings of its cars rise, on average, moving from subcompact to luxury. Again this is not the case for advertising expenditures. In fact, exactly the opposite for each corporation. This trend in advertising expenditures could arise due to the fact that these products are relatively more important for the profitability of the firm and/or the fact that the market faced by the lower quality products is larger. This in turn motivates the groupings we have chosen. Again the data exhibits considerable variability.

Table B2 gives test results when total media expenditures are used. Again we find little support for the theory. Many of the estimates of $\hat{\tau}$ are negative. This strongly suggests that signalling theory cannot explain advertising in the automobile market. When television advertising expenditures are used in testing (see Table B3), we find the strongest support for signalling theory. Tests of the theory using all the corporations products (ALL) still yield poor results, and the only positive rank correlation we find is for the foreign corporations. Within product classification, however we find many positive estimates of $\hat{\tau}$, consistently so in corporation D. While some of these estimates are significantly different from zero, none are large. Thus even this evidence provides little support for signalling within the corporation.

Section 6. Conclusion

Our goal as stated at the outset was to determine if there is any support for the signalling explanation of automotive advertising. To this end we have developed a model of advertising signalling within a durable goods industry. We showed the general results predicted by the signalling theory of advertising may be generated via a word of mouth communication mechanism between consumers which purchase a new product at its introduction and those which make subsequent purchases. Both pooling and separating equilibria were shown to exist within the unrefined model. However when standard belief refinements were imposed on the model the only equilibria which remained in the model were those which predict strong positive rank order correlation between the level of dissipative advertising and product quality.

This prediction was tested with data on advertising and product quality in the Canadian automobile market. Little, if any, support was found for the signalling explanation of advertising at the market level. In fact our rejection of this positive rank correlation prediction is strong since our tests examine it at its most basic level. We have tested the theory extensively and tried to control for any limitations in the data which could impede our ability to test the theory. At the firm level supporters of signalling explanations may point to the results of table B3 as support of the theory. However the fact that the magnitudes of the rank correlation statistics are so low, makes it difficult to conclude that individuals actually obtain any significant quality signal from the level of advertising they observe.

At best one could argue that the fact that we fail in the overwhelming majority of our tests to reject our null hypothesis of independence is evidence that undefeated pooling equilibria may exist²⁶. The considerable variability in our expenditure data however makes such an assumption implausible. We are therefore left with the following conclusion. We find no support for the signalling of product quality via advertising within the retail Canadian automotive industry over the period 1980-1988.

²⁶ See appendix B for a discussion of undefeated pooling equilibria.

TABLE A1
DATA INFORMATION

ALL AUTOMOBILES

CLASSIF	N	TELEVISION EXP.		TOTAL MEDIA EXP		QUALITY	
		\bar{x}	σ	\bar{x}	σ	\bar{x}	σ
ALL	590	285239.4	351554.5	532272.0	856267.0	80.73	13.40
SC	107	385911.6	385395.8	972129.0	1668847.3	77.09	12.24
CO	218	335602.2	372998.0	522054.9	498158.2	80.39	12.85
MD	100	203362.7	273248.3	327412.3	379397.8	84.23	11.59
LX	149	167031.5	245546.2	309036.2	351317.7	84.10	13.46
SP	67	188188.2	204974.9	317518.2	289136.2	81.14	13.88
TR	49	333492.1	461425.9	589687.5	715591.6	79.36	14.87

NEW AUTOMOBILES

CLASSIF	N	TELEVISION EXP.		TOTAL MEDIA EXP.		QUALITY	
		\bar{x}	σ	\bar{x}	σ	\bar{x}	σ
ALL	69	490556.9	372329.4	806717.8	609281.1	83.10	12.77
SC	12	687055.8	253759.4	1123934.7	773234.1	79.58	11.29
CO	35	481248.7	435207.1	750926.3	599005.3	79.97	13.53
MD	7	461285.7	296868.7	729687.7	426691.4	90.42	6.32
LX	13	384534.3	295504.1	659722.7	374821.3	91.07	7.31
SP	9	385204.7	190829.7	561656.0	259481.2	89.63	10.85

TABLE A2
X=TOTAL MEDIA EXPENDITURES
Y=QUALITY RATINGS

CL	N	$\hat{\tau}$	K	KL
ALL	590	-0.043	-7463	-1.562
SC	107	-0.047	-270	-0.727
CO	218	0.330	790	0.735
MD	100	-0.047	-236	-0.704
LX	149	-0.012	-127	-0.209
SP	67	0.023	51	0.277
TR	49	-0.035	-84	-0.728

† denotes significance at the $\alpha = .05$ level

‡ denotes significance at the $\alpha = .01$ level

TABLE A3
X=TELEVISION EXPENDITURES
Y=QUALITY RATINGS

CL	N	$\hat{\tau}$	K	KL
ALL	590	-0.010	-1750	-0.3667
SC	107	0.029	163	0.4397
CO	218	0.058	1372	1.2760
MD	100	-0.043	-214	-0.6440
LX	149	-0.001	-9	-0.0149
SP	67	0.023	50	0.2710
TR	49	-0.046	-54	-0.468

† denotes significance at the $\alpha = .05$ level

‡ denotes significance at the $\alpha = .01$ level

TABLE A4
X=TOTAL MEDIA EXPENDITURES (NEW MODELS ONLY)
Y=QUALITY RATINGS

CL	N	$\hat{\tau}$	K	KL
ALL	70	-0.084	-204	-1.036
SC	12	-0.045	-3	-0.208
CO	36	-0.047	-30	-0.409
MD	7	0.285	6	0.9483
LX	13	0.243	19	1.1867
SP	9	-0.361	-13	-1.6554

† denotes significance at the $\alpha = .05$ level

‡ denotes significance at the $\alpha = .01$ level

TABLE A5
X=TELEVISION EXPENDITURES (NEW MODELS ONLY)
Y=QUALITY RATINGS

CL	N	$\hat{\tau}$	K	KL
ALL	70	-0.014	-36	-0.1828
SC	12	-0.045	-3	-0.2075
CO	36	0.005	3	0.0409
MD	7	0.190	4	0.6272
LX	13	0.205	16	1.0010
SP	9	-0.083	-3	-0.3820

† denotes significance at the $\alpha = .05$ level

‡ denotes significance at the $\alpha = .01$ level

TABLE A6

X=TOTAL MEDIA EXPENDITURE AT INTRODUCTION - TOTAL MEDIA EXPENDITURE TWO YEARS
LATER
Y=QUALITY RATINGS

CL	N	$\hat{\tau}$	K	KL
ALL	69	-0.024	-56	-0.291
SC	12	-0.348	-23	-1.590
CO	35	-0.040	-24	-0.341
MD	7	0.476	10	1.568
LX	13	-0.012	-1	-0.062
SP	8	0.464	-13	-1.655

† denotes significance at the $\alpha = .05$ level

* denotes significance at the $\alpha = .01$ level

TABLE A7

X=TELEVISION EXPENDITURE AT INTRODUCTION - TELEVISION EXPENDITURE TWO YEARS
LATER
Y=QUALITY RATINGS

CL	N	$\hat{\tau}$	K	KL
ALL	69	0.072	168	0.872
SC	12	0.379	25	1.720†
CO	35	0.097	58	0.825
MD	7	-0.190	-4	-0.627
LX	13	-0.038	-3	-0.187
SP	8	-0.072	-3	-0.382

† denotes significance at the $\alpha = .05$ level

* denotes significance at the $\alpha = .01$ level

TABLE B1

DATA INFORMATION BY CORPORATION

ALL AUTOMOBILES

CORP	N	TELEVISION EXP.		TOTAL MEDIA EXP		QUALITY	
		\bar{x}	σ	\bar{x}	σ	\bar{x}	σ
A	192	255954.03	347263.96	433049.16	530036.71	78.02	12.58
B	106	334392.52	323739.29	685705.18	1227184.58	77.84	12.96
C	120	234329.99	295864.84	388262.65	368904.22	78.43	13.42
D	169	322411.55	400176.71	653199.31	1069050.54	87.33	12.34

SUBCOMPACT

CORP	N	TELEVISION EXP.		TOTAL MEDIA EXP		QUALITY	
		\bar{x}	σ	\bar{x}	σ	\bar{x}	σ
A	30	444192.13	487981.59	912327.97	723428.03	73.09	9.99
B	18	535275.88	258115.34	1583278.59	2529455.30	73.50	9.14
C	21	301762.32	231182.72	604073.97	484739.37	73.47	9.29
D	38	315652.79	383460.29	933248.91	2003066.76	83.94	13.52

COMPACT

CORP	N	TELEVISION EXP.		TOTAL MEDIA EXP		QUALITY	
		\bar{x}	σ	\bar{x}	σ	\bar{x}	σ
A	92	295548.96	321603.06	444369.15	455981.09	77.51	10.35
B	19	574423.83	404653.18	1029492.96	696632.41	71.78	14.06
C	54	261356.22	355720.58	373420.38	336044.11	79.68	15.16
D	50	397114.88	425333.48	639453.76	492775.26	89.98	7.80

MID SIZED

CORP	N	TELEVISION EXP.		TOTAL MEDIA EXP		QUALITY	
		\bar{x}	σ	\bar{x}	σ	\bar{x}	σ
A	27	53793.56	90049.35	92843.85	116834.52	83.14	12.26
B	26	275817.16	256847.22	394600.90	359212.03	86.96	8.48
C	27	178561.12	232431.84	303384.61	313305.95	83.24	7.74
D	20	344572.55	381949.83	589173.10	501576.27	83.50	16.75

LUXURY

CORP	N	TELEVISION EXP.		TOTAL MEDIA EXP		QUALITY	
		\bar{x}	σ	\bar{x}	σ	\bar{x}	σ
A	19	24884.05	43920.83	95191.94	89689.29	81.47	17.88

B	9	69315.67	80692.42	137621.56	105129.99	80.44	15.39
C	0	-	-	-	-	-	-
D	21	164513.68	197599.00	488471.59	300824.87	87.38	15.24

SPORT

CORP	N	TELEVISION EXP.		TOTAL MEDIA EXP		QUALITY	
		\bar{x}	σ	\bar{x}	σ	\bar{x}	σ
A	13	171898.21	196747.40	235696.32	207580.94	78.46	16.72
B	19	238294.37	189371.15	410556.69	322691.38	75.00	13.14
C	10	92725.01	97694.86	195726.10	181339.91	76.00	9.92
D	25	196763.46	235869.20	338073.21	304849.60	89.28	9.55

TABLE B2
RESULTS BY CORPORATION
X=TOTAL MEDIA EXPENDITURES
Y= QUALITY RATINGS

ALL AUTOMOBILES

CORP	N	τ	K	KL
A	192	-0.084	-1545	-1.737
B	106	-0.207	-1157	-3.162
C	120	-0.127	-926	-2.100
D	169	0.050	704	0.960

SUBCOMPACT

CORP	N	τ	K	KL
A	30	-0.110	-50	-0.895
B	18	0.120	19	0.725
C	21	-0.099	21	-0.641
D	38	0.179	126	1.588

COMPACT

CORP	N	τ	K	KL
A	92	0.024	101	0.341
B	19	0.105	18	0.633
C	54	-0.071	-102	-0.763
D	50	0.096	118	0.993

MIDSIZED

CORP	N	τ	K	KL
A	27	-0.273	-96	-2.008
B	26	-0.111	-36	-0.798
C	27	-0.293	-103	-2.153
D	20	0.289	55	1.789 [†]

LUXURY

CORP	N	τ	K	KL
A	19	-0.140	-24	-0.846
B	9	-0.444	-16	-1.695
C	0	--	--	--
D	21	0.148	31	0.949

SPORT

CORP	N	τ	K	KL
A	13	0.359	28	1.723 [†]
B	19	-0.304	-52	-1.832
C	10	-0.177	-8	-0.730
D	25	0.176	53	1.248

[†] denotes significance at the $\alpha = .05$ level

[‡] denotes significance at the $\alpha = .01$ level

TABLE B3
 RESULTS BY CORPORATION
 X=TELEVISION EXPENDITURES
 Y= QUALITY RATINGS

ALL AUTOMOBILES

CORP	N	τ	K	KL
A	192	-0.0072	-133	-0.150
B	106	-0.1619	-901	-2.460
C	120	-0.0379	-271	-0.616
D	169	0.0705	1001	1.366

SUBCOMPACT

CORP	N	τ	K	KL
A	30	0.0483	21	0.376
B	18	0.3203	49	1.870
C	21	0.0143	3	0.092
D	38	0.2532	178	2.256 [†]

COMPACT

CORP	N	τ	K	KL
A	92	0.112	467	1.579
B	19	0.105	18	0.633
C	54	0.081	116	0.868
D	50	0.055	67	0.564

MIDSIZED

CORP	N	τ	K	KL
A	27	-0.217	-76	-1.721
B	26	-0.212	-69	-1.533
C	27	0.216	-76	-1.599
D	20	0.179	34	1.109

LUXURY

CORP	N	τ	K	KL
A	19	0.070	12	0.449
B	9	-0.250	-9	0.998
C	0	--	--	--
D	21	-0.043	9	0.277

SPORT

CORP	N	τ	K	KL
A	13	0.359	28	1.723
B	19	-0.281	-48	-1.692
C	10	-0.044	-2	-0.183
D	25	0.157	47	1.110

† denotes significance at the $\alpha = .05$ level

‡ denotes significance at the $\alpha = .01$ level

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Appendix A

Proof of Result 0

The result may be proven by showing $\hat{\partial\rho}_1/\partial\tilde{q} < 0$.

$$\hat{\partial\rho}_1/\partial\tilde{q} = \frac{f_2(\tilde{q})[\partial f_1(\tilde{q})/\partial\tilde{q}] - f_1(\tilde{q})[\partial f_2(\tilde{q})/\partial\tilde{q}]}{[f_1(\tilde{q}) + f_2(\tilde{q})]^2}$$

The monotone likelihood ratio condition is given by $[\partial f_1(\tilde{q})/\partial\tilde{q}]/f_1(\tilde{q})$ is increasing in i . this condition therefore yields:

$$f_1(\tilde{q})[\partial f_2(\tilde{q})/\partial\tilde{q}] > f_2(\tilde{q})[\partial f_1(\tilde{q})/\partial\tilde{q}]. \quad \text{Q.E.D.}$$

Note the consumers' priors are irrelevant to signing the derivative.

Proof of Result 1

This result is most easily proven by showing

$$E_q(q)R_2^2 - R_2c_q + c_q^2/E_q(q) > 0. \quad (\text{a1})$$

To see this is true note that if $R_2 = c_q/E_q(q)$ then (a1) is equal to zero. However $p_2/E_q(q) > c_q/E_q(q)$ and $R_2 - p_2/E_q(q) > 0$. Therefore $R_2 > c_q/E_q(q)$, and since equation (a1) is strictly increasing in R_2 the result follows, Q.E.D.

Proof of Result 2

$$\pi_2 = 1/4 \hat{M}_2 \left[\frac{E_q(q)R_2^2 - 2R_2c_q + c_q/E_q(q)}{R_2} \right] \quad (\text{a2})$$

Let H and L denote the quality of any two firms with corresponding costs c_H and c_L . Assume $H > L$ and thus $c_H \geq c_L$. Then

$$\pi_2 | H = 1/4 \hat{M}_2 \left[\frac{E_q(H)R_2^2 - 2R_2c_H + c_H/E_q(H)}{R_2} \right] \text{ and}$$

$$\pi_2|L = 1/4 \hat{M}_2 \left[\frac{E_q(L)R_2^2 - 2R_2c_L + c_L/E_L(L)}{R_2} \right],$$

$$\text{so } \pi_2|H - \pi_2|L = 1/4 \hat{M}_2 \left[\frac{(E_q(H) - E_q(L))R_2^2 - 2R_2(c_H - c_L) + c_H/E_H(H) - c_L/E_L(L)}{R_2} \right] \quad (\text{a3})$$

For R_2 large this term mimics

$$1/4 \hat{M}_2 [(E_q(H) - E_q(L))R_2 - 2(c_H - c_L)]. \quad (\text{a4})$$

Since $E_q(H) - E_q(L)$ is positive the result holds, Q.E.D.

Proof of Result 3

From equation (12) it is clear that $\partial p_1 / \partial Q(\rho) = (1/2)R_1$. Thus part (a) of Result 3 is true. Denote the initial customer base by

$$\text{CB} = \left[\frac{R_1 - p_1/Q(\rho)}{R_1} \right] M_1 \quad (\text{a5})$$

then $\partial \text{CB} / \partial Q(\rho) = -M_1 \partial / \partial Q(\rho) \{p_1/Q(\rho)\}$ and

$$p_1/Q(\rho) = 1/2 \left[R_1 + \frac{c_q}{Q(\rho)} - \frac{\delta M_2 K}{2M_1 R_2 Q(\rho)} \right] \quad (\text{a6})$$

$$\partial / \partial Q(\rho) \{p_1/Q(\rho)\} = -(1/2) \frac{c_q}{Q(\rho)^2} + (1/2) \frac{\delta M_2 K}{2M_1 R_2 Q(\rho)^2} \quad (\text{a7})$$

For sufficiently large M_1 , the first term in (a7) must dominate Q.E.D.

Proof of the result that $\int E_q(q_1)f(\theta)d\theta < \int E_q(q_2)f(\theta)d\theta$.

The statement implies that $\int [E_q(q_1) - E_q(q_2)] f(\theta) d\theta < 0$. Denote $f_1(q_1 + \tilde{\theta})$, $f_2(q_1 + \tilde{\theta})$, $f_1(q_2 + \tilde{\theta})$, and $f_2(q_2 + \tilde{\theta})$ by f_1^1, f_2^1, f_1^2 , and f_2^2 respectively. Using this notation we can write

$$E_q(q_1) = \left[\frac{f_1^1}{f_1^1 + f_2^1} \right] q_1 + \left[\frac{f_2^1}{f_1^1 + f_2^1} \right] q_2$$

and

$$E_q(q_2) = \left[\frac{f_1^2}{f_1^2 + f_2^2} \right] q_1 + \left[\frac{f_2^2}{f_1^2 + f_2^2} \right] q_2,$$

so the numerator of $E_q(q_1) - E_q(q_2)$ is given by :

$$\begin{aligned} &= (f_1^1 q_1 + f_2^1 q_2) (f_1^2 + f_2^2) - (f_1^2 q_1 + f_2^2 q_2) (f_1^1 + f_2^1) \\ &= [f_1^1 f_2^2 (q_1 - q_2) + f_2^1 f_1^2 (q_2 - q_1)] \\ &= [f_1^1 f_2^2 (q_1 - q_2) - f_2^1 f_1^2 (q_1 - q_2)] \\ &= [(f_1^1 f_2^2 - f_2^1 f_1^2) (q_2 - q_1)] < 0 \text{ since } f_1^1 f_2^2 > f_2^1 f_1^2, \text{ Q.E.D.} \end{aligned}$$

Appendix B

NOTE

In the analysis conducted above we applied the Intuitive Criterion to rule out all possible pooling equilibria. Under this criterion the type q_1 firm chose \bar{A} to separate from the type q_j firm. However if the type q_j firm anticipated this move it may also choose \bar{A} and pool again with the q_1 type. The reason being: it is possible that $V(q_j, q_{p,i,j}) - \bar{A} > V(q_j, q_j) - A_{0,j}^*$, if the beliefs are governed by $Q(\bar{A}) \rightarrow q_{p,i,j}$, \bar{A} would be a strictly dominated strategy for the type q_1 firm.

In order to ensure $Q(\bar{A}) \rightarrow q_1$ it must be the case that $V(q_j, q_{p,i,j}) - \bar{A} \leq V(q_j, q_j) - A_{0,j}^*$. This always occurs at advertising level a , however it may also be the case that at a that $V(q_1, q_1) - a < V(q_1, q_{p,i,j}) - A_p^*$ and $\bar{A} = a$ would be a dominated strategy (see Figure 5)²⁷. Thus under the line of reasoning in this note pooling equilibria may exist. This reasoning is not new, the reader should consult Mailath (1990) for a discussion of equilibria of this type which he calls *Undefeated*. The following condition attempts to formalize the argument presented here.

[Figure 5 here]

Definition A necessary condition for pooling between any two successive types $q_1 > q_j$ in this model is defined as follows. Let $A_{0,j}^*$ be the equilibrium level of advertising required to separate q_j from all lower type firms. Let a be defined by

$$V(q_j, q_j) - A_{0,j}^* = V(q_j, q_{p,i,j}) - a.$$

That is, $a = V(q_j, q_{p,i,j}) - [V(q_j, q_j) - A_{0,j}^*]$. Define a necessary condition for pooling (NCP) the condition that

$$V(q_1, q_1) - a < V(q_1, q_{p,i,j}) - A_p^* \text{ where } A_p^* \in [A_{0,j}^*, a).$$

What the NCP represents is a situation in which the prior beliefs which result in an expectation of quality ($q_{p,i,j}$) are so close to q_1 that it is not profit maximizing for a firm of type q_1 to attempt to separate. If a

²⁷This result occurs because q_{pij} is close to q_1 so the type q_1 firm has little incentive to separate while the type q_j firm has a great incentive to pool.

firm of type q_1 chose $A_{0,1} \in [A_{0,j}^*, a)$ then a firm of type q_j will find it profitable to pool by definition, and subject to the elimination of dominated strategies we can see the value of $A_{0,1}$ which a type q_1 firm will choose is $A_{0,j}^*$. We call this condition necessary because if it did not hold the type q_1 firm would choose $A_{0,1} = a$ and the equilibrium would be overturned under the belief structure described within this note as well as the belief structure imposed by the Intuitive Criterion.

Appendix D

Constructing the Expenditure Deflator

Deflating our expenditure data using the CPI or one of its variants would be, at best, an ad hoc procedure since none of its components can be linked in any direct way to the way to the cost of advertising. Ideally one would like the deflator used to be related as closely as possible to the industry which produces the data of concern.

Although no Canadian government agencies provide a series based on the costs of advertising, the data which are needed to construct such a series are readily available. We obtained our data from December issues of the Canadian Advertising Rates and Data (CARD) monthly trade publication for the period 1980-1989 and constructed our deflator in the usual manner using the following data. For the television industry we use a weighted average (by viewership) of the cost of a thirty second spot during prime time charged by the CBC, CTV, and Global television networks. Data obtained from the magazine sector were the costs of full page color advertisements in Macleans and Time Canada with weighted by circulation. For the newspaper industry we used the cost per line of an advertisement in the Globe and Mail, the Toronto Star and the Toronto Sun again weighted by circulation. We use the cost of a 30 second advertisement during prime time on Toronto radio stations CFTO, CHUM and CFTR to construct our series for the cost of radio advertisements, where estimated audience sizes were used to weight each series. All series were given a base year of 1981 before combining. After constructing the series for each media type we combined them into our price deflator with weights determined by each industries average relative importance in terms of total advertisement billings for our automotive corporations²⁸.

²⁸The weighting used here was: 75 television, .15 magazines, .05 radio and .05 dailies. Other weightings did not affect the test results. Of course we deflated television expenditure data using only the television deflator constructed as outlined above.

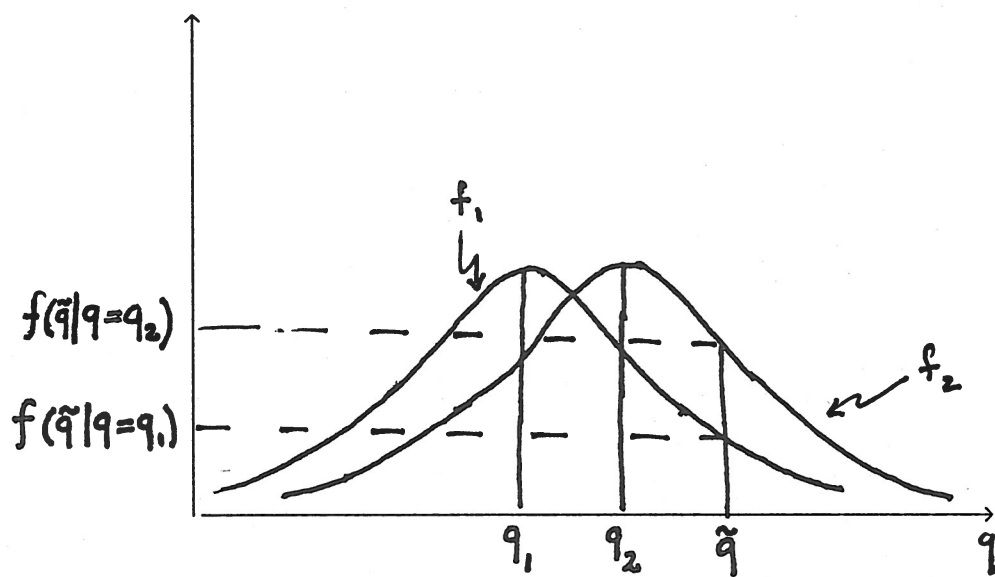


Figure 0

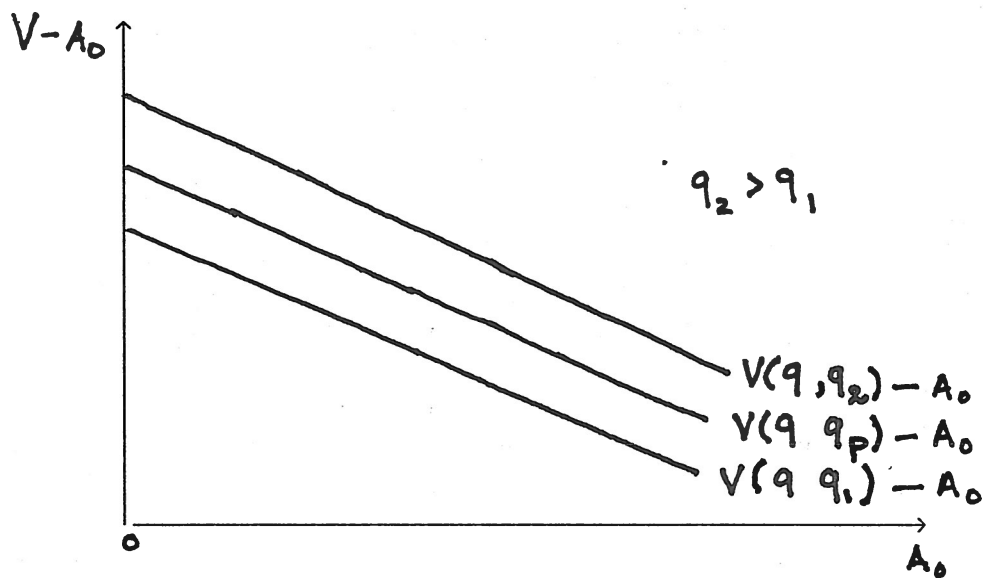


Figure 1

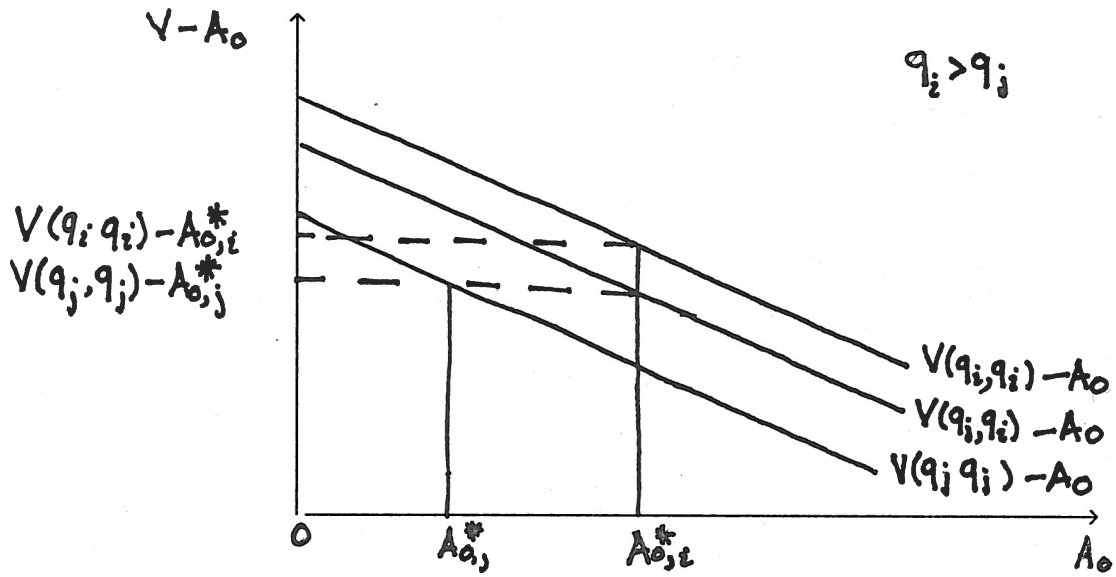


Figure 2

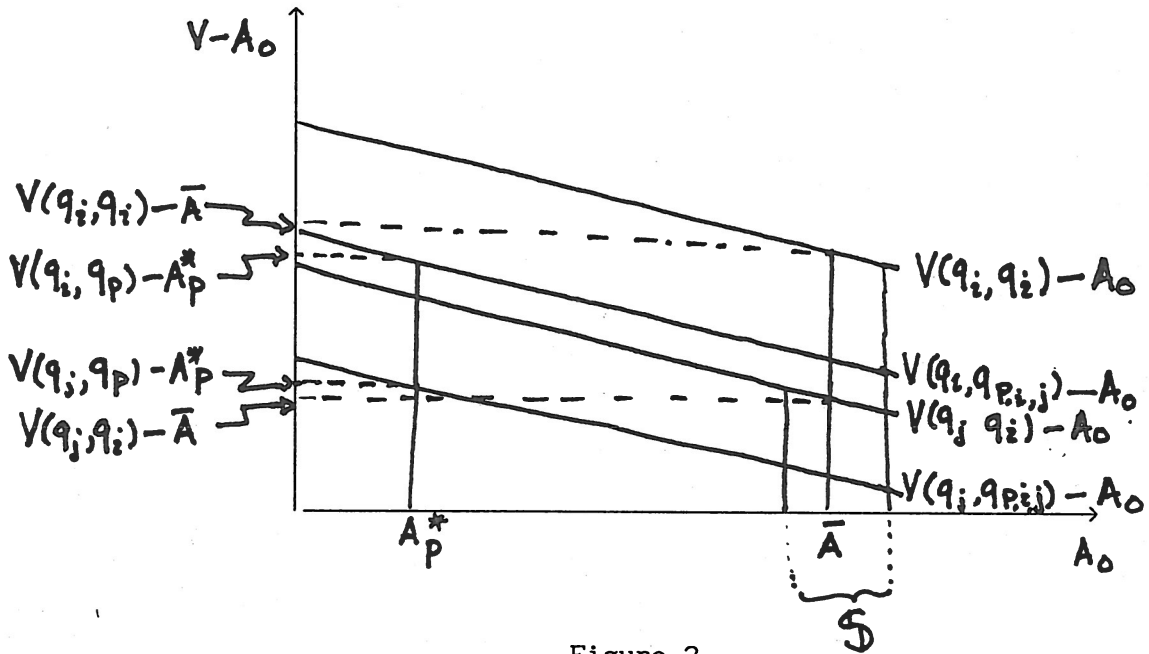


Figure 3

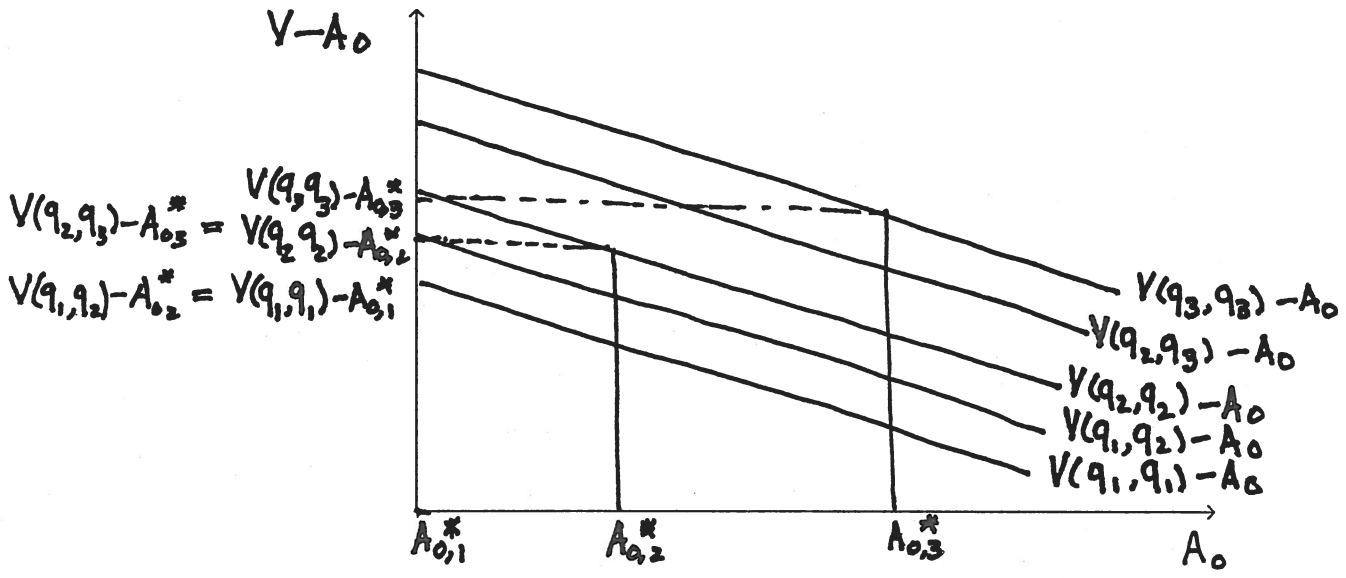


Figure 4

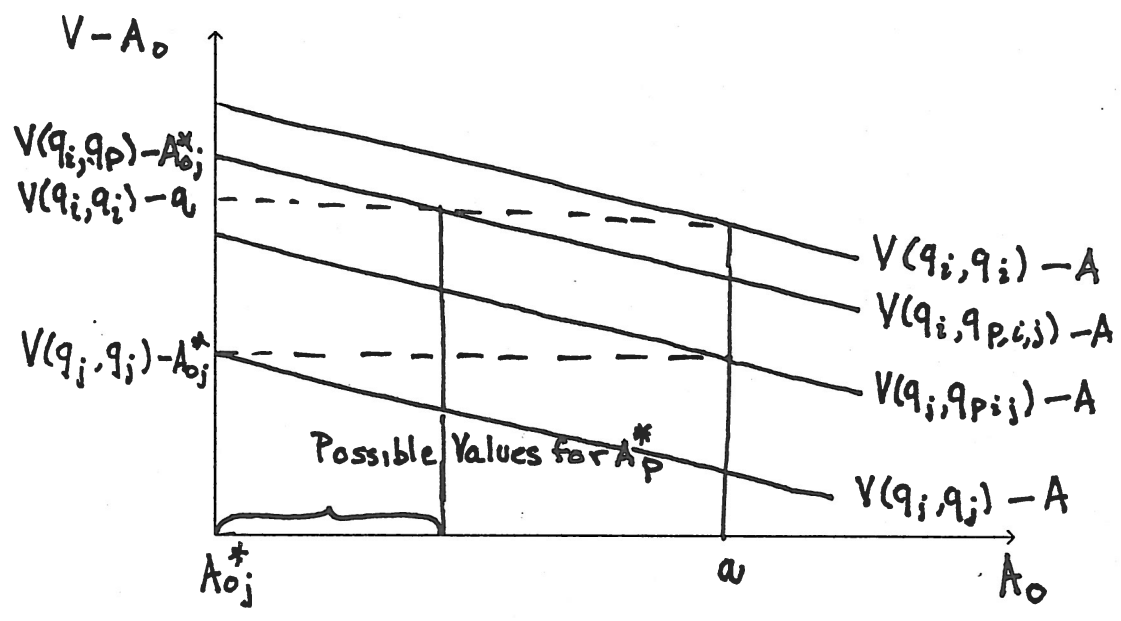


Figure 5