"ESTIMATION UNCERTAINTY AND OPTIMAL ADVERTISING DECISIONS"

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ABSTRACT

In this paper we develop a normative model that is built on an empirically relevant foundation. Notably, we observe that decision makers, among them advertisers, rely on estimated relationships in reaching resource allocation decisions, and we investigate the normative implications of this process. In particular, we explore the effects of uncertainty stemming from the estimation of parameters. In general, we find that ignoring estimation-related uncertainty leads to suboptimal decisions.

1 Introduction

Organizational decision making requires an assessment, which commonly includes objective estimates, of how the organization and its environment - the system - will react to internal decisions. Our concern in this article is to explore the effect that the estimation procedure used (and the inherent and unavoidable uncertainty entailed) has on optimal decisions when regression analysis is the procedure used to generate the estimates. Our approach can be extended to a much wider class of problems where the environmental response to the decision is known only stochastically. For the present paper, however, we confine our attention to the determination of optimal advertising expenditures when the response of sales to advertising is estimated through regression.

The latter problem - determining the optimal advertising budget - is in fact a key problem in advertising research. Given the annual outlays on advertising the problem is far from trivial.(1) Typically, market research analysts first estimate a sales response model and then incorporate the estimated model in the determination of optimal advertising outlays. The market research analyst conducts the optimization within an expected-profit-maximizing framework (implying risk neutrality) ignoring the two-fold uncertainty associated with the non-systematic component in the model (viz, the random error term) and that associated with the estimated parameters. See, e.g., Lambin, Naert, Bultez (1975) [marketing-mix optimization], Simon (1982) [price optimisation], and Corstjens and Doyle (1979) [distribution channel optimization].

Uncertainty has been incorporated into the main corpus of economic reasoning from two main streams of work. The first stream includes the contributions of Sandmo (1971), Baron (1971), Leland (1972) and Batra and Ullah (1974) (among others). In this context, the effects of uncertainty and risk preferences on production (and pricing) decisions of the firm have been explored. The second stream follows from extensions of the original capital asset pricing model (Sharpe (1964) ; Lintner (1965) ; Mossin (1966)) to the analysis of production decisions (Diamond (1967)) and welfare implications (Fama (1972)). A general survey of the comparative statics of the theory of the firm under uncertainty can be found in McCall (1971). The studies from these two streams concern only input demand and the supply reaction of firms to generalised uncertainty, none addresses the issue of estimation uncertainty, nor do these studies treat advertising as a decision variable. Two recent studies by Holthauser and Assmus (1982) and Jagpal and Brick (1982) consider the issue of response uncertainty in advertising - sales models. Employing a risk-return framework, the latter studies have focused their attention on developing algorithms to determine optimal advertising expenditures on the efficient frontier. They do not develop analytical decision rules, nor do they investigate the effects of the decision makers' risk preferences.

Horowitz (1977) has addressed the problem of normative advertising decisions under uncertainty for both price setters and price takers, with the aim of contributing to the debate on advertising and market power. He does not treat estimation uncertainty.

The model proposed in this paper has broader implications than previous work, insofar as the generality of the manager's risk preference function, the advertising-sales response function, and the variables that are incorporated into the analysis concerned. The analysis itself is carried further in terms of developing a panoply of comparative-static results that have heretofore gone unremarked and, to the best of our knowledge, unsuspected.

In general it is shown that optimal advertising expenditure and its reaction to exogenous shocks depend upon four critical "parameters" : the impact of advertising on both expected profits and the associated profit variance, the decision makers' risk preferences, and the specification of the advertising-sales response function. It is also shown that neglecting estimation uncertainty would lead to suboptimal (nonpreferred) decisions. Moreover, the extent of such suboptimality depends upon the appropriate form of the response function. In effect, even the <u>total</u> elimination of specification error will not assure optimal decisions, if the everpresent estimation uncertainty is ignored.

The paper will proceed as follows : Section Two discusses the model and arguments ; Section Three derives and interprets the optimality conditions ; Section Four derives and discusses comparative static results ; Section Five analyses and discusses the most commonly used functional forms in terms of the results of the previous sections ; and, a final section presents some concluding remarks.

2 The Model

Consider a price-taking, single-product firm that produces subject to constant marginal costs over the relevant range. The firm can influence the sales of its product by modifying its marketing effort, but management does not know with certainty the reaction of consumers to this marketing effort. Rather, the consumers' response is calculated from a "response function" estimated from historical data. Management then uses this estimated response function in determining the optimal marketing effort. Given the uncertainty, optimality is defined relative to an expected-utility-maximizing framework.

Without loss of generality, we will treat the marketing effort as consisting only of advertising, although other elements such as direct promotion, sales force, etc. could be introduced in a straightforward way. Our model is suited to the analysis of the annual planning of advertising outlays. Following the study by Clarke (1976), who has shown that for frequently-purchased consumer goods the effect of advertising does not extend beyond one year, we consider only contemporaneous advertising expenditures in the response function.

Thus, formally, management's problem is :

$$\max \; E[U(\pi)] \qquad (1)$$

w.r.t. A

$$\text{s.t. } \pi = [(\bar{P}-c)q - A - F]\,(1-\tau)$$

$$q = f(\bar{P}, A, \underline{\beta}, \underline{z}, \varepsilon)$$

where

q = quantity

$f(\cdot)$ = response function

$\bar{P}$ = given price

A = advertising expenditures

$\underline{\beta}$ = a vector of response function parameters

ε = the random disturbance term with variance of σ_{ε}^{2} ; the expectation $E[\varepsilon]$ will depend on the form of the response function

c = (constant) marginal cost

F = fixed costs

τ = (constant) tax rate

$\underline{z}$ = a vector of other relevant variables, such as competitors' prices and advertising decisions

$U(\pi)$ = a von Neumann-Morgenstern risk preference function

$E[\cdot]$ = expectations operator

In the interest of tractability we will approximate the risk preference function with a third-order Taylor expansion about $\bar{\pi}$, average profits at the risk-neutral optimum, say. The approximation implies that the fourth derivative of the utility function (and the fourth moment about the mean) is zero, which does not impose a serious constraint on the generality of our results.[2]

Performing the expansion and taking expectations gives us the following restatement of the objective function :

$$E[U(\pi)] = U(\bar{\pi}) + \frac{\sigma_\pi^2}{2} U''(\bar{\pi}) + \frac{E(\pi-\bar{\pi})^3}{6} U'''(\bar{\pi}) \qquad (1a)$$

where the primes denote the order of derivatives w.r.t. the argument.

It is assumed that $U' > 0$. We need not place any further restrictions on the risk preference function, although we shall be treating the cases where $U'' \leq 0$ since risk - preferring behavior ($U'' > 0$) may lead to non-convergent results.

We need not place any constraints on $f(\cdot)$ at this stage, although for non-trivial results we would expect $\frac{\partial q}{\partial A} > 0$ for at least some A. Later in the paper we will study the effects of positing the functional forms most frequently used in practice and exposited in the relevant literature, such as the linear and constant elasticity strictly concave (Cobb-Douglas) functions.

3 Optimality Conditions

Expressing σ_π^2 in terms. of σ_q^2 and taking the derivative of the Taylor Series expansion of $E[U(\pi)]$ in (1a) with respect to A, yields the following first-order condition for optimality :

$$\frac{\partial E[\cdot]}{\partial A} = U'(\bar{\pi}) \frac{\partial \bar{\pi}}{\partial A} + \frac{U'''(\bar{\pi})}{2} \frac{\partial \bar{\pi}}{\partial A} X \sigma_q^2$$

$$+ \frac{U''(\bar{\pi})}{2} \frac{\partial \sigma_q^2}{\partial A} X = 0 \qquad (2)$$

where

$$\sigma_\pi^2 = X \sigma_q^2$$

and

$$X = [(P-c)(1-\tau)]^2$$

This can be rewritten as :

$$\frac{\partial \bar{\pi}}{\partial A} (2 + k\sigma_\pi^2) - r \frac{\partial \sigma_\pi^2}{\partial A} = 0 \qquad (3)$$

where

$$r = - \frac{U''}{U'} \quad \text{(the Arrow-Pratt measure of absolute risk aversion)}$$

and

$$k = \frac{U'''}{U'}.$$

Equation (3) highlights the potential trade-off between the effect of advertising spending on expected profits and profit variance, depending on one's attitude toward risk. For the risk-neutral case ($r \equiv 0$) there is no trade-off ; expected profit maximization is the sole concern. This would give optimality conditions similar to the well-known Dorfman-Steiner (1954) results.(3) For the risk-averse decision maker, however, optimal advertising expenditures will be such that $\frac{\partial \bar{\pi}}{\partial A}$ and $\frac{\partial \sigma_\pi^2}{\partial A}$ have the same sign.(4) In other words, where the risk-neutral decision maker tries to maximize expected profits, risk aversion leads to the willingness to give up some expected profits (by spending more, or less, on advertising) in order to reduce the variance in profits.

This can be depicted as in Figure 1. The risk-averse decision maker will spend more (less) than one who is risk neutral, if the minimum variance in profits occurs at a higher (lower) rate of advertising expenditure than that required for maximizing expected profits. Essentially, the risk-neutral management will spend A^*_{RN} on advertising,(5) whereas the risk-averse management will spend between A_1 and A^*_{RN} or between A_2 and A^*_{RN} depending on the value of A for which σ_π^2 reaches its minimum.(6) They may end up spending identical amounts on advertising if, by coincidence, the $E[\pi]$ - maximizing A coincides with the σ_π^2-minimizing A. The risk lover would tend to move to an expenditure rate outside the $[A_1, A^*_{RN}]$ or $[A_2, A^*_{RN}]$ interval and may not find a convergent level.

The first-order conditions given in equation (2) can be used to give a new perspective on the issue of over- or under-advertising, which has been extensively debated in the marketing literature from a managerial point of view (c.f. Aaker and Carman (1982) for a recent review) and in the economics literature from a policy-making social welfare point of view (c.f. Comanor and Wilson (1967)). Rewriting (2) or (3) we get

$$\frac{\partial\bar{\pi}}{\partial A} = \frac{r\ X\ a\sigma_q^2}{2 + kX\sigma_q^2}, \qquad (4)$$

where $a\sigma_q^2 = \frac{\partial\sigma_q^2}{\partial A}$ and a is some function of A, among other arguments.

With the optimality condition expressed in this way, it is evident that the expected marginal profit contribution of advertising at the optimum may be positive or negative depending on the effect of advertising on quantity variance even for the risk-averse decision maker. Thus, what may appear to be suboptimal over-spending ($\frac{\partial\bar{\pi}}{\partial A} < 0$) or under-spending ($\frac{\partial\bar{\pi}}{\partial A} > 0$) behavior when compared to the certainty case, may be management's optimal response to the presence of uncertainty, given the effect of advertising on quantity variance.

INSERT FIGURE 1 ABOUT HERE

The second-order condition for an optimum is :

$$\frac{\partial^2 E[\cdot]}{\partial A^2} = \frac{\partial^2 \bar{\pi}}{\partial A^2} \left(\frac{2 + k\sigma_\pi^2}{2}\right) - r \left(\frac{\partial \bar{\pi}}{\partial A}\right)^2$$

$$+ r\sigma_\pi^2 a^2 \left[\frac{k\sigma_\pi^2}{2 + k\sigma_\pi^2} - \left(\frac{\left[1 + \frac{\partial a}{\partial A}\left(\frac{1}{a^2}\right)\right]}{2}\right)\right] < 0. \qquad (5)$$

Interpretation of this condition is ambiguous. For the risk-neutral case, it reduces to the standard $\frac{\partial^2 \bar{\pi}}{\partial A^2} < 0$. For the risk-averse case, the first two terms are negative so that it is sufficient that the last term be non-positive for the second-order condition to hold. For the non-positivity of the third term, it is sufficient that $\frac{\partial a}{\partial A} \geq a^2$. This condition requires that the variance be "sufficiently" increasingly sensitive to advertising. The case of the risk lover does not lend itself to an intuitively acceptable set of sufficient constraints to ensure the second-order conditions.

4 Comparative Statics

The necessary conditions for optimality imply that the optimal advertising expenditure is a function of k, r, P, c, τ, F and σ_q^2 ; the first two are related to the risk preferences of the decision maker, and the others to the environmental conditions. In this section, we shall explore the reaction of optimal advertising expenditures to parametric shifts in these quantities.

Letting γ be the generic name for any exogenous variable, the reaction of the endogenously-determined optimality condition to changes in these exogenous variables is well known to be given by

$$\frac{dA}{d\gamma} = - \frac{\partial^2 E[\cdot]/\partial A \partial \gamma}{\partial^2 E[\cdot]/\partial A^2}.$$

It immediately follows that where the second-order conditions are satisfied we have

$$\text{sgn}\ [\frac{dA}{\partial \gamma}] = \text{sgn}\ [\frac{\partial^2 E[\cdot]}{\partial A \partial \gamma}]\ .^{(7)} \tag{6}$$

In its generic form, applying this to (2) above gives the general formula for comparative-static analysis :

$$\frac{\partial^2 E[\cdot]}{\partial A \partial \gamma} = \frac{\partial^2 \bar{\pi}}{\partial A \partial \gamma}\ (2 + kX\sigma_q^2) + \frac{\partial k}{\partial \gamma} \cdot \frac{\partial \bar{\pi}}{\partial A} X\sigma_q^2 + \frac{\partial X}{\partial \gamma} [\frac{\partial \bar{\pi}}{\partial A} k\sigma_q^2 - ar\sigma_q^2]$$

$$+ \frac{\partial \sigma_q^2}{\partial \gamma} [\frac{\partial \bar{\pi}}{\partial A} kX - arX] - \frac{\partial a}{\partial \gamma} rX\sigma_q^2 - \frac{\partial r}{\partial \gamma} aX\sigma_q^2 \tag{7}$$

Substituting the desired exogenous variable for γ and taking the indicated derivatives in equation (7) will provide the qualitative results of comparative statics.

<u>Theorem 1</u> : The more risk averse the decision maker is, the less (more) he will spend on advertising, if advertising increases (decreases) the predicted quantity variance.

<u>Proof</u> : $\frac{\partial^2 E(\cdot)}{\partial A \partial r} = - ax\sigma_q^2$

and by (6)

$$\text{sgn}\ \frac{dA}{dr} = - \text{sgn}\ [a]$$

<u>Theorem 2</u> : The higher the extent of decreasing (increasing) absolute risk aversion, the more (less) the decision maker will spend on advertising, if increasing advertising increases the predicted quantity variance. The directions of change would be reversed, if advertising had the opposite effect on quantity variance.

<u>Proof</u> : $\frac{\partial^2 E(\cdot)}{\partial A \partial k} = a[\frac{r(X\sigma_q^2)^2}{2 + Xk\sigma_q^2}]$

and by (6)

$$\text{sgn}\ [\frac{dA}{dk}] = \text{sgn}\ [a]$$

The sense of this result becomes clear if one expresses changes in risk aversion as :

$$\frac{dr}{d\pi} = \frac{d\ [-\frac{U''}{U'}]}{d\pi} = r^2 - k.$$

Therefore

$$\frac{dr}{d\pi} \gtrless 0 \quad \text{as} \quad k \lessgtr r^2.$$

<u>Theorem 3</u> : If advertising increases the predicted quantity variance, a better (worse) fit of the estimated response function -

in terms of a mean preserving spread as in Rothschild and Stiglitz (1970) - implies higher (lower) advertising expenditures.

Proof : $\frac{\partial^2 E(\cdot)}{\partial A \partial \sigma_q^2} = \frac{\partial \bar{\pi}}{\partial A} kX - arX = arX \left[\frac{kX\sigma_q^2}{2 + kX\sigma_q^2} - 1\right]$

since $\frac{kX\sigma_q^2}{2+kX\sigma_q^2} < 1$,

by (6) we have $\text{sgn}\left[\frac{dA}{d\sigma_q^2}\right] = -\,\text{sgn}\,[a]$.

The sense of this conclusion may be better understood by referring to Figure 1 and equation (4). Say the initial optimal advertising expenditure were at a point between $A^{\star}_{RN}$ and A_2. By equation (4), a better fit (i.e. a reduction of σ_q^2 - note that $\sigma_\varepsilon^2 = \sigma_q^2(1 - R^2)$) is going to lead to a reduction in $\frac{\partial \bar{\pi}}{\partial A}$ which signifies a move toward A_2. This follows from rewriting equation (4) as :

$$\frac{\partial \bar{\pi}}{\partial A} = \frac{ar}{\frac{2}{\sigma_q^2} + kX} .$$

Theorem 4 : If advertising increases the predicted quantity variance, higher (lower) fixed costs will lead the decision maker to spend less (more) on advertising unless the decision maker exhibits sufficiently strong increasing absolute risk aversion.

Proof : $\frac{\partial^2 E(\cdot)}{\partial A \partial F} = aX\sigma_q^2\,(1 - \tau)\left[r^2\left(\frac{2}{2 + kX\sigma_q^2}\right) - k\right]$

Four cases can be distinguished :

(i) decreasing absolute risk aversion ($\frac{dr}{d\pi} < 0 \Rightarrow k > r^2$)

$$\text{sgn}\left[\frac{dA}{dF}\right] = -\,\text{sgn}\,[a]$$

(ii) constant absolute risk aversion ($\frac{dr}{d\pi} = 0 \Rightarrow k = r^2$)

$$\text{sgn}\left(\frac{dA}{dF}\right) = -\,\text{sgn}\,[a]$$

(iii) increasing absolute risk aversion -

$$\left(\frac{dr}{d\pi} > 0 \Rightarrow \frac{2r^2}{2 + kX\sigma_q^2} < k < r^2\right)$$

$$\text{sgn}\left[\frac{dA}{dF}\right] = -\,\text{sgn}\,[a]$$

(iv) strongly increasing absolute risk aversion -

$$\left(\frac{dr}{d\pi} > 0 \Rightarrow k < 0\right)$$

$$\text{sgn}\left[\frac{dA}{dF}\right] = \text{sgn}\,[a]\ .$$

Although this result confirms previous studies, in that optimal decisions under uncertainty are not invariant to changes in fixed costs (c.f. Sandmo (1971)), it also indicates that care has to be exercised in specifying the nature of the effects.

<u>Theorem 5</u> : If advertising increases the predicted quantity variance, increases (decreases) in marginal costs will lead to higher (lower) advertising expenditures, as long as the decision maker does not exhibit strongly increasing absolute risk aversion.

Proof : $$\frac{\partial^2 E(\cdot)}{\partial A \partial c} = \left\{ - \frac{(1 - \tau)}{(P - c)} (2 + kX\sigma^2) \right\}$$

$$+ \left\{ - q(1 - \tau) \left[\frac{(rkX\sigma_q^2)(arX\sigma_q^2)}{(2 + kX\sigma_q^2)} - a(r^2 - k) X\sigma_q^2 \right] \right\}$$

$$+ \left\{ - \frac{arX\sigma_q^2}{(P - c)} \left[\frac{2kX\sigma_q^2}{(2 + kX\sigma_q^2)} - 1 \right] \right\}$$

$$= \{A\} + \{B\} + \{C\}.$$

For $\{A\}$, $\{B\} < 0$ it is sufficient that $k \geq r^2$, $a \geq 0$. It is also sufficient that $k \geq 2/\sigma_\pi^2$ for $\{C\} \leq 0$.

Thus

$$\frac{dA}{dc} < 0.$$

If $k \leq 0$ (i.e. strongly increasing risk aversion) this result may be reversed.

Theorem 6 : If advertising increases the predicted quantity variance, increases (decreases) in tax rates will lead to lower (higher) spending on advertising as long as the decision maker does not exhibit strongly increasing absolute risk aversion.

Proof : $$\frac{\partial^2 E(\cdot)}{\partial A \partial (1 - \tau)} = \left\{ (P - c)^2 (1 - \tau) ar\sigma_q^2 \left[\frac{2Xk\sigma_q^2}{2 + kX\sigma_q^2} - 1 \right] \right\}$$

$$+ kr\bar{\pi}\sigma_\pi^2 \frac{\partial \bar{\pi}}{\partial A} - (r^2 - k)\, a\bar{\pi}\sigma_\pi^2$$

For the last two terms to be positive, it is sufficient that $k \geq r_{\tau}^2 a > 0$. It is also sufficient for the first term to be positive that $k \geq 2/\sigma_{\pi}^2$. In this case

$$\frac{dA}{d(1 - \tau)} > 0.^{(8)}$$

If $k \leq 0$ (i.e. strongly increasing risk aversion) the result is reversed.

Theorem 7 : The effect of price variations on the optimal advertising expenditure of a price-taker under uncertainty is ambiguous.

Proof : In the interest of brevity, we do not present the expression for $\partial^2 E[\cdot]/\partial A \partial P$ here. The sign of $\frac{dA}{dP}$, however, depends on the sign and relative magnitudes of the following : r, k, a, $\frac{\partial a}{\partial P}$, $\frac{\partial \sigma_q^2}{\partial P}$, $\frac{P - c}{P}$ and $|\varepsilon|$ where ε is the price elasticity.

Indeed, the ambiguity of the optimal advertising expenditure in response to a price variation is, in itself, a powerful result because it may not be intuitively obvious. Though managers and students of marketing or economics, if posed the question, might answer unambiguously as to the effect of price changes on optimal advertising, their answers may not be in agreement as to the direction of change. In light of Theorems 5 and 6, we observe that a change in either marginal cost or price would result in the same change in the margin (P - c) ; yet, the effects on optimal advertising depend fundamentally on the source of the change in the margin. Unlike marginal cost, price serves as an argument of the demand function as well as a component in the margin. Hence, because price changes provoke changes in the expected-profit function, the predicted quantity variance and their rates of change make an unambiguous determination of $\frac{dA}{dP}$ impossible.

The results of the comparative-static analysis are summarized in Table 1.

INSERT TABLE 1 ABOUT HERE

It is interesting to compare these results with the comparative statics under certainty. It is known that, under certainty, changes in fixed costs and tax rates will have no effect on optimal advertising outlays. Marginal cost increases will unambiguously reduce optimal advertising. The effect of price changes will depend on the relationship between the rate of advertising and price elasticity evaluated at the optimal advertising expenditures. Specifically,

$$\frac{dA}{dP} > 0 \quad \text{if} \quad \frac{\partial q}{\partial A} > \left|(P - c)\frac{\partial^2 q}{\partial A \partial P}\right|.$$

5 Special Cases

In the previous section we analysed the general case without postulating a functional form for the response function. In this section, we provide the results for two advertising-sales response functions frequently used by students and practitioners of the field : the separable and the constant elasticity, strictly concave functions.[9] We also provide an illuminating illustration of the underlying motivation for the risk-averse seller's behavior.

In order to highlight certain effects, we distinguish between two types of uncertainty :

(i) The parameters are known with certainty, and uncertainty enters only through a random error term of the demand response function. This we call the <u>infinite population case</u>.

(ii) Uncertainty is due not only to the random error term but also to the estimation of the parameters. That is, the true values of the parameters are <u>not</u> known with certainty. This we call the <u>finite population case</u>.

Suppose, for example, that the response function is of the form $q = \alpha_0 + \alpha_1 A + \alpha_2 A^2 + \alpha_3 P + \varepsilon$. Then, in the infinite-population case $\sigma_q^2 = \sigma_\varepsilon^2$ and $\partial\sigma_q^2/\partial A = 0$. As seen in Figure 2, the risk-averse seller's advertising optimum and that of the risk-neutral seller coincide. This is so, in terms of equation (3), since the risk-averse firm cannot reduce the profit variance ($\sigma_\pi^2 = X\sigma_q^2$) by redirecting advertising away from the risk-neutral optimum.

In the finite-population case, however, σ_q^2 (and hence σ_π^2) takes its minimum at $\bar{A}$ - the historical (sample) mean of advertising expenditures (for any P). Thus, if the minimum occurs at $\bar{A} < A^*_{RN}$, the risk-averse firm will spend less than A^*_{RN} in order to reduce the profit variance ; and, conversely if $\bar{A} > A^*_{RN}$. The constant-elasticity case is similarly illustrated, except that (a) $\partial\sigma_q^2/\partial A = a\sigma_q^2$, $a > 0$ even in the infinite-population case, and (b) σ_q^2 takes on its minimum at the average of the logarithms of historical advertising expenditures.

INSERT FIGURE 2 ABOUT HERE

Tables Two and Three summarize the comparative static results for the risk-neutral and varying risk preferences cases respectively.

To the extent that the functional form, separable in A, is the correct specification of the response function, neither risk preferences nor estimation risk influences either the optimality conditions or the comparative static results achieved under certainty. If a multiplicative form (non-separable in A) is appropriate, then failing to take the estimation risk and risk preferences into account leads to suboptimal decisions.

INSERT TABLES 2 AND 3 ABOUT HERE

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6 CONCLUSIONS

We have developed a normative model that is built on an empirically relevant foundation. Notably, we observe that most decision makers, among them advertisers, rely on estimated relationships in reaching resource allocation decisions. We explored the normative implications of this process and how these compared with actual behavior. In particular, we described the influence of uncertainty originating from the estimation of the parameters of the demand function.

In general, ignoring estimation-related uncertainty does lead to suboptimal decisions. Similarly, the optimal responses to exogenous changes would depend on whether one acknowledged the effects of estimation uncertainty.

Although it is beyond the intended scope of this paper, our analysis would permit us to offer counsel to advertisers as to how they may beneficially modify their behavior and to policy makers needing to better understand the reactions of advertisers for public-policy purposes : viz the effect of advertising on industrial structure.

TABLE 1

SUMMARY OF COMPARATIVE STATIC ANALYSIS

$(\text{sgn}\,[\frac{dA}{d\gamma}])$

γ	a > 0			a < 0		
	decreasing absolute risk aversion	increasing absolute risk aversion	strongly increasing absolute risk aversion	decreasing absolute risk aversion	increasing absolute risk aversion	strongly increasing absolute risk aversion
r	-	-	-	+	+	+
k	+	+	+	-	-	-
σ_q^2	-	-	-	+	+	+
F	-	-	+	+	+	-
c	-	-	+	+ (most likely)	+	-
τ	-	-	+	+ (most likely)	+	-
p	AMBIGUOUS			AMBIGUOUS		

TABLE 2

RISK NEUTRALITY : OPTIMALITY CONDITIONS AND COMPARATIVE STATICS

First-Order Condition : $\frac{\partial \bar{\pi}}{\partial A} = 0$ or $\frac{\partial \bar{q}}{\partial A} = \frac{\partial E(f)}{\partial A} = \frac{1}{P - c}$ (1)

Second-Order Condition : $\frac{\partial^2 \bar{\pi}}{\partial A^2} < 0$ This condition is always fulfilled for separable and/or strictly concave response functions.

Comparative Statics

	Infinite Population		Finite Population	
	Separable Function in Advertising	Strictly Concave (2) Multiplicative Function	Separable Function in Advertising	Strictly Concave Multiplicative Function
F	0	0	0	0
c	-	-	-	-
τ	0	0	0	0
P	+	$-$ (if $\lvert\varepsilon_P\rvert$ (3) $> \frac{P - c}{P}$) $+$ (if $\lvert\varepsilon_P\rvert < \frac{P}{P - c}$)	+	$-$ if $\lvert\varepsilon\rvert > \frac{P}{P - c} + \lvert\varepsilon_A\rvert q(P - c)\sigma^2_{\varepsilon_P}$ $+$ if $\lvert\varepsilon\rvert < \frac{P}{P - c} + \lvert\varepsilon_A\rvert q(P - c)\sigma^2_{\varepsilon_P}$

(1) For the finite population case, if the response function is multiplicative, the first-order order condition becomes : $\frac{\partial \bar{q}}{\partial A} = \frac{1}{P - c} + k$ where $\frac{\partial \bar{q}}{\partial A} = \frac{\partial f(b_o, \ldots, b_n, A, P)}{\partial A}$ and $k = -\frac{1}{2} \sum_{i=0}^{n} \frac{\partial^3 f}{\partial b_i^2 \partial A} S^2_{b_i}$ where $S^2_{b_i}$ is the estimated variance of b_i.

(2) $q = e^{b_0 + b_1 \ln A + b_2 \ln P + \varepsilon}$

(3) ε_P = price elasticity ; ε_A = advertising elasticity

TABLE 3

RISK PREFERENCES : OPTIMALITY CONDITIONS AND COMPARATIVE STATICS

First-Order Condition : $\frac{\partial \bar{\pi}}{\partial A} = 0$ or $\frac{\partial E(f)}{\partial A} = \frac{1}{p - c}$

except for : finite population and multiplicative response function : $\frac{\partial \bar{\pi}}{\partial A} = \frac{arx}{\frac{2}{\sigma_q^2} + kx}$

Second-Order Condition : $\frac{\partial^2 E}{\partial A^2} = - r(\frac{\partial \bar{\pi}}{\partial A})^2 + (\frac{\partial^2 \bar{\pi}}{\partial A^2}) + (\frac{kx\sigma_q^2}{2} \frac{\partial^2 \bar{\pi}}{\partial A^2}) + (kx \frac{\partial \bar{\pi}}{\partial A} \frac{\partial \sigma_q^2}{\partial A}) - \frac{rx}{2} \frac{\partial^2 \sigma_q^2}{\partial A^2} < 0$

Comparative Statics

	Infinite Population		Finite Population	
	Separable Function (a = 0)	Multiplicative Function (Strictly Concave) (a > 0)	Separable Function	Multiplicative Function (Strictly Concave) (a > 0 if $\ln A > \overline{\ln A}$)(1)
r	0	-	- sgn (a)	
σ_q^2	0	-	- sgn (a)	
k	0	+	sgn (a)	
F	0	- (+ for strong increasing absolute risk aversion)	- sgn (a) (sgn (a)) for strong increasing absolute risk aversion	
c	-	- (+ for strong increasing absolute risk aversion)	- sgn (a) (sgn (a)) for strong increasing absolute risk aversion	
τ	- (+ for strong increasing absolute risk aversion)	- (+ for strong increasing absolute risk aversion)	- (+ for strong increasing absolute risk aversion)	- sgn (a) (sgn (a)) for strong increasing absolute risk aversion
p	+	AMBIGUOUS	AMBIGUOUS	

(1) $\overline{\ln A}$: mean of lnA

FIGURE 1

THE EFFECT OF ADVERTISING ON EXPECTED PROFITS AND VARIANCE IN EXPECTED PROFITS

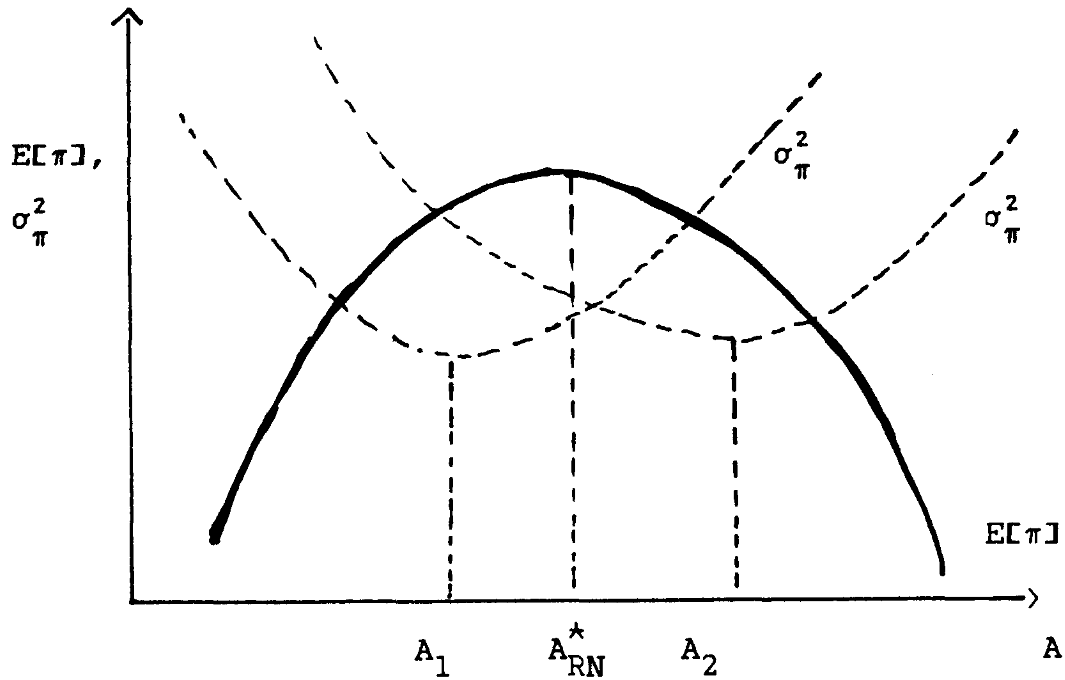
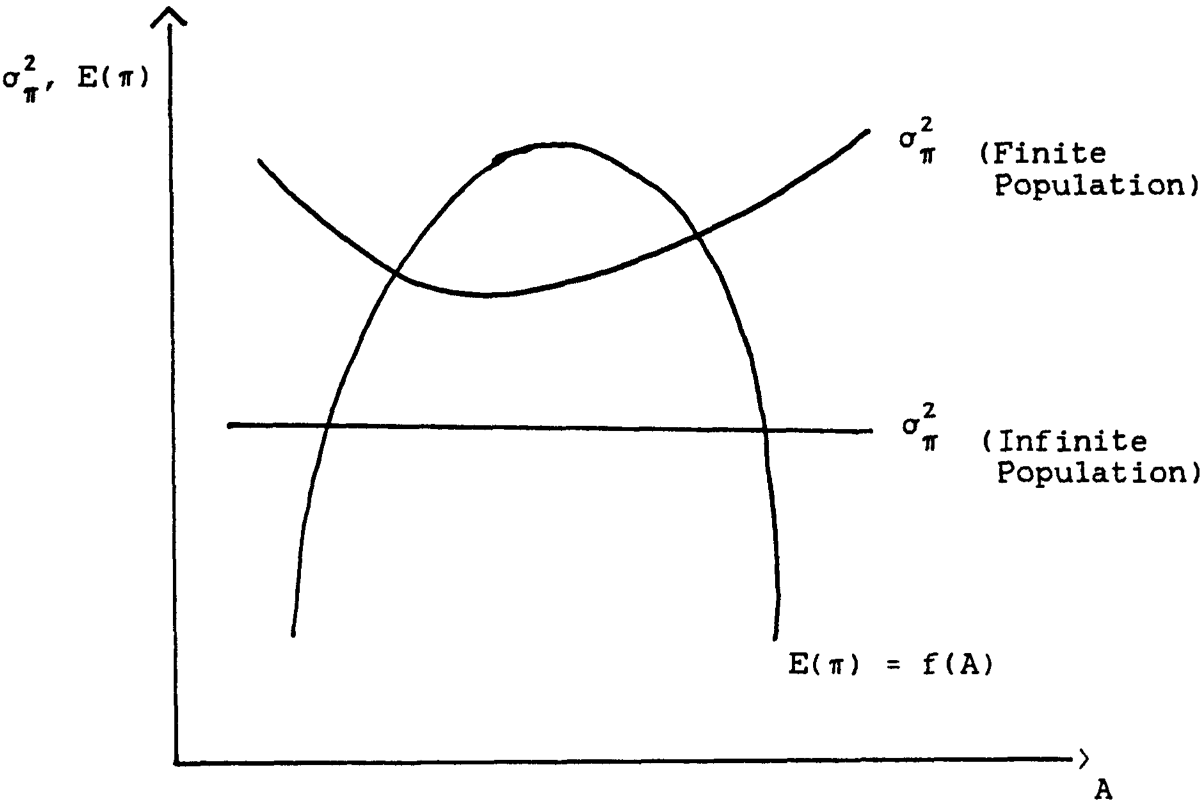


FIGURE 2



σ_π^2, $E(\pi)$
σ_π^2 (Finite Population)
σ_π^2 (Infinite Population)
$E(\pi) = f(A)$
A

FOOTNOTES

(1) For example, according to Advertising Age, in 1984 the largest advertiser (Procter and Gamble) spent $ 774 million, the one-hundredth largest advertiser spent almost $ 50 million.

(2) More precisely, we are assuming that the rate of change of the third- (and higher-) order moments are approximately zero and that the fourth derivative evaluated at $\bar{\pi}$ is approximately zero (or sufficiently small).

(3) We assume the firm is a price taker. Had we treated price as a decision variable, the conditions would have been identical to those obtained by Dorfman and Steiner.

(4) This is because both weighting factors are positive : r by definition of risk aversion and $(2 + k\sigma_{\pi}^2)$ because marginal utility is positive, i.e.

$$E[U'(\pi)] = U'(\bar{\pi}) + \frac{U'''(\bar{\pi})}{2}\sigma_{\pi}^2 > 0.$$

Multiplying by 2 and dividing by $U'(\bar{\pi})$ gives $2 + k\sigma_{\pi}^2 > 0$.

(5) This is not strictly correct but suffices for our purposes here. The reason, as we develop in greater detail elsewhere (Aykaç et al., 1985) is that when q is a nonlinear function of

its arguments the risk-neutral optimum is not equal to the optimum evaluated at the certainty-equivalent values of the parameters - i.e.

$$\frac{\partial E(q)}{\partial A} \neq E[\frac{\partial q}{\partial A}].$$

(6) The shape of σ_{π}^2 follows directly from the prediction confidence intervals from the estimation of the response function, since σ_{π}^2 is just a monotone transform of σ_q^2 (or, more precisely, of its sample value S_q^2).

(7) This explains why, in what follows, we will not be considering risk-loving behavior. As was shown above, the second-order conditions for the risk lover cannot be guaranteed to hold.

(8) Although the theorem is stated in terms of the tax rate (τ), the proof is carried out w.r.t. $(1 - \tau)$ for mathematical convenience. The results follow since τ and $(1 - \tau)$ move in opposite directions.

(9) Another frequently used response function is the logistic function $[Q = Q^{*}/(1 + \exp[-f(A)]$. As Ginsburg (1974) has shown, however, the optimum for these types of functions will always occur in the concave region. For our purposes, therefore, they do not differ from the strictly concave functions we consider.

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