DETAILED REPLY AND COMMENT ON RATCHFORD'S PAPER ON PRODUCT CHARACTERISTICS

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In the September 1977 issue (vol. 4) of Journal of Consumer Research, we published an article "Model of Consumer Reaction to Product Characteristics." The June 1979 issue (vol. 6) of this same journal contained an article "Operationalizing Economic Models of Demand for Product Characteristics" by Brian T. Ratchford that criticized our paper and presented an alternative approach. The June 1979 issue also contained a brief Comment by us on the Ratchford paper. A requirement for brevity imposed by the editor made it impossible for us to present our position in full. This report presents more detail on our arguments. All references to literature in this paper refer to one of the three articles cited previously or to references cited in one of the June 1979 articles.

One of Ratchford's concerns centers on the fate of Lancaster's model if our results and arguments are accepted. In his first paragraph, he writes that our conclusions "generally condemn the Lancaster theory". And in the first paragraph of his section on Ladd and Zober's Theory and Empirical Application he writes, "Gone are Lancaster's argument that some conclusions can be drawn about competitive viability of brands without knowledge of individual utility functions, and his concept that a group of goods sharing common characteristics provides a definition of an industry."

It was not our purpose, nor was it our accomplishment, to "condemn the Lancaster theory". It was our purpose to question the universal applicability of the theory before any empirical testing, to argue that there may exist commodities to which the theory does not apply and to argue that even where it is applicable, empirical work is required. For example, if the marginal utility of a characteristic is negative, the Lancaster model does apply if we do as Ratchford suggests and "rescale the attribute so that it becomes a 'good'." To do this, we must be able to identify the characteristics that have negative marginal utility. Is this always possible from a priori knowledge? We think not; empirical work is required, at least sometimes, to identify these characteristics. To use the argument of Hendler that is cited by Ratchford for handling characteristics that have positive marginal utility in some amounts and negative marginal utility in others, empirical work is needed to identify the point where marginal utility changes sign. It is not our position that "Lancaster's argument that some conclusions can be drawn about competitive viability of brands without knowledge of individual utility functions" is wrong. We are simply urging that empirical work is needed to identify those situations in which his argument does not apply. Finally, our argument does not overturn Lancaster's "concept that a group of goods sharing common characteristics provides a definition of an industry". If anything, our argument supports Lancaster's on this point.

One purpose of our paper, as stated in its second paragraph, was to demonstrate that relaxing some questionable assumptions of the Lancaster model does not destroy its usefulness because a number of useful implications can still be obtained.

Ratchford argues that a negative implicit price for a characteristic indicates "a negative marginal supply price of the characteristic for those who produce it," and cites Rosen for support. By "negative marginal supply price" we assume he means that producers impart more of the characteristic to the product as product price declines, and less as product price rises. Although his position is justified by Rosen, we do not accept its general applicability because it overlooks technical (production) interrelationships. Suppose a firm produces a product that possesses two characteristics and it can influence the price it receives by varying the amounts of the two characteristics per unit of product and will sell all it produces at the price it sets. Define q and p as price and quantity of output, x_1 and x_2 as the amounts of characteristics 1 and 2 in each unit of product, and define $c(q, x_1, x_2)$ as the average cost of production and $p(x_1, x_2)$ as the function relating price to quality. Suppose also that technical (production) restrictions require that x_1 and x_2 be related according to

(1) $x_1 = f(x_2)$

The firm's profit can be expressed as

(2) $\pi = qp(x_1, x_2) - qc(x_1, x_2, q)$

In determining the values of x_1 and x_2 that maximize π, the firm is restricted by the relation (1). The first-order conditions for this constrained profit-maximization problem are

(3) $q(\partial p/\partial x_1 - \partial c/\partial x_1) - \lambda = 0$

(4) $q(\partial p/\partial x_2 - \partial c/\partial x_2) + \lambda \partial f/\partial x_2 = 0$

(5) $x_1 - f(x_2) = 0$

where λ is an auxiliary variable (a Lagrange multiplier) whose value is to be determined. $\partial p/\partial x_i$ is the marginal effect of x_i on price and $\partial c/\partial x_i$ is the marginal effect of x_i on average cost of production. If (a) equation (3) is solved for λ, (b) the resulting expression is substituted for λ in (4), (c) $\partial f/\partial x_2$ is replaced by $\partial x_1/\partial x_2$, and (d) the resulting expression is solved for $\partial x_1/\partial x_2$, we obtain

(6) $$\partial x_1/\partial x_2 = - \frac{\partial p/\partial x_2 - \partial c/\partial x_2}{\partial p/\partial x_1 - \partial c/\partial x_1}$$

Assume that $\partial c/\partial x_1$ and $\partial c/\partial x_2$ are both positive: adding more of either characteristic to a unit of product increases the average cost of production. Assume also that $\partial p/\partial x_2 > 0$ (increasing x_2 increases the price that can be charged), but $\partial p/\partial x_1 < 0$ (increasing x_1 reduces the price that can be charged. Then the denominator of (6) is negative. If $\partial p/\partial x_2 > \partial c/\partial x_2$, the numerator is positive. Then

(7) $\partial x_1/\partial x_2 > 0$

Thus, even though consumers consider x_1 to be an undesirable characteristic, when the firm increases x_2 it must also increase x_1 for technological reasons. We know that technical relations, such as (1) do exist. An example is the relation between an automobile's exterior height, headroom, legroom, seat height and window area. Increasing a car's exterior height permits increasing headroom, legroom, seat height, and window area. Other things constant, an increase in headroom requires an increase in height.

This argument differs from Rosen's because Rosen ignores technical interrelationships. He has no restriction like (1). His first-order conditions for constrained maximization are $q(\partial p/\partial x_i - \partial c/\partial x_i) = 0$ from which it follows that $\partial p/\partial x_i = \partial c/\partial x_i$: the firm's price must rise with increased amounts of x_i if increasing x_i increases the average cost of production.

Ratchford is correct in his assertion that our discussion of advertising is not an application of our consumer model. We erred by failing to state that the discussion of advertising was an application of one of the models discussed in the section entitled Model of Firm's Reaction to Characteristics of Goods Used in Production, that immediately preceded our discussion of advertising. We treated advertising as a service that has various attributes.

Some of Ratchford's objections to our model come from our assumption of continuity or infinitely divisible goods. In several places he favorably cites Rosen's paper. Here is an example of different "scientific tastes". Rosen's model assumes goods are indivisible but the amounts of characteristics in various available goods are continuous, i.e., infinitely divisible. Evidently Rosen's continuity assumption does not bother Ratchford but ours does. We find Rosen's continuity assumption no more "convincing" or "realistic" than ours. According to the Rosen assumption, for example, there exists a linear combination of other cars that provides the same combination of all characteristics that a Ford Fairmont provides; and a combination of cars that provides exactly the same combination of characteristics that any other brand of car provides. More generally, suppose one unit of product 1 contains b_{11}, b_{21}, and b_{31} units of characteristics 1, 2, and 3. According to Rosen's assumption, for every value of b'_{11} in the range $b_{11} = L_{11} \leq b'_{11} \leq b_{11} + u_{11}$, $L_{11} > 0$, $u_{11} > 0$. there exists some product that has b'_{11} of characteristic 1 per unit of product. And further this argument is also true for characteristics 2 and 3. No matter what product is selected, another product can be found that contains slightly more or less of each characteristic. Rosen's assumption of continuity has no more, and no less, a priori appeal to us than does our continuity assumption. If characteristics are infinitely divisible, then some of the restrictions in Ratchford's model need to be changed. Specifically, the restrictions

$$v_i = \sum_j b_{ij} q_j$$

$$\sum_j p_j q_j + Y = K$$

should contain the sum of an infinite number of terms because infinite divisibility of characteristics requires that there be an infinite number of goods that provide each characteristic. When Rosen introduced his assumption of continuity he wrote (pp. 36-37) "this assumption represents an enormous simplification of the problem. It is obviously better approximated in some markets than in others, and there is no need to belabor its realism." The same applies to our continuity assumption.

To refute our assumption of divisibility, Ratchford cites the well known phenomenon of variation in prices of package sizes, where the price of the large box is lower per ounce than the price for the small box. The same objection applies to his model. His model has three brands, and one size of each. Which size? His model can be modified to incorporate different package sizes, by letting p_1', p_1'' and p_1''' and q_1', q_1'' and q_1''' be prices and number of packages bought of three different sizes of packages of brand one. Exactly this same modification can be made in our model.

As conceptual frameworks, we find Ratchford's deterministic model and his stochastic model useful and insightful. Our biggest concern with these models is the last point we discussed in our JCR paper (pp. 86-87): doubt of the accuracy of the estimated weights and our hypothesis that the weight of Y is difficult to estimate reliably. To show the nature of our concern, let us start with Ratchford's equation (4) and rewrite it as

$$\text{(R4)}' \quad u(v) = \sum_{i=1}^{N-1} w_i v_i + w_N Y$$

All this does is to extend Ratchford's analysis from 2 to N-1 products. Then equations (R5), (R6), and (R10) become

$$\text{(R5)}' \quad u(v/q_j) = \sum_{i=1}^{N-1} w_i b_{ij} + w_N (K-p_j)$$

$$(R6)' \quad \sum_{i=1}^{N-1} w_i b_{ij} - w_N p_j$$

$$(R10)' \quad \delta = \sum_{i=1}^{N-1} (w_i/w_N)(b_i' - b_i^*) - (p' - p^*)$$

And the LZ equation at the top of page 87 becomes

$$dK = -(w_1/\ w_N)\ db_{1j}$$

dK is a compensating variation in income.

Now let characteristic one be fuel consumption in km/liter and let us follow Ratchford (p. 81, line of text immediately after (R11) and table on p. 82) and use weight of price as w_N, and suppose b_{1j} declines by one km/liter, i.e., $db_{ij} = -1$. Then for consumer 1

$$dK_1 = -(.1052723/.0001136)(-1)$$

$$= \$926.69$$

and for consumer 2

$$dK_1 = -(.0986928/.0001549)(-1) = \$637.14$$

Consider the consumers' chosen cars. If each consumer were forced to accept another car, which sold for the same price as the chosen car and was exactly like the chosen car except that it ran one less kilometer on a liter of gas, Consumers 1 and 2 would, according to these results, have to be paid \$926.69 and \$637.14 for them to maintain the same level of utility they achieved from buying the chosen cars.

We believe that these results are completely unreasonable. Our position is perhaps best justified by a numerical example. Assume that Consumers 1 and 2 each drive 10,000 miles (16,095 km) annually, in a car that travels 25 miles per gallon (10.6 km/liter) of gasoline, and pays \$2 a gallon

($.53/liter) for gasoline. The consumers each spend the equivalent in Dutch Guilders of $804.75 annually for gasoline. Now reduce the km/liter from 10.9 to 9.6. Each consumer must now buy 1,676.56 liters of gas annually to travel 16,095 km. and must spend $888.58 for gasoline. Thus, the compensating variation in income for these consumers, dK_1 and dK_2, does not exceed $83.83 (= $888.58 - $804.75). Why is this so? If each consumer's income is increased by $83.83, the consumer can use the additional money to buy enough additional gasoline to allow the family still to drive 16,095 km without reducing its consumption of other goods and services. So after the decrease in fuel economy and the $83.83 increase in income, the consumer can still buy enough gasoline to drive the same distance as before and can buy the same amounts as before of all goods and services except gasoline. Thus dK does not exceed $83.83.

Why is this figure so much smaller than w_1/w_N? We suggest that it is smaller because Ratchford switches from one interpretation of w_N to another in mid-argument. Our w_N corresponds to Ratchfords w_3 in his equation (R_4). In (R_4), w_N (= w_3) is weight of a composite of other goods in the utility function. By the time Ratchford has reached (R10) and (R11) and his empirical work, w_N is weight of price. And we suggest that the change in interpretation comes between equations (R5) and R6). It is true that, if values of w_1, w_2, ..., w_N are known, the values of b_{ij} and p_j that maximize (R5) -- and (R5)' -- also maximize (R6) -- and (R6)'. This happens because K is a constant.

But we submit that this mathematical equivalence is <u>not</u> a psychological equivalence. This mathematical equivalence does not mean that the same values of w_1, w_2, ..., w_N are obtained by asking questions about characteristics 1, 2, ..., N-1 and price as are obtained by inquiring about these same characteristics and all other consumption. Ratchford gathered information about characteristics and price, used this information to obtain weights for characteristics and price, and interpreted the weight of price as being the weight of the composite good, and used this weight to compute monetary loss.

In our JCR paper we questioned the large size of the compensating variation for handling ease. Here, we argue that the compensating variation for fuel consumption is too large. The common element in the compensating variations is w_N. We now hypothesize that these compensating variations are too large because their common denominator -- the estimated value of w_N -- is too small. And we further conjecture that it is too small because Ratchford's questionnaire was constructed to estimate w_N as the weight for price rather than as weight for all other expenditures.

It is worthwhile to follow our line of argument further to determine the effect of incorrect estimation of w_N on Ratchford's measure of accuracy of choice. We have already argued that the estimated compensating variations are too large because estimated values of w_N in Ratchford's paper are too small and have used a numerical example to suggest that the maximum value of compensating variation in income for a decline in fuel economy is in the range of \$84.00. Suppose that the compensating variation is \$84, and that Ratchford's estimated values of w_N are too small, but his other weights are accurate. Then, for consumer 1, $w_1/w_N = 84$ and

(8) $w_N = w_1/84 = 0.1052723/84 = 0.001253$

For consumer 2, $w_N = .0986928/84 = 0.001175$. These values are much larger than Ratchford's weight of price that he used to measure accuracy of choice. Rewrite (R10) as

$$\delta_p = \sum_i (w_i/w_p)(b_i' - b_i^*) - (p' - p^*)$$

where w_p is used in the denominator to indicate weight of price. Our argument is that the denominator should be w_y, weight of other consumption. Write

$$\delta_y = \sum_i (w_i/w_y)(b_i - b_i^*) - (p' - p^*)$$

Because $w_y > 0$, $w_p > 0$, $w_y > w_p$, it follows that $\delta_p > \delta_y$, i.e., Ratchford's estimate of choice inaccuracy is too large. It can even happen that δp is positive whereas δy is negative.

In his table, Ratchford presents monetary losses for Consumers 1 and 2 from purchasing a car different from the "car that maximizes the consumer's preference" (Ratchford, p. 80). This is computed from (R10)' with $w_N = w_p$, and amounts of \$7.30. From (R10)' and the data for consumer 1 in Ratchford's table,

$$\delta_p = \$7.30 = \sum_i (w_i/.0001136)(b_i' - b_i^*) - (\$5,912 - \$4,720)$$

and

$$\sum_i (w_i/w_p)(b_i' - b_i^*) = \$1,199,30$$

Then, taking w_N from equation (8) as the proper value of w_y,

$$\sum_i (w_i/w_y)(b_i' - b_i^*) = \sum_i (w_i/w_p)(b_i' - b_i^*)(w_p/w_y)$$

$$\$1,199.30\ (.0001136/.001253) = \$108.73$$

and

$$\delta_y = \sum_i (w_i/w_y)(b_i' - b_i^*) - (p' - p^*) = \$108.73 - \$1,192$$

$$= -\$1,083.27$$

This is consistent with the hypothesis we expressed in our JCR paper that the market-expressed choice, i.e., the car actually purchased, comes closer to expressing the consumer's true preferences than does the interview-choice, and is inconsistent with Ratchford's hypothesis.

From R(10)' and the data for consumer 2 in Ratchford's table,

$$\delta_p = \$879.66 = \sum_i (w_i/.0001549)(b_i' - b_i^*) - (\$5,912 - \$6,184)$$

or

$$\sum_i (w_i/w_p)(b_i' - b_i^*) = \$607.66$$

Then

$$\sum_i (w_i/w_y)(b_i' - b_i^*) = \$80.11$$

And

$$\delta_y = 80.11 + 272 = \$352.11$$

which is still positive but is only four-tenths the size of Ratchford's measure of monetary loss.

We turn now to the issue of estimation of the weights and the difficulty of estimating w_N. We doubt that questions aimed at estimation of weights of characteristics and of price yield the same value of w_N as questions aimed at estimation of weights of characteristics and of other consumption because the two involve different frames of reference. In the first situation, the interviewee has to consider only the one product under investigation, its characteristics, and its price. In the second situation the interviewee has to consider the one product and its characteristics, and also has to consider all other consumption: meals at restaurants, hamburgers at home, dress clothing, jogging shoes, newspapers, electricity, lawn fertilizer, etc. The breadth of the frame of reference is the thing that leads us to suggest that weight of income is more difficult to estimate reliably than are other weights.