CAE Working Paper #04-04

Consumer Cognition and the Pricing in the 9's in Oligopolistic Markets

by

Kaushik Basu

April 2004

.

Consumer Cognition and Pricing in the 9's in Oligopolistic Markets

Kaushik Basu
Department of Economics
Cornell University
Ithaca, NY 14853
Fax: 1-607-255-2818
Email: kb40@cornell.edu

April 2, 2004

Abstract

The paper fully characterizes the Bertrand equilibria of oligopolistic markets where consumers may ignore the last (i.e. the right-most) digits of prices. Consumers, in this model, do not do this reflexively or out of irrationality, but only when they expect the time cost of acquiring full cognizance of the exact price to exceed the expected loss caused by the slightly erroneous amounts that would be purchased by virtue of ignoring the information concerning the last digits of prices. It is shown that in this setting there will always exist firms that set prices that end in nine though there may also be some (non-strict) equilibria where a non-nine price ending occurs. It is shown that all firms earn positive profits even in Bertrand equilibria. The model helps us understand in what kinds of markets we are most likely to encounter pricing in the 9's.

JEL Classification Numbers: D43, L13.

Acknowledgements: I am grateful to Talia Bar and Ted O'Donoghue for helpful comments

1 INTRODUCTION

A large body of research has confirmed what shoppers, the world over, know, namely, that a disproportionately large number of goods are priced to end in a nine. Hamburgers for 99 cents; shoes for 49 pounds; and so on. There is also a substantial literature that analyses this phenomenon of 'pricing in nines',[1] which is closely related to what is referred to in the marketing literature as the phenomenon of 'odd pricing' (see, e.g., Evans and Berman, 1997, p. 626). Clearly, this kind of pricing is evidence of consumer carelessness in processing the less important (that is, the right-hand) digits of a price. However, while the standard presumption is that the consumer treats the last digits as if they were zero[2], I had assumed in Basu (1997) that the consumers act rationally and assume the last digits to be whatever they are, on average, in reality. In other words, while I went along with the standard assumption that consumers do not look at the last digits carefully, I assumed that the consumers knew what those digits, typically, are and based their demand calculations by assuming them to be whatever they typically are. This provided an explanation for the phenomenon of pricing in the nines and, in addition, led to the unexpected welfare result that the producers were the ones who got hurt because of this phenomenon.

The aim of the present paper is to take that analysis further in two ways. In my previous paper the presumed market structure was that of a monopoly or, more precisely, several monopolies. It would be nice to extend the analysis to the more general case of an oligopolistic market. This is done in the present paper, which characterizes the Bertrand equilibrium and shows that the welfare implications of such a model can be quite interesting. It shows, for instance, how Bertrand oligopolists can earn positive profits in equilibrium. Secondly, in this paper consumer behavior is modeled from more basic axioms of rationality. The model helps us understand under what circumstances we are more likely to encounter the syndrome of pricing in the nines. It illustrates how certain kinds of consumer behavior which are popularly taken as evidence of psychological illusion or irrationality may be a consequence of a more fundamental rationality.

2 SKETCH OF THE ARGUMENT

Given the limits of the human brain, it is reasonable to assume humanbeings will not be fully informed. When a person goes through a supermarket buying goods, is it worthwhile for him to study and take in the price information of each product in full? It is not evident that the answer to this will be yes, contrary to what early textbook models of economics suggested. Indeed it may not be rational to take in so much information. If, for instance, he looked only at the dollar part of the prices and took his purchase decisions based on that, he would make a few wrong decisions, true, but the time saved by this strategem may be well worth that little loss. I shall later model the circumstances where such time-saving is worthwhile.

Once consumers begin to behave this way, a Bertrand firm may not find it worthwhile to undercut other firms by a small amount since this may go unnoticed by the consumers. If this happens, then the price cut would not lead to a higher demand and therefore would not be worthwhile. This could result in an equilibrium where, despite Bertrand competition, firms earn positive profits. One implication of this model is that 9-ending prices are less likely to occur in wholesale markets, where the buyer, by virtue of the fact that he makes large purchases, finds it rational to be sensitive to small price changes.

3 BASIC CONCEPTS AND NOTATION

Since formal, quantitative analysis of this problem is relatively new, it is useful to develop some algebra specifically suited to this kind of study.

In this paper, I shall be concerned with prices which treat a cent as an indivisable unit. Hence, a price is always expressed up to two places after the decimal, that is, by numbers like 1·50 or 12·95. Let $\mathbb{P}$ be the collection of all such non-negative numbers. For every $p \epsilon \mathbb{P}$ it will at times be useful to write it as (d, c) where d is the 'dollar part' of p and c the 'cent part' of p. Let ϕ be a function, on domain $\mathbb{P}$, such that, for every $p \epsilon \mathbb{P}$, $\phi(p) = (d, c)$, as defined above. I shall at times write $\phi(p) = (d(p), c(p))$. Hence, $d(12.95) = 12$ and $c(12.95) = 95$. Let ψ be the inverse of ϕ. That is, $\psi(\phi(p)) = p$, for all $p \epsilon \mathbb{P}$. Therefore, $\psi(12, 95) = 12.95$.

We shall be concerned in this paper with an industry where the aggregate demand function for the good in question is given by

$$x = x(p) \tag{1}$$

for all $p \epsilon \mathbb{P}$. And if p, $p' \epsilon \mathbb{P}$ such that $p > p'$, then $x(p) < x(p')$.

This industry has n identical firms. Each firm's per-unit cost of production is given by $k \epsilon \mathbb{P}$. For the problem to be non-trivial, I will assume that $x(k + 1) > 0$. I shall, on occasions, refer to the marginal cost as $(d(k), c(k))$ where $(d(k), c(k)) = \phi(k)$.

4 RATIONAL 'IRRATIONALITY' OF THE CONSUMER

While it is true that traditional economic theory was wrong (as the new 'behavioral economics' reminds us) in its assumption that consumers are always rational, it is also possible to err on the other side by treating every *seemingly* irrational behavior as irrational behavior. Consider, for instance, the fact that human beings take so many decisions without seriously weighing the pros and cons of the decision. Once we recognize that the act of weighing the pros and cons of a decision is itself costly in terms of time and the use of our limited (severely so, in most cases) brain capacity, it may make good sense to leave some decisions to gut feeling, reflexive action or simply picking the default option. These 'irrational' actions may, in other words, be rational at a more fundamental level (Basu, 1988, 1992, Section 12.4).

Consider now a consumer in a large store doing his week's shopping. He can stand in front of each competing brand, study the price fully, let that information sink in and then make a purchase. This way his purchase will be just right, given his needs, but he will end up having spent more time in the store than he would if he was prepared to make mistakes. If time is valuable it may be rational for him not to dwell too long on taking in every good's price information. Now, if a person is keen on economizing on acquiring information concerning some digits, it obviously makes sense to start with the right-most digits. When we are thinking of small purchases, as, for instance, in a grocery store, this will typically refer to the cents part of the price.

Let us formalize this obvious observation as follows. In making a purchase, the consumer can go about it in two ways. First, he could look at only the dollar part of the price and assume that the cent part of the price is whatever is the average cent parts of prices of all goods sold and then decide how much to purchase. Let us call this action A. Second, he could take in the price information fully; and then decide on how much to buy. I will call this action B.

Assume that the latter entails a (brain-capacity or time) cost of $b(> 0)$ whereas the former is costless. In other words, I am assuming that we have a sense of what the average of the cent parts of prices of all goods that are offered in the market is. This is the kind of information we acquire automatically in the act of going through life.

In this model we will consider only one good, which is sold by n producers - a typical oligopoly model. In other words, there will be n prices being offered in the market. The producer's (or seller's) behavior will be modeled in the next section. Let us describe a typical consumer's behavior here.

The consumer's utility function is given by $u = u(x, m)$, where x is the amount of the good consumed and m the amount of money left with the consumer after the purchase of the good. If the price of the good at which he purchases the product is p and his income is y, then $u = u(x,\, y - px)$. This is a semi-indirect utility function. Since y will be taken to be fixed throughout, we will suppress it and write the semi-indirect utility function as

$$v = v(x, p) \equiv u(x,\, y - px) \tag{2}$$

Note that the consumer's demand function, described above by (1), is easily derived from this. In particular, $x(p) = m[\arg\max_x v(x, p)]$ where m is the number of (identical) consumers.

To describe a consumer's cognition problem, it is convenient to, at times, abuse notation a little and write $\phi(p)$ in place of p in (1) and (2). That is, we will on occasion write the $v(\cdot)$-function as $v(x,\, (d, c))$ and the demand function as $x(d, c)$, where $(d, c) = \phi(p)$. In other words, $v(x, (d, c))$ and $x(d, c)$ refer to $v(x, \psi(d, c))$ and $x(\psi(d, c))$.

Suppose the consumer goes for action B and buys a good priced (d, c), then his total utility is

$$v^B = v(x(d, c),\ (d, c)) - b$$

If, on the other hand, he goes for action A, then his utility is given by

$$v^A = v(x(d, \bar{c}),\ (d, c)),$$

where $\bar{c} = (c_i + ... + c_n)/n$, given that producer i charges a price of (d_i, c_i).

The consumer will choose action A if and only if $Ev^A > Ev^B$, where the expectations operator is taken with respect to all the possible values of c.

This model of consumer cognition can be made more sophisticated in many different ways. First note that, any decision problem that involves costly evaluation, as in this exercise (recall $b > 0$), has an infinite regress problem. If making an evaluated choice between X and Y involves a cost, then making an evaluated choice between whether to make an evaluated choice between X and Y or to choose at random between them will involve some cost; and so on. Secondly, if the consumer knows the distribution of $c's$ on the market but not the c facing him, it is not typically the case that he will use the average value of c to decide how much to buy. This is merely an approximation of the precisely rational behavior. However, the main results of this paper (this will be obvious later) will not hinge on these refinements. The result will be invariant to many different formulations of consumer decision-making under limited brain capacity.

Fortunately, we do not need to model the full range of consumer behavior, when decision-making is costly. For the purpose of the present paper it is enough to assume that if the cent parts of all prices prevailing in the market is the same, then $Ev^A > Ev^B$, that is, the consumer will choose action A. The rationale behind this assumption is not hard to see. If the cent part of every price on the market is $\bar{c}$, then it is not unreasonable to assume that the consumer knows (from everyday life) that the cent part of a randomly selected good will almost certainly be $\bar{c}$. Hence $Ev^A \simeq Ev^B + b$. For a person placing a large order (for example, agreeing to a long-distance phone price for the next two years, or buying on the wholesale market) this may not be a realistic assumption. But for everyday retail shopping it seems fine; and in the present we will make use of this assumption.

5 SOPHISTICATED BERTRAND OLIGOPOLY

The game that we will consider here is one where the n firms and the m consumers take their decisions simultaneously. Each firm i announces its price (d_i, c_i) and each consumer j chooses $x_j \epsilon \{A, B\}$. Let us call this game 'the sophisticated Bertrand Oligopoly'.

An n-tuple of choices by the firms, $((d_1, c_1), ..., (d_n, c_n)) \equiv \langle d, c \rangle$, will be called a *sophisticated Bertrand equilibrium* if there exists $X = \{X_1, ..., X_m)$, where $X_j \epsilon \{A, B\}$, such that $(\langle d, c \rangle, X)$ is a Nash equilibrium of the sophisticated Bertrand oligopoly.

In conducting our analysis it is useful to distinguish between two kinds of (sophisticated Bertrand) equilibria. I shall say that an equilibrium is 'symmetric' if all identical agents behave the same way in equilibrium. Hence, in this model a 'symmetric equilibrium' is a sophisticated Bertrand equilibrium in which all consumers make the same choice and all firms set the same price. A sophisticated Bertrand equilibrium that is not symmetric is called an 'asymmetric equilibrium'.

Recall each firm's marginal cost of production is given by $(d(k), c(k))$. The main result of this paper is that every firm charging a price of $(d(k), 99)$ is always a sophisticated Bertrand equilibrium. And every firm charging a price of $(d(k)+1, 99)$ could be a sophisticated Bertrand equilibrium, depending on the parameters of the model. No other price can occur in a symmetric equilibrium. No price below $(d(k), 99)$ and no price above $(d(k)+1, 99)$ can ever be a sophisticated Bertrand equilibrium. In some markets there may exist an asymmetric equilibrium in which two prices prevail, one ending in 99 and another with a non-99 ending.

Before proving the result, let me illustrate it geometrically. Figure 1 shows the aggregate demand curve that the industry faces and each firm's marginal cost curve (as depicted by the horizontal line through point E). Since prices cannot be announced in units smaller than a cent, not all points on the demand curve, AB, are available but only a 'grid' of points, one cent apart. Some of these are illustrated by the round nodules marked on the line AB, for instance, points E, F, G, H and some more unlabelled ones. Let us initially consider only symmetric equilibria.

If this was a standard model, with consumers always fully cognizant of the prices being charged, the oligopoly would have exactly two possible (Bertrand) equilibrium points, at F and at E. That is, there is one Bertrand equilibrium where everybody charges the marginal cost $(d(k),\ c(k))$ and another Bertrand equilibrium where everybody charges one cent more than the marginal cost. In other words firms will earn zero profit or virtually zero profit.

In a sophisticated Bertrand oligopoly that the present paper is concerned with, F and E cannot be equilibrium points. Instead, point G is always an equilibrium; and point H may be an equilibrium.

To prove this, consider the case where all n firms change the price $(d(k), 99)$, that is, the price associated with point G and the consumer chooses action A (that is, ignores the actual cent information). If a firm charges a higher price, the dollar amount charged by this firm will be higher. So all consumers will notice the higher price and refuse to buy from this firm, which will therefore earn zero. If the firm charges a lower price (but one that is at least as large as $(d(k),\, c(k))$ no consumer will realize this. So the demand faced by this firm will be as before; and therefore its profit will be less. Since all firms charge the same price, the consumer has nothing to gain by evaluating each price information. In other words, he is better off choosing strategy A instead of B. Hence, no one benefits from an unilateral deviation, and so G depicts a sophisticated Bertrand equilibrium.

Now, it will be shown that point H can, under some conditions, be an equilibrium. H depicts the price $(d(k) + 1,\, 99)$. Suppose all firms charge the price at H, that is, $(d(k) + 1,\, 99)$, and every consumer chooses action A. Then each firm earns a profit of $[(d(k)+1, 99) - (d(k),\, c(k))]x((d(k)+1, 99))/n$, since $(d(k),\, c(k))\,\epsilon\,[(d(k), 0),\, (d(k)+1,\, 0))$. By the same logic as in the above paragraph no firm will find it worthwhile deviating to a higher price or to a lower price which is, at the same time, greater than or equal to $(d(k)+1, 0)$. So now consider a firm deviating to price $(d(k), 99)$, that is, to point G. This firm's profit will be equal to $[(d(k), 99) - (d(k),\, c(k))]x((d(k), 99))$. This is because a change in the dollar part of the price is noticed by all consumers. If $(d(k), 99) = (d(k),\, c(k))$, then clearly such a deviation is not worthwhile. But even if $(d(k), 99) > (d(k),\, c(k))$, it is obvious that if n is small and $(d(k),\, c(k))$ is close to $(d(k), 99)$, then it will not pay for any single firm to deviate to $(d(k), 99)$. And for the consumer a deviation from strategy A is not worthwhile for the same reason as before.

This establishes that for certain parameters H can be an equilibrium.

It will now be shown that there are no other (symmetric) equilibria in this game. Thus if G

and E are distinct points (i.e. $c(k) < 99$), then E cannot be an equilibrium. Likewise for F.

To prove this, first note that in no symmetric Nash equilibrium will the consumers choose action B. If the consumers prefer action B, it must be the case that there are firms i and j who charge different prices and manage to sell. But if the consumers chooses action B, then they are fully cognizant of prices and so no one will buy from the firm charging a higher price. This is a contradiction, which establishes that all consumers will choose action A in a Nash equilibrium.

If all consumers choose action A, then all firms will choose prices which end in 99. Hence, only prices like G, and H (the first and second points, above the marginal cost where the price ends in 9) can qualify. We have already shown that G is always an equilibrium and H may be an equilibrium. The proof is completed by showing that no price above H can be an equilibrium.

Without loss of generality, consider the next price above H, where the price ends in 99. This is shown by point J. If all firms charge this price, each firm will earn a profit of

$$\begin{aligned} P_1 &\equiv [(d(k)+2,99)-(d(k),c(k))]\frac{x((d(k)+2,99))}{n} \\ &= 2\frac{x((d(k)+2,99))}{n}+[(d(k),99)-(d(k),c(k))]\frac{x((d(k)+2,99))}{n} \end{aligned}$$

If one firm deviates to price $(d(k)+1,99)$, then such a firm will earn a profit of

$$\begin{aligned} P_2 &\equiv [(d(k)+1,99)-(d(k),c(k))]x((d(k)+1,99)) \\ &= x((d(k)+1,99))+[(d(k),99)-(d(k),c(k))]x((d(k)+1,99)) \end{aligned}$$

Since $n \geq 2$ and $x((d(k)+2,99)) < x((d(k)+1,99))$, it follows $x((d(k)+1,99)) > \frac{2x((d(k)+2,99))}{n}$. It is therefore obvious that $P_2 > P_1$. Hence, J cannot be sustained as an equilibrium. By a similar proof we can establish that for no $t \geq 3$ can each firm charging $(d(k) + t, 99)$ be an equilibrium.

This completes the proof of our main result for the symmetric case.

In this oligopolistic market there could be some asymmetric (sophisticated Bertrand) equilibria as well. But these will always belong to the following class. There will exist two prices $(d(k), 99)$ and $(d(k), x)$, where $c < x < 99$, *or* $(d(k)+1, 99)$ and $(d(k)+1, x)$, where $x < 99$, and each firm will announce one of the two prices. Some consumers will choose action B (I shall call them discerning consumers, since they act discerning in equilibrium) and others will choose action A.

To see this, consider a case where some consumers choose to be discerning and some non-discerning. It is first easy to see that all firms will charge prices that are identical in the dollar parts. If not, all consumers will ignore the firms charging a higher dollar price. It is easy to see (using the same kind of reasoning as before) that prices cannot be above $(d(k) + 1, 99)$. Hence, all firms will charge a price with dollar part equal to $d(k)$ or they will all set the dollar part equal to $d(k) + 1$.

Without loss of generality, let me focus on the $d(k)$-case. That is, it will be shown that there could be an equilibrium where two prices prevail: $(d(k), 99)$ and $(d(k), x)$, $c < x < 99$. Suppose there are more than two prices prevailing. In that case, there exists two firms charging prices $(d(k), a)$ and $(d(k), b)$ where $a < b < 99$. Hence, the only consumers who go to the firm charging price $(d(k), b)$ will be the non-discerning ones. In that case a firm charging $(d(k), b)$ could raise price to $(d(k), 99)$ without losing customers. This is a contradiction.

Hence, if there is an asymmetric equilibrium, there will exist two prices: $(d(k), 99)$ and

$(d(k), x)$, where $k < x < 99$. To see that there can be such an equilibrium, assume that there exists x, where $c < x$, and $\psi^* \epsilon (0, 1)$ such that if a fraction ψ^* of firms charge $(d(k), 99)$ and fraction $(1 - \psi^*)$ charge $(d(k), x)$, then consumers are indifferent between actions A and B. For future discussion I shall refer to this as the 'indifference axiom'. If no such x and ψ exist, that is, the indifference axiom is invalid, then the oligopoly will not have any asymmetric equilibrium. Let us here consider the interesting case where the indifference axiom holds; and let the x and ψ^* referred to below be precisely these values.

It will now be shown that if there exists a number $\phi^* \epsilon (0, 1)$, such that if a fraction ϕ^* of consumers choose A and a fraction $1 - \phi^*$ choose B, then firms are indifferent between charging $(d(k), 99)$ and $(d(k), x)$, then we do have an equilibrium in which some firms set price equal to $(d(k), 99)$ and some firms set price at $(d(k), x)$.

To see this consider ϕ to be a fraction and suppose $n\phi$ consumers choose action A. All others choose action B. Let $\bar{\pi}_{99}$ and $\bar{\pi}_x$ be the total profits earned by all firms charging a price of, respectively, $(d(k), 99)$ and $(d(k), x)$:

$$\bar{\pi}_{99} = n\psi^*\phi(99 - k)$$

$$\bar{\pi}_x = n(1 - \psi^*\phi)(x - k)$$

To understand this note that firms charging $(d(k), 99)$ will only get consumers who choose action A. There are $n\phi$ consumers who choose this action. Since these consumers choose among firms randomly, a fraction ψ^* of these consumers go to the firms charging $(d(k), 99)$ since ψ^* is the fraction of firms charging this price. From each consumer, such a firm earns a profit of $99 - k$.

This explains the value of $\bar{\pi}_{99}$. $\bar{\pi}_x$ is derived the same way by simply noting that all other consumers (that is, $n - n\psi^*\phi$ of them) go to firms charging $(d(k), x)$.

Let π_{99} and π_x be the profits earned by each firm charging, respectively, a price of $(d(k), 99)$ and $(d(k), x)$. Hence,

$$\pi_{99} = \frac{n\psi^*\phi(99-k)}{m\psi^*} = \frac{n\phi(99-k)}{m}.$$

$$\pi_x = \frac{n(1-\psi^*\phi)(x-k)}{m(1-\psi^*)}.$$

Let $\phi^* \epsilon (0,1)$ be the value of ϕ which makes $\pi_{99} = \pi_x$. That is,

$$\pi_{99} = \frac{n\phi^*(99-k)}{m} = \frac{n(1-\psi^*\phi^*)}{m(1-\psi^*)} = \pi_x.$$

If $n\phi^*$ consumers choose action A and $m\psi^*$ firms set price equal to $(d(k), 99)$ we have an equilibrium. Consumers, we already know by the indifference axiom, are indifferent between A and B. So none of them has an incentive to deviate. Observe next that π_{99} does not depend on ψ and that

$$\pi_x(\psi) \equiv \frac{n(1-\psi\phi^*)(x-k)}{m(1-\psi)}$$

is an increasing function of ψ. Hence, starting with $m\psi^*$ firms choosing $(d(k), 99)$, if one more firm switches to $(d(k), x)$ then this firm's profit will decline, since $\pi_{99} = \pi_x(\psi^*)$ and $\pi_{99} > \pi_x(\psi)$, for all $\psi < \psi^*$. And if a firm charging $(d(k), x)$ switches to charging $(d(k), 99)$ he will get the same profit as before. Hence, what we have is a Nash equilibrium or, equivalently, a sophisticated Bertrand equilibrium of an oligopoly.

To sum up, the model predidcts that prices will generally end in 9s but in some markets there will be two modal price endings, one of which will invariably be 9. It is interesting to note that the asymmetric equilibrium in which the non-9 ending occurs would exist only if the indifference axiom holds. It is arguable that for products where people buy large amounts of some commodity or agree to a per unit price and then buy the commodity or service over a long period of time the indifference axiom is less likely to be satisfied. In such cases a small price difference translates into a large loss or gain for the buyer and hence consumers are more likely to take cognizance of the exact price. Hence for these kinds of goods multiple prices are less likely to occur in the same market.

6 EMPIRICAL IMPLICATIONS

The model constructed in this paper explains why we see such widespread prevalence of prices that end in 99 cents. Of course, for more valuable goods where prices do not go into cents, what this model implies is that the last non-zero digit of the price will be a nine. Thus a car could have a price of $15,690 and a holiday in the Bahamas may command a price of $899.[3]

Unlike in a model of monopoly, we find that firms benefit from this phenomenon of pricing in the nines. This enables (sophisticated) Bertrand oligopolists to sustain a price above the marginal cost (and even above the prices that could prevail in the standard Bertrand oligopoly model with an exogenously fixed smallest unit of change). Also, unlike in a monopoly, some non-9 endings are now possible in equilibrium.

One natural way to extend the model is to suppose that if a person is planning on a very large purchase he takes cognizance of the exact per-unit price of the product since even a tiny difference in per-unit price could make a big difference to his cost. While I have not modeled this formally here, it is reasonable to expect that in such situations the indifference axiom discussed above will be violated and so we will invariably see only one price for each good. If we go a step further and introduce the idea of 'cautious behavior' on the part of consumers which is defined as taking account of the possibility of 'trembles' in prices whether or not there exists any price variability in the market, then it is likely that the dominance of 9-endings will break down. For goods, where the consumer places large orders on the basis of a per unit price, there will be a unique price but there will be no special reason for this to have a 9-ending. Hence, for goods like cement, housepaint, phone calls and long-term lawn-mowing contracts we will be less likely to see nine price endings. By the same kind of reasoning we would expect to see a wider use of prices ending in 9 in the retail market, where small quantities of goods are purchased, or in the market for perishable goods, as opposed to, for instance, the wholesale market.

In general this paper suggests that instead of assuming consumer irrationality and consumer psychological delusion if we simply assume that consumers have limited time for decision-making and limited brain capacity but they act rationally subject to these limitations, then we can get results which elude the standard literature on industrial pricing and mimic some of the results which behavioral economics derives only by assuming consumer irrationality.

This is not to suggest that consumers are never irrational but simply that we must not be too hasty to jump to the conclusion of irrationality either. Many interesting, non-standard results and testable propositions can be derived from models which deviate from the textbook neo-classical model, while retaining the precept of rationality.

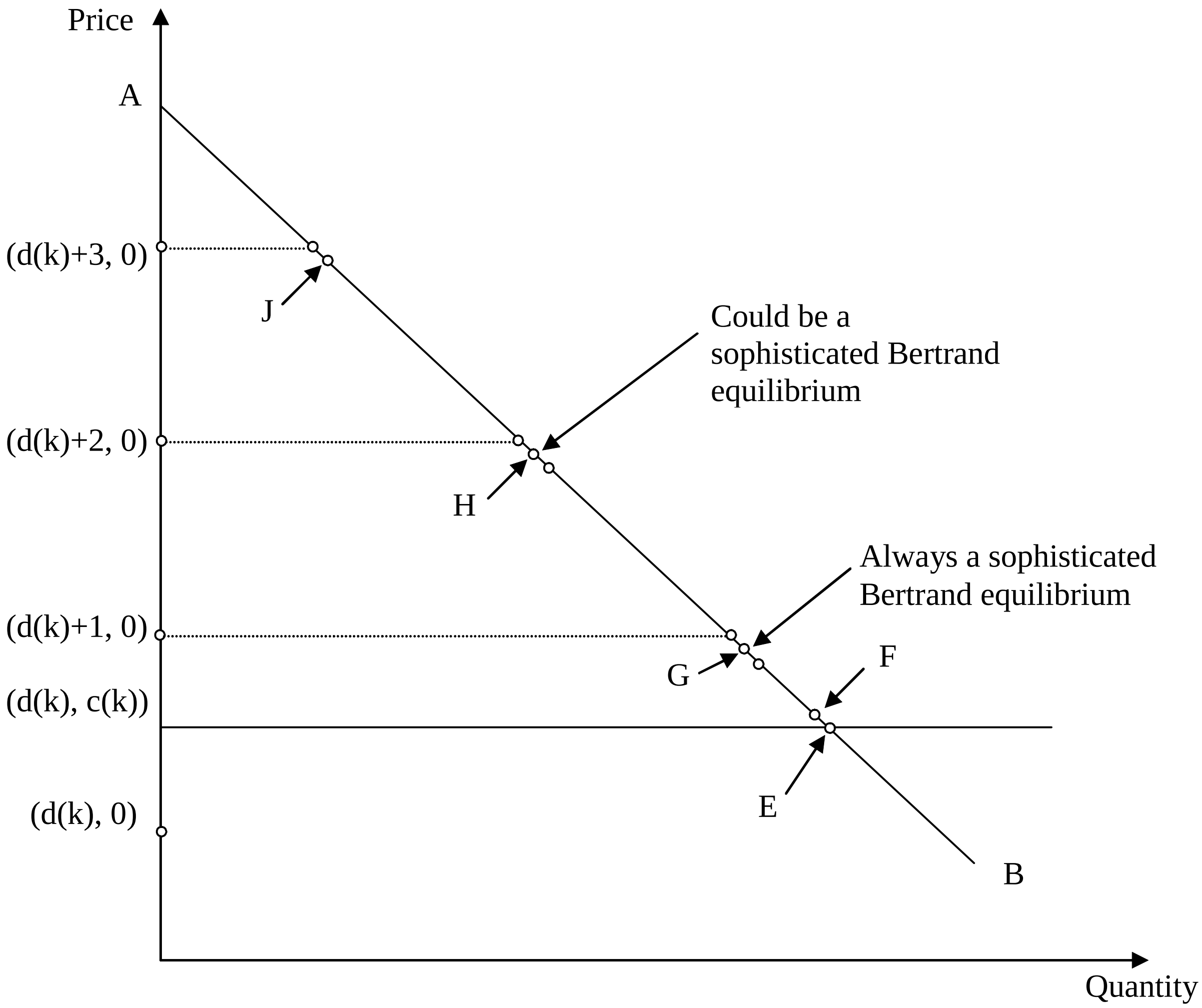
Price
A
(d(k)+3, 0)
J
Could be a
sophisticated Bertrand
equilibrium
(d(k)+2, 0)
H
Always a sophisticated
Bertrand equilibrium
(d(k)+1, 0)
G
F
(d(k), c(k))
E
(d(k), 0)
B
Quantity

Figure 1:

Notes

[1]See, for instance, Bader and Weinland (1932), Schindler and Kibarian (1996), Basu (1997), Shy (2000), Ruffle and Shtudiner (2003), Anderson and Simester (2003), Friberg and Matha (2003).

[2]See Gabor and Granger (1964), Wilkie (1990), Schindler and Kibarian (1996), Nagle and Holden (1995).

[3]There is indeed an open question about how far to the right the nines go. Why is the car not priced at \$15,699.99 and why does the Bahamas vacation not cost \$899.9? The formal result that we have discussed here is that if we think of every number as having an endless sequence of digits after the decimal point, then the last *non-zero* digit will tend to be 9. What we do not have a theory of is where the nines stop and the zeroes take over. At an informal level it is arguable that a car maker who sets a price at \$15,699.99 will frighten away customers by appearing extortionate. ("Would he not also have saved money by compromising on the quality of the break?" the customer may wonder.) But this is a separate problem that deserves to be investigated separately.

References

[1] Anderson, E. and Simester, D. (2003), 'Effects of $9 Price Endings on Retail Sales: Evidence from Field Experiments', *Quantitative Marketing and Economics*, vol. 1, 93-110.

[2] Bader, L. and Weinland, J.D. (1932), 'Do Odd Prices Earn Money?' *Journal of Retailing*, vol. 8, 102-4.

[3] Basu, K. (1992), *Lectures in Industrial Organization Theory*, Oxford: Blackwell Publishers.

[4] Basu, K. (1997), 'Why are so many Goods Priced to End in Nine? And Why This Practice Hurts the Producers?' *Economics Letters*, vol. 53, 41-44.

[5] Basu, K. (1988), 'Strategic Irrationality in Extensive-form Games', *Mathematical Social Science*, vol. 15, 247-260.

[6] Evans, J.R. and Berman, B. (1997), *Marketing*, Englewood Cliffs: Prentice Hall.

[7] Friberg, R. and Matha, T.Y. (2003), 'Does a Common Currency Lead to (more) Price Equalization? The Role of Psychological Pricing Points', mimeo: Stockholm School of Economics.

[8] Gabor, A. and Granger, C. (1964), 'Price Sensitivity of the Consumer', *Journal of Advertising Research*, vol. 4, 40-44.

[9] Nagle, T.T. and Holden, R.K. (1995), *The Strategy and Tactics of Pricing*, 2nd edition, Englewood Cliffs, NJ: Prentice Hall.

[10] Ruffle, B.J. and Shtudiner, Z. (2003), '99: Are Retailers Best Responding to Rational Consumers? Experimental Evidence', mimeo: Ben-Gurion University.

[11] Schindler, R.M. and Kibarian, T.M. (1996), 'Increased Consumer Sales through Use of 99 Ending Price', *Journal of Retailing*, vol. 72, 187-99.

[12] Shy, O. (2000), 'Why 99 Cents?' mimeo: University of Haiffa.

[13] Wilkie, W. (1990), *Consumer Behavior*, New York: Wiley and Sons.