$9.99: CAN "JUST-BELOW" PRICING BE RECONCILED WITH RATIONALITY?

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INTRODUCTION

Economists are proud of their ability to explain the determination of prices. Not only is it one of the first topics explained in a principles course, but the entire field of microeconomics is often referred to as "price theory." It is therefore surprising that economists have largely ignored one of the most prevalent pricing practices, the disproportionate use of prices ending in the number nine.

This practice has received considerable attention in the marketing and retailing literature where it is referred to as "just-below," "odd," or "psychological" pricing.[1] A popular rationale for this phenomenon is the consumer's alleged susceptibility to "price illusion." Price illusion refers to the hypothesis that consumers systematically underestimate prices with just-below endings. For example, an individual susceptible to price illusion would perceive a price of $599 as "$500 and something" rather than "almost $600."[2]

Economists, however, have paid scant attention to this practice, perhaps because it does not seem to fit into our traditional model of price determination[3]. If profit-maximizing producers set prices by demand, at the output for which $MC = MR$, why would a disproportionate number of those prices end in nine? The only way for MC curves of different shapes to lead to a preponderance of prices ending in nine is if demand becomes suddenly more elastic at these prices. This creates demand curves that are not twice differentiable and thus are troubling to manipulate in our mathematical models. Even worse, if consumers are fooled into thinking that a price of $5.99 is well below $6, consumer rationality itself appears to be threatened.

PRIOR RESEARCH

Many have speculated about the origins of just-below pricing. Landsberg [1992] notes that ninety-nine cent pricing became common soon after the invention of the cash register. The cash register made it easier for store owners to prevent employee theft since it kept a record of each transaction rung up by the employee. However, the employee could still pocket the money and not ring up the sale. If, on the other hand, the employee had to return some change to the customer, she would be more likely to open the cash register which could only be done by ringing up the sale. Hence by pricing items a penny below the dollar amount the incidence of employee theft could be reduced. Of course, given today's sales taxes, this does not explain the current popularity of ninety-nine cent pricing. Nor does it explain the use of just-below prices by mail-order stores, which usually receive payment by credit cards or checks.

The psychological effect of price endings on consumers' perceptions of prices and product quality has been the subject of much discussion in the marketing literature. Schindler [1991] provides several hypotheses about the significance of price-endings culled from a survey of the published literature and informal conversations with retailers and consumers. Many of these hypotheses have a common theme: price endings may be used by sellers to convey information to consumers. In a world in which information is costly, consumers may interpret price endings as a signal of such things as quality of the product [Whalen, 1980; Bolen, 1982; Alpert, 1971] or whether the product is low priced [Dodds and Munroe, 1985; Simon, 1989; Kotler, 1988; Nagle, 1987; Berman and Evans, 1986].

Many markets are characterized by informational asymmetry, in that the seller knows more about the quality of the product than the buyer. The classic example is the used car market, as described by Akerlof [1970]. The solution to the problem is for sellers of high quality products to "signal" buyers that their product is better than the "lemons." In the case of cars, Akerlof suggests that this signal may be in the form of a guarantee or the use of a brand name.

However, as Spence notes in reference to the labor market:

> signals ... are alterable and therefore potentially subject to manipulation....It is not difficult to see that a signal will not effectively distinguish one applicant from another, unless the costs of signaling are negatively correlated with productive capability. [1973, 358]

Guarantees are good signals because those with high quality items will find it less expensive to offer them. Of course, sellers may send many other signals to buyers; but if both high and low quality producers can send these signals with equal ease, rational consumers will ignore them.

Although much of the marketing literature claims a price ending in nine signals a low, discounted, or sale price, this argument is flawed. Since providing the signal is equally expensive for all producers, the nine ending will cease to carry any information. All producers, those with high and low prices, would use it. Consumers would thus learn that the nine ending contains no information and would come to ignore it. If the nine ending is not a sustainable signal one is left with the presumption that consumers are deluded by such prices. The following section presents an explanation of just-below pricing that is consistent with consumer rationality.

AN ECONOMIC MODEL OF NINE PRICE-ENDINGS

If sellers are rational, the prevalence of just-below pricing implies that profits are higher at prices like \$19.99 than at \$20. This requires that quantity demanded increase disproportionately when price falls from \$20 to \$19.99, suggesting that buyers are recalling the price as \$19 and something. To model this behavior we consider the costs and benefits of this apparently irrational act of ignoring the last digit(s) of a price.

Consider the benefits of paying heed to all the digits of prices in comparison shopping. If, by comparing the left-most digits, one would obtain a unique minimum price, the benefit of retaining additional digits is zero. If two or more prices have the same left-most digit then the additional digits do provide additional information. Ignoring further digits leads to a random selection among those prices with the same left-most digit and an expected price equal to the mean of those prices. The benefit of considering additional digits is the difference between that mean price and the expected minimum price, M_n.[4]

Let ρ be the probability that a comparison of the left-most d digits yields a "tie" between two or more prices such that

$$(1) \qquad \rho = \rho(d, F(p)),$$

where d = number of left-most digits retained and $F(p)$ = probability distribution of prices. The expected marginal benefit of retaining the next digit to the right (the $d+1$ digit) is

$$(2) \qquad B = \rho[\Sigma\rho_i/m - M_n] + (1 - \rho)0 = \rho[\overline{P} - M_n],$$

where m = the number of prices with the same left-most d digits.

Stigler notes that "Increased search will yield diminishing returns as measured by the expected reduction in minimum asking price" [1961, 215]. While the standard application of this is across prices, the same is true for digits of prices. The marginal benefit of processing and storing additional price information declines as we move toward the right-most digits, i.e., $\delta B / \delta d < 0$, where

$$(3) \qquad \delta B / \delta d = (\overline{P} - M_n)\, \delta\rho / \delta d + \rho\delta(\overline{P} - M_n) / \delta d.$$

Having examined the left-most digits, one may already know that the price in question is or is not the lowest price. Furthermore, the farther one goes to the right the lower the expected savings — the benefit of comparing the right-most digit is clearly less than the benefit of comparing the left-most digit.[5]

More formally, the first term on the right-hand side in equation (3) is negative since $(\overline{P} - M_n)$ is non-negative and $\delta\rho / \delta d$ is negative, i.e., the probability of a tie falls as one considers more digits. The second term is also negative, for two reasons. First, the more digits one retains the closer one comes to the minimum price. If, for example, one compares the thousands' digit alone, the mean of all prices with the identical thousands' digit may be hundreds away from the minimum price. On the other hand, a comparison of all but the ones' digit would at worst leave the shopper less than ten dollars from the minimum price.

Second, if prices are likely to end in nine the variance of the final digit will be smaller and the benefit of retaining that digit will be less. Indeed if all prices ended in nine it would be irrational to retain the last digit since the expected benefit would be zero ($\bar{P}$ would equal M_n). (Note that this would be a stable equilibrium. If customers do not consider the last digit(s), it is profit maximizing to make the last digit(s) equal to nine.)

Rational consumers will examine and retain additional digits of a price as long as the marginal benefits exceed the marginal costs. The costs of paying attention to additional digits include the time and effort required to collect and process this information. These costs vary across consumers because consumers differ in their abilities to store and retrieve digits. As the costs of storing and processing rise, fewer digits should be retained. Hence the number of digits retained would also vary across individuals. While, admittedly, the costs of obtaining and storing additional digits is small, the benefits are also small and decline as one moves to the right. As Simon notes, "in a world where attention is a scarce resource... We cannot afford to attend to information simply because it is there" [1978, 13].

How will sellers behave when faced with consumers who may not attend to all digits? We assume the sellers are profit-maximizing imperfect competitors choosing output so that

(4) $$MC = MR \text{ or } MC = p[1 + 1/\eta],$$

where η = the price elasticity of demand.

Suppose the seller faces a demand curve made up of x consumers who retain price endings and y customers who regularly disregard price endings. The total demand is

(5) $$Q(p) = xQ_1(p) + yQ_2(p),$$

where Q_1 = the demand by a typical consumer who retains price endings and
Q_2 = the demand by a typical consumer who regularly disregards price endings.

The price elasticity of demand may then be expressed as

(6) $$\eta = \alpha\eta_1 + (1\text{-}\alpha)\eta_2,$$

where α = the proportion of sales to consumers who retain price endings,
η_1 = the price elasticity of demand of the first group,
η_2 = the price elasticity of demand for the second group.

Thus the profit maximizing price satisfies

(7) $$MC = p[1 + 1/(\alpha\eta_1 + (1 - \alpha)\eta_2)].$$

Sellers will charge a "just-below" price like 24.99 instead of an "even" price such as \$25 if the marginal revenue of the additional units sold exceeds the marginal costs. From equation (7), marginal revenue is a function of the price elasticity of demand and the proportion of consumers who retain and process price endings. The more elastic the demand, the greater the benefit to the producer of setting a lower price. Customers who regularly ignore price endings will have a greater price elasticity between \$25 and \$24.99. The higher the proportion of such customers, the greater the benefit to the producer of prices ending in nine. If this model of just-below pricing is correct, we should expect to see more prices with nine endings for:

a. products with more elastic demand curves.
b. products sold to consumers who are less likely to recall and/or round off the price endings. Customers less adept at storing, retrieving and processing numbers will have greater responses to the one cent price difference and more nine ending prices should be found on products sold to these customers.
c. prices made up of more digits. The cost of retaining and processing additional digits rises as the number of digits increases. Customers will be less likely to recall and make use of the right-most digit when the price has many digits. As a result we should find more prices ending in nine when the price has more digits.

EMPIRICAL WORK

Following Ginzberg [1936], Kashyap [1995] and Schindler [1989] we focused our attention on an examination of catalog prices. Specifically, our data set includes prices of 81 garments randomly chosen from 27 women's clothing catalogs.[6]

The dependent variable *NINE* equals one if the price ends in a nine and 0 otherwise. We use the probit functional form to avoid the shortcomings of linear probability models. The linear probability model generates heteroskedastic errors, produces predictions outside the 0-1 range and depending on the distribution of independent variables may bias the coefficients [Pindyck and Rubinfeld, 1991].

The independent variables are *BUDGET, COVBUSN, DIGITS, SUIT, DRESS, CASUAL* and *PRICE*. In the absence of a direct measure of the price elasticity of demand for the product, we employ the proxy variable — *BUDGET*. *BUDGET* is equal to one if the catalog cover indicates that the products are low priced, on sale, marked down, or otherwise are "good buys." Consumers with high elasticities of demand will be disproportionately attracted to these catalogs. The decision to lower price by a small amount should be more attractive when the price elasticity is higher.

In the preceding section we argued that the incidence of just-below pricing would be affected by the proportion of consumers who pay attention to price endings. This proportion, however, is not directly observable. Hence we employ a proxy variable, *COVBUSN*, which equals one if the catalog cover contains the word business or career. If the targeted consumers are professionals, they are likely to be more educated and more accustomed to handling numbers. We hypothesize that just-below pricing would be less frequently employed in dealing with these customers, because they routinely round up or retain the extra digits in price comparisons.

DIGITS is the number of digits in the price. If the cost of recalling and processing an additional digit rises with the number of digits, this variable should be negatively correlated with α, the proportion of consumers who attend to price endings, and thus positively correlated with *NINE*.

SUIT, DRESS, and *CASUAL* are variables controlling for the type of item advertised. We would expect a negative correlation between *SUIT* and *NINE* since these items would more often be sold to professionals. We hypothesize that the demand for casual wear is more elastic and hence *CASUAL* and *DRESS* should be positively correlated with just-below prices.

PRICE is the price of the item. If the signaling model of just-below pricing is correct, nine endings should be negatively correlated with prices. The nine ending signal could not successfully persist unless it validly identifies less expensive items. A signal which did not correspond to lower prices would come to be ignored by rational consumers.

Results

The data suggest that prices ending in nine are more common than traditional microeconomic pricing models would suggest. If demand curves were smooth, we would predict that 10 percent of the price endings would be nines. In our sample, however, 45.6 percent of the prices ended in nine, enabling us to reject the null hypothesis that the true proportion is 0.1 at the 1 percent level.

The results of the probit regression are presented in Table 1. The Maddala, Cragg-Uhler, McFadden and Chow versions of R-squared for probit ranged from 0.30 to 0.45. The model correctly predicts 80 percent of the price endings.

The coefficient associated with *DIGITS* is positive and significant at the 5 percent level, consistent with the hypothesis that the nine-ending pricing strategy is more tempting to the seller when there are more digits. As expected, the coefficient associated with *COVBUSN* is negative and significant. Apparently, the use of prices ending in nine is a less profitable strategy when applied to professional customers. *BUDGET* is positive and significant. Prices ending in nine are more prevalent in publications advertising frugal prices, which are probably directed at consumers with more elastic demand curves.

The coefficients of the control variables, *SUIT, CASUAL*, and *DRESS* are disappointing. None are significantly different from zero at even the 10 percent level. It may be that the correlation between these variables and *PRICE, BUDGET* and *COVBUSN* masks their impact.

TABLE 1
Probit Results

VARIABLE NAME	ESTIMATED COEFFICIENT	T-RATIO
BUDGET	1.203	3.398[b]
COVBUSN	-1.600	-2.268[a]
SUIT	-4.468	-0.376E-03
CASUAL	-0.732	-1.369
DRESS	0.528	1.180
PRICE	0.149E-03	0.453E-01
DIGITS	0.391	2.203[a]
CONSTANT	-1.576	-3.004[b]
LOG OF LIKELIHOOD FUNCTION	-55.842	

a. Significant at the 5 percent level.
b. Significant at the 1 percent level.

If nine endings signal lower prices, as maintained in the marketing literature, the coefficient of *PRICE* should be negative. However, here it is positive and insignificantly different from zero. This result is quite robust. Over a range of independent variables and functional forms, price is a poor predictor of the use of nine endings. This result is maintained whether one models only ninety-nine cent endings or any price ending in a nine. Modeling price as a function of control variables and a dummy for a nine ending again fails to produce a negative coefficient. Nine endings are not a signal of lower prices within our sample.

These preceding empirical results must, of course, be interpreted with caution. Following others we have used mail-order catalogs for our source of data. The just-below pricing pattern needs to be investigated over a much wider range of products and sellers. In addition, this data does not include any consumer-related information involving income, computational capacity, frequency of purchase, or opportunity cost of time.

CONCLUSION

This paper is the first attempt to reconcile just-below pricing with consumer rationality. Consumers confront small but real costs of recalling and processing price digits. As more digits are considered, the marginal costs rise and the marginal benefits fall. As a result, it becomes rational for some consumers to disregard the right-most digits. In turn profit-maximizing sellers will charge prices ending in nine to these consumers more often. The empirical results are consistent with a such a model. We do not find support for the traditional marketing argument that nine price endings are signals to consumers that an item is low-priced.

NOTES

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1. Georgoff [1972] notes that the term "odd prices" is not clearly defined in the marketing literature. The same is true of the other phrases used to describe this pricing strategy. A survey of the literature shows that these terms are commonly used to describe prices which are just below an even denomination. Examples include prices ending in ninety-five or ninety-nine cents as well as a price such as $395.00 as opposed to $400. For expositional clarity we will use the term just-below prices to refer to prices ending in the number nine.
2. Several experimental studies have tried to test the hypothesis that consumers systematically underestimate odd prices, but the results are mixed [Ginzberg, 1936; Georgoff, 1972; Lambert, 1975; Schindler and Kibarain, 1993].
3. The only publication in an economics journal devoted to an examination of this pricing strategy is a one-page communication by Eli Ginzberg in a 1936 issue of the *American Economic Review*. Two other publications have also alluded to this phenomenon without attempting to provide a theoretical rationale for its prevalence. [Gabor and Granger, 1966; Kashyap, 1995]. As Kashyap notes, referring to firms' reluctance to cross certain threshold prices or price points, "there is no tight theoretical justification for this story,... " [1995].
4. The expected minimum price, M_n, when n sellers are samples from a probability distribution, $F(P)$, is $[1 - F(p)]^n dp$ [Rothschild, 1974].
5. This holds true if we assume that the distribution of prices is not known to the consumer. On the other hand, consider the example of a consumer shopping for a radio which she knows ranges in price from $20 to $29.99. Clearly, in this case the expected marginal benefit of comparing the left-most digit of the various prices is zero, while the marginal benefit of attending to digits further to the right is positive. However, while the marginal benefit may initially increase, it must eventually decline as one attends to additional digits. Further, this begs the question of how the consumer determined the initial reference price range.
6. Random numbers were employed to select three pieces of apparel from each catalog. All the catalogs were from Spring and Summer of 1994.

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