TWO PLUS TWO EQUALS SIX: AN ALTERNATIVE EXPLANATION OF WHY SO MANY GOODS PRICES END IN NINE.

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Abstract

The prevalence of prices ending in 99 cents is explained as the result of rational consumers rounding prices up. Monopolists are shown to be harmed by this practice whereas consumers may gain. The model is compared with two other models: Basu's (1997) model and one which assumes consumers round prices down.

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1. Introduction

Goods' prices commonly end in nine. Or, at least, they do in economies with decimal coinage. Those who remember the UK before decimalisation, when the coins consisted of pounds, shillings (£1=20 shillings) and pence (1 shilling = 12 pence), will recall prices typically ending in 11 pence. Those with even longer memories, when half-pennies and farthings (quarter pennies) still circulated, report that prices such as "three and eleven pence three farthings" or "19 shillings and eleven pence ha'penny" were common.[1] Casual empiricism suggests that non-economists view this practice as harming consumers, benefiting producers, and probably the result of some vaguely-specified form of consumer irrationality.

Basu (1997, 2006) summarises some of the main explanations for it.[2] Those that explain it within the confines of economic rationality use the idea that consumers save calculation time by reinterpreting the last, "less important" digits of a price. One plausible way to do this is to think in round numbers, i.e. to interpret a price of, say, \$7.56 as \$7.00. As we show below, this always gives monopolists the incentive to set the less important digits, henceforward the cents, as high as possible without triggering a change in the more important ones, henceforward the dollars.

[1] Such prices, the authors can confirm, used to be the staple of school arithmetic tests, no doubt contributing to the unpopularity of that subject.

[2] One he does not mention is the explanation attributed to Steven Landsburgh by Tim Harford (*The Financial Times,* 11th August 2006) in response to the question from a reader: that its origin is the need to keep shop staff honest by requiring them to give customers change and hence to put the transaction though the till. This explanation is less convincing where payments are increasingly made by credit and debit cards, and is also undermined by the fact that the prices of high-priced goods also tend to end in 9.

Basu's (1997, 2006) own explanation assumes consumers save calculation time not by rounding prices down but by presuming that each price ends with the same number of cents. This too induces monopolists to set the number of cents at 99. Hence the only rational number of cents for consumers to expect is 99. Prices ending in 99 can therefore be seen as a rational expectations equilibrium.

We suggest both models have weaknesses, and we propose an alternative which avoids these although it is in the same spirit. Its central idea is that to save calculation time whilst remaining within their budget constraint and recognising that monopolists profit-maximise, consumers round prices *up* not *down*. This also gives monopolists the incentive to set prices ending in 99 but nevertheless harms them whilst possibly benefiting consumers. So, 99-prices may be an example of consumers exploiting monopolists rather than the reverse.

We first establish the general argument, and then provide some illustrations.

2. The general argument.

Assume that in the typical market consumers have the utility function

$$U = u(x_1, x_2, ..., x_n) \qquad [1]$$

where x_i is the quantity of good *i*. They select x_i to maximise utility subject to the budget constraint

$$p_{A1}x_1 + p_{A2}x_2 + \ldots + p_{An}x_n \leq m \qquad [2]$$

where p_{Ai} is their interpretation of the price of good *i*, and *m* is their available resources.

For simplicity, we focus on good 1 and assume that all other prices and *m* are constant. Accordingly we write the market demand curve for x_1 as

$$x_1 = x_1(p_{A1}) \qquad [3]$$

The good is supplied by a monopolist who maximises profit, π_1, given by

$$\pi_1 = p_1 \cdot x(p_{A1}) - tc(x_1(p_{A1})) \qquad [4]$$

where p_1 is the good's actual price and $tc(x_1(p_{A1}))$ is the total cost of producing the quantity demanded.

In conventional theory $p_{A1} = p_1$, and it is straightforward to derive the profit maximising price, p_1^*, which here will be a function of *m* and the parameters of the utility and total cost functions, all of which are constant. Hence p_1^* is constant and p_{A1} equals it. From p_1^* one can work out x_1^*, the utility-maximising quantity demanded, via equation (3); U^*, the maximum level of the consumer's utility, from equation (1); and π_1^*, the monopolist's maximised profits, from equation (4).

In what follows we adopt Basu's convention of referring to any price, p_1, as (D_1, C_1) where D_1 is the dollar part of the price and C_1 its cent part. So, for example, $(3,45)$ represents the price \$3.45. Assume now that to save calculation time by using round numbers consumers round all prices *down*, i.e. the consumer treats an actual price, p_1 or (D_1, C_1), as p_{A1} or $(D_1, 0)$. So, when the monopolist sets a price of (D_1, C_1) the consumer interprets it as $(D_1, 0)$ and demands the quantity $x_1((D_1, 0))$. This gives monopolists the incentive to raise C_1 to 99 because the quantity demanded and production costs will be unaffected whilst revenue and profit will increase. As we show below, this practice and the monopolist's response to it may benefit the consumer.

A weakness of this explanation is its implication that consumers persistently violate their budget constraints. Consumers will, for each item, always be paying 99 cents more than they presume when deciding their demand. Hence, for each good, the difference between the actual and perceived price will be as large as it could be, and always positive. Since the budget constraint cannot be persistently violated, either the practice of rounding down is not persistent, or it is not pervasive, or the industrial structure is not typically monopolistic. But if any of these were true then the model would not explain the persistence and pervasiveness of prices ending in 99.

Basu's alternative assumes that consumers save calculation time not by rounding prices down, but by interpreting *any* price (D_1,C_1) as (D_1,EC_1) where EC_1 is the number of cents that consumers expect all prices to end in. So, rather than emphasising the gains from using round numbers Basu emphasises the saving in time from assuming a common ending for prices rather than examining the last part of each price. For any value of EC_1 monopolists still have the same incentive to set prices ending in 99. It follows that the rational value of EC_1 is 99. Hence, in Basu's model, consumers will expect prices to end in 99, and they will. Since consumers are basing their demands on correctly perceived prices they will satisfy their budget constraint exactly. As Basu points out, monopolists lose (or at least cannot gain) from this practice since their possible combinations of price and quantity are now severely restricted to the set of prices ending in 99 and the quantities demanded at those prices. We show below that consumers may gain or lose from this practice.

One weakness of Basu's model is that the advantage to consumers of using round numbers is lost. They save time by not looking at the cents part of prices (as they also would if they round prices down) but calculate using prices ending in 99. A second weakness is that not all prices *do* end in 99. As Basu himself remarks, there is no reason why the prices of goods supplied in a perfectly competitive market should end in 99. So it is not obvious that the rational value of EC_1 is 99. If it is not then it must be lower and the consumers' budget constraints may then be violated. To overcome this weakness one might assume that consumers apply different methods of interpreting prices to different market structures, but this is rather contrived and combines awkwardly with the presumed motive of the practice – to save calculation time.

Our alternative model is a variant of the round-down model. We assume that consumers use round numbers both to ease their calculations and to save time in Basu's sense, but we assume that consumers round prices *up* rather than *down*, i.e. consumers interpret a price (D_1, C_1) as $(D_1 + 1, 0)$ and demand $x_1((D_1 + 1, 0))$. Monopolist still have the incentive to set C_1 to 99 since, for a given value of D_1, the value of C_1 has no effect on the quantity demanded and hence on costs but a higher value will always raise revenue. So it will always be profit maximising to set C_1 to 99. Consumers who round prices up obtain all the advantages of rounding; furthermore they will find themselves miscalculating prices by only one unit of the lowest denomination of coinage - the price will always be the smallest possible amount *below* their interpretation of it; hence, they will always be slightly *within* their budget constraint. The practice is also quite consistent with some prices *not* ending in 99. So the practice is potentially persistent and pervasive, and, as we illustrate below, it may benefit consumers whilst always harming monopolists.

3. An Illustration

We illustrate some of these points with the following example. The typical consumer has the CES utility function,

$$U = \left[\alpha x_1^{\theta} + \beta x_2^{\theta}\right]^{1/\theta} \tag{5}$$

which, given the presumed budget constraint,

$$p_{A1}x_1 + p_{A2}x_2 \le m \tag{6}$$

implies the demand function,

$$x_1 = \frac{m}{p_{A1}\left(1 + \left(\frac{\beta}{\alpha}\right)^{\frac{1}{1-\theta}}\left(\frac{p_{A1}}{p_{A2}}\right)^{\frac{\theta}{1-\theta}}\right)} \tag{7}$$

The total cost of producing the quantity x_1 is tc_1 where

$$tc_1 = \gamma_1 + \gamma_2 x_1^2 \tag{8}$$

and γ_1 and γ_2 are positive constants.

Table 1 Illustrations and Comparisons

Both cases assume:

$$\gamma_1 = 0;\ \gamma_2 = 1;\ p_{A2} = p_2 = 1; \alpha = 0.3; \beta = 0.7;\ x_2 = \left(m - p_1^* x_1\right) / p_2$$

	p_1^*	p_{A1}	π_1^*	U^*
#1. $m = 3; \theta = 0.1$				
Conventional	4.40	4.40	0.7171	1.1099
Round-down	2.99	2.00	1.0316	1.1765
Basu	3.99	3.99	0.7164	1.1373
Round-up	4.99	5.00	0.7146	1.0759
#2. $m = 8.705; \theta = 0.4$				
Conventional	2.38	2.38	0.8532	4.3248
Round-down	2.99	2.00	1.3961	4.1289
Basu	2.99	2.99	0.8209	4.2152
Round-up	1.99	2.00	0.8171	4.4240

The table illustrates some key points. The column headed p_1^* shows that each method can cause price to rise or fall . The π_1^* column illustrates that whilst rounding-down can benefit monopolists the other two practices generally harm them. The reason is that all three practices restrict the price/quantity combinations that monopolists can choose from and, to that extent, worsen their options. For example, it is no longer open to them to offer a price of $4.40 and produce the level that would be demanded if consumers perceived the price to be $4.40 since, whichever the practice, consumers never “see” a price of $4.40. They can only offer prices ending in 99 and sell the quantity demanded given the consumers’ perception of that price. When consumers round prices down monopolists can sell more at those particular prices than they could before and so may make more profit. In the other two cases they cannot since either the 99-price is correctly perceived or it is rounded up.

The column headed U^* shows that each method can benefit or harm consumers. This is because each practice forces monopolists to offer possibilities not previously offered. For example, given the conditions in case #2 under conventional assumptions consumers would never be offered a price of \$1.99 or \$2.99. The different patterns of consumption that these new possibilities allow may or may not enable consumers to gain utility.

4. Conclusions

The 99-cent phenomenon can be plausibly explained as the result of rational consumers rounding prices up in order to save calculation time. This practice is consistent with consumers making the smallest possible mistakes about prices and operating within their budget constraints, with producers maximising profits, and with some prices not ending in 99.

References

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