our home turf. If hysteresis matters in these markets, as it probably does, American firms acquired a durable competitive advantage simply by being there first.

Do American firms really have such an advantage? We simply do not know, but I can offer one suggestive piece of evidence. In the Eurobond market, American companies lead in underwriting dollar-denominated debt issues, Japanese companies lead in Euroyen financing, German banks lead in Euromarks, the French lead in Eurosctfrance, and so on. That's hardly a proof, but it does point toward a home-court advantage.

CONCLUSION

One final, and very general, implication is worth mentioning. A shift away from dollars for any reason—including international diversification—should, other things equal, lead to a decline in the dollar's value. Indeed, worries that the shrinking international role of the dollar is putting downward pressure on the exchange rate seem to underlie recent concerns about the dollar's preeminence in world markets.

But what is declining is our international market share, not the absolute demand for dollars in world markets, which is growing rapidly. Furthermore, any influence of these developments on the exchange rate must be swamped by other more fundamental factors like actual and prospective monetary and fiscal policy. So it seems unlikely that the dollar is being weighed down by its loss of market share.

In sum, it would be going too far to say that the recent concern over the declining role of the dollar as the world's preeminent international currency is much ado about nothing. Rather, it is a bit too much ado about relatively little. The dollar's dominance has in fact declined, but only a bit—and rather slowly. Furthermore, the costs of this decline to the United States are hard to assess and look to be fairly minor. Of course, I might have a different assessment if the dollar was being rapidly dethroned and relegated to secondary status in world markets. But that, fortunately, is most emphatically not the case.

NOTES

This paper originated as a speech delivered at a conference sponsored by the Federal Reserve Bank of Dallas in September 1995. The author was then Vice-Chairman of the Board of Governors of the Federal Reserve Board. I owe thanks to Karen Johnson, Ruth Jaene, Catherine Mann, Richard Porter, and Lois Stark for information and assistance.
AN ECONOMIC MODEL OF NINE PRICE-ENDINGS

If sellers are rational, the prevalence of just-below pricing implies that prices are higher at price ± $1.99 than at $20. This requires that quantity demanded increase disproportionately when prices fall 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, $M_e$.

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

$$ p = p(d, P(p)), $$

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

$$ B = p[2p/m - M_e] + (1 - p)0 + p[P - M_e], $$

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., $SB/ld < 0$, where

$$ SB/ld = (P - M_e) dp/ld + p(P - M_e)/ld. $$

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.

More formally, the first term on the right-hand side in equation (3) is negative since $(P - M_e)$ is non-negative and $dp/ld$ 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 (P would equal $M_i$. 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 digits 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

$$MC = MR \text{ or } MC = p(1 + 1/\eta_2),$$

where $\eta_1$ = the price elasticity of demand. Suppose the seller faces a demand curve made up of consumers who retain price endings and y customers who regularly disregard price endings. The total demand is

$Q(p) = aQ_1(p) + yQ_2(p)$,

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

$$\eta = a\eta_1 + (1 - a)\eta_2,$$

where $\eta_1$ = the price elasticity of demand of the first group, $\eta_2$ = the price elasticity of demand of the second group.

Thus the profit maximizing price satisfies

$$MC = p(1 + 1/(a\eta_1 + (1 - a)\eta_2)).$$

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. Consumers 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 endings prices should be found on products sold to those 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], Kashey [1993] and Schindler [1979] 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.

The dependent variable $NINE$ equals one if the price ends in a nine and 0 otherwise. We use the profit 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 $BUDGET$, $COVGSN$, $DIGITS$, $SUIT$, $DRESS$, $CASUAL$ 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 \( a \), 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

<table>
<thead>
<tr>
<th>VARIABLE NAME</th>
<th>ESTIMATED COEFFICIENT</th>
<th>T-RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>BUDGET</td>
<td>1.203</td>
<td>3.300^b</td>
</tr>
<tr>
<td>COVBUSN</td>
<td>-1.090</td>
<td>-3.260^a</td>
</tr>
<tr>
<td>SUIT</td>
<td>-4.468</td>
<td>-3.76E-01</td>
</tr>
<tr>
<td>CASUAL</td>
<td>0.792</td>
<td>1.200</td>
</tr>
<tr>
<td>DRESS</td>
<td>0.208</td>
<td>1.100</td>
</tr>
<tr>
<td>PRICE</td>
<td>0.149E+05</td>
<td>0.45E-01</td>
</tr>
<tr>
<td>DIGITS</td>
<td>0.203</td>
<td>2.200^b</td>
</tr>
<tr>
<td>CONSTANT</td>
<td>-1.076</td>
<td>-3.000^b</td>
</tr>
<tr>
<td>LOG OF LIKELIHOOD FUNCTION</td>
<td>55.842</td>
<td></td>
</tr>
</tbody>
</table>

^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 rightmost digits. In turn profit-maximizing sellers will charge prices ending in nine to these consumers more often. The empirical results are consistent with 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

We wish to thank Professor William Brett for his help and encouragement on this project. We would also like to thank the editor and two anonymous referees for their comments.

1. Geoghegan (1972) notes that the term "odd price" 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 $99.00 as opposed to $100.00. For experimental 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 (Ginsberg, 1950; Geoghegan, 1972; Lembert, 1979; Schindler and Riehman, 1990).

3. The only publication in an economics journal devoted to an examination of this pricing strategy is a one-page communication by E. Ginsberg in a 1956 issue of the American Economic Review. Two other publications have also alluded to this phenomenon without attempting to develop a theoretical rationale for its prevalence. (Gibor and Granger, 1955; Kashyap, 1996). As Kashyap notes, referring to "fear" as the tendency to cross certain threshold prices or price points, "there is no tight theoretical justification for this study. . . ."

4. The expected minimum price, $P$, when sales are sampled from a probability distribution, P(D), is

\[ P = \sum \frac{P(D)}{} \]

5. This hold 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 $200. 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 relevance 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 1984.

REFERENCES


JUST-BELOW PRICING