If You Think 9-Ending Prices Are Low, Think Again

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ABSTRACT The 9-ending prices, which comprise between 40% and 95% of retail prices, are popular because shoppers perceive them as being low. We study whether this belief is justified using scanner price-data with more than 98-million observations from a large US grocery chain. We find that 9-ending prices are higher than non-9-ending prices, by as much as 18%. Two factors explain why shoppers believe, mistakenly, that 9-ending prices are low. First, we find that among sale prices, 9-ending prices are indeed lower than non-9-ending prices, giving 9-ending prices an aura of being low. Second, 9-ending prices were indeed lower than other prices. Shoppers therefore learned to associate 9-endings with low prices. Over time, however, 9-ending prices rose substantially, which shoppers failed to notice, because the continuous use of 9-ending prices for promoting deep price cuts draws shoppers' attention to them and helps to maintain and preserve the image of 9-ending prices as bargain prices.

The 9-ending prices comprise as much as 30%–95% of retail prices, far higher than 10% predicted by the uniform distribution. The effect of 9-ending prices on consumer demand and on sales volume is also well documented and widely recognized. Studies conclude that shoppers perceive 9-ending prices as lower than comparable non-9-ending prices.

Are 9-ending prices really lower than non-9-ending prices? This is a fundamental question in behavioral pricing, in light of the overwhelming popularity of 9-ending prices in many retail (both traditional and internet) settings, and the widespread belief that they are lower than comparable non-9-ending prices (Schindler, Parsa, and Naipaul 2011).

Surprisingly, empirical studies that directly address this question are rare. Schindler (2001) is a rare exception. In a data set that he collected over a 2-month period in 1997 at a US metropolitan area on 10 retail prices for 120 different goods, he finds (counter to the common belief) that the average 99-ending price of an item is 24.1% higher than the lowest price of the item in the comparison set, which the 10 price observations comprise.

We revisit the question, but unlike Schindler (2001), who focuses on 99-ending prices, we study 9-ending prices, noting that 99-ending prices are a subset of 9-ending prices. We use a large retail scanner price data from a major midwestern US supermarket chain.

The data set has several advantages. First, its size is more than 98-million weekly price observations over an 8-year period. Second, it includes the prices of 18,036 products. Third, the prices are the actual transaction prices, as recorded by scanners at the cash registers. Fourth, the data set is weekly, which corresponds to the common retail practice of weekly pricing cycle.

There are important differences between the data set that Schindler uses and the data set we employ. His data are *cross-section* and include the prices of 120 goods from 65 different retailers at a point in time, in one geographical location. We use a *panel data* that span an 8-year period, which contain the prices of thousands of goods in 29 product categories from a major US retailer. The size of the data sets also differs dramatically: Schindler's data contain 1,200 observations, while our data contain more than 98-million observations.

Still, some tests we run are similar to his, allowing us to compare our findings to his and confirm them. Given our data size, however, we go beyond Schindler's tests as follows. First, we conduct category-level analysis, for each of the 29 product categories. Second, the panel structure enables

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us to compare prices across stores, within stores, and over time. To exploit these possibilities, we estimate regression equations with fixed effects that control for stores, product subcategories, products, and weeks. This allows us to measure the gap between 9-ending and non-9-ending prices, while controlling for the variability across stores, for subcategory level inflation, and for products within stores. The differences we report are thus the residual price differences that remain within stores between similar goods on the same week, and for each product in each store over time. In contrast, Schindler (2001), compares 99-ending and non-99-ending prices across stores.

OVERVIEW

We report the following findings. First, at the category level, 9-ending prices are, on average, higher than non-9-ending prices. Second, at the product level, in most cases, 9-ending prices are, on average, higher than prices with other endings. Third, we find that sale prices are more likely to be non-9-ending than the corresponding regular prices. Fourth, among sale prices, 9-ending prices are, on average, lower than comparable non-9-ending prices. Fifth, over time, the overall frequency of 9-ending prices increased, as did the share of 9-ending prices among regular prices, but the share of 9-ending prices among sale prices decreased. We find that in parallel, over time, 9-ending regular prices became higher than non-9-ending regular prices, while 9-ending sale prices became lower than non-9-ending sale prices. These findings are robust to nine different tests of robustness.

The first three findings suggest that although consumers may think 9-ending prices are low, the data indicate otherwise. The fourth finding offers a possible explanation for why 9-ending prices are perceived as low: retailer's practice of using 9-ending prices to emphasize large price cuts during sales, may be guiding the shoppers toward associating 9-ending prices with low prices. The fifth finding points toward a possible mechanism that may have led the consumers to learn to associate 9-endings with low prices.

We proceed as follows. We start with a brief review of the relevant literature on 9-ending prices. Next, we describe the retail scanner price data that we use, discuss the corresponding descriptive statistics, and present the frequency distribution of the last digit in the prices. Next, we present and discuss the main econometric tests and report empirical findings. In addition, we briefly summarize the results of nine robustness tests that we run. We conclude the article by offering some caveats in light of the limitations of the data, and by discussing some possible avenues for future research in the context of behavioral pricing.

LITERATURE REVIEW

The overrepresentation of 9-ending prices is well documented using many types of data, for various types of goods, across different types of retailers, and across many countries. For example, Twedt (1965) finds that 64% of meat product prices in 70 cities are 9-ending. For advertised products, the average share of 9-ending prices is 57%. Friedman (1967) finds that 33.8% of the food prices are 9-ending. Kreul (1982) reports that the prices of 58% of the menu items at restaurants priced below $7 are 9-ending. Huston and Kamdar (1996) find that 45.6% of prices of clothing are 9-ending. Schindler and Kirby (1997) report that 30.7% of consumer goods prices are 9-ending. Stiving and Winer (1997) find that 50.5% and 36.1% of tuna and yogurt prices in their data, respectively, are 9-ending. Lee, Kauffman, and Bergen (2009) find that 38.7% of the prices in their internet data are 9-ending. Shlain (2018) studies data with 375 million observations and finds that 61% of the prices end with 9. In the data of DellaVigna and Gentzkow's (2019), 78% of the prices are 9-ending. Anderson, Jaimovich, and Simester (2015) report an even larger figure: 95% of their prices are 9-ending. Freling and colleagues (2010) offer a meta-study.

Recent findings that 9-ending prices are significantly more rigid than other prices got the attention of macroeconomists, as well as of monetary economists, because of the importance of the price rigidity for monetary nonneutrality. Some of these studies report also that 9-ending prices adjust asymmetrically: they are more rigid upward than downward, which is counter to the traditional Keynesian-type asymmetry. Examples include Blinder (1991); Kashyap (1995); Blinder et al. (1998); Knotek (2008, 2011, 2016); Eichenbaum, Jaimovich, and Rebelo (2011); Guimaraes and Sheedy (2011); Klenow and Malin (2011); Levy et al. (2011, 2020); Midrigan (2011); and Snir, Levy, and Chen (2017).

Empirical evidence suggests that shoppers perceive 9-ending price as low. Two leading explanations for these perceptions are level effect and image effect. According to the level effect, shoppers round prices down or process price information left to right, ignoring the rightmost digits (Basu 1997; Schindler and Kirby 1997; Stiving and Winer 1997; Thomas and Morwitz 2005; Ruffle and Shtudiner 2006). According to the image effect, 9-endings are a signal for low prices (Stiving 2000; Anderson and Simester 2003a).

For example, according to Schindler (1984), 9-endings indicate that the price has not been raised. Quigley and

Notarantonio (2015) and Schindler and Kibarian (1996) find that 99-endings indicate sale prices, and that in shoppers' mind, 99-ending prices are the lowest prices found. Bizer and Schindler (2005) find that shoppers are less attentive to the two rightmost digits. Shlain (2018) documents about 25% left-digit bias among shoppers.

Consistent with these findings, studies show that 9-ending prices lead to higher demand and consequently to higher sales volume. For example, Blattberg and Wisniewski (1987) find that 9-ending pricing increases sales by 10%. Schindler and Warren (1988) find consumers prefer 9-ending prices to 0-ending prices. Schindler and Kibarian (1996), Gendall, Holdershaw, and Garland (1997), Holdershaw, Gendall, and Garland (1997), and Anderson and Simester (2003a) also find that the use of 9-endings increases demand.

SCANNER PRICE DATA

Our retail scanner price data come from a large midwestern retail supermarket chain Dominick's Finer Food. During the period that the sampled data cover, 1989–1997, Dominick's was the second largest retailer in the Chicago metropolitan area, with 20%–25% of the market share (Srinivasan et al. 2004; Pofahl, Capps, and Love 2006).

The price data, which come from the chain's 93 stores, contain 98,914,300 weekly price observations for 18,036 products in 29 categories, from September 14, 1989, to May 14, 1997. These are the actual transaction prices that consumers paid each week, as recorded by the scanners at the checkout cash register and reflect retailer discounts. The price data comprise about 30% of the chain's revenue (Chevalier, Kashyap, and Rossi 2003).

The database is broad, covering food (perishables and nonperishables) and nonfood products. The sample period covers 400 weeks, but the length of individual time series varies depending on when the data collection for the specific category began and ended.

Although the prices are set on a chainwide basis, there is price variation across the stores depending on the local competitive environment (Barsky et al. 2003). In total, 95% of Dominick's stores follow a Hi-Lo ("Promo") format (Hoch et al. 1995; Ellickson and Misra 2008). Dominick's groups its stores into 16 zones, maintaining uniform regular prices within each zone but the same promoted prices chainwide (Dominick's Data Manual 2018, 19). See appendix A1, available online for store locations and pricing zones.

The number of Dominick's pricing zones increased over time, starting with three to four zones in 1989–90, and reaching 16 price zones in 1992 and beyond (Besanko, Dubé, and Gupta 2005). It appears, however, that the chain does not always respect the price zone boundaries in its pricing decisions (Chintagunta, Dubé, and Singh 2003). Its main pricing zones are *Cub-Fighter*, *Low*, *Medium*, and *High* (Dominick's Data Manual 2018, 19). Thus, for example, if a particular store is located near a Cub Food store, then the store may be designated a "Cub-fighter," and consequently it might pursue a more aggressive pricing policy in comparison to other stores that the chain operates (Barsky et al. 2003).[1]

DESCRIPTIVE STATISTICS AND THE DISTRIBUTION OF THE LAST DIGIT

Of the 29 product categories, the smallest category, bath soaps, has 418,097 weekly price observations, and the largest, soft drinks, 10,741,742 observations. In terms of the number of products, the oatmeal category is the smallest, with only 96 products, while the shampoo category is the largest, with 2,930 products. The average price in the data is $2.59. See appendix A2 for more detailed descriptive statistics by product category.

Figure 1 shows the frequency distribution of the last digit in the price data. The figure indicates that 9-ending prices are the most common with 63.9%, followed by 5-ending and 0-ending prices, with 11.4% and 4.7%, respectively. Prices that end with other digits are scarce and comprise only between 1.9% and 4.1% of the total number of observations in the data. Furthermore, as demonstrated by the category-level frequency distributions included in appendix E, 9-ending prices are also the most frequent in 28 of the 29 product categories in the data.

RESULTS OF THE ECONOMETRIC ANALYSES

Before presenting the findings, consider a sample price series' plot. Figure 2 depicts 379 weekly price observations of Nabisco Wheat Thins Low Salt, 10oz. The volatility that the series exhibit is consistent with Dominick's Hi-Lo pricing format. Focusing on the behavior of the price endings, we find that the price is 9-ending for 219 weeks (57.78%) and non-9-ending for 160 weeks (42.22%). The average 9-ending

1. For more details about Dominick's data, see Barsky et al. (2003), Chen et al. (2008), Chevalier et al. (2003), Müller and Ray (2007), Mehrhoff (2018), and Levy et al. (2010). The entire data set (which, in addition to the retail price, also includes retail margins, weekly sales, sales/discount/promotion indicator, consumer demographics, and other variables) and the Dominick's Data User Manual which accompanies it, can be downloaded from the web site of the Booth School of Business at the University of Chicago: https://www.chicagobooth.edu/research/kilts/datasets/dominicks.

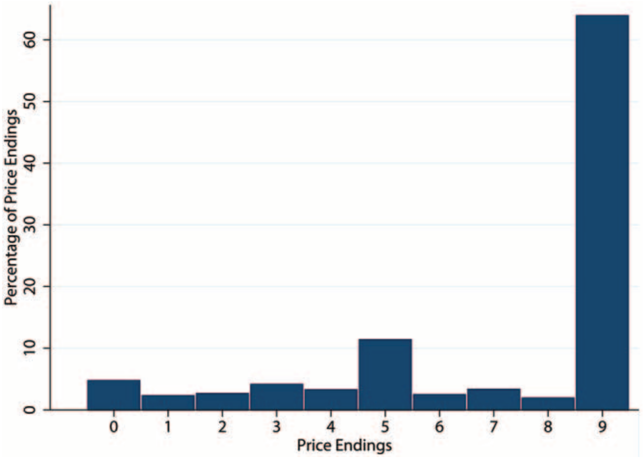

Figure 1. Frequency distribution of the last digit of the retail prices at Dominick's, September 14, 1989, to May 8, 1997. The figure was generated using all 98,914,300 weekly retail price observations of Dominick's, at 93 stores for 400 weeks, from September 14, 1989 to May 8, 1997. In app. E, we present the histogram plots of the frequency distribution of the last digit by product categories.

price, \$2.26, exceeds the average non-9-ending price, \$1.98. The difference is statistically significant at the 1% level ($p < .01$) using Wilcoxon rank-sum test, with the statistical value of $z = 11.18$.

The price series plot emphasizes four attributes that we find in our data. First, 9-ending prices are more common than non-9-ending prices. Second, 9-ending prices are more common among regular prices than among sale prices. Third, non-9-ending prices are more common among sale prices than among regular prices. Fourth, on average, 9-ending prices are higher than non-9-ending prices. These observations are typical for a large proportion of the products that are included in our data set. In appendix F, we present as an example, the plots of the time series of the retail prices of all the products in the snack crackers' category that have at least 208 weeks (the equivalent of 4 years) of data.

Average 9-Ending and Non-9-Ending Prices

We start with table 1, by comparing the average 9-ending and non-9-ending prices by product categories. In 22 of the 29 categories, the 9-ending prices exceed the non-9-ending prices by 18%, on average. This is the key finding we report in this article. In what follows, we assess the robustness of this finding.

9-Ending versus Non-9-Ending Prices for Individual Products at the Store-Level

The stores with higher than average prices could also have higher than average shares of 9-ending prices. In that case, even if 9-ending prices are the lowest in each store, across all stores they might still be higher than non-9-ending prices. Also, if 9-ending prices are more prevalent in subcategories with relatively high prices, then even if 9-ending prices are the lowest in each subcategory, we might still find the opposite at the category level. To test this, we calculate for each product at each store, the percentage difference between the average 9-ending and non-9-ending price. Figure 3 shows their frequency distribution for the entire data set, excluding the outliers (defined as differences in excess of 100% in absolute value). In appendix H, we show the distribution with all the observations.

The average of the distribution is $M = 5.97$ (SD $= 18.68$), confirming that 9-ending prices exceed non-9-ending prices on average. The median is 4.74, which suggests that the higher average 9-ending prices are not caused by outliers. The skewness is 0.43, meaning the distribution is skewed to the right. Kurtosis 23.7 exceeds 3, implying that the tail of the distribution is thicker than the normal distribution. Skewness and kurtosis tests reject the null of normality at the 1% level ($p < .01$). This confirms that 9-ending prices exceed non-9-ending prices at the level of individual products across the stores of the chain. In appendix G, we report 29 category-level frequency distributions with similar findings.

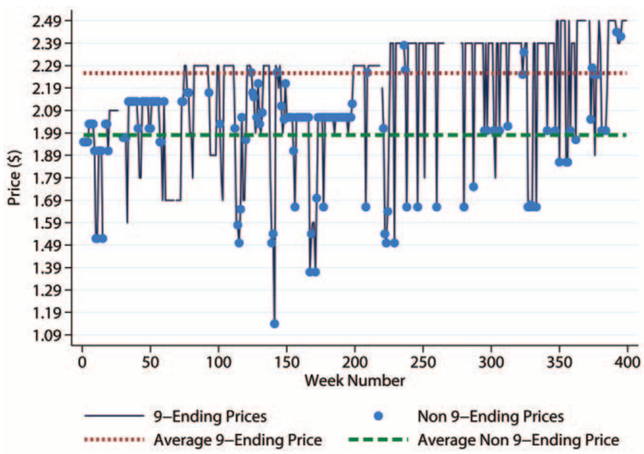

Figure 2. Retail price of Nabisco Wheat Thins Low Salt, 10oz (snack crackers' category, SKU: 1275660, store no. 122), Dominick's, September 14, 1989 to May 7, 1997. Observations where a blue dot appears to coincide with a 9-ending price point/line are the cases where the 9-ending price is right below the 0-ending price that follows immediately (e.g., \$1.49 and \$1.50). In app. F, we present the time series plots for all the products in the snack crackers category.

Table 1. Average 9-Ending and Non-9-Ending Prices, and the Percentage Difference between Them, Dominick's, September 14, 1989, to May 8, 1997

Category	9-ending (1)	Non-9-ending (2)	Percentage difference (3)
Analgesics	5.33	4.31	21.24
Bath soaps	3.15	3.24	−2.82
Beer	5.68	5.83	−2.61
Bottled juices	2.27	2.22	2.23
Cereal	3.08	3.14	−1.93
Cheese	2.53	2.42	4.45
Cigarettes	11.93	6.85	55.48
Cookies	2.06	2.21	−7.03
Crackers	2.08	1.90	9.05
Canned soups	1.21	1.09	10.44
Dish detergents	2.36	2.30	2.58
Front-end candies	0.74	0.53	33.38
Frozen dinners	2.33	2.42	−3.79
Frozen entrees	2.34	2.32	0.86
Frozen juices	1.32	1.44	−8.70
Fabric softeners	2.88	2.74	4.98
Grooming products	3.02	2.42	22.15
Laundry detergents	5.76	5.11	11.97
Oatmeal	2.65	2.66	−0.38
Paper towels	1.69	1.30	26.24
Refrigerated juices	2.28	2.19	5.51
Soft drinks	2.53	1.44	56.36
Shampoos	3.00	2.44	20.66
Snack crackers	2.20	2.12	3.25
Soaps	2.74	2.12	25.65
Toothbrushes	2.21	2.09	5.58
Tuna	1.99	1.63	19.96
Toothpastes	2.53	2.26	11.29
Toilet papers	2.51	1.64	42.56
Average of the positive percentage differences			17.99

Note.—In cols. 1 and 2, we report the average 9-ending and non-9-ending prices, respectively, in each one of Dominick's 29 product categories, calculated over all stores and weeks. In col. 3, we report the percentage difference between the average 9-ending and non-9-ending prices computed as a log-difference. There are 22 product categories with positive values in col. 3. All differences are statistically significant based on the Mann-Whitney test with $p < .01$.

Role of Upward Trend in the Prevalence of 9-Ending Prices

If 9-ending prices became more prevalent over time, then they might on average be high overall, even if they are lower than non-9-ending prices in any given year. The share of 9-ending prices (see table 2, panel A) increased from 51.9% in 1989 to 73.0% in 1997. Since inflation in this period was positive, this increase can explain why 9-ending prices are higher than non-9-ending prices. We test this formally by estimating log-linear OLS regressions with fixed effects, with *ln (price)* as the dependent variable, and 9-ending price dummy, which equals 1 if the price is 9-ending and 0 otherwise, as the key independent variable. The dummy's coefficient therefore gives the expected percentage difference between 9-ending and non-9-ending prices. We report the estimation results in table 3.

When we control for subcategories at the store level and for the overall price trend (col. 1), 9-ending prices exceed non-9-ending prices in 22 categories. In column 2, the 9-ending price dummy captures the gap within a store, on a given week, between prices of goods in the same subcategory. Here we find that 9-ending prices are higher than non-9-ending prices in 23 categories. Considering individual goods' prices, at individual stores over time, and comparing them when they are 9-ending and when they are non-9-ending (col. 3), we find that in 25 categories, 9-ending prices are higher than non-9-ending prices. Thus, 9-ending prices are higher than non-9-ending prices in a large majority of categories. This is true whether we compare the prices of products

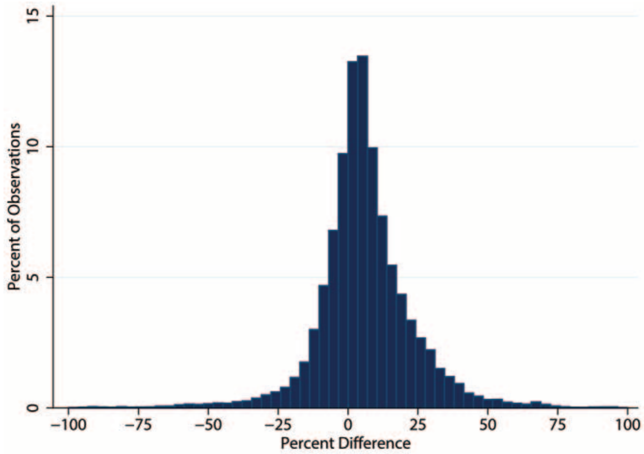

Figure 3. Frequency distribution of the percentage differences between the average 9-ending and non-9-ending prices, Dominick's, September 14, 1989 to May 8, 1997. Figure was produced using all 98,914,300 weekly retail price observations of Dominick's from 93 stores over 400 weeks, except the outliers. We define an outlier as a price difference of greater than 100% in absolute value. There were 1,654 such outliers, comprising about 0.2% of the total number of observations. Figure 1 in app. H presents the plot with all the data points (including the outliers).

Table 2. Share of 9-Ending Prices, Average 9-Ending and Non-9-Ending Prices, and the Percentage Difference between Them, Regular and Sale Prices, Dominick's, 1989–97

	(A) Share of 9-ending prices (%), among			(B) Average prices and percentage difference					
				Regular prices			Sale prices		
Year	All prices	Regular prices	Sale prices	9-ending	Non-9-ending	Percentage difference	9-ending	Non-9-ending	Percentage difference
1989	51.9	51.06	61.49	2.35	2.28	3.02	1.92	1.95	−1.55
1990	54.7	53.76	63.12	2.42	2.35	2.94	1.93	1.83	5.32
1991	55.8	55.37	59.07	2.73	2.29	17.57	2.15	1.87	13.95
1992	63.9	65.13	53.57	2.82	2.16	26.66	2.40	1.85	26.03
1993	63.8	65.23	52.10	2.70	2.43	10.54	2.39	1.83	26.70
1994	67.2	70.45	45.98	2.79	2.38	15.89	2.52	1.84	31.45
1995	66.7	70.96	40.74	2.89	2.26	24.59	2.62	1.84	35.34
1996	68.9	72.94	39.33	3.03	2.41	22.89	2.38	1.97	18.91
1997	73.0	75.14	47.58	3.17	2.47	24.95	2.82	2.06	31.40

within the same subcategories controlling for stores, across products in the same week at the store, and at the level of individual products in individual stores over time.

Regular Prices versus Sale Prices

Since consumers might be perceiving 9-ending prices as low because they associate 9-endings with sale prices (Schindler and Kibarian 2001), we compare the share of 9-ending prices among regular and sale prices. To identify sale-prices, we use a sales filter, which classifies a price as a sale price if it decreased, stayed low for 4 weeks or less, and then increased to the pre-sale level or above it (Dutta, Bergen, and Levy 2002; Levy, Dutta, and Bergen 2002; Nakamura and Steinsson 2008, 2011; Tsiros and Hardesty 2010; Chahrour 2011; Knotek 2016; Ray, Snir, and Levy 2020). We report the results in table 4. We find that in 28 categories, 9-ending prices are more common among regular prices than among sale prices. Thus, consumers' tendency to associate 9-endings with low prices cannot be explained by 9-ending prices being sale prices, as the shoppers are more likely to encounter 9-ending prices when they buy the goods at a regular price than at a sale price.

Another possibility is that if 9-ending prices are lower, on average, than non-9-ending prices among sale prices, consumers could associate 9-endings with price cuts (Schindler 2001, 2003, 2006). To test this, we run the above regressions separately for regular and sale prices (see table 5). Among regular prices, which in our data comprise 88.68% of all prices, 9-ending prices exceed non-9-ending prices in most categories, regardless of the specification we use. Among sale prices, when we compare the prices of individual goods when they are 9-ending and when they are non-9-ending (col. 6), that is true for only 12 categories. This suggests that Dominick's may be reinforcing the low price image of 9-ending prices by setting prices at 9-endings in case of particularly deep price cuts.

Dynamics of 9-Ending and Non-9-Ending Prices: Regular Prices versus Sale Prices

According to table 2, panel A, during 1989–97, the share of 9-ending prices among regular prices increased from 51.06% to 75.14%, while among sale prices it decreased from 61.49% to 47.58%. Thus, in the earlier period of the sample, 9-ending prices had stronger association with sales. During that period, the percentage difference between 9-ending and non-9-ending prices increased from 3.02% to 24.95% among regular prices, and from −1.55% to 31.40% among sale prices (panel B).

Next, we estimate a set of log-linear OLS regressions with fixed effects, one regression for each year, with the logarithm of prices as the dependent variable. A positive (negative) coefficient of the 9-ending dummy indicates that 9-ending prices are expected to be higher (lower) than non-9-ending prices (see table 6 for the estimation results).

In the regressions, we control for products in stores and for weeks. The coefficient estimates of the 9-ending dummy thus captures the average difference between 9-ending and non-9-ending prices, at the level of an individual product,

Table 3. Regression Analyses of the Percentage Difference between 9-Ending and Non-9-Ending Prices, Dominick's, September 14, 1989, to May 8, 1997

	(1)	(2)	(3)	N
Analgesics	.13 (.005)***	.13 (.005)***	.15 (.001)***	3,040,172
Bath soaps	.02 (.010)**	.03 (.010)***	.12 (.001)***	418,097
Beer	.03 (.009)***	.03 (.009)***	−.02 (.001)***	1,966,148
Bottled juices	.03 (.003)***	.03 (.003)***	.02 (.000)***	4,325,024
Cereal	−.02 (.001)***	−.02 (.001)***	.01 (.000)***	4,707,776
Cheese	.11 (.002)***	.08 (.001)***	.15 (.000)***	6,752,326
Cigarettes	.59 (.059)***	.02 (.005)***	.27 (.001)***	1,801,444
Cookies	−.09 (.003)***	.00 (.002)	−.03 (.000)***	7,568,352
Crackers	.06 (.001)***	.07 (.001)***	.03 (.000)***	2,228,268
Canned soups	.09 (.005)***	.09 (.005)***	.06 (.000)***	5,504,492
Dish detergents	.03 (.006)***	.03 (.004)***	.02 (.000)***	2,164,793
Front-end candies	.39 (.002)***	.38 (.002)***	.24 (.003)***	4,437,054
Frozen dinners	−.01 (.007)*	− .01 (.007)	.04 (.000)***	1,654,053
Frozen entrees	.06 (.005)***	.05 (.005)***	.01 (.000)***	7,172,075
Frozen juices	−.07 (.003)***	−.08 (.003)***	−.06 (.000)***	2,368,157
Fabric softeners	−.03 (.003)***	−.03 (.003)***	.02 (.001)***	2,278,995
Grooming products	.21 (.002)***	.16 (.002)***	.17 (.000)***	4,065,689
Laundry detergents	.10 (.003)***	.13 (.002)***	.12 (.001)***	3,277,444
Oatmeal	−.02 (.006)***	−.01 (.006)*	.01 (.004)***	981,037
Paper towels	.14 (.010)***	.14 (.010)***	.05 (.001)***	940,757
Refrigerated juices	.06 (.004)***	.06 (.004)***	.06 (.001)***	2,166,755
Soft drinks	.69 (.010)***	.30 (.005)***	.30 (.000)***	10,741,742
Shampoos	.16 (.012)***	.12 (.009)***	.12 (.000)***	4,666,565
Snack crackers	.03 (.004)***	.03 (.004)***	.05 (.000)***	3,487,564
Soaps	.15 (.003)***	.15 (.003)***	.11 (.006)***	1,835,196
Toothbrushes	−.03 (.005)***	−.01 (.005)***	.02 (.000)***	1,772,158
Tuna	.19 (.003)***	.19 (.003)***	.10 (.001)***	2,382,983
Toothpastes	.01 (.004)	.01 (.004)***	−.01 (.003)***	2,981,532
Toilet papers	.41 (.007)***	.41 (.007)***	.11 (.001)***	1,149,972
Dummies for weeks	√		√	
Dummies for product, store			√	
Dummies for subcategories, store	√			
Dummies for subcategories, store, weeks		√		

Note.—Coefficient estimates of a 9-ending dummy in log-linear OLS regressions with fixed effects, where the dependent variable is the log of the prices. The 9-ending dummy equals 1 if the price ends with 9, and 0 if the price ends with any other digit. In col. 1, regression includes controls for weeks and for subcategories-store. In col. 2, regression includes controls for subcategories-stores-weeks. In col. 3, regression includes dummies for weeks and for product-store. N denotes the number of observations. In parentheses, we report robust standard errors, clustered at the store level.

* $p < .10$.

** $p < .05$.

*** $p < .01$.

offered at a specific store. We find that at the product-store level during 1989–1992, 9-ending regular prices were lower than non-9-ending regular prices. Thus, in that period, 9-ending prices were indeed associated with lower regular and overall prices. During that period, however, 9-ending sale prices were sometimes higher and sometimes lower than non-9-ending sale prices.

Following 1993, we see a reversal: 9-ending regular prices become higher than non-9-ending regular prices, making 9-ending prices higher overall than non-9-ending prices. The

Table 4. Percentage of 9-Ending Prices, by Product Categories, among Sale Prices and among Regular Prices, and the Difference between Them, Dominick's, September 14, 1989, to May 8, 1997

Category	Sale prices (1)	Regular prices (2)	Difference (3)
Analgesics	67.3	86.8	−19.5
Bath Soaps	60.5	89.2	−28.7
Beer	90.8	96.6	−5.8
Bottled juices	43.3	51.8	−8.5
Cereal	38.7	39.7	−1.0
Cheese	41.0	65.2	−24.2
Cigarettes	4.3	16.5	−12.2
Cookies	42.6	77.8	−35.2
Crackers	34.3	68.3	−34.0
Canned soups	26.5	31.4	−4.9
Dish detergents	59.0	68.1	−9.1
Front-end candies	20.5	40.1	−19.6
Frozen dinners	27.2	62.4	−35.2
Frozen entrees	29.3	64.2	−34.9
Frozen juices	48.1	46.1	2.0
Fabric softeners	56.9	59.6	−2.7
Grooming products	56.5	88.8	−32.3
Laundry detergents	64.8	77.5	−12.7
Oatmeal	36.8	53.7	−16.9
Paper towels	48.3	50.3	−2.0
Refrigerated juices	53.5	57.7	−4.2
Soft drinks	64.8	87.4	−22.6
Shampoos	73.1	92.6	−19.5
Snack crackers	41.1	77.6	−36.5
Soaps	43.7	64.7	−21.0
Toothbrushes	69.6	78.1	−8.5
Tuna	32.2	50.6	−18.4
Toothpastes	62.8	63.9	−1.1
Toilet papers	52.7	53.5	−0.8
Average of the negative differences			−16.9

Note.—We identify sale prices using a sales filter that identifies a sale if the price decreases and then increases back to the previous level or above. In col. 1, we report the percentage of 9-ending prices among sale prices. In col. 2, we report the percentage of 9-ending prices among regular prices. In col. 3, we report the difference between the percentage of 9-ending prices in sale prices and in regular prices. All differences are statistically significant based on the *z*-scores proportions test, with $p < .01$.

9-ending sale prices, however, become lower (and in 1997, not higher) than non-9-ending sale prices. Thus, until 1993, a consumer who bought a given product at a given store was expected to get a better deal if s/he bought the good at a 9-ending price. After 1993, however, among regular prices, which comprise the vast majority of prices, the consumer got a better deal if s/he bought the good when its price was not 9-ending.

Thus, we find that 9-ending prices were lower in the early part of the sample until 1993 but rose significantly since then. The findings point toward a possible mechanism that lead consumers to associate 9-endings with low prices. Dominick's uses 9-ending prices to promote sales and to draw consumers' attention to particularly large price cuts, which seem to condition the shoppers to associate 9-endings with low prices. Therefore, if consumers paid more attention to sale prices, then they would have a reason to believe that 9-ending prices are lower than non-9-ending prices even after 1993.

Robustness Tests

To assess the robustness of our findings, we run nine sensitivity tests, which we discuss in detail in the online appendix. Below we briefly summarize the findings of these tests. See the corresponding sections of the appendix for more details of these tests and their results.

Comparison of 9-Ending and 0-Ending Prices. We compare 9- and 0-ending prices because low-price image of 9-ending prices could stem from consumers' tendency to judge 9-ending prices relative to nearby 0-ending prices. We find that 9-ending prices still exceed 0-ending prices in 21 of the 29 categories.

Role of 9-Endings as the Highest Possible Ending. The 9-ending prices could be higher than other prices for a technical reason: a 9-ending price exceeds any price with the same leftmost digits but that ends with any digit between 0 and 8. We find that in 21 categories, the average 9-ending prices are still higher than the average non-9-ending princes, even after accounting for the rightmost digit effect.

Regressions of Prices without Log-Transformation. We run the regression analyses presented in table 3 using the prices without a log-transformation. In great majority of the product categories, the expected 9-ending prices are still higher than the expected non-9-ending prices, regardless of the additional controls we include.

Role of Outlier Observations. We checked whether outlier values drive our results by excluding observations that are more than 2 SD away from the category average. We find that the expected 9-ending prices are still higher than non-9-ending prices, in most categories. This finding therefore is not driven by the outlier observations.

Using Dominick's Sale Dummy to Identify Sale Prices. We rerun the regular and sale price analyses by identifying the sale prices using Dominick's sale dummy (Peltzman 2000; Ray, Snir, and Levy 2020) instead of using a sale filter. The results we obtain are qualitatively unchanged. For regular prices, the expected 9-ending prices are usually higher than non-9-ending prices, while the expected 9-ending sale prices are lower than the expected non-9-ending sale prices. Thus, it does not matter what method we use to identify the sale prices.

Dynamics of 9-Ending and Non-9-Ending Prices Using Dominick's Sale Dummy. We repeated the analyses of Dominick's price-ending dynamics but this time using Dominick's sale dummy to identify sale prices. The results of the analysis are qualitatively identical to what we report above, and thus our conclusions remain unchanged.

Dynamics of 9-Ending and Non-9-Ending Prices at a Weekly Frequency. We repeated the dynamic analyses at a weekly frequency. If Dominick's sets high 9-ending regular prices and low 9-ending sale prices, then we could expect a negative correlation between 9-ending regular and sale prices: when 9-ending regular prices are high relative to non-9-ending regular prices, we would expect 9-ending sale prices to be low relative to non-9-ending sale prices. We estimated cross-correlations between the two series using weekly data, which allow noncontemporaneous correlations as well. We repeated these analyses twice, once using the sale filter and once using Dominick's sale dummy. The results are not in line with the hypothesized pricing patterns, suggesting that these processes are more long term in the sense that they take longer than just few weeks to develop.

Clustering the Regression Standard Errors at the Level of Price Zones. We repeated the analyses by clustering the regression standard errors at the level of price zones rather than at the level of stores. The findings are similar to what we report in the article.

Regressions of the Percentage Difference between 9-Ending and Non-9-Ending Prices. We repeated the analyses reported in table 6, using controls for stores, for categories, and for subcategories, rather than for individual products at individual stores. The estimation results we obtain are consistent with the findings we have reported above.

CONCLUSION, CAVEATS, AND FUTURE EXTENSIONS

Counter to common beliefs, we find that 9-ending prices tend to be higher than non-9-ending prices by as much as 18% on average. It appears that Dominick's supported and reinforced the belief that 9-ending prices are lower by using 9-endings for particularly low prices.

Data Limitations and Caveats

Dominick's data set is large, with more than 98-million observations for thousands of goods, and it has been used widely. Nevertheless, it has limitations. First, it comes from a single retailer, based in the Chicago metro area, making this a case study and raising questions about generalizability of our findings to other retailers, markets, and geographical areas. Second, Dominick's, as a midsize Hi-Lo retailer, may not be a good representative of the current retail landscape, which has a continuum of pricing formats (Bolton and Shankar 2003; Ellickson and Misra 2008). Third, Dominick's data set is dated, raising questions about generalizability of our findings to recent periods. Fourth, the explanation we are offering for the consumers' mistaken beliefs is based on "circumstantial evidence." The pricing pattern we find in the data can indeed produce in shoppers' minds an association between 9-endings and low prices. This explanation, however, requires more direct evidence and a stronger support.

Technological Innovations

Current technological innovations in retail pricing technologies, including digital signage, smart carts, price comparison apps, and so forth, offer consumers extraordinary amount of information with a click of a button, which can alter the way that retailers price. For example, with these technologies, shoppers might discover that 9-ending prices are not lower than prices that end with other digits. This can have important implications for retail pricing, promotional practices, and so forth. This is relevant, for example, in personalized pricing where sellers' access to big data can alter the way price endings are used to target individual shoppers (Dubé and Misra 2017; Bruno, Cebollada, and Chintagunta 2018).

Other Price Endings

The popularity of 9-ending prices is not universal. For example, they are rare in Poland and Hungary (Konieczny and Rumler 2007; Konieczny and Skrzypacz 2017). Moreover,

Table 5. Regression Analysis of the Percentage Difference between 9-Ending and Non-9-Ending Prices, Regular and Sale Prices, Dominick's, September 14, 1989, to May 8, 1997

	Regular prices				Sale prices			
Category	(1)	(2)	(3)	*N*	(4)	(5)	(6)	*N*
Analgesics	.13***	.13***	.15***	2,924,303	.00	.01*	−.01***	115,869
	(.005)	(.005)	(.000)		(.003)	(.003)	(.002)	
Bath soaps	−.01	−.01	.11***	405,439	.02***	.03***	−.04***	12,658
	(.011)	(.010)	(.001)		(.008)	(.007)	(.003)	
Beer	.02	.02**	−.04***	1,660,236	.11***	.09***	−.03***	305,912
	(.010)	(.010)	(.001)		(.010)	(.010)	(.002)	
Bottled juices	.02***	.02***	.02***	3,753,608	.06***	.05***	−.00**	571,416
	(.004)	(.003)	(.000)		(.003)	(.003)	(.001)	
Cereal	−.02***	−.02***	.01***	4,379,009	−.01***	−.02***	−.03***	328,767
	(.001)	(.001)	(.000)		(.003)	(.003)	(.001)	
Cheese	.12***	.08***	.16***	5,684,114	−.01***	−.01***	.03***	1,068,212
	(.002)	(.002)	(.000)		(.001)	(.001)	(.001)	
Cigarettes	.59***	.02***	.27***	1,793,459	.01	−.05***	.21***	7,985
	(.058)	(.005)	(.001)		(.201)	(.017)	(.019)	
Cookies	−.13***	−.03***	−.04***	6,725,729	−.06***	−.03***	−.03***	842,623
	(.003)	(.003)	(.000)		(.001)	(.001)	(.001)	
Crackers	.07***	.07***	.02***	1,943,794	−.08***	−.07***	−.06***	284,474
	(.002)	(.001)	(.000)		(.002)	(.001)	(.001)	
Canned soups	.09***	.08***	.06***	5,018,750	.12***	.11***	.01***	485,742
	(.005)	(.005)	(.000)		(.002)	(.002)	(.001)	
Dish detergents	.03***	.04***	.02***	1,973,399	−.04***	.05***	−.04***	191,394
	(.007)	(.004)	(.000)		(.003)	(.002)	(.001)	
Front-end candies	.39***	.38***	.24***	4,189,543	.18***	.20***	.06***	247,511
	(.002)	(.002)	(.000)		(.003)	(.004)	(.001)	
Frozen dinners	−.06***	−.07***	−.01	1,391,236	.07***	.04***	.01***	262,817
	(.006)	(.007)	(.000)		(.005)	(.006)	(.001)	
Frozen entrees	.01***	.00	−.05***	6,289,007	.00**	−.01*	.00*	883,068
	(.005)	(.005)	(.000)		(.000)	(.004)	(.001)	
Frozen juices	−.07***	−.08***	−.06***	2,016,638	−.07***	−.09***	−.02***	351,519
	(.003)	(.003)	(.000)		(.002)	(.002)	(.001)	
Fabric softeners	−.04***	−.05***	.01***	2,101,762	.10***	.15***	.01	177,233
	(.003)	(.003)	(.001)		(.003)	(.003)	(.002)	
Grooming products	.20***	.14***	.16***	3,806,684	.18***	.08***	.07***	259,005
	(.003)	(.002)	(.000)		(.004)	(.002)	(.001)	
Laundry detergents	.08***	.12***	.12***	3,002,713	.18***	.17***	.07***	274,731
	(.003)	(.002)	(.001)		(.005)	(.005)	(.001)	
Oatmeal	−.03***	−.03***	−.01***	898,099	−.05***	.00	−.03***	82,938
	(.005)	(.005)	(.000)		(.004)	(.004)	(.002)	
Paper towels	.15***	.15***	.07***	807,388	.03***	.01**	.01***	133,369
	(.010)	(.010)	(.001)		(.005)	(.005)	(.002)	
Refrigerated juices	.07***	.08***	.07***	1,702,858	.01***	.01***	.01***	463,897
	(.005)	(.005)	(.001)		(.002)	(.002)	(.001)	
Soft drinks	.76***	.34***	.30***	8,516,259	.56***	.14***	.20***	2,225,483
	(.011)	(.007)	(.001)		(.007)	(.003)	(.001)	
Shampoos	.15***	.11***	.10***	4,416,767	−.08***	−.05***	−.00	249,798
	(.013)	(.010)	(.000)		(.005)	(.003)	(.001)	

Table 5. (*Continued*)

Category	Regular prices (1)	(2)	(3)	N	Sale prices (4)	(5)	(6)	N
Snack crackers	.01**	.02***	.03***	3,019,467	−.03***	−.03***	−.04***	468,097
	(.006)	(.006)	(.000)		(.001)	(.001)	(.001)	
Soaps	.16***	.15***	.12***	1,662,739	.07***	.07***	.01***	172,457
	(.004)	(.004)	(.001)		(.003)	(.003)	(.001)	
Toothbrushes	−.04***	−.02***	.02***	1,662,831	.01**	.00	−.07***	109,327
	(.004)	(.005)	(.000)		(.005)	(.005)	(.001)	
Tuna	.20***	.20***	.10***	2,183,367	−.03	−.05	−.01***	199,616
	(.003)	(.003)	(.001)		(.003)	(.003)	(.002)	
Toothpastes	−.00	.00	−.02***	2,709,365	.01***	.03***	−.03***	272,167
	(.004)	(.004)	(.000)		(.002)	(.002)	(.001)	
Toilet papers	.43***	.43***	.13***	983,422	.20***	.23***	−.03***	166,550
	(.008)	(.008)	(.001)		(.005)	(.005)	(.002)	
Dummies for weeks	√		√		√		√	
Dummies for product, store			√				√	
Dummies for subcategories, store	√				√			
Dummies for subcategories, store, weeks		√				√		

Note.—Coefficient estimates of a 9-ending dummy in a number of log-linear OLS regressions with fixed effects, where the dependent variable is the log of the prices. In cols. 1–3, we report the results when we estimate the regression using data on regular prices only. In cols. 4–6, we report the results when we estimate the regression using data on sale prices only. We identify sale prices using a sales filter that identifies a sale if the price decreases and then increases back to the previous level or above. In cols. 1 and 4, regression includes controls for weeks and for subcategories-store. In cols. 2 and 5, regression includes controls for subcategories-stores-weeks. In cols. 3 and 6, regression includes dummies for weeks and for product-store. *N* denotes the number of observations. In the parentheses we report robust standard errors, clustered at the store level.

* $p < .10$.

** $p < .05$.

*** $p < .01$.

there are other common endings. For example, 0-ending prices are common because they may signal quality (Stiving and Winer 1997; Stiving 2000; Schindler et al. 2011), because of their cognitive convenience (Wadhwa and Zhang 2015; Snir, Chen, and Levy 2020; Chen, Snir, and Levy, forthcoming), and because they reduce the amount of the change used in transactions (Knotek 2008, 2011).

For example, the price of Coca-Cola was fixed for more than 70 years at 5 cents because raising it by less than 100% would require the use of multiple coins, making it less convenient for shoppers (Levy and Young 2004, 2021; Young and Levy 2014). Doubling it to 10 cents would preserve the single-coin price, but it was considered too risky because that would mean a price increase of 100%. Moreover, some numbers' symbolic significance leads to their overuse (Schindler 1991). For example, prices that end with 8 are common in Hong Kong, Japan, and China because 8 is considered a lucky number, and because its resemblance to a mountain, 八, signifies prosperity. More work is needed to better understand the cognitive and cultural determinants of such pricing practices.

Public Policy Aspects

The 9-ending prices are debated in countries where low denomination coins are not used because transactions with small changes require rounding, if 9-ending prices are used. For example, In Israel, after 1-agora and 5-agora coins were abolished, the law required the final bills be rounded to the nearest 10-agora. However, Israeli retailers kept using 9-ending prices extensively, irritating consumers who claimed that the practice is unethical given the absence of the 1-agora coin. In response, in January 2014, the Ministry of

Table 6. Annual Regressions of the Percentage Difference between 9-Ending and Non-9-Ending Prices, Dominick's, September 14, 1989, to May 8, 1997

	All observations		Regular prices		Sale prices	
Year	9-Ending	*N*	9-Ending	*N*	9-Ending	*N*
1989	−.03*** (.005)	2,570,474	−.03*** (.005)	2,362,875	.03*** (.011)	207,599
1990	−.05*** (.005)	9,228,965	−.04*** (.005)	8,366,677	−.02*** (.004)	862,288
1991	−.04*** (.003)	10,650,384	−.04*** (.003)	9,552,147	.02 (.013)	1,098,237
1992	−.00 (.003)	13,731,259	−.02*** (.003)	12,343,849	.02*** (.009)	1,387,410
1993	.02*** (.002)	14,023,602	.01*** (.002)	12,549,782	.00 (.004)	1,473,820
1994	.06*** (.002)	13,645,820	.04*** (.002)	11,905,363	−.03*** (.002)	1,740,457
1995	.07*** (.002)	13,424,315	.05*** (.002)	11,544,459	−.04*** (.002)	1,879,856
1996	.10*** (.002)	14,238,652	.07*** (.002)	12,524,236	−.02*** (.003)	1,714,416
1997	.09*** (.003)	5,156,434	.06*** (.003)	4,769,776	.00 (.003)	386,658

Note.—Coefficient estimates of a 9-ending dummy in fixed effect log-linear OLS regressions, where the dependent variable is the log of the prices. Regressions are estimated for each year over all stores and products. The 9-ending dummy equals 1 if the price ends with 9, 0 otherwise. Regressions include controls for product-store and for weeks. *N* denotes the number of observations. We identify sale prices using a sale filter that identifies a sale if the price decreases and then increases back to the previous level or above.
*** $p < .01$.

the Economy banned the use of 9-ending prices (Ater and Gerlitz 2017; Snir et al 2017, 2020).

A related question concerns the use of 9-endings for sale prices, to draw the shoppers' attention to price cuts, while simultaneously setting most 9-ending prices higher than non-9-ending prices. Recent studies document similar behavior. For example, Levy et al. (2020) find that in the same Dominick's data set, new prices are 9-ending more often after price increases than after price decreases. Chakraborty and colleagues (2015) find that at UK supermarkets many individual prices fell, but the overall basket prices rose, concluding that small price cuts were used to disguise increases in the basket price. Anderson et al. (2017) report that in their data temporary price cuts were offered along with regular price increases simultaneously, concluding that the retailer was trying to mask the regular price increases.

These findings are in line with what Akerlof and Shiller's (2015, vii, 1) call a *phishing equilibrium*, stating "if we have some weakness . . . in the phishing equilibrium someone will take advantage of it." The 9-ending prices might be a phishing-equilibrium where consumers use 9-endings as signal for low prices, and retailers respond by setting 9-ending prices higher than non-9-ending prices. Retailers gain because this enables them to conceal price increases, while buyers gain by saving the costs of the time as well as the costs of the cognitive efforts that are needed—what Shugan (1980) and Kashyap (1995) call "thinking costs"—for noticing, processing, and assessing these price changes.

Future Research

Future research should explore further the issues raised here. In particular, given the importance of 9-ending prices, it is essential to study them using a variety of data sets, across different markets and geographical areas, and in more recent time periods. In particular, there is a need for more studies that compare 9-ending and non-9-ending prices. Besides the work of Schindler (2001) and this article, no study assesses directly the validity of the widespread belief that

9-ending prices are lower than comparable non-9-ending prices.

More studies are also needed to assess the effect of 9-ending prices on consumer demand and on the sales volume, a question that we did not address in this article. For example, how much of the effects of 9-ending prices on consumer demand are context-dependent, as reported by Macé (2012)? How much of these effects vary across markets? While several studies confirm the positive effect that 9-ending prices have on consumer demand and on sales, there are exceptions. For example, in field experiments, rounding up 9-ending prices to 0-endings led to greater profits (Diller and Brielmaier 1995; Bray and Harris 2006).

Our attempt to shed light on the process that leads the shoppers to associate 9-endings with low prices is suggestive. It is likely that such processes develop slowly over long periods of time, and thus 8 years of data cannot be too informative on the mechanisms that govern them. Future research should therefore explore processes through which shoppers learn from salient cues that shape their long-term beliefs to better understand the mechanisms that govern such learning processes (Anderson and Simester 2003b, 2009).

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