Not All Price Endings Are Created Equal: Price Points and Asymmetric Price Rigidity

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Abstract

There is evidence that 9-ending prices are more common and more rigid than other prices. We use data from three sources: a laboratory experiment, a field study, and a large US supermarket chain, to study the cognitive underpinning and the ensuing asymmetry in rigidity associated with 9-ending prices. We find that consumers use 9-endings as a signal for low prices, and that this signal interferes with price information processing. Consequently, consumers are less likely to notice a bigger price when it ends with 9, or a price increase when the new price ends with 9, in comparison to a situation where the prices end with some other digit. We also find that retailers respond strategically to this consumer bias by setting 9-ending prices more often after price increases than after price decreases. 9-ending prices, therefore, usually increase only if the new prices are also 9-ending. Consequently, there is an asymmetry in the rigidity of 9-ending prices: they are more rigid than non 9-ending prices upward but not downward.

1. INTRODUCTION

The economics literature has been paying increased attention to studying the sources of nominal price rigidity.[1] One of the recent theories of price rigidity is the *price point theory*, which posits that prices tend to get "stuck" at certain endings (Kashyap, 1995, Blinder et al., 1998).

Levy et al. (2011), for example, use data on 474 consumer electronic goods from 293 internet sellers as well as data from a large US supermarket chain and find that 9 is the most frequent ending for the penny, dime, dollar and ten-dollar digits.[2] They also report that 9-ending prices are more rigid than non 9-ending prices. Moreover, the rigidity of 9-ending prices seems to have macroeconomic significance.[3] Knotek (2010), for example, provides evidence that 9-endings may be a more important source of price rigidity than menu costs.

Our goal in this research is to shed more light on the link between 9-endings and price rigidity. We use experimental data, field data, and supermarket data to study the cognitive underpinning and the ensuing asymmetry in the rigidity of 9-ending prices. The experimental and field data suggest that 9-endings as a signal for low prices interfere with price comparisons and recall of price changes. Consequently, consumers are less likely to recognize a bigger price that ends with 9 and less likely to notice a price increase when the new price ends with 9. For price decreases, however, 9-endings do not seem to play a

[1] See, for example, Rotemberg (1982, 1987, 2005, 2010), Mankiw (1985), Carlton (1986), Lach and Tsiddon (1992, 1996), Konieczny (1993), Warner and Barsky (1995), Danziger (1999), Dutta, et al. (2002), Ball and Romer (2003), Levy and Young (2004), Bils and Klenow (2004), Zbaracki, et al. (2004), Nakamura and Steinsson (2008, 2009), Kehoe and Midrigan (2008, 2010), Klenow and Kryvtsov (2008), Levy, et al. (2010), Midrigan (2011), and Eichenbaum, et al. (2011). For recent surveys, see Willis (2003), Wolman (2007), and Klenow and Malin (2011).

[2] Benford law, also known as the significant digit law, predicts that in many naturally occurring settings such as tables, measurements, etc., the distribution of the leftmost digits is logarithmic, and not uniform as one would perhaps expect (Varian, 1972; Hill, 1995). For example, the probability of 1 occurring as the leftmost digit is $\log_{10} 2 \approx 0.301$, the probability of 2 occurring as the leftmost digit is $\log_{10}(3/2) \approx 0.176$, etc. This surprising fact was discovered in 1881 by Newcomb (1881), who noticed that the pages of logarithm tables containing numbers starting with 1 were more worn out than the other pages. Benford (1938) studied over 20,000 different data sets, including areas of rivers, baseball statistics, numbers in magazine articles, and the street addresses of the first 342 people listed in the book *American Men of Science* and concluded that these indeed obeyed the law. Under Benford law, the probabilities of the digits tend to being uniformly distributed as we move from left to right. For the second left-most digits the skew is from 12 percent for 0 down to 8.5 percent for 9. Nigrini (2002, Ch. 7) shows that as a first approximation, the last-two digits are equally likely for each combination from 00 to 99 in three-digit and higher numbers. Therefore, the distribution of the rightmost digits that Levy, et al. (2011) report in their data cannot be explained by Benford law.

[3] 0- and 5-ending prices, which are common at vending machines and convenient stores, are another example of price points (Cecchetti, 1986). They are known as *convenient* prices because they reduce the number of coins used in a transaction. Knotek (2010, 2011) finds that convenient prices are more rigid than other prices. In the data studied by Levy, et al. (2011), 9-ending prices are more common and more rigid than 0- and 5-ending prices, although 0 and 5 are considered *cognitively more accessible* numbers than 9 (Dehaene and Mehler, 1992).

significant role in recall accuracy, presumably because of retailer's use of alternative signals for price decreases.

Retailers that act strategically, therefore, have an incentive to keep prices at 9-endings after increases but not after decreases. Data from Dominick's Finer Food, a large Midwestern US supermarket chain, support this hypothesis. Specifically, we find that prices after increases are more likely to end with 9 than after decreases. In other words, 9-endings are more rigid than other price endings upward but not downward.

We further demonstrate that this asymmetry in rigidity goes beyond *price-endings* to 9-ending *prices*. We find that 9-ending prices are less likely to increase than other prices but are as likely to decrease as other prices. Thus, we offer an explanation for the price rigidity associated with 9-endings. In addition, we document and offer an explanation for the asymmetry in the rigidity of 9-ending prices.

The paper is organized as follows. In section 2, we present our hypotheses. In section 3, we describe the data and discuss the findings. Section 4 concludes.

2. TESTABLE HYPOTHESES

Empirical evidence suggests that individuals process multi-digit information from left to right. Thus, individuals comparing two numbers that differ in one digit are usually faster and more accurate if the numbers differ in their left-most digits than the middle or the right-most digits (Poltrock and Schwartz, 1984). The marketing literature extends this finding to prices by *assuming* that consumers process multi-digit *price* information from left to right (Stiving and Winer, 1997, Schindler and Kirby, 1997, Schindler and Chandrashekaran, 2004). The marketing literature also suggests that consumers often use 9-endings as a signal for low prices. For example, they are more likely to report that a price is one of the lowest in its category if it ends with 9 (Schindler, 2001, 2006).

Following the literature, we hypothesize that 9-endings will not affect number comparisons because the endings do not have any particular significance in comparison of general numbers, but they will affect the comparison of prices because the use of 9-endings as a signal for low prices may interfere with the left-to-right *price* information processing. We therefore hypothesize that consumers will be less accurate in comparing two prices when the bigger of the prices is 9-ending. In addition, we also hypothesize that consumers are less accurate in recalling an increase if the new price is 9-ending, because 9-ending might help disguise the price increase.

Retailers are likely to respond strategically to these consumer perceptions by choosing 9-ending prices after price increases to reduce the likelihood that the consumers will notice the price increase. 9-ending prices, therefore, are likely to remain 9-ending even after several price increases. Retailers are less likely, however, to set 9-ending prices after price decreases because they are interested in ensuring that the consumers notice price cuts. Price cuts, therefore, are often promoted by highly visible signals such as sale signs, discount signs, large price tags, colorful shelf and/or end-of-the-isle price displays, leaflets, etc (Nevo, 2002). The use of these alternative signals is likely to make it less critical to use 9-endings as another signal of low prices. We therefore predict that 9-endings prices will be more likely to decrease to non 9-ending prices than they will be to increase to non 9-ending prices. In other words, 9-ending will be more rigid than other endings upward but not downward.

Finally, we hypothesize that the asymmetric rigidity of *9-endings* will lead to asymmetry in the rigidity of *9-ending prices*. That is because if 9-endings usually increase only to new 9-endings, then 9-ending prices will be less likely to increase—they will increase only when the shock that causes the price change is large enough to make it optimal to set a new 9-ending price. In contrast, since 9-ending prices can decrease to other digits, they will not necessarily be less likely to decrease than other prices.

3. DATA AND ANALYSES

3.1. Evidence from a Laboratory Experiment

In this section we discuss the results of a lab experiment which we have conducted to study the effects of 9-endings on price and number comparisons. In Section 3.1.1 we discuss the experimental settings. In Section 3.1.2, we show that 9-endings seem to affect price comparisons but not number comparisons. In Section 3.1.3, we extend these findings by testing the hypothesis that 9-endings affect price comparisons because 9-endings are a signal of low prices.

3.1.1. Experimental Settings

The experiment was conducted at a computer lab at Texas A&M University. The participants were 206 undergraduate business students that participated for partial course credit. The median participant age was 20, 66 percent were female, 21 percent reported that they shop in a supermarket once a month or less, 34 percent—once every two weeks, 35 percent—every week, and 10 percent—twice a week or more. The experiment was run with 30–40 participants in each session. Participants needed less than 15 minutes to complete the task.[4]

We employed a 2×2×2×3 mixed design with 2 stimuli types (number, price), 2 levels of comparison difficulty (low, high), 2 numbers of digits (three digits, four digits), and 4 locations for the different digit (none, left-most, middle, right-most digit). The first three factors are between-subjects, and the last within-subjects.

The first factor, type of stimuli, was manipulated as follows. In the *number comparison* condition, two numbers were presented in each comparison, with one number shown on each side of the computer screen. The numbers were either the same or differed in one digit. Participants were asked to press the letter "A" on the keyboard if the left number was larger, "L" if the right number was larger, or the "space" if the two numbers were equal. Participants completed one practice block followed by four actual experimental blocks, each composed of 75 comparisons, with 10 percent of the numbers ending with 9. Right before each comparison, participants were shown a picture of an abacus on a computer screen for 1,000 milliseconds, followed by another computer screen with a fixation "+" sign in the middle of the screen for 500 milliseconds.

To make the price condition comparable to the number condition, the prices that participants had to compare were presented as regular three or four digit numbers, without any price or dollar marks. The only differences between the price condition and the number condition were in the instructions sheet, where they were told that they will compare prices rather than numbers, and in the picture that the participants saw before each comparison. In the price condition, the participants saw a picture of a supermarket's aisle instead of the abacus.

The second factor, *comparison difficulty*, was manipulated by asking participants to identify the smaller or the larger of the two numbers/prices. We believe this affects

[4] We use *e-prime* to implement the experiment and to collect the data.

comparison difficulty because empirical evidence suggests that in many pairs of semantic opposites, one adjective is *marked* and the other is *unmarked*.[5] It has been shown that people need more time and make more mistakes when they process marked than unmarked adjective. For example, problems containing marked adjectives such as *shorter*, *duller* or *worse* are harder to solve than equivalent problems containing unmarked adjectives such as *taller*, *brighter* and *better* (Lachman et al., 1979). It is therefore likely that participants who are asked to identify the smaller of two numbers/prices will find the task cognitively more demanding than participants that are asked to identify the larger of two numbers/prices because *large* is an unmarked adjective while *small* is a marked adjective.[6] We refer to the condition in which participants were asked to identify the larger number/price as the *find-large* condition and the condition in which participants were asked to identify the smaller number/price as the *find-small* condition. Since heuristic information processing is more prevalent for more difficult tasks (Kahneman and Frederick, 2002, Thomas and Morwitz, 2005; Chen, et al., 2008), we expect that participants will use 9-endings as a signal more often in the cognitively more difficult *find-small* price condition than in the *find-large* price condition.

The third factor, number of digits, was manipulated by asking participants to compare either three-digit or four-digit numbers/prices. We include this factor because a large proportion of consumption good prices are either 3-digit or 4-digit numbers (Levy et al., 1997 and 2011, Dutta et al. 1999, Bergen et al. 2008).

The within-subject factor was manipulated by presenting two numbers/prices in each comparison that were either the same or differed in exactly one digit.

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[5] According to Lachman, et al. (1979, p. 396), some words are more complex than others because they are *marked*. In general, negative word forms are considered marked while positive ones are unmarked. "These [marked] words are governed by more restrictions on their use, and are less salient semantically than unmarked terms. Bipolar adjectives illustrate the principle. The pair of words *good* and *bad* is bipolar, but they are not entirely symmetrical. *Good* can mean either very good or somewhat neutral; while *bad* must mean bad. Consider the questions, *"How good is your physics class*?" and "*How bad is your physics class*?" The latter question presumes the class is bad, while the former does not presume it is good. In this pair, the word bad is marked, while the word good is unmarked." Other examples include *above* (unmarked) and *below* (marked), *happy* (unmarked) and *unhappy* (marked), *honest* (unmarked) and *dishonest* (marked), *lion* (unmarked) and *lioness* (marked), etc.

[6] It seems that identifying the smaller of two numbers/prices was indeed more difficult than identifying the larger of two numbers/prices. Participants needed, on average, 1,027 ms to identify the larger of two numbers/prices and 1,067 ms to identify the smaller of two number/prices. The difference is statistically significant ($t = 11.6$, $p < 0.01$). Participants who were asked to identify the smaller numbers/prices also made significantly more mistakes than participants who were asked to identify the smaller numbers/prices. The participants in the find-small conditions made mistakes in 15.4% of the cases, whereas participants in the find-large conditions made mistakes in 7.4% of the cases ($z = 28.7$, $p < 0.01$).

In all conditions, participants were instructed to respond as quickly and accurately as possible. In addition, participants were told that 10 percent of them would be selected at random and paid according to their performance.[7] Only data from the four non-practice blocks were used for the analyses. A total of 55,346 observations were obtained. The average response time was 1.05 seconds and 89 percent of the responses were correct.

3.1.2. Results for the Entire Data Set

We use a probit model with random effects to control for correlations between responses given by the same participant. The dependent variable is a dummy which equals 1 for an accurate response and 0 otherwise.

To control for the effects of the between-subjects factors, we include three dummies. The *price-comparison* dummy equals 1 for the price condition and 0 for the number condition. The *find-small* dummy equals 1 for the find-small condition and 0 for the find-large condition. The *three-digit* dummy equals 1 for the three-digit condition and 0 for the four-digit condition. We also include the interactions between these dummies.

To test the hypothesis that 9-endings interfere with price comparisons, we include in the regression a *9-ending* dummy which equals 1 if the right-most digit of at least one of the two numbers/prices compared is 9, and 0 otherwise. We also include in the regression an interaction term between *9-ending* and *price-comparison*. We expect that 9-endings will not affect number comparisons and that consequently the coefficient of *9-ending* will be statistically insignificant. We expect, however, that 9-endings will have a negative effect on the likelihood that consumers make correct responses in the price condition. We, therefore, expect that the interaction between *9-ending* and *price-comparison* will be negative and significant.

To test whether participants process numerical/price information digit by digit, we include three dummies for the locations of the different digits. We also include interactions between the location dummies, the *price-comparison* dummy and the *find-*

[7] Participants could earn up to $10 if they needed less than one second to give correct responses to all comparisons. In each comparison, they lost 5¢ for every second beyond the first second and they lost 10¢ for every incorrect response. The one second threshold was based on a pre-test, which showed that on average one second was needed for a comparison. The average payment to participants selected was about $5.10.

small dummy.[8] The three location dummies are (i) *left-most* which equals 1 if the two numbers/prices differ in their left-most digit and 0 otherwise, (ii) *middle* which equals 1 if the two numbers/prices differ in their middle digits and 0 otherwise, and (iii) *right-most* which equals 1 if the two numbers/prices differ in their right-most digit and 0 otherwise.

We expect that in number comparisons, participants will compare prices digit by digit and, thus they will make fewer mistakes if the two numbers differ in their left-most digits than in their middle- or the right-most digits. In the *price-comparison* condition, however, we expect that participants will use 9-endings as a signal instead of comparing the prices digit by digit. We also expect that they will use the 9-ending signal more often in the cognitively more difficult *find-small* condition than in the less difficult *find-large* condition. We thus expect that in the find-small condition the likelihood of a correct response will depend more on the 9-ending signal and less on the location of the different digits. If this hypothesis is correct, then the overall effect of the location dummies in the find-small price condition will be insignificant.

Since zero is another common price-ending and may signal quality (Schindler and Kirby 1997, Stiving 2000), we include in the regression a *0-ending* dummy which equals 1 if the right-most digit of at least one of the two numbers/prices compared is zero and 0 otherwise. We also include an interaction term between *0-ending* and *price-comparison*, to check if *0-ending* affects number and price comparisons differently.

We also include a *gender* dummy which equals 1 if a participant is female and 0 otherwise, a *low-shopping-frequency* dummy which equals 1 if a consumer shops once a month or less and 0 otherwise, and the interaction of *low-shopping-frequency* and *price-comparison* to check if shopping frequency affects number and price comparisons differently. Since participants may be more likely to notice a big difference than a small difference, we also include *digit-difference* which equals the absolute value of the difference between the digits of the two numbers/prices (Monroe and Lee 1999; Tomas and Morwitz 2005).[9] The estimation results are reported in the first column of Table 1.

The coefficient estimates of the control variables suggest that in our data, there are no significant gender differences ($\beta = 0.14$, SE = 0.091, $p > 0.10$). As expected,

[8] All the interactions between the *location dummies* and *three-digit* dummies are statistically insignificant and adding them to the regression does not affect any of the other results.

[9] For example, if the numbers are 3.87 and 3.57, the difference between the digits is $|8-5| = 3$.

participants are more accurate if the difference between the digits is large (β = 0.03, SE = 0.005, $p < 0.01$). The coefficient of *low-shopping-frequency* is insignificant (β= –0.16, SE = 0.134, $p > 0.10$), but the interaction between *price-comparison* and *low-shopping-frequency* is negative and significant (β = –0.46, SE = 0.195, $p < 0.05$). It therefore seems that frequent shoppers are more accurate than infrequent shoppers in comparing prices, but shopping frequency does not affect the accuracy in comparing numbers. This suggests that participants use different cognitive processes for comparing prices and for comparing numbers and that the cognitive process frequent shoppers use for comparing prices is more efficient than that used by infrequent shoppers.

The coefficients of the location dummies and their interactions with *find-small* and *price-comparison* provide further evidence that participants use different cognitive processes for comparing prices versus numbers. We find that in both the *find-large* and *find-small* number conditions, the comparison accuracy is affected by the location of the different digits. Participants are most accurate if the numbers differ in their left-most digit, and least accurate if the numbers differ in their right-most digit.[10]

In the price condition, however, we find that participants' accuracy varies with the location of the different digit only in the *find-large* condition. In the *find-small* price condition, the differences are statistically insignificant.[11]

The results therefore suggest that in both the *find-large* and the *find-small* number conditions, participants compare numbers digit-by-digit. Consequently, they are most accurate when the numbers differ in their left most location and least accurate when the numbers differ in their right-most location. In the *price comparison* condition, however, participants seem to process the price information digit-by-digit only in the cognitively easier *find-large* condition. In the more difficult *find-small* condition, the participants appear to have used a different process, because the locations of the different digits had only a small effect on the likelihood of a mistake.

Further analyses suggest that the process that the participants used in the price

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[10] Find-large: $\chi^2(\beta_{RM} < \beta_{LM}) = 45.2,\ p \le 0.01.$ Find-small: $\chi^2(\sum_{c\in\mathbf{C}} \beta_{LM\times c} > \sum_{c\in\mathbf{C}} \beta_{M\times c} > \sum_{c\in\mathbf{C}} \beta_{RM\times c}) = 12.39,\ p < 0.01$, $\mathbf{C} = \{1,\ \textit{find-small}\}$, where M, RM, and LM denote middle, right-most, and left-most, respectively.

[11] Find-large: $\chi^2(\sum_{c\in\mathbf{C}} \beta_{LM\times c} > \sum_{c\in\mathbf{C}} \beta_{M\times c} > \sum_{c\in\mathbf{C}} \beta_{RM\times c}) = 45.16,\ p < 0.01$. Find-small: $\chi^2(\sum_{c\in\mathbf{C}} \beta_{LM\times c} > \sum_{c\in\mathbf{C}} \beta_{M\times c} > \sum_{c\in\mathbf{C}} \beta_{RM\times c}) = 0.83,\ p > 0.10$, where $\mathbf{C} = \{1, \textit{price-comparison}, \textit{find-small}, \textit{price-comparison} \times \textit{find-small}\}$, and M, RM, and LM denote middle, right-most, and left-most, respectively.

condition is related to the price-ending. Whereas the coefficient of *9-ending* is not significant ($\beta = -0.02$, SE = 0.03, $p > 0.10$), the coefficient of the interaction of *9-ending* and *price-comparison* is negative and marginally significant ($\beta = -0.07$, SE = 0.042, $p < 0.10$), suggesting that 9-endings are used by participants as a signal when they compare prices but not when they compare numbers. It seems that, consequently, they are more likely to make errors when they encounter 9-ending prices than when they encounter non 9-ending prices. In the next section we provide evidence that this is because participants use 9-endings as a signal for low prices.

3.1.3. Results When the Bigger Price Is 9-Ending

If 9-endings affect price comparisons because they signal low prices, then they should affect the likelihood of a correct response only when they appear in the greater price. We test this hypothesis by focusing on the price condition which we split into two subsamples. In the first subsample, we include all the trials in which the two prices compared are equal. In the second subsample, we include all the trials in which the two prices compared differ. We estimate a separate model for each subsample. We expect that 9-endings should not affect the comparison accuracy in the first subsample because both prices are 9-ending and, therefore, the signaling value of the price-ending should be of no use to consumers. For the second subsample, we expect that 9-endings will have a negative effect on the comparison accuracy when the bigger price ends with 9 but not when the smaller price ends with 9. In the subsample of unequal prices, therefore, we include in the regression a *bigger-9-ending* dummy which equals 1 if the bigger price ends with 9 and 0 otherwise. If participants use 9-ending as a signal for low prices, then the coefficient of *bigger-9-ending* should be negative and significant. In addition to the 9-ending dummies, we include in the regressions all the controls as in the previous subsection. We do not include, however, the location variables and their interactions because they cause multicolinearity in the subsample of equal prices. The estimation results are reported in the middle and right columns of Table 1.

In both subsamples, the coefficients of *9-ending* are insignificant, suggesting that when prices are equal or when the smaller prices end with 9, 9-endings do not affect the comparison accuracy (in the equal price subsample: $\beta = -0.09$, SE = 0.078, $p > 0.10$; in the unequal price subsample: $\beta = 0.14$, SE = 0.090, $p > 0.10$). In the subsample of unequal prices, however, the coefficient of *bigger-9-ending* is negative and significant ($\beta = -0.26$, SE = 0.087, $p < 0.01$). It therefore seems that when the bigger of the two prices ends with 9, participants frequently identify it mistakenly as being the smaller one.

3.2. Evidence from a Field Study

In the previous section, we show that 9-endings interfere with price information processing in a lab setting. It is likely that 9-endings will interfere with price information processing to an even greater extent in a real supermarket setting because in a supermarket setting the cognitive load is usually greater than in the lab. In this section we present evidence suggesting that this is indeed the case. In Section 3.2.1 we show that, consistent with the hypothesis that 9-endings are a signal for low prices, consumers associate 9-endings with price cuts. In Sections 3.2.2 and 3.3.3 we provide evidence that 9-endings reduce the likelihood that consumers will correctly notice price increases. Finally, in Section 3.3.4 we show that consumers are less likely to notice an increase from a non 9-ending price to a 9-ending price but are more likely to notice an increase from a 9-ending to non 9-ending price.

The field study was conducted in Israel. Respondents were 365 shoppers at three supermarkets located in different cities and serving consumers from different socio-economic backgrounds. Consumers exiting the supermarkets were approached by interviewers, and only those who shopped in the same supermarket in the previous week were given a questionnaire composed of a list of 52 goods in 12 categories.[12] Goods were defined by their brand name and package size. For each good, the interviewers asked the respondents whether or not they purchased it on both their current and previous shopping trips. If the answer was yes, then the respondents were asked to indicate whether the good's price had increased, decreased or remained the same from the previous week to the current week. If the answer was no, the interviewers quickly continued to the next good. Respondents were given a large chocolate bar at the end of the interview as a token for their participation.

[12] The categories are: dairy products, fresh fruits and vegetables, basic goods (such as salt, sugar and cooking oil), soft drinks, cooking and baking products, canned food, coffee and tea, frozen food, sweets and crackers, meat, and laundry detergent.

The average age of the respondents were 40, they spent NIS 175 per shopping trip on average, and visited the supermarket once a week.[13] About 56 percent of the respondents were women, and 23 percent observe religious practices. The average respondent needed about 10 minutes to complete the questionnaire and gave an average of 12.1 responses with 65.3 percent of those responses being correct.

3.2.1. Recall of Price Changes

The results from our lab experiment suggest that participants use 9-endings as a signal for low prices. We therefore hypothesize that, *ceteris paribus*, 9-endings will increase the likelihood that a consumer will respond that a price had decreased rather than increased or remained unchanged. To test this hypothesis, we estimate a multi-probit regression of the probability that a consumer replied that a price had increased, decreased or remained unchanged. The dependent variable is an index variable which equals –1 if the consumer replied that a price had decreased, 0 if the consumer replied that the price had remained unchanged and 1 if the consumer replied that the price had increased.

If consumers use 9-endings as a signal for low prices, then they should be more likely to recall a 9-ending price as a low price relative to a similar price that is not 9-ending. Consumers should therefore be more likely to respond that a price had decreased rather than increased or remained unchanged when the price is 9-ending than when the price is similar but not 9-ending. We therefore hypothesize that, *ceteris paribus*, the *9-ending* dummy, which equals 1 if the price ends with 9 and zero otherwise, will have a positive effect on the probability of recalling a price decrease.

As controls, we include the same location dummies as defined in section 3.1.1, *gender* which equals 1 if a consumer is female and 0 otherwise, *religious* which equals 1 if a consumer is ultra-religious and 0 otherwise, *academic-degree* which equals 1 if a consumer has an academic degree and 0 otherwise, *frequent-shopper* which equals 1 if a consumer shops more than once a week and 0 otherwise, *large-expenditure* which equals 1 if a consumer spends on average more than NIS 300 per shopping trip and 0 otherwise, *age* which equals 1 if a consumer is 55-years-old or older and 0 otherwise, the *previous*

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[13] The exchange rate during the sample period was about NIS 4.40 per US$1. Source: www.boi.gov.il/deptdata/mth/average/averg05h.htm.

week price, *price-difference* which equals the absolute value of the difference between the prices in the current and previous weeks, *price-increase* which equals 1 if the price has increased and 0 otherwise, *price-decrease* which equals 1 if the price has decreased and 0 otherwise, and *0-ending* which equals 1 if the price ends in zero and 0 otherwise.[14]

The estimation results are reported in Table 2. The first column summarizes the effect of each variable on the probability that a consumer replied that a price had decreased relative to the probability that the price had remained unchanged. The second column summarizes the probability that a consumer replied that a price had increased relative to the probability that he replied that the price had remained unchanged.

The effect of 9-ending on the likelihood that a consumer replied that the price had increased suggest that there is no significant difference between the likelihood that consumers will respond that a 9-ending price had increased and the likelihood they will respond that the price is unchanged (β = 0.05, SE = 0.070, $p > 0.10$). At the same time, the effect of *9-ending* on the likelihood that a consumer replied that a price had decreased is positive and significant (β = 0.25, SE = 0.075, $p < 0.01$).[15] Thus, in supermarkets as in the lab, it seems that 9-endings affect price comparisons because the consumers associate 9-endings with low prices.

3.2.2. Recall Accuracy in the Entire Data Set

The results of the previous section suggest that consumers associate 9-endings with price cuts. We therefore hypothesize that consumers will be less accurate in noticing price increases when the new prices are 9-ending than when they are not 9-ending.

To test this hypothesis, we estimate a probit regression of the likelihood that a consumer correctly notices a price change. The dependent variable is a dummy variable which equals 1 if a consumer correctly recalled whether a price has increased, decreased

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[14] We include a dummy for ultra-religious consumers because they tend to have low incomes and large families, and therefore they tend to face tighter budget constraints than other consumers. We include a dummy for 55-years old or older consumers because empirical evidence suggests that consumers belonging to this age group are often less accurate in recalling prices than other consumers (Macé, 2012).Our findings are consistent with these observations.

[15] Interestingly, we find that independent of 9-endings, when the prices had actually decreased, the consumers are not only more likely to respond that the prices had decreased but they are also more likely to respond that the prices had increased relative to the probability that they will say that the prices remain unchanged, Thus, it seems that when prices decrease the consumers sometime remember that there was a price change but they do not always remember whether the change was an increase or a decrease.

or remained unchanged, and 0 otherwise.[16]

The key independent variable is the *9-ending* dummy which we expect to have a negative coefficient. The controls are the same as in section 3.2.1.

The estimation results are reported in the first column of Table 3. The coefficients of the controls for the location of the different digits suggest that, consistent with the lab results and with previous studies, consumers are more likely to notice a price change if the left most digit changes than if the middle digit changes ($\beta = 0.37$, SE = 0.094, $p < 0.01$). The coefficient of the right most digit suggests, however, that in a supermarket environment many consumers do not process prices from left to right, digit by digit. Rather, it seems that the right most digits are more important than the middle digits in assisting the consumers in noticing price changes because the coefficient of the right most digit is positive ($\beta = 0.39$, SE = 0.067, $p < 0.01$) but that of the middle digit is negative ($\beta = -0.70$, SE = 0.083, $p < 0.01$). Thus, the results suggest that consumers tend to use both the right most and the left most digits in processing price change information and pay less attention to the middle digits. However, the effect of the right most digit becomes less positive when the right most digit is a 9 ($\beta = -0.25$, SE = 0.048, $p \leq 0.01$), suggesting that unlike other endings, 9-ending reduce the likelihood that the consumers will correctly notice a price change. Next we test if this is because the consumers associate 9-endings with low prices.

3.2.3. Recall Accuracy for Price Increases vs. Price Decreases

To assess the effect of 9-endings on the likelihood of noticing price increases and price decreases, we split the sample into two. The first subsample includes all the observations on price decreases. The second subsample includes all the observations on price increases and on prices that remained unchanged.[17] For each subsample, we estimate a random-effect probit model of the likelihood that consumers correctly notice price changes. The dependent variable in the first subsample is a dummy which equals 1

[16] For example, if the price of Coca-Cola increases from NIS 5.49 to NIS 5.99, the dependent variable equals 1 if a consumer replied that the price has increased and 0 if a consumer replied that the price has either decreased or has remained unchanged.

[17] The findings remain the same if we split the data into three subsamples: price increases, price decreases, and prices that remain unchanged. We find, however, that the effect of 9-endings for price increases and for unchanged prices are similar, and, therefore, we pool the observations on price increases and unchanged prices together to strengthen the statistical power of our tests.

if a consumer correctly noticed a price decrease and 0 otherwise. The dependent variable in the second regression is a dummy which equals 1 if a consumer correctly noticed that a price has increased or that a price has remained unchanged and 0 otherwise. In both regressions we include the same set of controls as in the previous two sections. The estimation results are summarized in the second and fourth columns of Table 3.

We find that the coefficient of *9-ending* is negative and significant in the regression on increased and unchanged prices ($\beta = -0.28$, S.E. = 0.051, $p < 0.01$), but is insignificant in the regression on decreased price ($\beta = -0.17$, S.E. = 0.225, $p > 0.10$). Thus, the negative effect 9-endings have on the likelihood of correctly noticing a price change seems to be due to 9-endings reducing the likelihood of noticing price increases and prices that are unchanged. At the same time, 9-endings do not have a significant effect on the likelihood that consumers will notice a price decrease.[18] A possible explanation of these results is that a price that is 9-ending after a price decrease may also be 9-ending before the decrease. Therefore, both the new and the old prices are recalled as low. Alternatively, it might be that the retailers use other signals, such as shelf tags and leaflets to promote price decreases, and that next to these more conspicuous signals, 9-endings have only a small incremental effect on the likelihood of noticing a price decrease (Nevo, 2002, Macé, 2012).

To tease apart these two possibilities and to learn more about the effects of 9-endings on the likelihood of noticing price increases, we next study the differences in the effects of price changes from 9-endings and to 9-endings on the probabilities of noticing price increases and price decreases.

3.2.4. Recall Accuracy "From" and "To" 9-Ending Prices

We estimate separate probit regressions for price increases and price decreases. The dependent variables in the regressions are therefore the same as above. However, whereas in the previous section we used one 9-ending dummy, here we split it into three dummies: (i) *from-9-to-9* which equals 1 if a 9-ending price changed to another 9-ending price and 0 otherwise, (ii) *from-9-to-other* which equals 1 if a price changed from a 9-ending price

[18] These results are consistent with the findings in the lab experiment that 9-ending decreases the probability of identifying a bigger price but does not help in identifying a smaller price.

to a non 9-ending price, and 0 otherwise and (iii) *from-other-to-9* which equals 1 if a price changed from a non 9-ending price to a 9-ending price, and 0 otherwise.

We found above that 9-endings may interfere with the process of noticing price increases. If this is because consumers interpret 9-endings as low prices then in the regression of prices that increase or remain unchanged, the dummy variable *from-9-to-other* will have a positive coefficient while the dummy variable *from-other-to-9* will have a negative coefficient. That is because if consumers use 9-endings as a signal for low prices then they are likely to recall 9-ending prices as low and non 9-ending prices as high. Thus, they are more likely to notice a price increase if the price changes from a 9-ending which is perceived as low to a non 9-ending which is perceived as high, and less likely to notice a price increase when the price changes from non 9-ending to 9-ending.

At the same time, the results reported in the previous section suggest that 9-endings are less important for identifying prices decreases. If this is because consumers are less likely to notice price decreases when prices decrease from 9-endings to another 9-ending prices, then the coefficient of *from-9-to-9* should be negative in the regression of price decreases. If, on the other hand, the insignificant effect of 9-endings on price decreases is due to the retailers' use of other signals (e.g., shelf signs) to promote price cuts, then the coefficients of all three 9-ending dummies should be insignificant in the regression of price decreases. The estimation results for price decreases are reported in the third column of Table 3 and the results for price increases are reported in the fifth column.

We find that for price increases and unchanged prices, when a non 9-ending price changes to a 9-ending price, consumers are less likely to identify a price increase ($\beta = -0.51$, S.E. = 0.260, $p < 0.05$). Consumers are more likely to identify a price increase, however, when a 9-ending price changes to a non 9-ending price ($\beta = 0.47$, S.E. = 0.251, $p < 0.10$). When both the old and the new price end with 9, there is no statistically significant effect on the likelihood that consumers will notice the price increase ($\beta = -0.21$, S.E. = 0.172, $p > 0.10$). Together with the lab findings on the use of 9-endings as a signal for low prices, these results suggest that the negative effect that 9-endings have on consumers' ability to notice price increases is because they are more likely to perceive changes from 9-ending to non 9-ending prices as price increases and less likely to perceive changes from non 9-ending prices to 9-ending prices as price increases.

For price decreases, however, we find that none of the three 9-ending dummies are statistically significant ($\beta_{other\text{-}to\text{-}9}$ = –0.19, S.E. = 0.327, $p > 0.10$; $\beta_{9\text{-}to\text{-}9}$ = –0.37, S.E. = 0.285, $p > 0.10$; $\beta_{9\text{-}to\text{-}other}$ = –0.39, S.E. = 0.396, $p > 0.10$). This suggests that the weak effect of 9-endings on the likelihood of noticing a price decrease is because retailers often use other signals to promote price decreases. It seems that the use of alternative signals enables the consumers to notice price decreases whether or not the prices ends with 9. It therefore seems that although 9-endings might be a valid signal in many cases for low prices, it is not necessarily a signal for price decreases. We test this hypothesis directly in the next section with data from a large US supermarket chain. In addition, we test some implications of the consumer perceptions that we documented for an asymmetry in the rigidity of 9-ending prices.

3.3. Evidence from a Large US Supermarket Chain

Our findings suggest that consumers are more likely to notice price increases from 9-ending to non 9-ending prices but less likely to notice price increases from non 9-ending to 9-ending prices. If retailers act strategically, then following price increases they should be more likely to set the new prices to 9-ending, especially if the pre-increase prices were 9-ending.

The findings also suggest that although consumers tend to perceive 9-endings as a signal for low prices, 9-endings do not assist the consumers in noticing price cuts. It is thus less likely that the retailers will set post-decrease prices to 9-ending in comparison to post-increase prices, especially when the reduced prices are promoted (Nevo, 2002).

These results suggest that for price increases, 9-endings are likely to be more rigid than other endings because 9-endings will usually increase only to new 9-endings whereas other price endings will not be restricted to increase to any specific ending. For price decreases, on the other hand, 9-endings are likely to be as flexible as other endings. We test these hypotheses in sections 3.3.1 – 3.3.3. In section 3.3.4 we further test whether the rigidity of *9-endings* leads to rigidity of *9-ending prices*. It may be expected that if 9-endings usually increase only to new 9-endings but are unrestricted when they decrease, 9-ending prices will be more rigid than other prices upwards but not downwards.

We use scanner price data from Dominick's Finer Food, a large Midwestern US supermarket chain, operating about 130 stores in the Chicago Metro area. Dominick's price data contain 98,691,750 weekly price observations for an 8-year period (i.e., 1989−1997) for 18,037 different products (SKU's) in 29 categories.[19] These are actual transaction prices that consumers have paid each week, as recorded by the chain's scanners at the checkout cash registers. Because there are many missing observations and many discontinuities in the data, we had to exclude the end-points of all the incomplete segments along with the end points of the individual time series. This left us with 81,085,330 weekly price observations. The average price in the data is $2.63.

Consistent with the figures reported by Levy, et al. (2011), we find that 62 percent of the prices in our data end with 9. A total of 21,211,525 prices changed during the sample period, with the average price change of 45¢. About 52 percent of the price changes are price increases and 48 percent are price decreases. Thus, out of the 81,085,330 million observations, 13.9 percent are price increases and 12.4 percent are price decreases. According to the Dominick's sales dummy, about 91 percent of the price decreases are sale prices (11.5 percent of the prices are sale prices).

3.3.1. Transition Probability Analysis

We begin our analysis by summarizing the number of price increases and decreases for each possible digit and then presenting the data in transition probability matrices.

Table 4 summarizes information on the 11,127,908 price increases in the data by breaking down all the observations on weekly price increases that occur in the Dominick's data by all possible transition paths for the last digit. Table 5 reports similar data for the 10,083,617 price decreases. A comparison between Tables 4 and 5 provides some preliminary evidence that prices are more likely to be 9-endings after price increases than after price decreases. According to Table 4, there are 666,431 more price increases from non 9-ending to 9-ending than from 9-ending to non 9-ending. For price

[19] The product categories include analgesics, bath soaps, beers, bottled juices, cereals, cheese, cigarettes, cookies, crackers, canned soups, dish detergents, front end entrees, frozen dinners, frozen entrees, frozen juices, fabric softeners, grooming products, laundry detergents, oat meals, paper towels refrigerated juices, soft drinks, shampoos, snack crackers, soaps, toothbrushes, canned tuna and salmon, toothpaste and toilet papers. Excluding the highly regulated categories of cigarettes and beers (Levy, et al. 2011, footnote 2) from the analysis does not affect the results we report below. For more details about Dominick's data, see for example, Barsky, et al. (2003), Chevalier, et al. (2003), and Chen, et al. (2008). Dominick's data can be downloaded from the University of Chicago Business School's web site: http://research.chicagobooth.edu/marketing/databases/dominicks/index.aspx.

decreases, on the other hand, Table 5 suggests that there are 682,002 fewer price decreases from non 9-ending to 9-ending than from 9-ending to non 9-ending. Thus, it seems that following price increases the share of 9-ending prices increases, but following price decreases their share drops.

More evidence that 9-endings are more rigid upward than downward comes from Tables 6 and 7, which present the transition probabilities for price increases and decreases. In these tables, each row gives the probabilities that a price starting with a given ending digit (column) will, after a change, end with any of the ten possible digits. For example, the figure 0.051 in the top left cell of Table 6 tells that the probability that a price ending with 1 will remain 1-ending after a price increase is 5.1 percent.

The figures in the diagonal cells of each table give the probability that a new price will have the same ending as the old price. Comparing these figures suggest that 9-endings are more rigid than other digits, because the probability that a 9-ending will remain a 9-ending is considerably greater than the probability that any other ending will remain unchanged. In addition, considering each row in these tables, when prices change the new prices end with 9 more often than with any other digit.

Comparing the last two columns of Tables 6 and 7, however, we find that a larger proportion of the prices end with 9 after price increases than after price decreases. In addition, there is a higher probability for a 9-ending price to remain 9-ending after an increase than after a decrease (61.19% vs. 58.38%).

Thus, overall, the results of the transition probability analysis are consistent with the hypothesis that 9 is used more frequently as the last digit after a price increase than after a price decrease.

3.3.2. 9-Endings in Price Increases vs. Decreases

Next, we study the upward and downward rigidity of 9-endings by estimating a probit model of the probability that a new price after a change ends with 9. The dependent variable is a dummy which equals 1 if the new price ends with 9 and 0 otherwise. The regression includes a dummy for *price decrease*, which equals 1 in case of a price cut and 0 otherwise, *sale price* which equals 1 if the new price is a sale price and 0 otherwise, and *previous 9-ending* which equals 1 if the previous price is 9-ending and 0 otherwise.[20] We also include the price before the change, the size of the price change and category fixed effects. The estimation results are reported in Table 8.

The coefficient of the dummy for *previous 9-ending* is positive and significant (β = 0.08, SE < 0.01, $p < 0.01$), supporting the hypothesis that 9-endings are more rigid than other endings. For example, the probability that a good priced at $2.39 will increase to another 9-ending price after an increase of about 4% is 88%. In addition, non 9-ending prices also tend to become 9-ending after price increases. For example, we find that the probability that a good priced at $2.38 will increase after a change of about 4% to a 9-ending price is 86%. Thus, the probability that an 8-ending price will remain 8-ending or that it will increase to any other digit but 9 is smaller than 14%.

However, the dummy for *price decrease* is negative and significant (β = –0.14, SE = 0.00, $p < 0.01$), suggesting that 9-endings are less rigid downward than upward. Moreover, the likelihood that the price will end with 9 is lower for a sale price cut than for a regular price cut (β = –0.45, SE < 0.001, $p < 0.01$), suggesting that retailers are even less likely to use 9-endings when price decreases are promoted.[21]

3.3.3. Likelihood of Changes in the Right-Most Digit

As a robustness check, we estimate a SURE regression of the likelihood that the right-most digits will be adjusted after a price change. We use the SURE framework to simultaneously estimate one equation for the probability that the right-most digit will adjust, the second for the probability that the middle digit will adjust and the third for the probability that the left-most digit will adjust. The dependent variable in the first equation is a dummy variable which equals 1 if the right-most digit adjusts and 0 otherwise. The dependent variable in the second equation is a dummy variable which equals 1 if a middle digit adjusts and 0 otherwise. The dependent variable in the third equation is a dummy variable which equals 1 if the left-most digit adjusts and 0 otherwise.

To facilitate a comparison with the results of the previous sections, we use the same

[20] We use the *sales* dummy variable included in the Dominick's dataset to identify sale prices. This is an imperfect measure because some of the sales are not recorded (Peltzman, 2000). This is likely to reduce the estimated effect of sales on the likelihood that prices end with 9 because it makes the subsample of sale prices more similar to the rest of the sample. The measured effect, therefore, is likely to be smaller than the actual effect.
[21] Sale prices are also considered price cuts. The coefficient of the *sale-prices* dummy should therefore be interpreted as the effect of sales that is beyond the effect of a regular price cut.

independent variables. To test the hypothesis that the right-most digit is less likely to change when the old price was 9-ending than when it was not 9-ending, we include in the regression the *previous 9-ending* dummy. To test the hypothesis that 9-endings are more likely to change after a price decrease than after a price increase, we include in the regressions an interaction term between *previous price-ending* and *price decrease*.

As controls we include dummies for *price decrease*, *previous price*, *size of price change*, interaction of *price decrease* and *size of price change* and fixed effects for the 29 categories. Studies suggest that there are fewer price decreases than increases that involve a change in the right-most digits because there are usually more frequent small (up to about 10 cents) price increases than decreases (Peltzman, 2000, Ray, et al. 2006, Chen et al., 2008, Midrigan, 2011). We therefore expect that the sign of the coefficient of *price decrease* in the regression for the right-most digit will be negative but the coefficient of the interaction of the *size of price changes* and *price decrease* will be positive. The estimation results are reported in Table 9.

The coefficient of the *previous 9-ending* dummy is negative and significant (β = −0.50, SE = 0.0002, $p \leq 0.01$) whereas its interaction with *price-decreases* is positive and significant (β = 0.05, SE = 0.0003, $p \leq 0.01$). Thus, we again find that 9-endings are more rigid upward but less so downward than other price endings.

3.3.4. Rigidity of 9-Ending Prices

Levy et al. (2011) and Knotek (2011) report that 9-ending prices are more rigid than other prices. If one of the causes of this is the rigidity of 9-endings, then our results suggest that 9-ending prices should be more rigid upward than other prices but not more rigid downward than other prices. We pose this hypothesis because if increasing 9-ending prices to non 9-ending prices is likely to be noticed, then 9-ending prices themselves (vs. the price-ending) should be less likely to change upward—they will increase only when the shock that causes the price change is large enough to make it optimal to set a new 9-ending price. Downward, however, there should be smaller difference between 9-ending and non 9-ending prices, because 9-endings do not have a significant effect on consumers noticing price decreases.

We test this hypothesis by estimating a multi-logistic regression of the probability that a price will increase, decrease or remain unchanged. The dependent variable in the regression is an index variable which equals −1 if the price has decreased, 0 if the price has remained unchanged, and 1 if the price has increased. Similar to Levy et al. (2011), we use the *previous 9-ending* dummy to control for the effects of 9-endings on the price rigidity. We expect that the effect of this dummy will be negative on the likelihood of price increase but less so on the likelihood of price decrease.

We also include the *change in the wholesale* price, *sale price* which equals 1 if the price in the previous week was a sale price and 0 otherwise, and fixed effects for the 29 categories.[22] We include the change in the wholesale price because prices are more likely to change when the wholesale price changes. We include the sale price because sale prices are temporary prices and, consequently, sale prices are more likely to change than regular prices.[23] The estimation results are reported in Table 10.

We find that while the coefficient capturing the effect of 9-ending on price increases is negative and significant ($\beta = -0.36$, SE = 0.001, $p < 0.01$), the coefficient capturing the effect of *9-ending* on price decreases is positive and significant ($\beta = 0.19$, SE = 0.001, $p < 0.01$). Thus, it seems that while 9-endings are significantly less likely to increase than other prices, they are slightly more likely to decrease than other prices. The effect of 9-endings on the upward rigidity is, however, stronger than the corresponding effect on the downward rigidity (Wald-$F = 15.0$, $p < 0.01$) and, therefore, when we consider all types of changes we find that 9-ending prices are significantly more rigid than other prices, confirming the findings of Levy, et al. (2011).

D. CONCLUSION

In this paper, we suggest that consumers' cognitive constraints are a possible explanation for the rigidity of 9-ending prices. Using data from a lab experiment we show that consumers use 9-endings as a signal for low prices and that this signal sometimes interferes with price comparisons. Consequently, 9-endings increase the likelihood that

[22] Estimating the model without the highly regulated beer and cigarettes categories yield results similar to what we report here.

[23] As a robustness check, we estimated versions of the model with and without the fixed effects, and including in the regression the lagged wholesale price, the average price of each good in each store, and the average retailer's markup on each good. We also replaced the sale price dummy with a dummy which equals 1 if the good was on any type of promotion in the previous week, and 0 otherwise. The main conclusions remain unchanged in all these specifications.

consumers will mistakenly interpret a higher price as being lower, especially when the consumers face a high cognitive load.

Evidence from a field study confirms the results of the lab experiment and suggests that consumers are less accurate in recalling increases from non 9-ending to 9-ending prices but are more accurate in recalling increases from 9-ending to non 9-ending prices. The results of the field study also suggest that although 9-endings seem to be used as a signal for low prices, they do not have a significant effect on the likelihood that the consumers will notice a price cut, perhaps because price cuts are often promoted by other signals such as leaflets, colorful shelf signs and large price tags.

These results therefore suggest that by strategically keeping 9-ending prices after price increases the retailers can reduce the likelihood that consumers will notice a price increase. In other words, 9-endings should be more rigid upward than other endings. On the other hand, since 9-endings do not significantly affect the recall of price decreases, 9-endings should not be more rigid downward than other endings. Using data from a large Midwestern US supermarket chain, we indeed obtain evidence that 9-endings are more rigid than other endings for price increases but not for price decreases. Finally, we find evidence suggesting that the asymmetric rigidity of 9-endings leads to a similar asymmetry in the rigidity of 9-ending prices: 9-ending prices are more rigid upward than other prices but not downward.

Our findings therefore suggest that the 9-ending pricing might be an equilibrium. In this equilibrium consumers use 9-endings as a signal for low prices and the retailers respond by setting and keeping 9-endings after price increases. Retailers gain because this strategy enables them to disguise price increases, while consumers gain from minimizing the cognitive costs of paying attention to the penny digit (Basu, 1996, 2005).

Our results suggest that it is important to understand the role of 9-endings as a signal, because it likely has implications for market structure, demand and inflation. The results also suggest that technologies that reduce menu costs (e.g., electronic shelf labels) may not necessarily affect the rigidity of 9-ending prices, whereas technologies that influence consumer cognition (e.g., search engines), may. Further research on the sources and the extent of consumers' price cognition is needed for a better understanding of market and macroeconomic outcomes of price points and the ensuring price rigidity.

REFERENCES

Anderson, E and D Semester (2003), "Effects of $9 Price-Endings on Sales: Evidence from Field Experiments," ***Quantitative Marketing and Economics*** 1(1), 93–110.

Ball, L. and D. Romer (2003), "Inflation and the Informativeness of Prices," ***Journal of Money, Credit and Banking*** 35(2), 177–196.

Barsky, R., et al. (2003), "What Can the Price Gap between Branded and Private Label Products Tell Us about Markups?" In R. Feenstra and M. Shapiro, Eds., *Scanner Data and Price Indexes* (Chicago, IL: University of Chicago Press), pp. 165–225.

Basu, K. (1997), "Why Are So Many Goods Priced to End Nine? And Why This Practice Hurts Producers," ***Economics Letters*** 54(1), 41–44.

Basu, K. (2006), "Consumer Cognition and Pricing in the Nines in Oligopolistic Markets," ***Journal of Economics and Management Strategy*** 15(1), 125–141.

Benford, F. (1938), "The Law of Anomalous Numbers," ***Proceedings of the American Philosophy Society*** 78, 551–572.

Bergen, M., et al. (2008), "On the Inefficiency of Item Pricing Laws: Theory and Evidence," ***Journal of Law and Economics*** 51(2), 209–250.

Bergen, M., R. Kauffman and D. Lee (2005), "Price Points and Price Rigidity on the Internet: A Massive Quasi-Experimental Data Mining Approach," manuscript.

Bils, M. and P. Klenow (2004), "Some Evidence on the Importance of Sticky Prices," ***Journal of Political Economy*** 112(5), 947–985.

Blinder, A., et al. (1998), *Asking about Prices* (NY, NY: Russell Sage Foundation).

Carlton, D. (1986), "The Rigidity of Prices," ***American Economic Review*** 76, 637–658.

Chen, H., et al. (2008), "Asymmetric Price Adjustment in the Small," ***Journal of Monetary Economics*** 55(4), 728–737.

Cecchetti, S. (1986), "The Frequency of Price Adjustment: A Study of the Newsstand Prices of Magazines," ***Journal of Econometrics*** 31(3), 255–274.

Chevalier, J., et al. (2003), "Why Don't Prices Rise during Peak Demand Periods? Evidence from Scanner Data," ***American Economic Review*** 93, 15–37.

Danziger, L. (1999), "A Dynamic Economy with Costly Price Adjustments," ***American Economic Review*** 89(4), 878–901.

Dehaene, S. and Mehler, J. (1992), "Cross-Linguistic Regularities in the Frequency of Number Words," ***Cognition*** 43, 1–29.

Dutta, S., et al. (1999), "Menu Costs, Posted Prices, and Multiproduct Retailers," ***Journal of Money, Credit and Banking*** 31(4), 683–703.

Dutta, S., et al. (2002), "Price Flexibility in Channels of Distribution: Evidence from Scanner Data," ***Journal of Economic Dynamics and Control*** 26(11), 1845–1900.

Eichenbaum, M., N. Jaimovich, and S. Rebelo (2011), "Reference Prices, Costs and Nominal Rigidities," ***American Economic Review*** 101, 234–262.

Hill, T. P. (1995), "A Statistical Derivation of the Significant-Digit Law," ***Statistical Science*** 10(4), 354–363.

Kahneman, D. and S. Frederick (2002), "Representativeness Revisited: Attribute Substitution in Intuitive Judgment," in Gilovich, T. et al. (Eds.), *Heuristics and Biases* (UK: Cambridge University Press), pp. 49–81.

Kashyap, A. (1995), "Sticky Prices: New Evidence from Retail Catalogs," ***Quarterly Journal of Economics*** 110(1), 245–274.

Kalayanaram, G. and R. Winer (1995), "Empirical Generalization from Reference Price Research," ***Marketing Science*** 14(3), G161–G169.

Kehoe, P. and V. Midrigan (2008), "Temporary Price Changes and the Real Effects of Monetary Policy," NBER WP No. 14392.

Kehoe, P. and V. Midrigan (2010), "Prices Are Sticky After All," RSR 413, Fed of Mpls.

Klenow, P. and O. Kryvtsov (2008), "State-Dependent vs. Time-Dependent Pricing: Does it Matter for Recent US Inflation?" ***Quarterly Journal of Economics*** 123, 863–904.

Klenow, P. and B. Malin (2011), "Microeconomic Evidence on Price-Setting," in B. Friedman and M. Woodford (Eds.), *Handbook of Monetary Economics*, 3A-B (NY, NY: North Holland), pp. 231–284.

Knotek, E. (2010), "The Roles of Menu Costs and Nine Endings in Price Rigidity," Research Working Paper No. 10-18, Federal Reserve Bank of Kansas City.

Knotek, E. (2011), "Convenient Prices and Price Rigidity: Cross-Section Evidence," ***Review of Economics and Statistics*** 93(3), 1076–1086.

Konieczny, J. (1993), "Variable Price Adjustment Costs," ***Economic Inquiry*** 31, 488–98.

Lach, S. and D. Tsiddon (1992), "The Behavior of Prices and Inflation: An Empirical Evidence of Disaggregate Price Data," ***Journal of Political Economy*** 100, 349–89.

Lach, S. and D. Tsiddon (1996), "Staggering and Synchronization in Price Setting: Evidence from Multiproduct Firms," ***American Economic Review*** 86, 1175–1196.

Lachman, R., et al. (1979), *Cognitive Psychology and Information Processing: An Introduction* (Hillsdale, NJ: Lawrence Erblaum Associates).

Levy, D., et al. (1997), "The Magnitude of Menu Costs: Direct Evidence from Large U.S. Supermarket Chains," ***Quarterly Journal of Economics*** 112, 791–825.

Levy, D., et al. (2002), "Heterogeneity in Price Rigidity: Evidence from Primary Micro Level Data," ***Journal of Money, Credit, and Banking*** 34, 197–220.

Levy, D., et al. (2010), "Holiday Price Rigidity and Cost of Price Adjustment," ***Economica*** 77, 172–198.

Levy, D., et al. (2011), "Price Points and Price Rigidity," ***Review of Economics and Statistics*** 93(4), 1417–1431.

Levy, D. and A. Young (2004), "The Real Thing: Nominal Price Rigidity of the Nickel Coke, 1886–1959," ***Journal of Money, Credit and Banking*** 36, 765–799.

Macé, S. (2012), "The Impact and Determinants of Nine-Ending Pricing in Grocery Retailing," ***Journal of Retailing*** 88(1), 115–130.

Mankiw, N.G. (1985), "Small Menu Costs and Large Business Cycles: a Macroeconomic Model of Monopoly," ***Quarterly Journal of Economics*** 100, 529–539.

Mazumdar, T. and P. Papatla (2000), "An Investigation of Reference Price Segments," ***Journal of Marketing Research*** 38, 246–258.

Midrigan, V. (2011), "Menu Costs, Multi-Product Firms, and Aggregate Fluctuations," ***Econometrica*** 79, 1139–1180.

Monroe, K. and A. Lee (1999), "Remembering vs. Knowing: Issues in Buyers' Processing of Price Info," ***Journal of Academy of Marketing Science*** 27(2), 207–225.

Nakamura, E. and J. Steinsson (2008), "Five Facts about Prices: A Reevaluation of Menu Cost Models," ***Quarterly Journal of Economics*** 123(4), 1415–1464.

Nakamura, E. and J. Steinsson (2011), "Price Setting in Forward-Looking Customer Markets," ***Journal of Monetary Economics*** 58(3), 220–233.

Nevo, A. (2002), "Measuring Market Power in the Ready to Eat Cereal Industry," ***Econometrica*** 69, 307–342.

Newcomb, S. (1881), "Note on the Frequency of the Use of Digits in Natural Numbers," ***American Journal of Mathematics*** 4, 39–40.

Nigrini, M. (2002), *Using Microsoft Access for Data Analysis and Interrogation*.

Peltzman, S. (2000), "Prices Rise Faster than They Fall," ***Journal of Political Economy*** 108, 466–502.

Poltrock, S. and D. Schwartz (1984), "Comparative Judgments of Multidigit Numbers," ***Journal of Experimental Psychology*** 10, 32–45.

Ray, S., et al. (2006), "Asymmetric Wholesale Pricing: Theory and Evidence," ***Marketing Science*** 25, 131–54.

Rotemberg J (1982) "Sticky Prices in the US" ***Journal of Political Econ*** 90 1187–1211.

Rotemberg, J. (1987), "The New Keynesian Microfoundations," ***NBER Annual***, 69–104.

Rotemberg, J. (2005), "Customer Anger at Price Increases, Changes in the Frequency of Price Adjustment, and Monetary Policy" ***Journal of Monetary Economics***, 829–52.

Rotemberg, J. (2010), "Altruistic Dynamic Pricing with Customer Regret," ***Scandinavian Journal of Economics*** 112(4), 646–672.

Ruffle, B. and Z. Shtudiner (2006), "99: Are Retailers Best Responding to Rational Consumers?" ***Managerial and Decision Economics*** 27, 459–75.

Schindler, R. (1984), "Consumers Recognition of Increases in Odd and Even Prices," ***Advances in Consumer Research*** 11, 459–462.

Schindler, R. (2001), "Relative Price Level of 99-Ending Prices: Image vs. Reality," ***Marketing Letters*** 12(3), 239–247.

Schindler, R. (2006), "The 99 Price-Ending as a Signal of a Low-Price Appeal," ***Journal of Retailing*** 82(1), 71–77.

Schindler, R. and R. Chandrashekaran (2004), "Influence of Price-Endings on Price Recall: a by-Digit Analysis," ***Journal of Product and Brand Management*** 13, 514–524.

Schindler, R. and P. Kirby (1997), "Patterns of Right Most Digits Used in Advertised Prices," ***Journal of Consumer Research*** 24, 192–200.

Snir, A. and D. Levy (2011), "Shrinking Goods and Sticky Prices," Working Paper.

Stiving, M. (2000), "Price-Endings When Prices Signal Quality," ***Management Science*** 46(12), 1617–1629.

Stiving, M. and R. Winer (1997), "An Empirical Analysis of Price-Endings with Scanner Data," ***Journal of Consumer Research*** 24(1), 57–67.

Thomas, M. and V. Morwitz (2005), "Penny Wise and Pound Foolish: The Left-Digit Effect in Price Cognition," ***Journal of Consumer Research*** 32, 54–64.

Varian, H. (1972), "Benford's Law," ***American Statistician*** 26(3), 65–66.

Warner, E. and R. Barsky (1995), "The Timing and Magnitude of Retail Store Markdowns," ***Quarterly Journal of Economics*** 110(2), 321–352.

Willis, J. (2003), "Implications of Structural Changes in the US Economy for Pricing Behavior and Inflation Dynamics," ***Fed of KC Economic Review*** (1st Q.), 5–26.

Wolman, A (2007), "The Frequency and Costs of Individual Price Adjustment: A Survey," ***Managerial and Decision Economics*** 28(6), 531–552.

Zbaracki, M., et al. (2004), "Managerial and Customer Costs of Price Adjustment: Direct Evidence from Industrial Markets," ***Review of Economics and Statistics*** 86, 514–33.

Table 1. Probability of a Correct Response
(Lab Experiment)

	All Observations	Observations on Unequal Prices	Observations on Equal Prices
Female	0.14 (0.091)	0.14 (0.166)	–0.13 (0.195)
Low Shopping Frequency	–0.16 (0.134)	–0.78*** (0.206)	–0.11 (0.236)
Digit-Difference	0.03*** (0.005)	0.04*** (0.008)	
Price-Comparison	–0.03 (0.208)		
Find-Small	0.41 (0.181)**	–0.31 (0.196)	0.32 (0.253)
Three-Digits	0.12 (0.203)	0.04 (0.227)	–0.20 (0.840)
Price-Comparison × Find Smaller	–0.32 (0.252)		
Price-Comparison × Three Digit	–0.10 (0.297)		
Three-Digits × Find Smaller	0.03 (0.251)	–0.15 (0.304)	–0.53 (0.366)
Price-Comparisons × Three-Digits × Find-Small	–0.19 (0.371)		
Price-Comparison × Low-Shopping-Frequency	–0.46** (0.195)		
Right-Most	–0.72*** (0.058)		
Middle	–0.46*** (0.056)		
Left-Most	–0.38*** (0.0617)		
Find-Small × Right-Most	–0.82*** (0.083)		
Find-Small × Middle	–0.98*** (0.080)		
Find-Small × Left-Most	–1.00*** (0.086)		
Price-Comparison × Right-Most	0.18** (0.078)		
Price-Comparison × Middle	0.10 (0.075)		
Price-Comparison × Left-Most	0.18** (0.083)		
Price-Comparison × Find-Small × Right-Most	0.58*** (0.113)		
Price-Comparison × Find-Small × Middle	0.60*** (0.108)		
Price-Comparison × Find-Small × Left-Most	0.45*** (0.118)		
0-Ending	0.13** (0.048)	0.03 (0.055)	0.20 (0.109)
9-Ending	–0.02 (0.030)	0.14 (0.090)	–0.09 (0.078)

Price-Comparison × 0-Ending	–0.04 (0.068)		
Price-Comparison × 9-Ending	–0.07* (0.042)		
Bigger-9-Ending		–0.26*** (0.087)	
Constant	1.92*** (0.161)	1.55*** (0.191)	2.03*** (0.224)
Number of Observations	55,346	20,905	5,982
χ^2	1127***	67.02***	11.44

Notes

1. The table reports estimation results of a probit model for the probability of a correct response in the lab experiment.
2. Standard errors are reported in parentheses.
3. The asterisks indicate statistical significance as follows: * $p < 10\%$, ** $p < 5\%$, and *** $p < 1\%$.

Table 2. Probability of Responding that the Price Has Decreased or Increased Relative to Responding that It Has Remained Unchanged
(Field Study)

	One Dummy for 9-Ending	
	Price Decreases	Price Increases
Intercept	-1.50*** (0.104)	-1.64*** (0.099)
Female	-0.21*** (0.064)	-0.03 (0.061)
Ultra-religious	0.42*** (0.072)	-0.19** (0.078)
Academic Degree	0.04 (0.064)	0.03 (0.061)
More than One Trip per Week	-0.34*** (0.062)	-0.16** (0.059)
More than NIS 300 per Shopping Trip	0.11* (0.061)	0.40*** (0.058)
Older than 55	0.09 (0.101)	0.42*** (0.087)
Price Increase	0.21 (0.184)	1.24*** (0.167)
Price Decrease	1.37*** (0.173)	0.50** (0.177)
Previous Price	-0.0006 (0.003)	0.01*** (0.002)
Relative Size of the Price Change	0.99*** (0.270)	0.64** (0.253)
Left-Most	0.43** 0.143)	0.37** (0.136)
Middle	-0.23 (0.149)	0.032 (0.146)
Right-Most	0.53*** (0.148)	0.33** (0.140)
0-Ending	0.07 (0.280)	0.18 (0.246)
9-Ending	0.25*** (0.075)	0.05 (0.070)
χ^2	997.0***	

Notes
1. The table reports estimation results of a multi-probit model for the probability that consumers have identified a price change as a decrease or as an increase relative to no-change.
2. Standard errors are reported in parentheses.
3. The asterisks indicate statistical significance as follows: * $p < 10\%$, ** $p < 5\%$, and *** $p < 1\%$.

Table 3. Probability of a Correct Response
(Field Study)

	All Observations	Price Decreases		Price Increases and Unchanged Prices	
	(1)	(2)	(3)	(4)	(5)
Intercept	0.85*** (0.110)	-0.63 (0.442)	-0.49 (0.460)	0.88*** (0.115)	
Female	0.078 (0.066)	0.30 (0.244)	0.30 (0.246)	0.08 (0.067)	0.08 (0.069)
Ultra-Religious Consumer	0.20** (0.097)	0.70*** (0.261)	0.71*** (0.262)	0.01 (0.103)	0.12 (0.102)
Academic Degree	0.07 (0.087)	-0.03 (0.223)	0.02 (0.230)	0.05 (0.091)	0.058 (0.091)
More than One Trip a Week	0.26*** (0.083)	0.58** (0.244)	0.58** (0.246)	0.28*** (0.087)	0.26*** (0.0087)
More than NIS 300 per Shopping Trip	-0.33*** (0.082)	-0.42* (0.228)	-0.43* (0.230)	-0.306*** (0.087)	-0.317*** (0.086)
Older than 55	-0.31** (0.139)	-0.23 (0.369)	-0.21 (0.371)	-0.33** (0.147)	-0.34** (0.146)
Price Increase	-1.19*** (0.109)			-1.41*** (0.125)	-1.26*** (0.168)
Price Decrease	-1.30*** (0.111)				
Previous Price	-0.004* (0.002)	-0.009 (0.009)	-0.01 (0.009)	-0.005** (0.002)	-0.007*** (0.002)
Relative Size of the Price Change	0.30* (0.156)	2.30*** (0.637)	2.34*** (0.646)	0.28* (0.163)	0.17 (0.171)
Right-Most	0.39*** (0.067)	0.53** (0.224).	0.53** (0.232)	0.27*** (0.074)	0.259*** (0.075)
Middle	-0.68*** (0.083)	-2.46*** (0.341)	-2.43*** (0.344)	-0.27*** (0.098)	-0.22** (0.102)
Left–Most	0.37*** (0.094)	0.05 (0.235)	0.03 (0.242)	0.47*** (0.121)	0.46*** (0.123)
0-Ending	-0.32 (0.177)	-0.25 (0.800)	-0.38 (0.820)	-0.23 (0.185)	-0.20 (0.187)
9-Ending	-0.25*** (0.048)	-0.17 (0.225)		-0.28*** (0.051)	
From 9 to 9			-0.37 (0.285)		-0.21 (0.172)
From other to 9			-0.19 (0.327)		-0.51** (0.260)
From 9 to other			-0.39 (0.39)		0.47* (0.251)
Number of Observations	6031	581	581	5450	5450
χ^2	657.1***	76.1***	76.6***	379.0***	393.2***

Notes
1. The table reports estimation results of a model for the probability that consumers correctly noticed price changes.
2. Standard errors are reported in parentheses.
3. The asterisks indicate statistical significance as follows: * $p < 10\%$, ** $p < 5\%$, and *** $p < 1\%$.

Table 4. Number of Price Increases by Last Digit Transition Conditional on Price Change, From Starting Last Digit to Ending Last Digit (Dominick's Supermarket Chain)

To From	0	1	2	3	4	5	6	7	8	9	Total
0	52220	49440	57290	51071	59052	146046	36341	36371	21471	510368	**1019670**
1	19714	11592	32891	36082	22361	82552	17615	17992	9758	250578	**501135**
2	19052	12852	13971	31059	24457	71746	17606	18315	11020	219896	**439974**
3	32342	14838	12720	22186	35801	91381	25105	30233	20650	276937	**562193**
4	27807	14233	18953	18294	17973	83883	32131	29448	16597	407026	**666345**
5	71960	27938	26607	30642	22894	95999	53189	57838	35845	434267	**857179**
6	34171	21683	30291	27491	29433	64958	16144	62799	26886	348738	**662594**
7	25919	17724	19195	21522	15911	64240	10347	18768	20133	259618	**473377**
8	23266	19638	15572	19660	11288	43781	12438	10384	12194	144984	**313205**
9	375266	232480	219279	237710	244248	442311	148026	184838	101823	3446255	**5632236**
Total	**681717**	**422418**	**446769**	**495717**	**483418**	**1186897**	**368942**	**466986**	**276377**	**6298667**	**11127908**

Table 5. Number of Price Decreases by Last Digit Transition Conditional on Price Change, From Starting Last Digit to Ending Last Digit (Dominick's Supermarket Chain)

To From	0	1	2	3	4	5	6	7	8	9	Total
0	54084	17158	17949	30621	25067	63785	31284	21720	20180	299244	**581092**
1	36712	7625	10561	12005	11458	26678	17684	14758	16887	145963	**300331**
2	48426	24809	10735	10612	15591	28193	31045	15021	12808	155622	**352862**
3	43046	34152	24184	21746	16052	28926	22828	20325	17007	186520	**414786**
4	51237	18814	22475	26765	17104	24179	25770	15299	9703	201933	**413279**
5	118288	58245	61170	81408	66277	78183	57110	58170	34593	432636	**1046080**
6	27931	17089	17583	22715	33287	29721	13125	10762	8794	137556	**318563**
7	29442	16405	18157	27297	40953	46246	51441	17955	9659	176757	**434312**
8	17356	8163	10629	15364	20905	29743	22460	18234	9879	76137	**228870**
9	504886	175390	157429	223539	357851	372173	342096	242018	118988	3499072	**5993442**
Total	**931408**	**377850**	**350872**	**472072**	**604545**	**727827**	**614843**	**434262**	**258498**	**5311440**	**10083617**

Table 6. Price Increases: Transition Probability Matrix by Last Digit Conditional on Price Change, From Starting Last Digit to Ending Last Digit (Dominick's Supermarket Chain)

To / From	0	1	2	3	4	5	6	7	8	9
0	0.051213	0.048486	0.056185	0.05009	0.057913	0.143229	0.035640	0.035669	0.021057	0.500523
1	0.039339	0.023131	0.065633	0.07200	0.044621	0.164730	0.035150	0.035903	0.019472	0.500021
2	0.043303	0.029211	0.031754	0.07059	0.055587	0.163069	0.040016	0.041627	0.025047	0.499793
3	0.057528	0.026393	0.022626	0.03946	0.063681	0.162544	0.044655	0.053777	0.036731	0.492601
4	0.041731	0.021360	0.028443	0.02745	0.026973	0.125885	0.048220	0.044193	0.024908	0.610834
5	0.083950	0.032593	0.031040	0.03575	0.026709	0.111994	0.062051	0.067475	0.041817	0.506623
6	0.051572	0.032724	0.045716	0.04149	0.044421	0.098036	0.024365	0.094777	0.040577	0.526322
7	0.054753	0.037442	0.040549	0.04546	0.033612	0.135706	0.021858	0.039647	0.042531	0.548438
8	0.074284	0.062700	0.049718	0.06277	0.036040	0.139784	0.039712	0.033154	0.038933	0.462904
9	0.066628	0.041277	0.038933	0.04221	0.043366	0.078532	0.026282	0.032818	0.018079	0.611880

Table 7. Price Decreases: Transition Probability Matrix by Last Digit Conditional on Price Change From Starting Last Digit to Ending Last Digit (Dominick's Supermarket Chain)

To / From	0	1	2	3	4	5	6	7	8	9
0	0.093073	0.029527	0.030888	0.052696	0.043138	0.109767	0.053837	0.037378	0.034728	0.514968
1	0.122238	0.025389	0.035165	0.039973	0.038151	0.088829	0.058882	0.049139	0.056228	0.486007
2	0.137238	0.070308	0.030423	0.030074	0.044184	0.079898	0.087981	0.042569	0.036297	0.441028
3	0.103779	0.082336	0.058305	0.052427	0.038699	0.069737	0.055036	0.049001	0.041002	0.449678
4	0.123977	0.045524	0.054382	0.064763	0.041386	0.058505	0.062355	0.037019	0.023478	0.488612
5	0.113077	0.055679	0.058475	0.077822	0.063357	0.074739	0.054594	0.055608	0.033069	0.413578
6	0.087678	0.053644	0.055195	0.071305	0.104491	0.093297	0.041201	0.033783	0.027605	0.431802
7	0.067790	0.037772	0.041806	0.062851	0.094294	0.106481	0.118443	0.041341	0.022240	0.406982
8	0.075833	0.035667	0.046441	0.067130	0.091340	0.129956	0.098134	0.079670	0.043164	0.332665
9	0.084240	0.029264	0.026267	0.037297	0.059707	0.062097	0.057078	0.040380	0.019853	0.583817

Table 8. Probability that a New Price Ends with 9
(Dominick's Supermarket Chain)

	Coefficient
Intercept	0.81 (0.01)***
Previous Price	0.11 (0.00)***
Price Difference	0.24 (0.00)***
Price Decrease	–0.14 (0.00)***
Previous Price-Ending with 9	0.08 (0.00)***
Sale Price	–0.45 (0.00)***
Number of Observations	21,211,140
LR Test	2952421***

Notes
1. The table reports estimation results of a probit model for the probability that the new price (after a price change) ends with 9.
2. Standard errors are reported in parentheses.
3. The asterisks indicate statistical significance as follows: * $p < 10\%$, ** $p < 5\%$, and *** $p < 1\%$.

Table 9. Probability of the Price Digits Adjusting
(Dominick's Supermarket Chain)

	The Adjusted Digit Is		
	Left-Most Digit	Middle Digit	Right-Most Digit
Previous Price	0.003*** (0.00007)	–0.002*** (0.00006)	–0.02*** (0.00006)
Price Difference	0.20*** (0.0002)	0.03*** (0.0001)	–0.02*** (0.0001)
Price Difference × Price Decrease	0.009*** (0.0002)	0.01*** (0.0002)	0.01*** (0.0002)
Price Decrease	0.10*** (0.0003)	0.13*** (0.0003)	–0.03*** (0.0003)
Previous Price-Ending with 9	0.22*** (0.0003)	0.26*** (0.0002)	–0.50*** (0.0002)
Sale Price	0.05*** (0.0004)	0.05*** (0.0002)	0.04*** (0.0002)
Previous Price-Ending with 9 × Price Decrease	–0.22*** (0.0004)	0.01*** (0.0002)	0.05*** (0.0003)
Intercept	0.08*** (0.002)	0.71*** (0.002)	0.85*** (0.002)
Number of Observations	21,211,140		
System Adjusted R^2	0.23***		

Notes
1. The table reports estimation results of a SURE model for the probability that the right-most digit, the left-most digit, and the middle digit adjust as a result of a price change.
2. Standard errors are reported in parentheses.
3. The asterisks indicate statistical significance as follows: * $p < 10\%$, ** $p < 5\%$, and *** $p < 1\%$.

Table 10. Probability of Price Increases and Decreases Relative to Price Remaining Unchanged
(Dominick's Supermarket Chain)

	Price Decreases	Price Increases
9-Ending	0.19*** (0.001)	-0.36*** (0.001)
Wholesale Price Change	-8.86*** (0.007)	6.15*** (0.006)
Sale Price in Previous Week	1.04*** (0.04)	4.34*** (0.002)
Constant	-2.30*** (0.001)	-2.14*** (0.0.1)
χ^2	1.99×10^{7}***	
Observations	81,085,440	

Notes
1. The table reports estimation results of a Multi-logit model for the probability of a price decrease and increase relative to the prices remaining unchanged.
2. Standard errors are reported in parentheses.
3. The asterisks indicate statistical significance as follows: *** $p < 1\%$.