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Not all price endings are created equal: Price points and asymmetric price rigidity☆

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ABSTRACT: We document an asymmetry in the rigidity of 9-ending prices relative to non-9-ending prices. Consumers have difficulty noticing higher prices if they are 9-ending, or noticing price-increases if the new prices are 9-ending, because 9-endings are used as a signal for low prices. Price setters respond strategically to the consumer-heuristic by setting 9-ending prices more often after price-increases than after price-decreases. 9-ending prices, therefore, remain 9-ending more often after price-increases than after price-decreases, leading to asymmetric rigidity: 9-ending prices are more rigid upward than downward. These findings hold for both transaction-prices and regular-prices, and for both inflation and no-inflation periods.

JEL Classification**:** E31, L16, C91, C93, D80, M31

Keywords**:** Asymmetric Price Adjustment, Sticky/Rigid Prices, 9-Ending Prices, Psychological Prices, Price Points, Regular/Sale Prices

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"If the prior price ended with 99 cents, there is a lower probability of a price change. The size of this effect is striking ... [although it] is generally not a central feature of price rigidity analysis and models. The magnitude of the effect that we report suggests that this feature of retail pricing deserves greater attention." ***Eric Anderson, Nir Jaimovich and Duncan Simester (2015, p. 820)***

1. Introduction

Asymmetric price rigidity is important as it can lead to asymmetric effect of aggregate demand (Ball, et al. 1988, Cover 1992, DeLong and Summers 1988), it has implications for optimal inflation rate (Ball and Mankiw 1994), and it can explain inflationary effects of sectoral shocks that change relative prices (Ball and Mankiw 1995).[1] Also, it can add a kink to the Phillips curve, leading to asymmetric output loss from negative-positive inflation surprises (Kuran 1983). Therefore, as Ellingsen, et al. (2006) emphasize, it is of interest to monetary policy makers.

We document a surprising form of price adjustment asymmetry, which existing theories cannot explain.[2] Using four different datasets (laboratory experiment data, a field study data, and retail price data from two countries) to study the behavior of both consumers and retailers, we offer several new observations about the way retail price information is processed and interpreted by consumers, and the systematic price setting patterns that strategic retailers follow in response.

We report the following findings on consumer behavior. In the lab, (1) consumers process price/number digit information left-to-right when the task requires low cognitive effort, but not when the task requires high cognitive effort. (2) They use 9-endings as a signal for low prices: in 4% of the cases where the bigger of the two prices compared was 9-ending participants wrongly identified the 9-ending prices as smaller. In the field study (a real setting), we find that (3) shoppers pay greater attention to the right-most and the left-most digits, than to the middle digits: they are 19%–29% more likely to correctly notice a price change if the change occurs in the left-most or the right-most digit, relative to a change in a middle digit. (4) Shoppers are 11% less

[1] Asymmetric price adjustment has been documented for consumer products (Anderson et al 2015, McShane et al 2016, Peltzman 2000), processed food (Chen et al 2008, Ray et al 2006), manufacturing (Blinder et al 1998), deposit interest rate (Hannan and Berger 1991), gasoline (Davis and Hamilton 2004), foreign exchange (Gopinath and Itskhoki 2010), and fruits/vegetables (Ward 1982), in the US, Canada, and European Union (Hall et al 2000, Álvarez et al 2006, Amirault et al 2004, Levy and Smets 2010).

[2] These include menu cost with inflation (Tsiddon 1993, Ball and Mankiw 1994), with asymmetric shocks (Ball and Mankiw 1995), and with channels of processing (Ray et al 2006), fair pricing (Rotemberg 2005, Anderson and Simester 2010, Chen et al. 2018), consumer inattention (Chen et al 2008), and inventories and capacity constraints (Loy et al 2016, Antoniou et al 2017).

likely to notice a price increase if the new price (the price following the increase) ends with 9.

We report the following findings about retail price behavior. (5) 9-endings are 6% more likely to be observed following a price increase than a price decrease. (6) 9-ending prices are more rigid upward than downward. Specifically, they are 32% more rigid upward than non 9-ending prices, while they are only 12% more rigid downward than non 9-ending prices. (7) The average increase in 9-ending prices is 12% larger than the average decrease in 9-ending prices.

Our empirical strategy is as follows. First, focusing on consumers' behavior, we show that in both the lab experiment and the field study, consumers use 9-endings as a signal for low prices. Consumers are less likely to notice higher prices if they end with 9, and less likely to notice price increases if the new prices end with 9. We do not observe these effects in case of price decreases.

Second, we explore the retailers' pricing practices. We hypothesize that strategically minded retailers keep prices at 9-endings more often after price increases than after price decreases. Consequently, 9-ending prices are more rigid upward than downward because they are more likely to increase to higher 9-ending prices (i.e., price increases will usually occur in multiples of 10¢), but price decreases are less restricted, because they do not need to be multiples of 10¢.

We test these hypotheses using price data from a large US retail chain Dominick's, and find that 9-ending prices are indeed more common after price increases than after price decreases. Also, as we hypothesize, they are more rigid upward than downward. An analysis of the Entry-Level-Item CPI data from Israeli retail supermarket and drugstore chains yields similar results.

Recent studies find that what matters for the macroeconomy are regular prices, not sale prices (e.g., Anderson et al. 2017, Kehoe and Midrigan 2015, Midrigan 2011, Eichenbaum et al. 2011), and therefore it is important to distinguish between regular and sale prices. For that purpose, we examine whether the asymmetric rigidity of 9-ending prices that we document is due to 9-ending regular prices going down to non-9-ending sale prices. Because in Dominick's data 9-ending prices are more likely to be regular prices than sale prices, we check whether the asymmetry also holds when we exclude sale prices. We explore these questions by running some additional tests.

First, we use the Dominick's sales indicator dummy variable as a control, wherever relevant. Second, we re-estimate all the regressions using regular prices only, by excluding from the analyses all sale related price changes using Dominick's sales indicator dummy variable. Third, we repeat the analyses using the sale filter of Nakamura and Steinsson (2008, 2011). Fourth, we repeat these analyses for the inflation-period and no inflation-period samples. We find that all the main results we are reporting in the paper hold for both the transaction prices and regular prices, irrespective of the estimation method used, irrespective of the inflationary environment, and irrespective of the sale filter used to separate regular prices and transaction prices. Often, the effects we are documenting are in fact stronger for regular prices than for transaction prices.

The paper is organized as follows. In section 2, we lay out the hypotheses. In section 3, we describe the data and the findings. In section 4, we check robustness. We conclude in section 5.

2. Testable hypotheses and empirical strategy

People process multi-digit number information from left to right. Thus, when comparing two numbers that differ in one digit, people are usually faster and more accurate, if the numbers differ in their left-most digits than in the middle or the right-most digits (Poltrock and Schwartz 1984). The literature extends this finding to prices by assuming that consumers process multi-digit price information from left to right (Stiving and Winer 1997).[3] However, there is also evidence that consumers use 9-endings as a signal for low prices, suggesting that at least when the right-most digit is 9, they process the right-most digit information (Schindler 2001, 2006).[4] We suggest that if consumers perceive 9-endings as a signal for low price, then 9-ending prices might have a

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[3] For example, consumers might perceive 9-ending prices as lower if price information is processed from left to right, and consumers ignore the 9-endings. Then, a price such as $2.99 might be perceived as $2.9 or even as $2, and thus cheaper than the actual price (Thomas and Morwitz 2005).

[4] Another theory suggests that consumers process all digits in the price information but perceive a 9-ending price as a gain from the next round price. That is, $2.99 is a gain of 1¢ from $3, and is perceived as much cheaper than $3.00 (Schindler and Kirby 1997), because of the disproportional impact of the 1¢ gain on consumers' perceptions (Kahneman and Tversky 1979). Also, 9-ending prices can signal low prices simply for the common belief that they are linked with sales (Anderson and Simester 2003).

negative effect on the likelihood that consumers will notice a price increase.

Focusing first on the consumer side, we use a lab experiment to test the hypothesis that 9-endings do not affect number comparisons because the endings have no particular significance in processing numeric information, but they affect the comparison of prices because the use of 9-endings as a signal for low prices might interfere with the left-to-right numeric price information processing. We thus hypothesize that consumers will be less accurate in comparing two prices when the higher price is 9-ending, compared to the situation where the lower price is 9-ending.

Next, we use field data on price recall to test the hypothesis that consumers are less accurate in recalling a price increase when the new price is 9-ending. If they interpret 9-ending prices as low, then they might not notice that a 9-ending price has increased, compared to the previous week.

In light of our findings concerning the consumers' behavior, we next focus on retail price behavior. We start by testing the hypothesis that retailers might respond strategically to consumer heuristics by choosing 9-ending prices more often after price increases, to reduce the likelihood that consumers will notice the increases. In such situations, prices that end in 9 are likely to remain 9-ending even after price increases. Retailers are less likely, however, to set 9-ending prices after price cuts because they use other means to ensure that the cuts are noticed. Indeed, price cuts are often promoted by using sale/discount signs, end-of-the-isle displays, large and colorful price tags, newspaper inserts, and leaflets distributed in stores (Nevo 2002). Therefore, 9-ending prices are more likely to decrease than to increase to non 9-ending prices. In other words, 9-endings will be more rigid than other endings upward but less so downward.

In the last step, we test the hypothesis that because 9-endings are more rigid upward than downward, 9-ending prices will also be more rigid upward than downward. Indeed, we show that the asymmetric rigidity of 9-endings translates into an asymmetric rigidity of 9-ending prices.

3. Data and econometric analyses

In this section, we discuss the four datasets that we have assembled for this study, and describe the results of their econometric analyses. We begin with a laboratory experiment.

3.1. Evidence from a laboratory experiment

We start by describing the setup and the structure of the experiments we conducted. That is followed by two sets of econometric analyses of the data that these experiments generated.

3.1.1. Experimental setting and design

The goal of the experiment is to examine the effect of 9-endings on the way individuals process price information, in price comparison situations. We run the experiment at the Texas A&M University with 206 undergraduate students, with a median age 20, 66% female, 21% shop once a month or less, 34%—once every 2 weeks, 35%—every week, and 10%—twice a week or more. On average, the participants needed less than 15 minutes to complete the comparison task.

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

The type of stimuli was manipulated as follows. In the number-comparison condition, two numbers were shown on the computer screen. The numbers were either the same or differed in one digit. Participants had to press A (L) if the left (right) number was larger, or the space bar if they were equal. One practice block was followed by four experiment blocks of 75 comparisons each, with 10% of the numbers ending with 9. Before each comparison, participants saw an image of an abacus on the screen for 1,000ms, followed by another screen with a "+" sign for 500ms. The number condition serves as a baseline, to understand how consumers compare prices.

To make the price- and number-conditions comparable, the prices were shown as 3- or 4-digit numbers, without the $ sign. The only difference was in the instructions, which indicated price or number comparisons, and in the image shown, which in the price condition was a supermarket aisle rather than an abacus. Comparison difficulty was manipulated by asking participants to identify the smaller or the larger of two numbers/prices. The comparison difficulty differs because "smaller" is a marked while "larger" is an unmarked adjective.[5] People need more time, and they make more mistakes, when they process marked adjectives such as shorter, duller, or worse, than their unmarked equivalents, taller, brighter, or better (Lachman et al 1979). Thus, the task of identifying the smaller of two numbers/prices is cognitively more demanding than the task of identifying the larger of two numbers/prices. Since heuristics are often used in dealing with difficult tasks (Kahneman and Frederick 2002), we expect to see more reliance on 9-endings as a signal for low prices, and thus more frequent errors associated with 9-ending prices, in the cognitively more difficult find-small price condition, than in the find-large price condition.

The number of digits was manipulated by asking participants to compare 3-digit or 4-digit numbers/prices, which is the range of many consumer goods' prices (Bergen et al. 2008, Barsky et al. 2003). The within-subject factor for the different digit location was manipulated by showing two numbers/prices that either were the same or differed in exactly one digit, e.g., 3.45 and 3.75.

The participants were asked to respond as quickly and accurately as possible. [6] They were told that 10% of them would be selected at random and paid based on their performance. They could earn up to $10 if they used 1 second or less on average to answer correctly all comparison questions. The payoff was cut by $5 if their average response time per comparison exceeded 1 second, and by $1 for every incorrect response. The 1-second threshold was set based on a pre-test, which showed that the participants needed an average of 1 second for a comparison. The average payment they received was $5.10. In the empirical analysis, we use the data obtained from the non-practice blocks only. In total, the lab experiments yielded 55,346 observations.

[5] Cognitive psychologists view some words as more complex if they are marked (Lachman et al. 1979, p. 396). Marked words are "governed by more restrictions on their use, and are less salient semantically than unmarked terms… The pair of words good and bad…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." Thus, "bad" is marked while "good" is unmarked. Other examples include above (unmarked) and below (marked), happy (unmarked) and unhappy (marked), honest (unmarked) and dishonest (marked), etc.
[6] See Online Appendix A for the instructions that were given to the participants and for other details on the laboratory experiment.

We find that the average response time in the lab experiment was 1.05 seconds, and 89% of the responses were correct. Also, we find that identifying the smaller number/price was indeed harder for participants. They needed, on average, 1,067ms (1,027ms) to identify the smaller (the larger) number/price (t = 11.6, p < 0.01). The identification of the smaller number/price also produced more mistakes than the larger number/price (15.4% vs. 7.4%, z = 28.7, p < 0.01).

3.1.2. The effect of 9-endings on the accuracy of price- and number-comparisons

We hypothesize above that participants use 9-endings as a signal for low prices, and therefore they are more likely to make a mistake in comparing prices (but not when comparing numbers) when one of the prices compared is 9-ending, than when neither of the prices is 9-ending.

The descriptive statistics are consistent with this hypothesis. In both the number and price treatments, participants are more likely to give a correct answer when none of the prices/numbers compared ends in 9. We find that the likelihood of giving a correct answer when none of the prices (numbers) is 9-ending is 89.34% (88.54%). When at least one of the prices (numbers) is 9-ending, the probability is 87.91% (87.79%). The difference is statistically significant in the price treatment (z = 3.11, p < 0.01), but not in the number treatment (z = 1.59, p > 0.10).

These descriptive statistics are suggestive. To test that these results are robust to the inclusion of various control variables, we estimate the following linear probability regression model:

$$accurate_{ij} = \alpha + \beta_1 9\text{-}ending_{ij} + \beta_2 9\text{-}ending_{ij} \times price\text{-}comparison_{ij} + \gamma_1 right\text{-}most_{ij} + \gamma_2 middle_{ij} + \gamma_3 left\text{-}most_{ij} + X_{ij}\delta + \phi_i + u_{ij} \quad (1)$$

where the dependent variable, $accurate_{ij}$, is a dummy that equals 1 if participant i answered question j accurately, and 0 otherwise. *9-ending* is a dummy which equals 1 if the right-most digit of at least one of the two numbers/prices compared is 9, and 0 otherwise. *Left-most*/*middle*/*right-most* are three location dummies (1 if the numbers/prices compared differ in the left-most/middle/ right-most digit respectively, and 0 otherwise). They control for the possibility that participants process the price/number information left-to-right and, therefore, they will make fewer mistakes when the prices/numbers compared differ in their left-most digits than in their right-most digits.

The matrix *X* includes further controls, ϕ is the participants' random effects, and *u* is the error term.[7] The key coefficients are the coefficients of 9-*ending* and the interaction of 9-*ending* and *price comparison*. If 9-endings have an effect on the way consumers process price information but not on the way they process number information, then the coefficient of 9-*ending* should be insignificant. That is because in the number condition, participants will not use 9-endings as a signal. In the price condition, however, we hypothesize that they use 9-endings as a signal and, consequently, the coefficient of the interaction of 9-*ending* and *price comparison* should be negative. We report the econometric model estimation results in column (1) of Table 1.

We find that while the coefficient of *9-ending* is not significant ($\beta_1 = -0.001$, $p > 0.10$), the coefficient of its interaction with *price-comparison* is negative and significant ($\beta_2 = -0.01$, $p < 0.05$). Thus, the regression results are consistent with the findings we report using the descriptive statistics: in the number condition, 9-endings do not affect the likelihood of a correct response. In the price condition, however, 9-endings reduce the likelihood of a correct response by about 1%. Given that the percentage of correct responses in the price treatment is 89%, a 1% increase in the likelihood of making a mistake is not trivial, because it implies that when at least one of the prices is 9-ending, the likelihood of an error increases from 11% to 12%, an increase of 9%.

In both the number and the price treatments, when participants had to identify the *smaller* of the two numbers/prices compared, the likelihood of a correct response did not depend on the location of the different digit, whereas when participants had to identify the *larger* of the two

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[7] Controls include *price-comparison* (1= price, 0 = number), *find-small* (1 = find-small, 0 = find-large), *3-digit* (1 = 3-digit, 0 = 4-digit), and interactions of the location dummies with *price-comparison* and *find-small*, to control for the possibility that different cognitive processes are used in comparing prices/numbers, or if the task is cognitively more demanding. As 0 is another common price ending and might signal quality (Snir et al 2018), we include a *0-ending* dummy (1 = the right-most digit of at least one of the two numbers/prices compared is 0, and 0 otherwise), and its interaction with *price-comparison*, to see whether *0-ending* affects number/price comparisons differently. Other controls include *gender* (1 = female, 0 = male), *low-shopping-frequency* (1 = once a month or less, and 0 otherwise), and its interaction with *price-comparison* to see whether shopping frequency affects number/price comparison tasks differently, and *digit-difference* which equals as the absolute value of the difference between the digits of the numbers/prices compared (Monroe and Lee 1999). E.g., the digit difference between 3.87 and 3.57 is |8 – 5| = 3.

numbers/prices, it did. Thus, when participants face more difficult tasks, they rely more on heuristics. We find that 9-endings serve as such a heuristic in the price condition.[8]

3.1.3. The effect of 9-endings on the accuracy of price-comparisons when the two prices differ

If 9-endings signal low prices, then they will more likely affect the response accuracy when they appear in the higher of the two prices compared. To test this, we split the price condition sample in two. Subsample 1 (2) includes the trials in which the prices compared are equal to (different from) each other. We estimate a separate model for each. We do not expect 9-endings to affect the comparison accuracy in subsample 1 because in this subsample, when one price ends with 9, the other price also ends with 9. In subsample 2, 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 subsample 2, thus, we include in the regression a *bigger-9-ending* dummy (1 if the bigger price ends with 9, and 0 otherwise). If the participants use 9-endings as a signal for low prices, then the coefficient of *bigger-9-ending* will be negative. We include also all the controls as in section 3.1.2, except the location dummies and their interactions because of a multicollinearity in subsample 1. Columns 2 and 3 in Table 1 report the estimation results.

In both subsamples, the coefficient of *9-ending* is not significant. Therefore, when prices are equal or when the smaller price ends with 9, 9-endings do not affect the comparison accuracy (subsample 1: $\beta = -0.007$, $p > 0.10$; subsample 2: $\beta = 0.02$, $p > 0.10$). In subsample 2, however, the coefficient of *bigger-9-ending* is negative and significant ($\beta = -0.04$, $p < 0.05$). Thus, if the bigger price is 9-ending, the participants are more likely to mistakenly think that it is smaller, compared to the situation where it ends with another digit, consistent with the hypothesis that consumers use 9-endings as a low price signal (Anderson and Simester 2003, Schindler 2006).

3.2. Evidence from a field study

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[8] Indeed, in Online Appendix J, Table 1D, we show that when we use a probit model to estimate the probability of a correct response, the estimation results suggest that the likelihood of a correct response in the number condition depends on the location of the different digit, but in the price condition, it does not.

The goal of the field study is to examine the effects of 9-endings in a real shopping setting, where the cognitive load and the mental effort is likely to be higher than in the lab. We examine the effect of 9-endings on the likelihood of noticing price changes. If consumers interpret a 9-ending price as a low price, they will be less likely to notice that a 9-ending price has increased.

We surveyed 365 Israeli consumers at three supermarkets in three cities. Consumers exiting the stores were shown a list of 52 items in 12 product categories (dairy products, fresh fruits and vegetables, salt, sugar, cooking oil, soft drinks, cooking and baking products, canned food, coffee and tea, frozen food, sweets, crackers, meat, and laundry detergent), and were asked to mark the items they have bought on their current and previous shopping trips. For each item they marked, they were asked to indicate whether in their opinion the price of the item had increased, decreased, or remained the same, in comparison to the same item's price the last week.[9]

The average participant in our survey is 40 years old, shops once a week, and spends NIS175.00 per visit on average.[10] 56% of the consumers sampled are women, and 23% are religious. The questionnaire took an average of 10 minutes to fill out. On average, each consumer responded to questions on 12.1 products listed, and 65.3% of the responses were accurate.[11]

3.2.1. Consumers' recall accuracy in the entire data set

If 9-endings signal low prices, then consumers will be less accurate in noticing price changes when the new prices are 9-ending than when they are not. The descriptive statistics support this prediction: Consumers correctly recalled whether a price has increased, decreased, or remained unchanged in 74.15% of the cases when the price was not 9-ending, and in 62.55% of the cases when the price was 9-ending. The difference is statistically significant ($z = 8.2$, $p < 0.01$).

[9] See Online Appendix B for the questionnaire we used in the field study.
[10] The exchange rate at the time was NIS4.37 for $1.
[11] A sample selection bias could be an issue here because we do not have the proportion, nor the socio-demographic information, of the participants who declined to participate in the survey. However, based on parameters such as age, education, etc., our sample seems reasonable representative of the populations of the cities, where we collected these survey data. See Online Appendix X for details on the consumers in our sample.

As a more formal test, we estimate the following linear probability regression model:

$$accurate_{ij} = \alpha + \beta_1 9\text{-}ending_{ij} + \gamma_1 right\text{-}most_{ij} + \gamma_2 middle_{ij} + \gamma_3 left\text{-}most_{ij} + X_{ij}\delta + \phi_i + u_{ij} \qquad (2)$$

where $accurate_{ij}$ is a dummy which equals 1 if consumer *i* correctly recalled the price change direction (increased/decreased/remained unchanged) of good *j*, and 0 otherwise. *9-ending* and the location dummies are defined above.[12] One of the controls included in the matrix *X* (see footnote 12) is the *previous week's price*, which controls for the possibility that consumers' accuracy varies with the price level. We report the model estimation results in column (1) of Table 2.

We find that when a price is 9-ending, consumers are about 7% less likely to correctly recall whether or not the price has increased/decreased/remained unchanged ($\beta_1 = -0.07, p < 0.01$). We also find that they are more likely to notice a price change if either the right-most ($\gamma_1 = 0.10, p < 0.01$) or the left-most ($\gamma_3 = 0.09, p < 0.01$) digit changes than if a middle digit ($\gamma_2 = -0.20, p < 0.01$) changes. *Previous week's price* is not statistically significant.

Consistent with the laboratory experiment results reported in section 3.2.1, these findings suggest that when consumers face situations where the cognitive load and the mental effort needed are high, they do not process price information left-to-right, but rather, they process the left-most- and the right-most-digits before the middle one. Further, the difference between the coefficients of *9-ending* and *right-most* suggests that although a 9-ending cannot completely cancel out the positive effect that a change in the right-most digit has on consumers' recall accuracy of price changes ($F_{\beta_1=-\gamma_1} = 45.5, p < 0.01$), it does reduce this effect considerably.

3.2.2. Consumers' recall accuracy of price increases vs. price decreases

In the lab experiment, we observed that 9-endings interfered with the price comparisons when

[12] Controls include *female* (1 = female, 0 = male), *religious* (1 for ultra-religious, and 0 otherwise), *academic-degree* (1 = college degree, and 0 otherwise), *frequent-consumer* (1 = more than once a week, and 0 otherwise), *large-expenditure* (1 = more than NIS300 per visit, and 0 otherwise), *age* (1 = 55y-old or older, and 0 otherwise), *the previous week's price*, absolute value of the *price-change*, *price-increase* (1 if the actual price has increased, and 0 otherwise), *price-decrease* (1 if the actual price has decreased, and 0 otherwise), and *0-ending* (1 if the actual price ends with 0, and 0 otherwise). We include dummies for (i) ultra-religious since they have low incomes and large families, and thus face tighter budget constraints, and for (ii) 55+ year olds because they are less accurate in recalling prices (Macé 2012). The findings we report are consistent with these observations.

the bigger price was 9-ending. Specifically, we found that 9-endings decreased the probability of identifying the bigger price but did not help in identifying the smaller price (section 3.1.3). This suggests that 9-endings have a stronger effect on consumers' recall accuracy of price changes when the 9-ending appears in the bigger price. In other words, 9-endings have a stronger effect when the new price is 9-ending after a price increase than after a price decrease.

To test this hypothesis, we split the sample in two. Subsample 1 (2) includes the observations on price increases (price decreases). For each, we estimate a random-effect linear probability model of the likelihood that consumers correctly notice price changes. The dependent variable in subsample 1 (2) is a dummy which equals 1 if a consumer correctly noticed a price increase (a price decrease), and 0 otherwise. Using this specification, we re-estimate regression (2), using the full list of controls as in 3.2.1. We report the estimation results in columns (2) and (4) of Table 2.

The effect of *9-ending* is negative and significant in the regression of price increases ($\beta = -0.11$, $p < 0.05$), but is small and not significant in the regression of price decreases ($\beta = -0.01$, $p > 0.10$). Thus, the negative effect of 9-endings on the likelihood of correctly noticing a price change seems to be due to the 9-endings reducing the likelihood of noticing price increases. 9-endings, however, do not appear to have a significant effect on the likelihood of noticing price decreases.

3.2.3. Consumers' recall accuracy "from" and "to" 9-ending prices

To further understand the effects of 9-endings on consumers' ability to recall price changes, we break the *9-ending* dummy in regression (2) into three dummy variables: *from-9-to-9* (1 if a 9-ending price changed to a 9-ending price, and 0 otherwise), *from-9-to-other* (1 if a 9-ending price changed to a non 9-ending price, and 0 otherwise), and *from-other-to-9* (1 if a non 9-ending price changed to a 9-ending price, and 0 otherwise). With this specification, we estimate regression (2) with the full list of control variables as above, for price increases and price decreases separately.

If consumers use 9-endings as a signal for low prices, as our findings so far suggest, then 9-endings are more likely to reduce the likelihood that the consumers will notice a price change, if a given price increases from a non-9-ending price to a 9-ending price. We therefore hypothesize that in the sample of price increases, the coefficient of *from-other-to-9* dummy will be negative.

Similarly, because we find that for price decreases 9-endings do not have a significant effect on the likelihood of noticing price decreases, we expect that the coefficient estimates will not be significant for any of the 9-ending dummies that we include for price decreases in the regression equation. We report the model estimation results in columns (3) and (5) of Table 2.

For price increases, we find that, as we hypothesize, when a non 9-ending price changes to a 9-ending price, consumers are less likely to notice a price increase (β = –0.22, $p < 0.01$).[13]

For price decreases, we find that none of the three 9-ending dummy variables are significant, consistent with the results we report in section 3.2.2. Our results therefore suggest that 9-endings have a negative effect on the recall of price increases, but not on the recall of price decreases.[14]

3.3. Evidence from a large U.S. supermarket chain

So far we have focused on the consumers' behavior with regard to 9-ending prices. Next, we consider the price-setters' behavior by analyzing the dynamic adjustment patterns of retail prices at a supermarket chain. Our lab experiment and field studies suggest that consumers are less likely to notice price increases if the new price ends with 9. For price decreases, however, we find that 9-endings do not affect the recall accuracy. Retailers that act strategically, therefore, will have greater incentive to keep prices at 9-endings after price increases than after price decreases. This predicts asymmetry in the likelihood that 9-ending prices will change. Specifically, 9-ending prices will be more likely to increase if the shock that triggers it is large enough to merit a change that is a multiple of 10¢, but they will be less restricted in the case of price decreases.

To examine the asymmetry in the rigidity of 9-endings prices, we study price data from a large

[13] This could explain why retailers often use non 9-endings for discounted prices. If the discounted prices are not 9-ending but the regular price are, consumers are less likely to notice the bounce-back from the discounted price to the regular price.
[14] A possible explanation is that price cuts are often promoted by other means such as end-of-the-aisle displays, sale and discount signs, larger and/or more colorful price tags, leaflets and newspaper inserts, etc., and consequently the effect of 9-endings is small.

US retail supermarket chain Dominick's, operating over 130 stores in the greater Chicago area. The data contain 98,691,750 weekly price observations for 18,037 different products (UPCs - Universal Product Codes) in 29 product categories, during 1989–1997. We exclude the end-points and incomplete segments of the individual price series, leaving us with 81,982,683 observations. The average price in the sample is $2.34, and 62% of the prices end with 9.[15] There are a total of 20,839,462 prices changes, including 52.5% increases and 47.5% decreases, with the average price change of 43¢. For more details about these data, see Barsky, et al (2003).[16]

3.3.1. Transition probability analysis: asymmetric transition of 9-endings

Table 3 reports 10-state Markov chain transition probability matrix for price increases and decreases for the last digit. The figures on the diagonals of the matrices suggest that 9-endings are more rigid than other digits, as the probability of a 9-ending to remain a 9-ending exceeds the probability that any other ending will remain unchanged. In addition, looking at the table rows, we see that when prices change, the new prices end with 9 more often than with any other digit.

The last columns of the two panels indicate that a larger share of the prices end with 9 after price increases than after price decreases. Moreover, there is a statistically significant higher probability for a 9-ending price to remain a 9-ending after a price increase than after a decrease, 61.65% vs 56.55% (z = 174.0, p < 0.01). Thus, new prices are more likely to end with 9 after price increases than after price decreases, confirming asymmetry in the 9-ending price rigidity.

3.3.2. Asymmetric rigidity of 9-endings

To further assess the asymmetry in the rigidity of 9-endings, we estimate a linear probability model of the likelihood that the new price, following a price change, ends with 9 by estimating:

$$end9_{ijt} = \alpha + \beta_1 price\text{-}decrease_{ijt} + \beta_2 Previous\text{-}9\text{-}Ending_{ijt} + X_{ijt}\gamma + u_{ijt} \qquad (3)$$

where $end9_{ijt}$ is a dummy variable which equals 1 if the new price of a good i in store j in week t

[15] In the full sample of Dominick's data with 98,691,750 observations, 69% of the prices are 9-ending (Levy et al 2011). Figure 2B in Online Appendix Z shows the frequency distribution of the last digit in our sample with 81,982,683 observations.
[16] The Dominick's dataset can be downloaded from http://research.chicagobooth.edu/marketing/databases/dominicks/index.aspx.

ends with 9, and 0 otherwise. The key independent variable is *price decrease* dummy (1 = price decrease, and 0 otherwise). *Previous 9-ending* dummy (1 if the pre-change price is 9-ending, and 0 otherwise) controls for the rigidity of 9-endings.[17] Table 4 reports the model estimation results.

The coefficient of *previous-9-ending* is positive (β_2 = 0.09, $p < 0.01$), suggesting that 9-endings are indeed rigid: 9-ending prices are 9% more likely to end with 9 than other endings following a price change. However, the coefficient of *price decrease* is negative and significant (β_1= –0.06, $p < 0.01$), suggesting that we are 6% less likely to see 9-endings following a price decrease than a price increase. Therefore, the estimation results confirm the observation conveyed by the transition probability matrices: although 9-endings usually change to 9-endings, retailers are more likely to set a price at 9-ending following a price increase than a price decrease.

3.3.3. Asymmetric rigidity of 9-ending prices

Recent studies find that *9-ending prices* are more rigid than other prices (Levy, et al. 2011, Anderson, et al. 2015, Knotek 2016). The findings we present above suggest an asymmetry in this rigidity. That is, we expect that 9-ending prices will be more rigid upward than other prices but not necessarily more rigid downward than other prices. We pose this hypothesis because if an increase from 9-ending prices to non 9-ending prices is likely to be noticed, then 9-ending prices themselves should be less likely to increase—they will increase only when the shock that triggers the price change is large enough to make it optimal to set a higher 9-ending price. Downwards, however, there could be smaller or no difference between 9-ending and non 9-ending prices, because 9-endings do not help consumers notice price decreases.

To test this hypothesis, we first look at the proportion of price increases and decreases in our data. Looking at increases, we find that 10.9% of all 9-ending prices and 17.5% of all non 9-ending prices increased. When we look at decreases, we find that 11.6% of all 9-ending prices

[17] Controls include *price level* (the price without the penny-digit), *price change* (the absolute difference between the post-change and pre-change prices), and fixed effects for the stores.

and 12.9% of all non 9-ending prices decreased. Thus, although 9-endings change less often than other prices in both directions, the effect is much more pronounced for price increases (10.9% vs. 17.5%, or a 37.7% difference) than for price decreases (11.6% vs. 12.9%, or a 10.1% difference).

Next, we estimate a multinomial-logit regression model of the probability that a price will increase, decrease, or remain unchanged:

$$P\left(direction\text{-}\Delta P_{ijt} = k\right) = \frac{exp\left(\beta_k previous\text{-}9\text{-}ending_{ijt} + X_{ijt}\gamma_k\right)}{1+\sum_{l=1}^{2} exp(\beta_l previous\text{-}9\text{-}ending_{ijt} + X_{ijt}\gamma_l)} \quad (4)$$

The dependent variable, $direction\text{-}\Delta P_{ijt}$, is an index variable, which attains the values k = 0/1/2 if the price of a good i in store j in week t has remained unchanged/decreased/increased, respectively. We include *previous-9-ending* dummy to control for the effect of 9-endings on price rigidity, expecting its effect on the likelihood of price increases to be negative but less so on the likelihood of price decreases.[18] Table 5 reports the model estimation results.

The effects of *previous-9-ending* on price increases and decreases are both negative (β_2 = –0.44, $p < 0.01$, and β_1 = –0.17, $p < 0.01$, respectively), implying that 9-ending prices are more rigid than other prices. What is perhaps more important however, is that the difference in their magnitude is both large as well as statistically significant (χ^2 = 324.6, $p < .001$), which confirms that 9-ending prices are more rigid upward than downward.

Indeed, setting all variables to their average values and setting all the dummy variables to zero, we find that changing a price from a non 9-ending to a 9-ending is associated with a cut in the likelihood of a price increase from 6% to 4.1%, a reduction of 32.6%. Changing the price from a non 9-ending to a 9-ending is associated with a cut in the likelihood of a price decrease from 14.6% to 12.9%, a reduction of 11.7%. These figures therefore imply that the effect of 9-endings on price increases is almost three times larger than their effect on price decreases.

[18] Controls include the *absolute value of % change in wholesale price*, a dummy for *sale price in the previous week* (1 if the price was a sale price, and 0 otherwise) as sale prices are more likely to change than regular prices, *price level*, and store dummies. Some wholesale price changes were suspiciously large. We therefore drop 238,279 observations with changes of 200% or more.

3.3.4. Asymmetry in the size of price changes

If 9-ending prices are more rigid upward than downward, then we would expect that when they do increase, they will increase by more than when they decrease. That is, the average increase of 9-ending prices should be larger than their average decrease. We indeed find that the average increase of 9-ending prices is 25.8%, significantly larger than the average decrease, 18.8% (t = 423.3, $p < 0.01$). To test this formally, we estimate the following regression model:

$$\left|\%\,price\text{-}change_{ijt}\right| = \alpha + \beta_1 previous\text{-}9\text{-}ending_{ijt} + \beta_2 previous - 9\text{-}ending_{ijt} \times price\text{-}\mathrm{decrease}_{ijt} + \mathrm{X}_{ijt}\gamma + \mathrm{u}_{ijt} \qquad (5)$$

where the dependent variable, $\%\ price\text{-}change_{ijt}$, is the percentage price change of a good i in store j in week t. The main independent variables are the *previous-9-ending* dummy, and its interaction with the *price decrease* dummy.[19] Table 6 reports the model estimation results.

As expected, the coefficient of *previous-9-ending* is positive (β = 0.05, $p < 0.01$), while the coefficient of the interaction of *previous-9-ending* with *price decrease* is negative (β = –0.07, $p <$ 0.01). Thus, consistent with the findings discussed above that 9-ending prices are more rigid upward than downward, we also find that when 9-ending prices increase, they increase by 5% more than the expected price change of non-9 ending prices. When 9-ending prices decrease, they decrease by 7% less than the expected price change of non-9 ending prices. The expected change when 9-ending prices increase is, therefore, 5%+7%=12% larger than when 9-ending prices decrease. The difference is statistically significant ($F = 23.1, p < 0.01$).

3.3.5. 9-ending price increases and consumer inattention

An alternative explanation for our findings in the lab experiment and in the field study, is that consumers are inattentive to increases in 9-ending prices, if these tend to be small. Indeed, since processing price information is cognitively demanding and time-consuming, consumers could

[19] Controls are *price level*, the *absolute value of % change in the wholesale price*, dummies for *sale prices* in the *current* and *previous week*, and *store* dummies. The sale price dummies are included as both the drop to a sale price and the bounce-back, likely differ from other price changes. The wholesale price is included since retail price changes is likely to be correlated with it (Anderson et al 2017, McShane et al 2016). We exclude the observations with wholesale price changes of 200% or more.

ignore price changes, if they expect these changes to be small (Mullainathan and Banerjee 2008).

However, according to the data, the average absolute (percentage) price increase when the new price is 9-ending is \$0.46 (25.5%), which is larger than the average price increase when the new price is not 9-ending, \$0.34 (23.2%). The differences are statistically significant at 1%: for absolute price increases t = 350, and for % price increases t = 58.1.

As a further test, we check whether or not the price increase is smaller when the new price is 9-ending, in comparison to a situation where the new price ends with some other digit. For this purpose, we run the following linear regression model:

$$price\text{-}increase_{ijt} = \alpha + \beta 9\text{-}ending_{ijt} + X_{ijt}\gamma + u_i \qquad (6)$$

where the dependent variable, $price\text{-}increase_{ijt}$, is the price-increase of a good i in store j in week t. The main independent variable is *9-ending*, which equals 1 if the price after the increase is 9-ending and 0 otherwise. The matrix of controls X includes fixed effects for the store, the year, and the UPC. We estimate this regression twice. In the first, *price-increase* is measured in absolute terms (dollars). In the second, *price increase* is measured in relative terms (percents).

The results (see Table 15A in Online Appendix T) show that in the regression of absolute price increase, the coefficient estimate of *9-ending* is 0.014 (p < 0.01). This suggests that when the new price is set at a 9-ending, the expected price increase is 1.4¢ larger than when the new price is set at a different ending. In the regression of relative price increases, the coefficient estimate of *9-ending* is 0.015 (p < 0.01), meaning that when the new price is set at a 9-ending, the expected price increase is 1.5% larger than when the new price is set at a different ending.

Thus, both regressions suggest that the price increase is larger when the new price (that is, the price following the increase) is set at a 9-ending, in comparison to the situation where the new price is set at some other ending. Therefore, consumers should not have any less incentive to pay attention to 9-ending price increases. To the contrary, they should be paying more attention to 9-

ending price increases, which is counter to the above competing hypothesis.

3.4. Evidence from the Israeli supermarkets and drugstores

As a further test, we use Entry-Level-Item (ELI) supermarket and drugstore data collected by the Israeli Central Bureau of Statistics (CBS) for CPI compilation. Since the field data in section 3.2 came from Israel, for robustness it is useful to show that the results that hold for the US data, hold for the Israeli data as well, which would suggest a broader relevance of our findings.

The data from January 2002–December 2013, include 190,807 monthly price observations for 11,313 different goods in 99 product categories, as well as the type of the stores, and the district where the stores are located. The minimum price in the sample is NIS 0.45 ($0.11) and maximum NIS 999.99 ($250). The average price is NIS 22.83 ($5.71), and the standard deviation is 55.07.

The share of 9-ending prices in the Israeli price data is 65.5%, which is similar to the proportion found in the Dominick's data, suggesting that 9-ending prices are as prevalent in Israel as in the US.[20] The CBS data does not contain information on wholesale prices or sales, and thus we cannot replicate the above tests exactly. We can nevertheless assess asymmetric rigidity of 9-ending prices by estimating the same type of regressions as we estimated above.

3.4.1. Transition probability analysis: asymmetric transition of 9-endings

Table 7 reports 10-state Markov chain transition probability matrix for price increases and decreases for the last digit, conditional on a price change. The figures on the diagonals suggest that the probability of a 9-ending to remain a 9-ending exceeds the probability that any other ending will remain unchanged. Thus, at the Israeli retail chains as at Dominick's in the U.S., 9-endings are more rigid than other endings.[21] In addition, looking at the table rows, we see again that after a price change, the new price ends with 9 more often than with any other digit.

The last columns of the two panels of Table 7 indicate that a larger proportion of the prices

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[20] Figure 2A in Online Appendix Y shows the frequency distribution of the last digit in the Israeli supermarket & drugstore prices.

[21] Figures 1A and 1B in Online Appendix Q show the probability that a price with a given end-digit will end with the same digit following a price increase and decrease, for Dominick's and for the Israeli supermarket and drugstore chains, respectively.

end with 9 after price increases than after price decreases. In particular, the probability is higher for a 9-ending price to remain a 9-ending following an increase than following a decrease, 83.22% vs 81.56%. Moreover, this difference is statistically significant ($z = 4.4$, $p < 0.01$). Thus, new prices at Israeli retail outlets are more likely to end with 9 after price increases than after price decreases, similar to the findings for Dominick's in the U.S., as discussed in section 3.3.1.

3.4.2. Asymmetric rigidity of 9-endings

To assess the asymmetry in the rigidity of 9-endings more formally, we estimate the regression equation given in (3). The dependent variable is a dummy, which equals 1 if the new price ends with 9, and 0 otherwise. The main independent variable is *price-decrease*.[22]

The estimation results reported in Table 8 show that the coefficient estimate of *previous*-9-*ending* is positive ($\beta_2 = 0.40$, $p < 0.01$), implying that 9-ending prices are 40% more likely to end at 9 than other endings after a price change. However, the coefficient estimate of price decrease ($\beta_1 = -0.03$, $p < 0.01$) is negative and significant. We thus conclude that in Israel, as in the US, we are more likely to see 9-endings following price increases than following price decreases.

3.4.3. Asymmetric rigidity of 9-ending prices

Looking first at the descriptive statistics, we find that the percentage of price increases (decreases) of 9-ending prices, 17.9% (14.6%), is larger than the percentage of price increases (decreases) when the price is not 9-ending, 17.3% (12.0%). However, we shall note that unlike the Dominick's data, where we have a single retailer, with a single store format, carrying 29 product categories, and operating in the same area, the Israeli data covers multiple chains, in multiple store formats (supermarkets/drugstores), covering 99 product categories, and operating in different parts of Israel. This variation introduces considerable heterogeneity in the Israeli data.

To test whether or not 9-ending prices are more rigid upward than downward, therefore, we need to control for this heterogeneity in the data. We estimate a multinomial-logit regression

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[22] Controls include *previous-9-ending*, *price level*, absolute value of *price change*, and product *category* and *district* dummies.

model of the probability that a 9-ending price will increase, decrease or remain unchanged, as in regression equation (4). Similar to section 3.3.3, the dependent variable is an index variable, which equals 0/1/2 if the price has remained unchanged/decreased/increased, respectively. The main control variable is *previous-9-ending* (1 if the price in the previous month was 9-ending).[23] The model estimation results are reported in Table 9.

The coefficient estimates of *previous-9-ending* are both negative, suggesting that 9-ending prices are more rigid than other prices. However, they are more rigid upward ($\beta_2 = -0.34, p < 0.01$) than downward ($\beta_1 = -0.28, p < 0.01$). The difference is statistically significant ($\chi^2 = 3.8$, $p < 0.05$). Thus, once we control for the heterogeneity in the data, we find that in the Israeli retail price data, like in the U.S. retail price data, the rigidity of 9-ending prices is asymmetric.

Setting all variables equal to their average values and setting all the dummies to zero, we find that compared to a non 9-ending price, a 9-ending reduces the likelihood of a price increase from 19.9% to 15.5%, a reduction of 22.4%. In contrast, compared to a non 9-ending price, a 9-ending reduces the likelihood of a price decrease from 10.3% to 8.5%, a reduction of 17.6%. As in the US, therefore, the effect of 9-endings is larger on price increases than on price decreases.

3.4.4. Asymmetry in the size of price changes

Next, we test the differences between the size of price increases and price decreases when a price is 9-ending. As expected, the average increase of a 9-ending price, 28.2%, exceeds the average decrease, 20.0% ($t = -28.4$, $p < 0.01$). As a formal test, we estimate the regression model in equation (5), where the dependent variable is the absolute value of the percentage price change. As the independent variables, the regression includes *previous-9-ending* and its interaction with *price decrease*, *price-level*, and dummies for product *categories* and for *district*s.

The estimation results, reported in Table 10, suggest that when 9-ending prices increase, they

[23] The matrix of controls *X* includes *price level*, and dummies for product *categories*, and for the *districts*.

increase by 5% more than the expected change in non 9-ending prices. The interaction of *9-ending* with *price decrease* is negative (β = –0.09, p < 0.01). Thus, when 9-ending prices decrease, they decrease by 9% less than the expected change in other prices. The results are, therefore, similar to the results we obtained for the Dominick's data: The expected increase in a 9-ending price is 5%+9%=14% larger than the expected decrease in a 9-ending price. The difference is statistically significant ($F = 7.7, p < 0.01$).

3.4.5. 9-ending price increases and consumer inattention

As in the case of Dominick’s, we next explore the link between the size of price increases and 9-endings, to assess the possibility that people are inattentive to increases in 9-ending prices because these tend to be small. In the Israeli data, the descriptive statistics provide conflicting evidence: The average absolute (percentage) price increase, NIS3.3 (26.4%), is smaller (larger) when the new price is 9-ending than when the new price is not 9-ending, NIS4.4 (21.8%). The differences are statistically significant at 1%: for absolute price increases, t = 4.2, and for % price increases, t = 5.2.

Therefore, to formally assess whether or not 9-ending price increases are smaller than the increases of prices with other endings, we estimate regression equation (6). The dependent variable, $price\text{-}increase_{ijt}$, is the price-increase of a good i in store j in week t. The main independent variable is *9-ending*, which equals 1 if the price is 9-ending and 0 otherwise.[24] We estimate this regression twice. In the first, *price-increase* is measured in absolute terms (in NIS). In the second regression, *price increase* is measured in relative terms (in percent).

The estimation results (reported in Table 15B in Online Appendix T) indicate that in the regression of absolute price increases, the coefficient estimate is positive, although not statistically significant ($\beta = 0.31, p > 0.10$). In the regression of relative price increases, the

[24] The matrix of controls X includes dummies for the *year* and for the product *categories*.

coefficient estimate is negative but statistically not significant ($\beta = -0.01, p > 0.10$).

Therefore, the results for the Israeli data suggest that there is no difference between the price increase when the new price (the price following the increase) is set at a 9-ending, and when the new price is set at some other ending. Thus, in Israel as in the U.S., consumers do not have less incentive to pay attention to increases in 9-ending prices, in comparison to other prices.

4. Robustness

We run numerous robustness tests and analyses, which are discussed in detail in online appendices as follows. (1) We check if the results we report in Table 1 are robust to dropping most of the controls and leaving only the *9-ending* and *0-ending* dummies, and their interactions with the dummy for the *price-comparison* treatments (Appendix W). (2) We check if the results we report in Table 1 and Table 2 are robust to different estimation strategies. For that purpose, we estimated all the regressions discussed in Sections 3.1.2 and 3.1.3 again using (a) fixed effects, (b) pooled OLS, and (c) probit. The results of these analyses are presented and discussed in Appendix J and Appendix K, respectively. (3) We check if the results we report for Dominick's transaction prices also hold for regular prices. Note that in Dominick's data, 9-endings are more likely to be regular prices than sale prices, as the figures in Table 14A in Appendix O indicate. It is possible, therefore, that the asymmetric rigidity of 9-ending prices that we are documenting, is primarily driven by 9-ending regular prices going down to non 9-ending sale prices. To control for this possibility, we repeated all the tests and analyses after excluding the sale prices and their bounce-backs to regular prices. To identify the sale prices, we used the Dominick's sales indicator variable, which is included in the Dominick's dataset. These results are discussed in Appendices L–N. (4) In Appendices M and N, we also test whether the results are robust to the inclusion of outlier observations of the wholesale prices.[25] (5) We check whether our results are

[25] We repeat these analysis using probit models to estimate equations (3)–(5). See Online Appendices E and F.

driven by inflation, since Chakraborty et al. (2015) find that retailers try to camouflage price increases during inflationary periods. This might be relevant in our case because during the sample period covered by the Dominick's data (i.e., 1989–1997), the U.S. experienced a moderate inflation, with an annual inflation rate between 5% (the first year of the sample) and 2.5% (the last year of the sample). These results are discussed in Appendices D and V. (6) It is well-known that Dominick's sale indicator variable is incomplete (Peltzman 2000, Dominick's User Manual 2013). As a further test, therefore, we repeat (3)–(5) again, but this time using the sale filter of Nakamura and Steinsson (2008, 2011). Following their algorithm, we categorize a price as a sale price if the price first decreases, stays at the low level for up to four weeks, and then bounces back to a price that is equal or higher than the pre-sale price. The results of these estimations are reported in a series of tables and accompanying discussions, in Appendix D,[26] and in Appendices L–N. (7) There is also a possibility that our results for the Dominick's data are affected by the removal of the end–points, and by missing observations. We therefore interpolate the missing price observations in the Dominick's data using the preceding values, i.e., we set a price missing in week t to equal its value in week t–1. This expands the dataset from 81,982,683 to 94,695,300 observations. The results of the estimations using the expanded (i.e., interpolated) dataset are reported in Appendix D. Additional robustness tests using Dominick's data include: (8) An analysis of the probability of a change in the right-most digit (Appendix G). (9) A comparison of the levels of 9-ending and non 9-ending prices (Appendix H). (10) A test of whether or not non 9-ending prices also exhibit asymmetric rigidity (Appendix U). Finally, (11) we also assess the possibility that the results for the Israeli CPI data are affected by inflation, or by possible changes in the pricing strategy over time, which we capture by adding a linear time trend to the regression (Appendix I). (12) In Appendices I, P, R and S, we examine whether the

[26] In these analyses, we use a probit regression model for estimating regression equations (3)–(5).

results for the Israeli supermarkets and drugstores also hold for regular prices using a sale filter of Nakamura and Steinsson (2008, 2011). (13) Using the field study data, we study the consumers' recall of price changes by analyzing the probability of responding that the price has decreased or increased relative to responding that it has remained unchanged (Appendix C). The findings we report in all these appendices are all consistent with the results reported in the paper.[27]

5. Conclusions and implications for macroeconomics

We document asymmetric adjustment of 9-ending prices using four datasets. In two different retail price datasets (one from the U.S. and another from Israel), we find that 9-ending prices are more rigid upward but not downward, in comparison to non 9-ending prices. The lab experiment and the field data suggest that the asymmetry is due to consumers' use of 9-endings as a signal for low prices. Retailers seem to take advantage of the consumers' heuristic processing of 9-ending price information, by strategically keeping prices at 9-endings more often after price increases than after price decreases, leading to the asymmetric rigidity of 9-ending prices.

This finding is important for several reasons. First, 9-ending is a dominant feature of many retail prices, a fact that has been mostly ignored by macroeconomists until very recently. In our data, 62%–65% of the prices end with 9. Some studies report even higher figures. Anderson et al. (2015), for example, find that over 95% of the prices in their data are 9-ending. Moreover, Levy et al. (2011) show that 9 is the most frequent ending at the penny, dime, dollar and ten-dollar digits in the traditional retail price data, as well as in the internet price data they study.

Second, studies using micro-level data report that 9-ending prices are far more rigid than other prices, which should be of interest to macroeconomists in light of the prevalence of the 9-ending prices. With the exception of Kashyap (1995) and Blinder et al. (1998), however, much of the sticky price literature ignores this by relying almost exclusively on menu cost to generate price

[27] Consider the following observation: in the 90 tables we present (80 in Online Appendices, 10 in the paper), only two coefficients are inconsistent with our predictions. These are the coefficients of the interaction term of *9-ending* dummy and *price decrease*, in Tables 6a' and 6a''', both in Online Appendix D.

rigidity. Indeed, recent studies note the importance of the rigidity of 9-ending prices. Anderson, et al. (2015), for example, call for greater attention of macroeconomists to 9-ending prices.

Third, the asymmetry we document is interesting because it is opposite to the standard Keynesian asymmetry, which is usually characterized by "prices that are sticky downward but not upward" (Ball et al. 1988, p. 12). We report the exact opposite: we find that 9-ending prices are more rigid upward than downward, which is surprising and worthy of our attention.

Fourth, our findings add to the growing literature on strategic retail pricing and its effects on inflation. For example, Chakraborty et al. (2015) study pricing at British supermarkets and find that while basket prices rose, many individual prices fell. The frequent small price cuts, they conclude, "were used to disguise the basket price increases" (p. 71). Using data for a US retailer, Anderson, et al. (2017) find that discounts increase when regular prices increase in response to a wholesale price increase. They conclude that the retailer is "trying to mask the associated regular price increase" (p. 3). Thus, in these studies, the retailers deliberately disguise their basket price increases by frequent sales and small price cuts, as to not antagonize customers (Rotemberg 2005, Blinder et al 1998).[28] The retailers we study also seem to follow a strategy of "hiding" price increases, but they choose to adopt a different tactic. They use 9-endings to mask price increases by taking advantage of consumers' mental and cognitive constraints that limit their ability to fully process price and price change information, and their tendency to interpret 9-ending prices as low prices. The outcome, however, is similar: there are discrepancies between the price changes as perceived by consumers and the actual price changes implemented by the retailers.[29]

[28] Frequent small price decreases to conceal overall basket price hike that Chakraborty et al (2015) find, seems counter to the evidence of Chen et al (2008) who find frequent small price increases, which they explain by consumer inattention to small price changes. Using a game theoretic model, Chakraborty et al (2015) show that both strategies ("many small price cuts with few large price hikes," and "many small price hikes with few large price cuts") are Nash equilibria, and thus theoretically possible.

[29] These findings are in line with the key point of Akerlof and Shiller (2015, pp. vii, 1): "…our free-market system tends to spawn manipulation and deception…if we have some weakness…in the phishing equilibrium someone will take advantage of it." 9-ending pricing can be a fooling-equilibrium where consumers rely on 9-endings as a signal for low prices and retailers respond by setting/keeping 9-endings after price increases. Retailers gain because this enables them to conceal price increases while shoppers gain by saving the costs of cognitive efforts ("thinking costs," Shugan 1980) needed for noticing and assessing price changes.

The work ahead is challenging, particularly on the theory front. As far as we know, Knotek (2016) is the only study that considers theoretically the macroeconomic implications of 9-ending prices. He shows that in a model that contains both menu cost and 9-ending prices, menu cost plays a marginal role as a source of price rigidity, once the profit benefit of 9-ending prices is allowed, which is significant because menu cost has been the leading explanation for price rigidity (Anderson et al. 2015). He finds that the model generates movements in output distinct from those of the simple menu cost model. In light of these findings, the asymmetry in the rigidity of 9-ending prices that we document can potentially have macroeconomic significance.[30]

The existing empirical evidence (e.g., Cover 1992) suggests that expansionary monetary policy has a stronger impact than a contractionary monetary policy, which can be explained by the traditional downward price rigidity (e.g., De Long and Summers 1988, Ball and Mankiw 1994). Our findings suggest that in a model that incorporates 9-ending prices with asymmetric rigidity, this Keynesian type asymmetric effect of monetary policy will likely be weaker (if not reversed), because the asymmetry we are documenting here is in the opposite direction.

Future work should therefore explore ways of incorporating 9-ending price phenomenon in macroeconomic/monetary economy models, by constructing dynamic stochastic general equilibrium models that incorporate structural motives for the optimality of 9-ending prices. This is challenging since our findings suggest that consumers use 9-ending as a heuristic for low prices.[31] Whatever the motive for the use of 9-endings, however, the finding that 9-endings affect consumers' price perceptions by lulling them into thinking that 9-ending prices are lower than they actually are, can lead to kinks or discontinuities in the demand function, which would be

[30] Knotek's model, however, is set in a partial equilibrium framework, where revenues or demand have no structural role. In addition, he does not model or derive optimal price setting policy, etc. His model is also agnostic about the reason for the use of 9-ending prices, and thus the model does not explain why retailers choose 9-ending pricing.

[31] Other explanations for the use of 9-ending prices also rest on some form of heuristics. E.g., consumers might truncate the last digit or round prices up/down, etc. (Schindler and Kirby 1997, Schindler 2001, 2006, Stiving and Winer 1997, Stiving 2000, Monroe and Lee 1999). Basu (1997) is an exception: he shows that 9-ending prices can be a rational expectations equilibrium.

present in the firm's profit function as well.[32]

Besides confronting the resulting technical challenges, such models would have to confront the stylized facts of Klenow and Malin (2011) and others, as well as some of the facts that we are documenting here about the asymmetric rigidity of 9-ending prices. These models, when available, will enable us to assess the aggregate dynamics that 9-ending prices might generate, and consequently, help us understand the implications of the rigidities and the asymmetries that 9-ending prices generate, for monetary policy and for macroeconomics.

[32] The overrepresentation of 9-ending prices cannot be the outcome of Benford law, which argues that in naturally occurring data, the distribution of left-most-digits (LMD) is logarithmic, not uniform (Varian 1972). E.g, the $p(\text{LMD} = 1) = \log 2 = 0.3$, $p(\text{LMD} = 2) = \log 3/2 = 0.17$, etc. This was discovered by Newcomb (1881), who noticed that in public libraries, the pages of logarithm tables containing numbers starting with 1 were more worn out than other pages. Benford (1938) confirmed these findings. Under the Benford law, the probability of digits approaches uniform distribution as we move from left to right. For the second left-most digits the skew is from 12% for 0, down to 8.5% for 9. Nigrini (2002) shows that the last 2-digits are equally likely for each combination from 00 to 99 in 3-digit and higher numbers. Benford law, thus, cannot explain the phenomenon of 9-ending prices.

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Table 1
Probability of a correct answer – lab experiment

	(1) All observations	(2) Equal prices	(3) Unequal prices
9-Ending	−0.001 (0.004)	-0.007 (0.007)	0.02 (0.015)
Price Comparison×9-Ending	−0.01 (0.005)**		
Bigger-9-Ending			−0.04 (0.016)**
Right-Most	−0.08 (0.022)***		
Middle	−0.05 (0.023)**		
Left-Most	−0.04 (0.020)*		
Constant	0.94 (0.028)***	0.97 (0.021)***	0.92 (0.033)***
N	55,346	5,982	20,905
χ^2	196.2***	10.3	51.3***

The table reports estimation results of a linear model with random effects for the probability of a correct answer. The dependent variable is the *accurate* dummy (1 if the answer is correct, 0 otherwise). Its average equals 0.89. The independent variables are the dummies 9-*ending* (1 if at least one of the prices compared ends in 9), *Price-comparison* (1 if participants had to compare prices), *Bigger* 9-*ending* (if the bigger of the two prices/numbers compared ends with 9), and location dummies *Right-most/Middle/Left-most* (1 if the two prices/numbers compared differed in their right-most/middle/left-most digits, respectively). Other controls are *Find-small* (1 if participants had to identify the smaller of the two prices/numbers), *3-digits* (1 if the prices/numbers compared were 3-digit), 0-*ending* (1 if at least one of the prices/numbers compared ended in zero), *Female* (1 for women), *Low shopping frequency* (1 if the participant reported shopping once a month or less), all the interactions of *price-comparison*, *find-small* and *3-digits*, the interactions of the location dummies with *price-comparison* and with *find-small*, and the interaction of *low shopping frequency* and *price-comparison*. Column (1) uses all observations. Column (2) uses observations on equal prices. Column (3) uses observations on unequal prices. Standard errors, clustered at the participant level, are reported in parentheses. * p < 10%, ** p < 5%, and *** p < 1%. See Table 1A in Online Appendix J for more details.

Table 2
Probability of a correct answer – field study

	All observations	Price increases		Price decreases	
	(1)	(2)	(3)	(4)	(5)
9-Ending	−0.07 (0.015)***	−0.11 (0.051)**		−0.01 (0.057)	
From 9 to 9			−0.05 (0.061)		−0.06 (0.080)
From other to 9			−0.22 (0.073)***		−0.01 (0.090)
From 9 to other			0.05 (0.074)		−0.09 (0.097)
Right-Most	0.10 (0.020)***	0.15 (0.039)***	0.16 (0.040)***	0.11 (0.045)**	0.11 (0.047)**
Middle	−0.20 (0.028)***	−0.08 (0.046)*	−0.12 (0.050)**	−0.45 (0.051)***	−0.44 (0.054)***
Left–Most	0.09 (0.025)***	0.11 (0.033)***	0.11 (0.032)***	−0.01 (0.037)	−0.01 (0.038)
Intercept	0.76 (0.030)***	0.28 (0.087)***	0.28 (0.091)***	0.42 (0.087)***	0.45 (0.095)***
N	6,031	639	639	581	581
χ^2	640.0***	124.5***	135.3***	562.8***	560.7***

The table reports estimation results of linear models with random effects for the probability of a correct answer. The dependent variable is the *accurate* dummy (1 if the answer is correct and 0 otherwise). Its average equals 0.65. The independent variables are dummies *9-ending* (1 if at least one of the prices ends in 9), *From 9 to 9* (1 if both the previous and the current prices end in 9), *From other to 9* (1 if the previous price didn't end in 9 and the current one does), *From 9 to other* (1 if the previous price ended in 9 and the current one does not), and *Right-most*/*Middle*/*Left-most* (1 if the two prices/numbers compared differed in their left-most/middle/right-most digit). Regressions (2)–(5) also include the following controls: *Female* (1 for women), *Ultra-Religious* (1 if the consumer is orthodox), *Academic degree* (1 if the consumer has academic degree), *More than one trip a week* (1 if consumer reported making more than one shopping trip a week), *More than NIS 300/shopping trip* (1 if the consumer spends more than NIS300.00 (about $70) per shopping trip on average), *Older than 55* (1 if 55 or older), *Price increase/decrease* (1 if the price increased/decreases relative to the previous week), *Previous price* (the price of the good in the previous week), and *Relative size of the price change* (the absolute percentage change in the price). Column (1) uses all observations. Columns (2) and (3) use only observations on price increases. Column (2) uses one dummy, *9-ending*, to control for 9-ending prices. Column (3) splits the *9-ending* dummy into three dummies (*from 9 to 9*, *from other to 9*, and *from 9 to other*). Columns (4) and (5) are similar to (2) and (3) but for price decreases. Standard errors, clustered at the participant level, are reported in parentheses. * p < 10%, ** p < 5%, and *** p < 1%. See Table 2A in Online Appendix K for more details.

Table 3
10-State Markov chain transition probability matrix for price increases and decreases by last digit, conditional on a price change, from starting last digit to ending last digit – Dominick's

A. Price increases										
	To									
From	0	1	2	3	4	5	6	7	8	9
0	5.560	4.900	5.850	5.040	5.850	13.84	3.540	3.470	2.090	49.86
1	3.800	2.510	6.430	8.010	4.420	15.45	3.350	3.480	1.830	50.71
2	4.390	2.880	3.770	6.970	5.600	15.79	3.910	4.020	2.430	50.25
3	5.590	2.650	2.360	5.410	6.190	15.54	4.270	5.240	3.160	49.59
4	3.950	2.090	2.740	2.750	3.110	12.30	4.810	4.370	2.430	61.45
5	8.170	3.000	2.920	3.470	2.620	12.85	5.960	6.630	4.030	50.35
6	5.180	3.250	4.660	3.720	4.550	9.890	2.650	9.320	4.000	52.79
7	5.510	3.770	4.240	4.580	3.180	12.41	2.130	4.880	4.080	55.22
8	6.840	6.140	4.550	6.390	3.620	13.67	3.170	3.250	3.720	48.66
9	6.660	4.070	3.880	4.210	4.350	7.780	2.480	3.220	1.700	**61.65**
B. Price decreases										
	To									
From	0	1	2	3	4	5	6	7	8	9
0	10.18	3.000	3.300	5.210	4.180	10.68	5.490	3.770	3.120	51.06
1	12.52	2.730	3.610	4.260	4.030	8.180	6.010	5.110	5.700	47.86
2	14.32	7.220	3.500	3.230	4.720	7.310	9.050	5.240	3.270	42.14
3	10.24	9.390	5.670	5.810	3.920	6.760	5.260	5.400	3.940	43.61
4	12.63	4.730	5.720	6.600	4.910	5.910	6.570	3.980	2.390	46.56
5	11.33	5.610	6.170	8.050	6.340	7.830	5.690	5.680	3.280	40.01
6	9.360	5.400	5.470	7.330	10.73	9.270	4.730	3.850	2.770	41.08
7	7.060	3.810	4.180	6.350	9.610	10.57	11.81	4.430	2.180	40.02
8	7.780	3.610	4.710	6.980	9.650	12.89	9.970	8.380	4.210	31.82
9	8.650	3.080	2.670	3.980	6.200	6.440	5.910	4.460	2.060	**56.55**

Table 4
Probability that a new price ends with 9 – Dominick's

Price Decrease	−0.06 (0.004)***
Previous 9-Ending	0.09 (0.005)***
Price Level	0.02 (0.002)***
Price Change	0.0008 (0.00004)***
Constant	0.43 (0.007)***
R^2	0.03
N	20,839,462

The table reports the results of a linear regression for the probability that a new price ends with 9, conditional on a price change. The dependent variable is a dummy that equals 1 if the post-change price is 9-ending and 0 otherwise. The average of the dependent variable is 0.54. *Price decrease* is a dummy that equals 1 if the price change is negative. *Previous-9-ending* is a dummy that equals 1 if the pre-change price was 9-ending. *Price level* is the price without the penny digit. *Price change* is the absolute value of the price change. The regression also includes the *store* dummies (not reported). *** $p < 1\%$. Standard errors, clustered at the UPC level, are reported in parentheses.

Table 5
Probability of price increases and decreases relative to the price remaining unchanged – Dominick's

	Price decreases	Price increases
Previous 9-Ending	−0.17 (0.016)***	−0.44 (0.013)***
Absolute Value of % Change in Wholesale Price	8.26 (0.118)***	7.35 (0.113)***
Sale Price Indicator in Previous Week	0.35 (0.015)***	3.01 (0.015)***
Price Level	−0.15 (0.011)***	0.08 (0.005)***
Constant	−1.62 (0.030)***	−3.00 (0.019)***
χ^2	151,654.2***	
N	81,734,333	

The table reports estimation results of a multinomial-logit probability model of a price decrease/increase relative to the prices remaining unchanged. The dependent variable is an index variable and equals 0/1/2 if the price remained unchanged/decreased/increased. The controls are *Previous-9-ending* (1 if the price was 9-ending), *Absolute value of % change in wholesale price*, *Sale price indicator in previous week* (1 if it was on sale), and *Price level* (price minus the penny digit). *** $p < 1\%$. Standard errors, clustered at the UPC level, are reported in parentheses.

Table 6
The size of a 9-ending price change – Dominick's

Previous 9-Ending	0.05 (0.003)***
Previous 9-Ending × Price-Decrease	−0.07 (0.003)***
Price Level	0.0005 (0.0009)
Absolute Value of % Change in Wholesale Price	0.55 (0.017)***
Sale Price Indicator in Previous Week	0.04 (0.002)***
Sale Price Indicator	0.002 (0.002)
Constant	0.13 (0.004)***
R^2	0.06
Number of Observations	20,601,077

The table reports estimation results of a linear regression of the % price change, conditional on a price change. The dependent variable is the absolute % price change (average = 0.22). The independent variables are *previous-9-ending* (1 if the pre-change price was 9-ending), *price-decrease* (1 if the price change is negative), the *absolute value of the % change in the wholesale price*, *sale price indicator in previous/current week* (1 if the good was on sale in the previous/current week), and store dummies. *** $p < 0.01\%$. Robust standard errors, clustered at the UPC level, are reported in parentheses.

Table 7
10-State Markov Chain Transition Probability Matrix for Price Increases and Decreases by Last Digit Conditional on Price Change, From Starting Last Digit to Ending Last Digit – Israeli Supermarkets and Drugstores

A. Price Increases

From	To 0	1	2	3	4	5	6	7	8	9
0	46.160	0.774	1.162	0.904	0.855	9.519	0.645	0.419	0.565	38.996
1	14.362	4.787	2.128	15.957	4.255	15.426	5.319	10.106	3.723	23.936
2	12.030	2.256	7.143	4.511	4.511	21.053	4.511	6.015	2.256	35.714
3	14.539	1.418	4.610	1.773	3.191	10.284	5.319	7.801	10.993	40.071
4	8.031	2.850	4.145	5.440	4.663	10.104	2.073	2.332	3.627	56.736
5	15.649	1.013	0.767	0.338	0.368	49.923	1.258	0.736	1.013	28.935
6	13.475	2.128	5.674	9.574	5.674	7.801	2.837	3.191	3.546	46.099
7	9.504	7.438	2.893	8.264	4.132	13.636	2.066	4.959	3.719	43.388
8	7.372	2.564	1.603	4.167	5.449	6.090	2.244	6.410	1.923	62.179
9	9.798	0.407	0.600	0.497	0.828	3.169	0.551	0.421	0.510	83.219

B. Price Decreases

From	To 0	1	2	3	4	5	6	7	8	9
0	50.276	0.212	0.212	0.127	0.191	7.958	0.191	0.255	0.233	40.344
1	41.284	6.422	0.917	1.835	3.670	3.670	1.835	4.587	1.835	33.945
2	32.824	7.634	4.580	4.580	3.053	4.580	0.763	4.580	2.290	35.115
3	28.571	8.844	2.041	5.442	5.442	8.163	4.082	2.041	0.680	34.694
4	23.214	4.167	3.571	2.976	9.524	1.786	2.381	1.190	1.190	50.000
5	17.586	0.449	0.987	0.987	1.211	55.182	0.583	0.404	0.314	22.297
6	20.979	1.399	7.692	8.392	3.497	14.685	4.895	1.399	4.196	32.867
7	21.849	5.042	4.202	2.521	7.563	16.807	3.361	4.202	0.000	34.454
8	28.906	0.781	1.563	3.125	1.563	10.938	13.281	4.688	6.250	28.906
9	12.841	0.154	0.154	0.291	0.725	2.730	0.434	0.346	0.769	81.558

Table 8

Probability that a new price ends with 9 – Israeli supermarkets and drugstores

Price Decrease	−0.03 (0.007)***
Previous 9-Ending	0.40 (0.012)***
Price Level	−0.0002 (0.0003)
Price Change	−0.00002 (0.0001)
Constant	0.33 (0.010)***
R^2	0.25
N	59,852

The table reports the estimation results of a linear regression for the probability that a new price ends in 9, conditional on a price change. The dependent variable is a dummy which equals 1 if the new price ends with 9, and 0 otherwise (average = 0.68). The controls are *Price decrease* (1 if a price change is negative), *Previous-9-ending* (1 if the pre-change price was 9-ending), *Price level* (price without the penny digit), the absolute value of *Price change*, and dummies for *product categories* and for *districts*. *** $p <$ 0.01. Robust standard errors, clustered at the product category level, are reported in parentheses.

Table 9

Probability of price increases and decreases relative to price remaining unchanged – Israeli supermarkets and drugstores

	Price Decreases	Price Increases
Previous 9-Ending	–0.28 (0.017)***	–0.34 (0.015)***
Price Level	–0.01 (0.001)***	0.003 (0.0003)***
Constant	–1.68 (0.087)***	–1.32 (0.061)***
χ^2	27,370.8***	
N	190,807	

The table reports the estimation results of a multinomial-logit regression of the probability of a price decrease/increase relative to the price remaining unchanged. The dependent variable is an index variable (0/1/2 if the price has remained unchanged/decreased/ increased, respectively). Controls are *Previous 9-ending* (1 if the pre-change price was 9-ending), *Price level* (price without the penny digit), dummies for product *categories* and for *districts*. *** p < 0.01. Robust standard errors, clustered at the product category level, are reported in parentheses.

Table 10

The size of 9-ending price change – Israeli supermarkets and drugstores

Previous 9-Ending	0.05 (0.008)***
Previous 9-Ending×Price-Decrease	–0.09 (0.015)***
Price Level	0.0007 (0.0001)***
Constant	0.06 (0.007)***
R^2	0.04
N	59,855

The table reports estimation results of a linear regression of the percentage price change, conditional on price change (average = 0.22). Controls are *Previous 9-ending* (1 if the pre-change price was 9-ending), *Price-decrease* (1 if the price change is negative), *Price level* (price without the penny digit), and dummies for product *categories* and for *districts*. *** $p < 0.01$. Robust standard errors, clustered at the product category level, are reported in parentheses.

Online Supplementary Appendix

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

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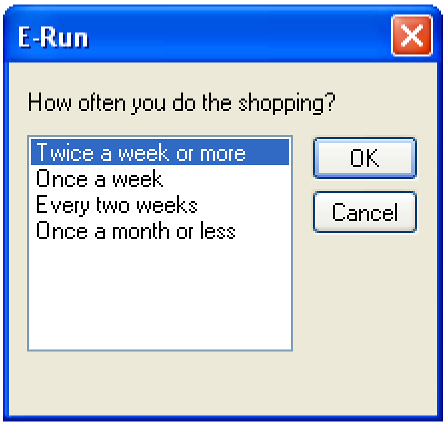
Appendix A. Description of the Lab Experiment

In this appendix, we provide a description of the lab experiment which was conducted at the Texas A&M University. We also present the instruction sheets that the participants read before they began the experiment. The experiment was fully computerized. We used *e-prime* to run the experiment.

In the first stage of the experiment, participants were asked to indicate their

1. Gender
2. Age
3. The frequency of shopping

Figure 1. A screenshot of the shopping frequency question



Next, participants were presented with the instructions (see below). We employed four treatments. In the first treatment, the participants were told that they will be shown pairs of *numbers* and that for each pair they will have to identify the *larger* of the two numbers.

In the second treatment, the participants were told that they will be shown pairs of *numbers* and that for each pair they will have to identify the *smaller* of the two numbers.

In the third treatment, the participants were told that they will be shown pairs of *prices* and that for each pair they will have to identify the *larger* of the two prices.

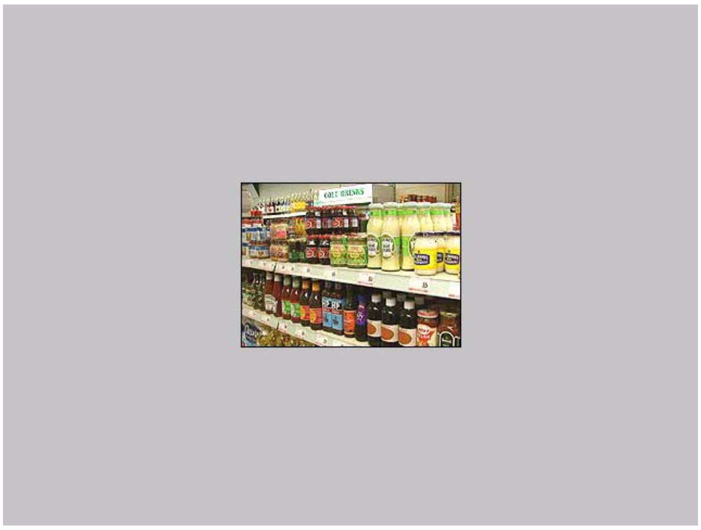
In the fourth treatment, the participants were told that they will be shown pairs of *prices*, and that for each pair, they have to identify the *smaller* of the two prices.

After participants read the instructions, they completed one practice block followed by four experiment blocks. Each block consisted of 75 number/price comparisons. Ten percent of the numbers/prices were 9-ending. The procedure we used for each comparison was as follows.

First, participants were presented with an image. In the two number treatment conditions, the image was of an abacus. In the two price treatments conditions, the image was of an aisle in a supermarket. The images appeared on the computer screen for 1,000 milliseconds.

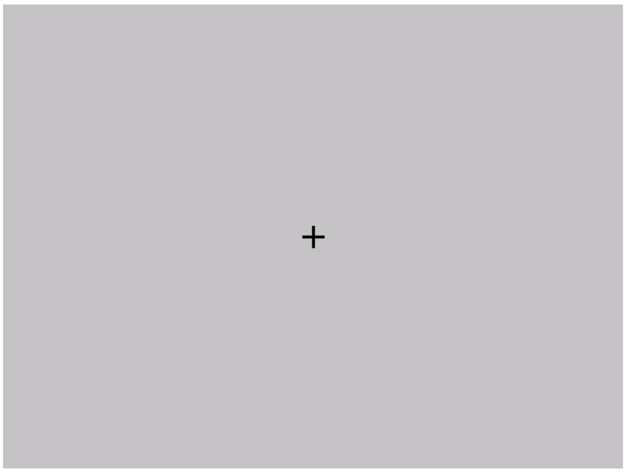
Figure 2. An abacus - the image shown in the number treatment

Figure 3. A supermarket aisle – the image shown in the price treatmen



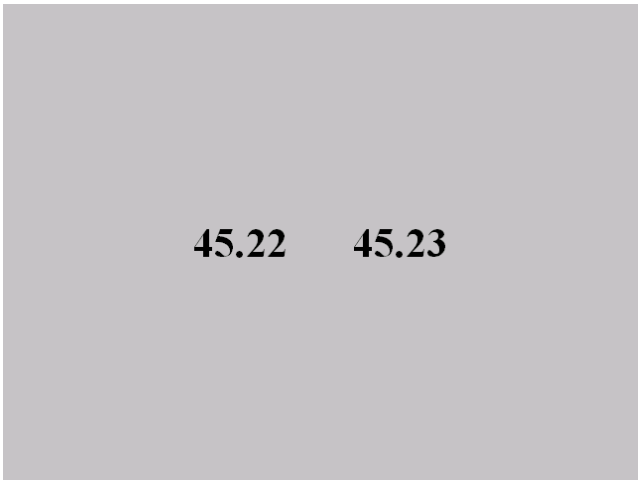
When the image disappeared, it was replaced by a fixation “+” sign in the middle of the screen for 500 milliseconds. When the "+" disappeared, a pair of numbers/prices appeared. In all treatment conditions, the numbers/prices appeared as pure numbers, without any signs (e.g. no “$” signs).

Figure 4. Fixation sign "+"



The pair of numbers/prices remained on the screen until the participant responded by pressing an appropriate key. After a participant responded, the pair of numbers/prices disappeared and another pair of numbers/prices appeared on the screen, etc., until the participant completed the block. Participants then had a break until they pressed a key and the next block began.

Figure 5. A pair of numbers/prices compared



Participants were told at the beginning of the experiment that 10 percent of them will be selected at random and paid according to their performance in the experiment blocks. Participants could earn up to $10 if they used less than 1 second to answer correctly all comparisons. At the end of the experiment, the computer calculated the <u>average</u> response time and the number of errors for each participant. They lost $5 for every second beyond the first and $1 for every incorrect response. For example, if a participant made two mistakes, and spent <u>an average</u> of 1.5 seconds per comparison, then s/he earned $10-[2\times 1+5\times(1.5-1)]=\$5.5$. The 1-second threshold was set based on a pre-test, which showed that on average 1 second was needed for a comparison. The average payment to participants selected was $5.10

Below we include the instruction sheets presented to the participants before they began each treatment. The manipulation for *finding large/small* was between subjects.

<u>**Note**</u>:

Each participant saw and read the instructions for either *finding large* or *finding small*, <u>but not both</u>.

Instruction Sheet – Number Comparison

Identify the Larger Number

Howdy!

The purpose of this experiment is to examine how people compare numbers.

Each comparison includes a pair of numbers, one on each side of your screen.

In some cases the numbers are the same; in other cases they are different. When the numbers are different, they differ in one digit only.

Your goal is to decide which of the two numbers is larger as fast and as accurately as you can.

If you think that the number on the LEFT is larger, press the "A" key.
If you think that the number on the RIGHT is larger, press the "L" key.
If you think that the two numbers are equal, press the SPACE bar.

Before each pair of numbers is presented, an image will appear on your screen to help you concentrate.

To reward you for your speed and accuracy, 10% of the participants will be randomly selected to each win up to $10 in cash. Specifically, at the end of the experiment, we will calculate the amount of time it took you to answer all the questions. You will have one second free of charge, but each additional second will cost you $5. In addition, every wrong judgment will cost you $1. Therefore, if you spend an average of 1.5 seconds on each judgment and you make a total of 2 wrong judgments during the experiment, you will receive $5.50.

Please enter your e-mail address below in case you win.

Your e-mail address: ___________

To familiarize yourself with how the experiment works, let’s start with a trial period. Your performance during this period will not be used to determine your payoff.

If you have any questions, please raise your hand and the lab administrator will be happy to help you.

If you don’t have any questions, press any key to start the trial period.

Instruction Sheet – Number Comparison

Identify the Smaller Number

Howdy!

The purpose of this experiment is to examine how people compare numbers.

Each comparison includes a pair of numbers, one on each side of your screen.

In some cases the numbers are the same; in other cases they are different. When the numbers are different, they differ in one digit only.

Your goal is to decide which of the two numbers is smaller as fast and as accurately as you can.

If you think that the number on the LEFT is smaller, press the "A" key.
If you think that the number on the RIGHT is smaller, press the "L" key.
If you think that the two numbers are equal, press the SPACE bar.

Before each pair of numbers is presented, an image will appear on your screen to help you concentrate.

To reward you for your speed and accuracy, 10% of the participants will be randomly selected to each win up to $10 in cash. Specifically, at the end of the experiment, we will calculate the average amount of time it took you to answer all the questions. You will have one second free of charge, but each additional second will cost you $5. In addition, every wrong judgment will cost you $1. Therefore, if you spend an average of 1.5 seconds on each judgment and you make a total of 2 wrong judgments during the experiment, you will receive $5.50.

Please enter your e-mail address below in case you win.

Your e-mail address: ___________

To familiarize yourself with how the experiment works, let’s start with a trial period. Your performance during this period will not be used to determine your payoff.

If you have any questions, please raise your hand and the lab administrator will be happy to help you.

If you don’t have any questions, press any key to start the trial period.

Instruction Sheet – Price Comparison

Identify the Larger Price

Howdy!

The purpose of this experiment is to examine how people compare product prices.

Each comparison includes a pair of prices, one on each side of your screen.

In some cases the prices are the same; in other cases they are different. When the prices are different, they differ in one digit only.

Your goal is to decide which of the two prices is larger as fast and as accurately as you can.

If you think that the price on the LEFT is larger, press the "A" key.
If you think that the price on the RIGHT is larger, press the "L" key.
If you think that the two prices are equal, press the SPACE bar.

Before each pair of prices is presented, an image will appear on your screen to help you concentrate.

To reward you for your speed and accuracy, 10% of the participants will be randomly selected to each win up to $10 in cash. Specifically, at the end of the experiment, we will calculate the average amount of time it took you to answer all the questions. You will have one second free of charge, but each additional second will cost you $5. In addition, every wrong judgment will cost you $1. Therefore, if you spend an average of 1.5 seconds on each judgment and you make a total of 2 wrong judgments during the experiment, you will receive $5.50.

Please enter your e-mail address below in case you win.

Your e-mail address: ___________

To familiarize yourself with how the experiment works, let’s start with a trial period. Your performance during this period will not be used to determine your payoff.

If you have any questions, please raise your hand and the lab administrator will be happy to help you.

If you don’t have any questions, press any key to start the trial period.

Instruction Sheet – Price Comparison

Identify the Smaller Price

Howdy!

The purpose of this experiment is to examine how people compare product prices.

Each comparison includes a pair of prices, one on each side of your screen.

In some cases the prices are the same; in other cases they are different. When the prices are different, they differ in one digit only.

Your goal is to decide which of the two prices is smaller as fast and as accurately as you can.

If you think that the price on the LEFT is smaller, press the "A" key.
If you think that the price on the RIGHT is smaller, press the "L" key.
If you think that the two prices are equal, press the SPACE bar.

Before each pair of prices is presented, an image will appear on your screen to help you concentrate.

To reward you for your speed and accuracy, 10% of the participants will be randomly selected to each win up to $10 in cash. Specifically, at the end of the experiment, we will calculate the average amount of time it took you to answer all the questions. You will have one second free of charge, but each additional second will cost you $5. In addition, every wrong judgment will cost you $1. Therefore, if you spend an average of 1.5 seconds on each judgment and you make a total of 2 wrong judgments during the experiment, you will receive $5.50.

Please enter your e-mail address below in case you win.

Your e-mail address: ___________

To familiarize yourself with how the experiment works, let's start with a trial period. Your performance during this period will not be used to determine your payoff.

If you have any questions, please raise your hand and the lab administrator will be happy to help you.

If you don't have any questions, press any key to start the trial period.

At the End of the Practice Block (All Treatments)

This is the end of the trial period.

Press any key to begin the experiment. There are a total of four blocks in the experiment. Your performance during all four blocks will be used to determine your payoff.

At the Beginning of Each of the Four Block of Trials (All Treatments)

To begin the next block, press any key to continue.

Appendix B. Description of the Field Study

The field study was conducted at three supermarkets in different cities in Israel. The surveyors, undergraduate economics students at Bar-Ilan University, approached shoppers as they were exiting the shops and asked them to participate in a survey.

If the shoppers' response was positive, then they were asked to look at a list of 52 products and mark those that they have purchased in both the current and the previous shopping trips.

For each product the shoppers marked, they were asked to indicate whether the price has increased, decreased or remained unchanged relative to the price on their previous shopping trip.

After responding to the questions on price changes of the products they have purchased, the shoppers were asked to answer several questions which were designed to help us learn about their socio-demographic background.

They were also given a list of supermarkets' attributes and were asked to rank on a scale from 1 to 5, how important the attributes were for them.

The survey was done in Hebrew, and thus the questionnaires were also in Hebrew. Below, we present an English translation of the questionnaire.

(1) Please respond only for the goods that you have purchased on both the current and previous visits to the supermarket

For each good that you have purchased, please indicate whether the good's price has: increased, decreased or remained unchanged.

Product Name	Product Price		
Milk 3% (in carton), Tnuva	Increased	Decreased	Unchanged
Hard Cheese, 32% fat, 200g, Emek	Increased	Decreased	Unchanged
Cheese 5%, 250g, Ski	Increased	Decreased	Unchanged
Chocolate Milk, 225ml, Yotvata	Increased	Decreased	Unchanged
Milky Pudding, 170ml, Strauss	Increased	Decreased	Unchanged
Cottage Cheese, 250g, Tnuva	Increased	Decreased	Unchanged
Tomatoes (Fresh), 1kg	Increased	Decreased	Unchanged
Cucumbers (Fresh), 1kg	Increased	Decreased	Unchanged

Red Bell Peppers (Fresh), 1kg	Increased	Decreased	Unchanged
Lemons (Fresh), 1kg	Increased	Decreased	Unchanged
Melons (Fresh), 1kg	Increased	Decreased	Unchanged
Cooking Oil, Sunflower, 1L, Milomor	Increased	Decreased	Unchanged
Persian Rice, 1kg, Sugat	Increased	Decreased	Unchanged
Spaghetti, 1kg, Perfecto	Increased	Decreased	Unchanged
Sugar, 1kg, Super Class (in paper bag)	Increased	Decreased	Unchanged
Salt, 500g, Melach-Yam	Increased	Decreased	Unchanged
Coca-Cola Diet, 6-pack, 1.5L	Increased	Decreased	Unchanged
Coca-Cola, 6-pack, 1.5L	Increased	Decreased	Unchanged
Mineral Water, 6-pack, 1.5L, Mei Eden	Increased	Decreased	Unchanged
Beer, 6-pack, 330cc, Goldstar	Increased	Decreased	Unchanged
Beer, 6-pack, 330cc, Heineken	Increased	Decreased	Unchanged
Wine, Tirosh, 1L, Yikevei Karmel	Increased	Decreased	Unchanged
Baking Powder Pack, 10g, Super Class	Increased	Decreased	Unchanged
Aluminum Foil, 2-pack, 7.5m x 45cm, Nikol	Increased	Decreased	Unchanged
Chicken Soup Powder, 400g, Osem	Increased	Decreased	Unchanged
Paper Towels, 6-pack, Sano-Sushi	Increased	Decreased	Unchanged
Pickles in Brine, Size M-L, 560g, Beit Hashita	Increased	Decreased	Unchanged
Canned Tuna, 170g, Starkist	Increased	Decreased	Unchanged
Tomato Paste, 100g, Tari Nir	Increased	Decreased	Unchanged
Ketchup, 750g, Osem	Increased	Decreased	Unchanged
Classic Tea, 100 bags (Green-Pack), Wissotzki	Increased	Decreased	Unchanged
Instant Coffee, 200g, Elite	Increased	Decreased	Unchanged
Petit Beuerre, "Hagiga," 250g, Elite	Increased	Decreased	Unchanged
Nile Perch, Filet, 1kg, Dali-Dag	Increased	Decreased	Unchanged
Schnitzel, 700g, Of-Tov	Increased	Decreased	Unchanged
Frozen Green Beans, 800g, Sunfrost	Increased	Decreased	Unchanged
Frozen Pizza, 550g, Maadanot	Increased	Decreased	Unchanged
Chicken (Whole, Fresh Meat), 1kg	Increased	Decreased	Unchanged
Minced Beef (Fresh Meat), 1kg	Increased	Decreased	Unchanged
Kinder Eggs, 3-pack	Increased	Decreased	Unchanged
Bamba, 25g, Osem	Increased	Decreased	Unchanged
Bisli, 70g, Osem	Increased	Decreased	Unchanged
Milk Chocolate, 4-pack, 100g, Elite	Increased	Decreased	Unchanged
Chewing Gum, Must, 28g, Elite	Increased	Decreased	Unchanged
Dish Detergent, 750g (Green-Pack), Palmolive	Increased	Decreased	Unchanged
Laundry Detergent, 4kg, Ariel	Increased	Decreased	Unchanged
Tooth Paste, 150g, Aquafresh	Increased	Decreased	Unchanged
Hand Soap, Neka-7	Increased	Decreased	Unchanged
Liquid Soap, 3-pack, 1L, Keff	Increased	Decreased	Unchanged
Shampoo, 750g, Head & Shoulders	Increased	Decreased	Unchanged

(2) Demographic Information

1. Gender:

Male	Female

2. Age:

Up to 24	24–35	35–46	46–55	56–65	Over 65

3. Education:

Primary	Secondary	Academic	Professional	Other

4. Household Size:

1	2	3	4	5	6 or more

5. How would you classify the extent of your observance of religious practices?

Ultra-Religious	Religious	Conservative	Secular	Other

6. Number of cars in your family's possession:

0	1	2	3 or more

7. How many supermarkets do you visit on a regular basis?

0	1	2	3 or more

8. How often do you visit this particular supermarket?

More than once a week	Once a week	Once every two weeks	Seldom

9. How much do you spend, on average, when visiting this particular supermarket?

Up to NIS 100	NIS 10–200	NIS 200–300	More than NIS 300

10. Indicate how important you find each of the following attributes when you consider a supermarket:

Attribute Category	Not important at all	Little importance	Important	Very important	Necessary
Cleanliness	**1**	**2**	**3**	**4**	**5**
Order	**1**	**2**	**3**	**4**	**5**
Variety of brands	**1**	**2**	**3**	**4**	**5**
Service	**1**	**2**	**3**	**4**	**5**
Number of cashiers	**1**	**2**	**3**	**4**	**5**
Prices	**1**	**2**	**3**	**4**	**5**
Discounts and promotions	**1**	**2**	**3**	**4**	**5**
Parking	**1**	**2**	**3**	**4**	**5**
Distance from home	**1**	**2**	**3**	**4**	**5**
Access to public transport	**1**	**2**	**3**	**4**	**5**

Appendix C. Shoppers' Recall of Price Changes – Field Study

We hypothesize in the paper that consumers perceive 9-endings as a signal for low prices (Stiving and Winer, 1997). As a test for this hypothesis, we estimate a multinomial-probit regression of the probability that a shopper indicated that a price had increased, decreased, or remained unchanged relative to the price in the previous week. The dependent variable is an index variable which equals –1/0/1 if the reply was that the price had decreased/remained unchanged/increased.

If 9-endings signal low prices, then 9-endings should increase the likelihood that a shopper will think that a price had decreased, rather than increased/remained unchanged. The effect of *9-ending* dummy (1 if the current price ends with 9, 0 otherwise) on the probability of recalling a price cut should therefore be positive. Controls include location dummies, *gender* which equals 1 (0) if a shopper is female (male), *religious* (1 for ultra-religious, 0 otherwise), *academic-degree* (1 if s/he has a college degree, 0 otherwise), *frequent-shopper* (1 if s/he shops more than once a week, 0 otherwise), *large-expenditure* (1 if s/he spends more than NIS300 per visit, 0 otherwise),[1] *age* (1 if s/he is 55y-old or older, 0 otherwise), the *previous week price*, *price-change* which equals the absolute value of the price change, *price-increase* (1 if the actual price increased, 0 otherwise), *price-decrease* (1 if the actual price decreased, 0 otherwise), and *0-ending* (1 if the actual price ends in zero, 0 otherwise).[2] Table 11a reports the estimation results.

The first (second) column shows the results for the probability that a shopper

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[1] At the time we conducted the field study, NIS300 were equivalent to about $75.

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

indicated that a price had decreased (increased) relative to the probability that it had remained unchanged.

The coefficients of price increase are positive and significant only in the price increase regression ($\beta = 1.24$, $p < 0.01$). The coefficients of price decreases, however, are positive and significant in both regressions ($\beta_{decrease} = 1.37$, $p < 0.01$, $\beta_{increase} = 0.50$, $p < 0.05$). It seems, therefore, that when a price increases, consumers that notice the price change identify it correctly as a price increase. When a price decreases, however, it seems that some of the consumers that notice the price change, mistakenly recall it as a price increase.

The coefficient of *9-ending* in the second column is statistically insignificant, suggesting that there is no difference between the likelihood that shoppers indicated that a 9-ending price had increased and the likelihood they indicated that it is unchanged ($\beta = 0.05$, $p > 0.10$). However, *9-ending* positively affects the likelihood shoppers indicated that a price had decreased ($\beta = 0.25$, $p < 0.01$).

Taken together, the results suggest that when shoppers see that a price ends in 9, they are more likely to assume that the price has decreased than when the price ends with other digits. It therefore seems that consumers in supermarkets not only perceive 9-ending prices as low prices, but also as prices that are likely to be lower than the prices in previous weeks.

Table 11a. Probability of Responding that the Price Has Decreased or Increased Relative to Responding that It Has Remained Unchanged - Field Study

	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)	0.03 (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: The table reports estimation results of a multinomial-probit model for the probability that consumers have identified a price change as a decrease or as an increase relative to no-change. Standard errors are reported in parentheses. * p < 10%, ** p < 5%, and *** p < 1%.

Appendix D. Robustness Check with Dominick's Data

In this appendix, we address the question whether the findings that we discuss in the paper using Dominick's actual transaction prices also hold for Dominick's regular prices (that is, after removing observations on sales). Indeed, the evidence suggests that 9-endings are less common as sale prices than as regular prices, as we show in Appnedix O below (Schindler, 2001). Therefore, the asymmetric rigidity of 9-ending prices could be an artifact of 9-ending prices being more often regular prices than sale prices.

In addition, in the analyses that follow, we control for the possibility that retailers use different pricing strategies in inflation and no-inflation periods. Chakraborty et al. (2015) show that retailers in the UK use different mixtures of price increases and decreases in inflation and in no-inflation periods. We therefore test whether our results on the asymmetry in the rigidity of 9-ending prices hold for both inflation and no-inflation periods.

To address these issues, we conduct four-sets of robustness checks using Dominick's data. In each case, we run all the regressions and tests as in the paper using observations on (1) regular prices, (2) regular prices in inflation periods, and (3) regular prices in no-inflation periods. For the ease of comparison, we also report the results using the actual transaction prices (i.e. sale prices included).

In the first set of tests, we use Dominick's sale indicator variable (which is included in Dominick's data set) to remove all observations on sale prices and the prices following the sales (i.e., the bounce-back prices). We use the resulting dataset, which contains only regular prices, to re-run all the tests and analyses. The results of these analyses are summarized in Tables 3a–6a.

In the second set of tests, we use a greater number of observations than we use in the paper. The additional observations are obtained by interpolating the missing observations in the Dominick's data. The results of the analyses of this expanded dataset are summarized in Tables 3a'–6a'.

In the third set of tests, we use an alternative indicator for sales. Instead of using the Dominick's sale indicator variable, we use a sale filter following Nakamura and

Steinsson (2008, 2011). The results of these analyses are summarized in Tables 3a''–6a''.

In the fourth set of tests, we use the same expanded dataset that we use in the second robustness test, along with Nakamura and Steinsson's (2008, 2011) sale filter to identify observations pertaining to sale prices. The results of these analyses are summarized in Tables 3a'''–6a'''.

Discussion of Tables 3a–6a

Tables 3a–6a summarize the results of the first set of our robustness tests using Dominick's data. In this set of tests, we focus on regular prices and on possible differences between inflation and no-inflation periods. We focus on regular prices because our results suggest that 9-ending prices are less likely to be sale prices than regular prices (Schindler, 2001). It is therefore possible that some of the rigidity of 9-ending prices that we report in the paper is due to 9-endings being more common in regular prices than in sale prices.

We also test whether there are differences in the rigidity of 9-ending prices between inflation and no-inflation periods. Chakraborty et al. (2015) report that in their sample of UK prices, retailers use different pricing strategies in periods of relatively high inflation and in periods of low inflation. This might be relevant also for the Dominick's data because during the sample period 1989–1997 that Dominick’s data cover, the US was experiencing a moderate inflation, with an annual rate of between 5% (the first year of the sample) and 2.5% (the last year of the sample).

To run these robustness tests, we first remove from the dataset all the observations that the Dominick's sale indicator variable identifies as sale prices. In addition, we remove every price in week t if the price in week $t-1$ was a sale price, to eliminate a possible effect of price bounce-backs following sales. Our dataset of regular prices therefore includes only observations on regular prices that are not bounce-back prices.

Second, we split the sample of regular prices into two subsamples: The inflation period sample of regular prices and the no-inflation period sample of regular prices. Following Chen et al. (2008) and Levy et al. (2011), we classify observations as belonging to the inflation period sample if they were collected in a month with a positive CPI inflation, and to the no-inflation period otherwise.

Tables 3a–3d present the transition probability matrix by last digit for price increases (Panel A) and price decreases (Panel B) conditional on a price change. The figures in Table 3a are based on the analysis of all the actual transaction prices. Table 3a is therefore identical to Table 3 in the paper and is given here to facilitate comparisons.

Table 3b reports the results of the analysis of regular prices. The figures in Tables 3b and 3c are based on the analysis of the regular prices pertaining to inflation-periods and no-inflation-periods, respectively.

According to the figures in Tables 3b–3d, we find that *regular* 9-ending prices are more likely to end with 9 after they increase than after they decrease. I.e., the probability of a 9-ending *regular* price to remain 9-ending is greater when the price increases than when the price decreases. For the samples of regular prices, we find that the probabilities that a 9-ending will remain 9-ending following a price increase are 71.09%, 71.76% and 70.08% in Tables 3b, 3c and 3d, respectively. The equivalent probabilities for price decreases are 42.30%, 40.58% and 45.07%, respectively.

Comparing these results to the ones summarized in Table 3a (actual transaction prices, same as Table 3 in the paper), we find that in Table 3a the corresponding probabilities are 61.65% after a price increase and 56.55% after a price decrease. Thus, *the extent of the asymmetry we find for regular prices is in fact stronger than the asymmetry we find in the paper, where we use the actual transaction prices (i.e. sales included).*

In Table 4a, we report the results of four regressions of the probability that a post-change price will be 9-ending conditional on a price change. The first column of the table presents the results for the actual transaction prices (same as Table 4 in the paper). The second column presents the results for regular prices. The third column presents the results for regular prices during inflation periods. The fourth column presents the results for regular prices during no-inflation periods.

Comparing the results in the second, third, and fourth columns with the results in the first column we find that when we remove sales and bounce-back prices, the likelihood of a price remaining 9-ending somewhat decreases relative to the results reported in the paper (Column 1), especially in inflation periods (Column 3: $\beta = 0.06$, Column 1: $\beta = 0.26$). Nevertheless, all the coefficients of 9-ending dummy are positive and significant. It therefore seems that consistent with the results reported in the paper, both for regular and for sale prices and in both inflation and in no-inflation periods, when a pre-change price is 9-ending, the likelihood that the post-change price will be 9-ending is greater than when the pre-change price ends in a different digit.

Further, according to the figures in the table, when we use the actual transaction prices (Column 1), which include sale prices, the coefficient of price decrease is –0.08. When we use the sample of regular prices, we find that the coefficients are –0.44, –0.48, –0.37, for regular prices, for regular prices in inflation periods and for regular prices in no-inflation periods, respectively. Thus, *the probability that a price will be 9-ending following a price decrease is smaller in the sample of regular prices than in the sample that includes sale prices*.

In Table 5a, we report the estimation results of multinomial-logit regressions of the likelihood that a price will either increase or decrease relative to remaining unchanged. The left-most panel presents the results for the actual transaction prices (same as Table 5 in the paper), the next panel reports the results for regular prices, the penultimate panel presents the results for regular prices in inflation periods, and the right-most panel presents the results for regular prices in no-inflation periods.

Comparing the results presented in the second, third, and fourth panels with the results presented in the first panel, we find that when we use regular prices (i.e., after we remove sales), the effect of 9-endings on the probability of both price increases and decreases is much stronger than when we use the actual transaction prices. The coefficient of 9-ending in the first panel (actual transaction prices, including sales) is –0.17 for price decreases and –0.44 for price increases.

In the second panel, which reports the results for regular prices, the coefficient of 9-ending is –0.39 for price decreases and –0.93 for price increases. This increase in the rigidity of 9-ending prices when we exclude sale prices from the data likely reflects the greater rigidity of regular prices relative to sale prices. Still, the coefficient of 9-ending indicates a greater rigidity in the price increase regression than in the price decrease regression. The coefficient of 9-ending in the price increase regression is more than double, in absolute terms, the coefficient in the price decrease regression and this difference is statistically significant ($\chi^2 = 88{,}149,\ p < 0.01$). Therefore, regular 9-ending prices are also significantly more rigid upward than downward, like the actual transaction prices.

The figures in Panels 3 and 4 that summarize the results for inflation and no-inflation periods, respectively, are similar to the ones in the second panel. It therefore seems that the asymmetric effect of 9-endings on increases and decreases of regular prices is of a similar magnitude in both inflation and in no-inflation periods.

In Table 6a, we compare the absolute size of price changes when prices increase and decrease. The table reports the results for the actual transaction prices (same as Table 6 in the paper), for regular prices, for regular prices in inflation periods, and for regular prices in no-inflation periods.

The results in the first column suggest that when we use the actual transaction prices, including sales, then when 9-ending prices increase, the expected change in the price is about 6% greater than the expected change in prices with other endings. The negative sign of the interaction term between price-decreases and 9-ending suggest that when 9-ending prices decrease, the expected change is about 1% less (6% – 7%= –1%) than the expected change in prices with other endings.

The results in Columns 2–4 suggest that the results are similar when we remove sale and bounce-back prices. In the second column, for example, which summarize the results for regular prices, we find that when 9-ending prices increase, the expected change is about 5% greater than the expected change in prices with other endings. When 9-ending prices decrease, on the other hand, the expected change is about 2% less (5% – 7%= –2%) than the expected change in prices with other endings. The results in Columns 3 and 4 that report the results for inflation and for no-inflation periods, respectively, are similar.

We therefore find that whether we include sales or not, and whether we focus on inflation periods or on no-inflation periods, when 9-ending prices increase, the expected price change is greater than the expected price change when prices with other endings change. This is consistent with the finding above that 9-ending prices are more rigid upward than prices with other ending. That is because if prices change infrequently, when they do change, the change is expected to be relatively large. However, because 9-ending prices are less rigid downward than upward, the 9-ending price decreases will not necessarily be larger than the decreases in prices with other endings. The finding that the expected price changes are slightly smaller when 9-ending prices decrease than when prices with other digits change could be an outcome of retailers and producers using signals other than 9-endings to inform consumers about large price cuts.

Table 3a. 10-State Markov Chain Transition Probability Matrix for Price Increases and Decreases by Last Digit Conditional on Price Change, from Starting Last Digit to Ending Last Digit (Dominick's; Actual Transaction Prices)

A. Price Increases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	5.560	4.900	5.850	5.040	5.850	13.84	3.540	3.470	2.090	49.86	100
1	3.800	2.510	6.430	8.010	4.420	15.45	3.350	3.480	1.830	50.71	100
2	4.390	2.880	3.770	6.970	5.600	15.79	3.910	4.020	2.430	50.25	100
3	5.590	2.650	2.360	5.410	6.190	15.54	4.270	5.240	3.160	49.59	100
4	3.950	2.090	2.740	2.750	3.110	12.30	4.810	4.370	2.430	61.45	100
5	8.170	3	2.920	3.470	2.620	12.85	5.960	6.630	4.030	50.35	100
6	5.180	3.250	4.660	3.720	4.550	9.890	2.650	9.320	4	52.79	100
7	5.510	3.770	4.240	4.580	3.180	12.41	2.130	4.880	4.080	55.22	100
8	6.840	6.140	4.550	6.390	3.620	13.67	3.170	3.250	3.720	48.66	100
9	6.660	4.070	3.880	4.210	4.350	7.780	2.480	3.220	1.700	**61.65**	100

B. Price Decreases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	10.18	3	3.300	5.210	4.180	10.68	5.490	3.770	3.120	51.06	100
1	12.52	2.730	3.610	4.260	4.030	8.180	6.010	5.110	5.700	47.86	100
2	14.32	7.220	3.500	3.230	4.720	7.310	9.050	5.240	3.270	42.14	100
3	10.24	9.390	5.670	5.810	3.920	6.760	5.260	5.400	3.940	43.61	100
4	12.63	4.730	5.720	6.600	4.910	5.910	6.570	3.980	2.390	46.56	100
5	11.33	5.610	6.170	8.050	6.340	7.830	5.690	5.680	3.280	40.01	100
6	9.360	5.400	5.470	7.330	10.73	9.270	4.730	3.850	2.770	41.08	100
7	7.060	3.810	4.180	6.350	9.610	10.57	11.81	4.430	2.180	40.02	100
8	7.780	3.610	4.710	6.980	9.650	12.89	9.970	8.380	4.210	31.82	100
9	8.650	3.080	2.670	3.980	6.200	6.440	5.910	4.460	2.060	**56.55**	100

Table 3b. 10-State Markov Chain Transition Probability Matrix for Price Increases and Decreases by Last Digit Conditional on Price Change, from Starting Last Digit to Ending Last Digit (Dominick's; Regular Prices)

C. Price Increases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	3.710	2.490	4.510	3.870	4.680	15.51	2.590	2.810	1.420	58.40	100
1	2.300	2.250	4.280	6.810	3.710	16.52	3.070	3.170	1.500	56.38	100
2	2.330	1.870	3.650	4.950	4.150	17.03	3.390	3.680	2.010	56.93	100
3	3.600	2.130	2.110	5.660	3.970	16.21	2.970	4.300	2.120	56.92	100
4	1.970	1.580	2.430	2.540	2.850	10.46	2.970	3.340	1.860	70	100
5	5.300	2.590	2.600	3.160	2.320	14.73	4.470	5.430	2.960	56.44	100
6	3.180	2.580	4.080	3.290	4.120	10.82	2.260	6.850	2.510	60.32	100
7	3.410	2.870	4	4.070	2.790	13.54	1.690	5.080	2.540	60.02	100
8	4.560	5.730	4.280	6.400	3.340	15.28	2.960	3.200	3.360	50.88	100
9	3.210	2.650	2.790	3.640	3.070	7.920	1.870	2.570	1.210	**71.09**	100

D. Price Decreases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	7.660	2.300	3.140	4.800	4.220	11.43	3.810	3.430	3.040	56.16	100
1	10.61	3.490	3.010	4.100	4.350	11.72	5.940	7.180	7.170	42.42	100
2	11.48	10	4.150	3.700	5.580	9.740	6.980	6.870	5.130	36.37	100
3	7.800	11.02	7.740	6.720	4.200	8.510	5.070	6.210	5.270	37.47	100
4	6.920	7.520	9	9.440	5.690	7.630	5.040	5.640	3.880	39.22	100
5	9.200	8.470	9.860	11.21	9.570	8.350	4.140	5.880	4.570	28.77	100
6	5.690	6.190	7.410	8.340	9.740	14.59	5.200	4.520	3.660	34.66	100
7	4.420	4.360	4.620	6.530	7.460	13.76	20.91	4.770	3.300	29.88	100
8	5.740	4.430	5.580	7.280	7.440	15.31	9.830	10.96	5.560	27.88	100
9	4.770	4.830	4.940	4.900	9.030	9.640	7.060	8.120	4.400	**42.30**	100

Table 3c. 10-State Markov Chain Transition Probability Matrix for Price Increases and Decreases by Last Digit Conditional on Price Change, from Starting Last Digit to Ending Last Digit (Dominick's; Regular Prices, Inflation Periods)

A. Price Increases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	3.550	2.520	4.640	3.910	4.540	14.62	2.660	2.940	1.380	59.24	100
1	2.110	2.220	4.280	6.700	3.470	16.58	3.020	3.080	1.430	57.11	100
2	2.120	2.120	3.590	5.070	4.200	16.89	3.440	3.650	1.920	56.99	100
3	2.970	2.190	1.720	4.960	3.720	15.73	2.910	4.220	2.210	59.37	100
4	1.880	1.730	2.350	2.480	2.760	10.21	3.040	3.280	1.990	70.28	100
5	4.790	2.560	2.710	3.390	2.280	13.74	4.230	5.450	2.870	57.98	100
6	2.830	2.520	4.180	3.340	4.330	10.99	2.210	7.560	2.600	59.45	100
7	3.160	2.740	3.640	4.210	2.970	12.70	1.630	5.090	2.550	61.32	100
8	4.250	6.270	3.990	6.010	3.520	14.79	2.800	3.310	3.190	51.87	100
9	3.120	2.570	2.720	3.600	3.090	7.670	1.800	2.520	1.140	**71.76**	100

B. Price Decreases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	7.240	2.040	2.790	4.360	4.030	11.60	3.450	3.080	3.030	58.37	100
1	11.54	3.200	2.810	3.860	4.100	11.74	5.810	6.800	6.430	43.72	100
2	11.64	11.65	3.800	3.520	4.900	8.570	7.170	6.340	5.100	37.32	100
3	8.510	11.79	7.560	6.290	4.760	8.120	5.200	5.510	5.180	37.07	100
4	7.060	7.300	9.020	9.810	5.510	6.920	5.080	5.890	3.620	39.79	100
5	9.220	8.610	10.28	11.52	10.29	8.160	4.110	5.790	4.350	27.67	100
6	5.880	6.090	7.510	8.240	9.890	14.81	5.370	4.390	3.570	34.24	100
7	4.710	4.480	4.270	6.390	8.040	12.45	23.63	4.310	2.950	28.77	100
8	4.980	4.300	5.070	7.150	8.140	14.93	10.40	12.03	5.290	27.72	100
9	4.920	4.980	5.160	4.980	9.460	9.820	7.370	8.160	4.580	**40.58**	100

Table 3d. 10-State Markov Chain Transition Probability Matrix for Price Increases and Decreases by Last Digit Conditional on Price Change, from Starting Last Digit to Ending Last Digit (Dominick's; Regular Prices, No-Inflation Periods)

A. Price Increases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	4.010	2.440	4.260	3.800	4.940	17.13	2.470	2.580	1.500	56.87	100
1	2.620	2.290	4.270	6.990	4.130	16.43	3.170	3.310	1.610	55.18	100
2	2.690	1.450	3.760	4.750	4.060	17.29	3.300	3.720	2.150	56.83	100
3	4.590	2.040	2.720	6.770	4.360	16.95	3.070	4.440	1.980	53.08	100
4	2.120	1.340	2.550	2.640	2.990	10.84	2.860	3.440	1.660	69.56	100
5	6.090	2.620	2.430	2.810	2.390	16.28	4.850	5.400	3.110	54.02	100
6	3.730	2.680	3.920	3.210	3.780	10.54	2.350	5.730	2.370	61.70	100
7	3.790	3.070	4.540	3.850	2.500	14.80	1.800	5.060	2.510	58.07	100
8	5.110	4.800	4.770	7.080	3.040	16.13	3.240	3.020	3.650	49.16	100
9	3.340	2.760	2.880	3.690	3.030	8.300	1.970	2.640	1.310	**70.08**	100

B. Price Decreases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	8.250	2.660	3.620	5.420	4.480	11.20	4.330	3.930	3.050	53.05	100
1	9.180	3.950	3.340	4.480	4.740	11.69	6.140	7.770	8.320	40.41	100
2	11.23	7.530	4.690	3.970	6.590	11.50	6.690	7.670	5.180	34.95	100
3	6.830	9.960	7.980	7.320	3.440	9.030	4.880	7.160	5.380	38.01	100
4	6.690	7.890	8.980	8.840	5.990	8.810	4.980	5.230	4.320	38.27	100
5	9.180	8.270	9.260	10.75	8.530	8.610	4.180	6	4.880	30.34	100
6	5.420	6.330	7.260	8.490	9.520	14.27	4.960	4.730	3.780	35.26	100
7	3.940	4.150	5.180	6.750	6.550	15.85	16.55	5.510	3.850	31.66	100
8	6.750	4.590	6.250	7.450	6.530	15.82	9.070	9.550	5.910	28.08	100
9	4.540	4.600	4.590	4.770	8.350	9.360	6.560	8.060	4.110	**45.07**	100

Table 4a. Probability that a New Price Ends with 9

(Dominick's; Actual Transaction Prices; Regular Prices; Regular Prices, Inflation Periods; Regular Prices, No-Inflation Periods)

	Actual transaction price changes	Regular price changes	Regular price changes, Inflation periods	Regular price changes, No-inflation periods
Sales Price Indicator	-0.28*** (0.0006)			
Price Level	0.10*** (0.0002)	0.09*** (.0004)	0.11*** (0.0005)	0.08*** (0.0006)
Price Change	-0.11*** (0.0005)	-0.16*** (.0011)	-0.17*** (0.0015)	-0.14*** (0.0017)
Price Decrease	**-0.08*** (0.0008)**	**-0.44*** (.0013)**	**-0.48*** (0.0017)**	**-0.37*** (0.0020)**
Previous 9-Ending	**0.26*** (0.0006)**	**0.10*** (.0011)**	**0.06*** (0.0015)**	**0.16*** (0.0018)**
Constant	-0.09*** (.0007)	-0.16*** (.0013)	-0.15*** (0.0017)	-0.17** (0.0020)
Observations	20,839,462	5,199,236	3,097,053	2,102,183

Notes: The table reports the results of a probit regression for the probability that a new price ends with 9. Standard errors are reported in parentheses. *** $p < 1\%$

Table 5a. Probability of Price Increases and Decreases Relative to Price Remaining Unchanged

(Dominick's; Actual Transaction Prices; Regular Prices; Regular Prices, Inflation Periods; Regular Prices, No-Inflation Periods)

	Actual transaction prices		Regular prices		Regular prices, Inflation periods		Regular prices, No-Inflation Period	
	Price Decreases	Price Increases	Price Decreases	Price Increases	Price Decreases	Price Increases	Price Decreases	Price Increases
Sale Price Indicator in Previous Week	0.35*** (0.0001)	3.01*** (0.0008)	N/A					
Previous 9-Ending	**-0.17*** (0.0008)**	**-0.44*** (0.0007)**	**-0.39*** (0.001)**	**-0.93*** (0.001)**	**-0.37*** (0.0018)**	**-0.97*** (0.0017)**	**-0.43** (0.0022)**	**-0.88*** (0.002)**
Absolute Value of the Percentage Change in the Wholesale Price	8.23*** (0.0030)	7.33*** (0.0027)	5.74*** (0.006)	5.32*** (0.006)	5.59*** (0.007)	5.20*** (0.007)	5.95*** (0.009)	5.48*** (0.009)
Price Level	-0.15*** (0.0003)	0.08*** (0.0002)	-0.06*** (0.0005)	0.09*** (0.0003)	-0.08*** (0.0007)	0.09*** (0.0005)	-0.03*** (0.0008)	0.10*** (0.0005)
Constant	-1.74*** (0.0008)	-3.01*** (0.0009)	-2.93*** (0.001)	-2.83*** (0.001)	-2.85*** (0.002)	-2.79*** (0.002)	-3.05*** (0.002)	-2.87*** (0.002)
χ^2	2.46×10^7		2.04×10^7		1.19×10^7		8.65×10^6	
Observations	81,734,333		58,614,646		34,178,422		24,436,224	

Notes: The table reports estimation results of a Multinomial-logit model for the probability of a price decrease and increase relative to the prices remaining unchanged. Standard errors are reported in parentheses.
*** $p < 1\%$.

Table 6a. The Size of 9-Ending Price Changes

(Dominick's; Actual transaction prices; Regular Prices; Regular Prices, Inflation Periods; Regular Prices, No-Inflation Periods)

	Actual transaction prices	Regular prices	Regular prices, Inflation periods	Regular prices, No-Inflation Periods
Previous 9-Ending	**0.06*** (0.003)**	**0.05*** (0.0009)**	**0.04*** (0.001)**	**0.05*** (0.001)**
Previous 9-Ending × Price Decrease	**-0.07*** (0.0003)**	**-0.07*** (0.001)**	**-0.07*** (0.002)**	**-0.08*** (0.001)**
Price Level	0.0005*** (0.00007)	0.001*** (0.0002)	0.0009** (0.0004)	0.002*** (0.002)
Absolute Value of the Percentage Change in the Wholesale Price	0.55*** (0.0005)	0.72*** (0.002)	0.76*** (0.003)	0.67*** (0.002)
Sale Price Indicator in Previous Week	0.03*** (0.0002)	N/A		
Sale Price Indicator	0.002*** (0.0002)			
Constant	0.13*** (0.0003)	0.08*** (0.002)	0.08*** (0.001)	0.08*** (0.0008)
R^2	0.06	0.03	0.02	0.06
Observations	20,601,077	5,015,511	2,989,011	2,026,500

Notes: The table reports estimation results of a linear regression of the percentage price change, conditional on the price changing. Standard errors are reported in parentheses. *** $p < 1\%$.

Discussion of Tables 3a'–6a'

Tables 3a'–6a' summarize the results of our second set of robustness tests. In these tests, we expand the Dominick's dataset by employing the following interpolation procedure. Whereas in the paper we exclude observations if we do not observe the prices in both weeks *t* and $t-1$, here we assume that if we do not have an observation on a price in week *t* then the price is the same as in week $t-1$. This interpolation procedure allows us to expand the sample size from 81,982,683 to 94,695,300 observations.

The results derived from the analyses of this expanded dataset are likely to be less reliable than those from our main dataset because when we make assumptions about missing observations we might introduce both "false" price changes and/or "false" long price spells. For example, consider a case where the actual prices in five consecutive weeks were 5.00, 4.75, 4.75, 4.50 and 4.50, but the three middle observations are missing. With the interpolation procedure we employ, we will get only one price change rather than two, and it will be twice the size of the actual price changes. This is an important shortcoming. We nevertheless use this dataset as part of our robustness analysis to demonstrate that our results are not driven by missing observations.

To make the results comparable with the results of the robustness tests discussed above as well as with the results reported in the paper, we report four sets of results. In the first set, we use all the observations in the expanded dataset (including observations on sale prices), which we term "all prices." In the second, we use only regular prices by using the Dominick's sale indicator variable to exclude the observations on sale prices and the prices following sales (bounce-back prices). In the third, we use only observations on regular prices from inflation periods. In the fourth, we use only observations on regular prices from no-inflation periods.

Tables 3a'–3d' present the transition probability matrix by last digit for price increases and decreases conditional on a price change. Table 3a' reports the results for the entire expanded dataset, "All Prices" (94,695,300 observations). Table 3b' reports the results for regular prices. Table 3c' reports the results for regular prices in inflation periods. Table 3d' reports the results for regular prices in no-inflation periods.

The main results are similar to those we report in the paper. In all tables, we find that prices are more likely to change to 9-endng prices when they increase than when they decrease.

For example, in Table 3a', which presents the results for all prices in the expanded sample (including sale prices), we find that when prices increase, 65.13% of the 9-ending prices change to 9-endings. We find that for price decreases however, only 58.31% of the 9-ending prices change to 9-endings. This is comparable to the results we report in the paper: 61.65% and 56.55 for price increases and decreases, respectively.

Moreover, we find that the differences in the likelihood that post-change prices will become 9-ending after price increases vs after price decreases is *even greater when we use regular prices than when we use the full expanded sampl*e. For example, in Table 3b' we find that when prices increase, 73.40% of the 9-ending prices change to 9-ending prices but only 46.43% of the 9-ending prices change to 9-ending prices when prices decrease. Similarly, in Tables 3c' and 3d', the corresponding figures are 74.01% vs 44.81%, and 72.49% vs 48.94%, respectively, again suggesting stronger asymmetric rigidity of regular prices than the actual transaction prices that we report in the paper (Table 3).

In Table 4a', we report the results of four regressions of the probability that a post-change price will be 9-ending conditional on a price change. The first column presents the results for all prices in the expanded sample (including sale prices). The second column presents the results for regular prices. The third column presents the results for regular prices in inflation periods. The fourth column presents the results for regular prices in no-inflation periods.

We find, consistent with the results reported in the paper, that 9-ending prices are likely to remain 9-ending after a price change. The coefficients of 9-ending in all four regressions are similar, between 0.20 and 0.28, suggesting that in both inflation and no-inflation periods the rigidity of 9-ending prices are about the same.

We find again, however, that *the asymmetry in the likelihood that a price will be 9-ending is greater when we use regular prices than when we use all prices*. The coefficient of price decreases in Column 2 (regular prices), –0.45, is about four times as large, in absolute value, as the coefficient in Column 1 (all prices in the expanded sample), –0.11.

In Table 5a', we report the results of a multinomial-logit regression of the likelihood that a price will either increase or decrease relative to remaining unchanged. The left-most panel presents the results for all prices in the expanded sample (including sale prices), the next panel presents the results for regular prices, the penultimate panel presents the results for regular prices in inflation periods, and the right-most panel presents the results for regular prices in no-inflation periods.

The results are similar to what we report in Table 5a. We find that when we use all prices in the expanded sample (Panel 1) 9-ending prices are significantly less likely to both decrease (β = –0.15) and increase (β= –0.31) than other prices, but the upward rigidity is significantly greater than the downward rigidity.

The coefficients of 9-ending dummy in the price decrease regressions are –0.39, –0.38 and –0.41 for regular prices, for regular prices in inflation periods, and for regular prices in no-inflation periods, respectively. The corresponding figures in the price increase regressions are –0.87, –0.90 and –0.83, respectively. Thus, whether we use all prices in the expanded sample or only observations on regular prices, and both in inflation and in no-inflation periods, 9-ending prices are significantly more rigid upward than downward.

In Table 6a', we compare the size of price changes when prices increase and decrease. The columns of the table report the results for all prices in the expanded sample, for regular prices, for regular prices in inflation periods, and for regular prices in no-inflation periods.

We find that the coefficients of the 9-ending dummy in all four columns is 0.02 compared to 0.06 in the paper. It therefore seems that when we expand the dataset by interpolating the missing observations (by assuming that missing prices equal the previous weeks' prices), we artificially introduce small price changes.

Second, we find that in the first column (actual transaction prices) the coefficient of the interaction term between 9-ending dummy and price decreases is 0.01, suggesting that the size of 9-ending price decreases is larger than the size of 9-ending price increases. This is in contrast with our expectations and we suspect that this is because the interpolation procedure is artificially introducing price changes that are different from the ones that have actually taken place.

When we focus on regular prices only, however, we obtain results that are consistent with our hypothesis. The coefficients of the interaction between 9-ending dummy and price decreases in Columns 2, 3, and 4 are –0.01. It seems, therefore, that even after expanding the sample size through interpolation, when we use either regular prices, or regular prices in inflation periods, or regular prices in no-inflation periods, in all cases we find that 9-ending price increases are larger than 9-ending price decreases. In other words, the interpolation may have introduced many small, temporary price increases that affected mostly the results for the actual transaction prices but had smaller effect on the results for regular prices.

Table 3a'. 10-State Markov Chain Transition Probability Matrix for Price Increases and Decreases by Last Digit Conditional on Price Change, from Starting Last Digit to Ending Last Digit (Dominick's; All Prices; Expanded Sample)

A. Price Increases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	4.670	4.240	5.130	4.620	5.320	13.16	3.180	3.200	1.850	54.63	100
1	3.800	1.980	6.020	8.100	4.260	15.08	3.210	3.470	1.750	52.33	100
2	4.240	2.670	3.010	6.760	5.430	15.61	3.730	4.070	2.270	52.21	100
3	5.410	2.490	2.320	4.430	5.880	15.52	4.050	5.320	2.950	51.62	100
4	3.690	1.910	2.550	2.720	2.540	11.43	4.400	4.070	2.200	64.50	100
5	7.850	2.750	2.710	3.550	2.480	10.95	5.630	6.500	3.730	53.85	100
6	4.930	3.100	4.350	3.750	4.260	9.780	2.150	9.160	3.750	54.78	100
7	5.170	3.420	3.950	4.740	3.020	12.29	1.960	3.710	3.750	57.98	100
8	6.610	5.960	4.280	6.440	3.460	13.88	3.120	3.410	3.240	49.62	100
9	5.990	3.510	3.420	4.010	3.910	7.350	2.180	3.010	1.500	**65.13**	100

B. Price Decreases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	9.070	3.050	3.230	5.270	4.230	10.74	5.310	3.710	3.050	52.33	100
1	12.26	2.460	3.540	4.240	4.050	8.180	6.020	5.130	5.630	48.50	100
2	14.04	6.970	3.250	3.250	4.810	7.340	8.750	5.320	3.210	43.06	100
3	10.09	9.440	5.420	5.550	4.010	6.800	5.150	5.570	3.930	44.04	100
4	12.58	4.630	5.600	6.520	4.540	5.650	6.170	3.820	2.290	48.19	100
5	11.64	5.590	6.080	7.880	6.230	7.860	5.520	5.780	3.250	40.17	100
6	9.450	5.430	5.470	7.280	10.77	9.340	4.020	3.750	2.790	41.71	100
7	7.050	3.780	4.140	6.230	9.250	10.51	11.70	4.290	2.180	40.87	100
8	7.660	3.530	4.600	6.840	9.420	12.87	9.980	8.410	4.210	32.50	100
9	8.770	2.920	2.550	3.690	6.060	6.150	5.420	4.230	1.900	**58.31**	100

Table 3b’. 10-State Markov Chain Transition Probability Matrix for Price Increases and Decreases by Last Digit Conditional on Price Change, from Starting Last Digit to Ending Last Digit (Dominick’s; Regular Prices; Expanded Sample)

A. Price Increases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	2.960	2.130	3.870	3.570	4.090	14.49	2.270	2.590	1.260	62.77	100
1	2.310	1.730	4.040	6.990	3.570	16	2.930	3.170	1.420	57.83	100
2	2.220	1.740	2.880	4.890	4.040	16.77	3.220	3.790	1.880	58.55	100
3	3.480	2.040	2.140	4.540	3.790	16.13	2.850	4.490	2.020	58.52	100
4	1.830	1.430	2.250	2.540	2.270	9.660	2.670	3.120	1.670	72.55	100
5	5.060	2.430	2.440	3.350	2.210	12.38	4.210	5.430	2.740	59.74	100
6	2.950	2.480	3.810	3.380	3.840	10.68	1.730	6.700	2.400	62.03	100
7	3.180	2.580	3.690	4.310	2.650	13.35	1.570	3.760	2.380	62.54	100
8	4.360	5.580	4	6.490	3.180	15.54	2.930	3.400	2.830	51.67	100
9	2.800	2.280	2.480	3.550	2.780	7.460	1.660	2.500	1.080	**73.40**	100

B. Price Decreases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	7.400	2.210	3.080	4.750	4.160	11.34	3.660	3.310	2.850	57.24	100
1	10.44	2.910	2.750	3.960	4.200	11.79	5.910	7.070	6.950	44.04	100
2	11.19	9.380	3.900	3.640	5.480	10.03	6.850	6.650	4.940	37.95	100
3	7.650	10.92	7.420	6.260	4.340	8.420	4.940	6.120	5.020	38.93	100
4	6.850	7.180	8.620	9.300	5.160	7.450	4.790	5.410	3.630	41.61	100
5	9.550	8.200	9.490	10.87	9.170	8.270	4	5.890	4.410	30.16	100
6	5.630	6.220	7.370	8.320	9.720	14.51	4.310	4.520	3.570	35.84	100
7	4.320	4.380	4.490	6.620	7.320	13.64	20.28	4.580	3.270	31.08	100
8	5.590	4.270	5.360	7.030	7.410	15.30	9.570	11.09	5.240	29.13	100
9	4.550	4.410	4.580	4.550	8.600	9.230	6.340	7.380	3.920	**46.43**	100

Table 3c'. 10-State Markov Chain Transition Probability Matrix for Price Increases and Decreases by Last Digit Conditional on Price Change, from Starting Last Digit to Ending Last Digit (Dominick's; Regular Prices, Inflation Periods; Expanded Sample)

A. Price Increases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	2.960	2.190	4	3.580	4.010	13.68	2.340	2.740	1.230	63.28	100
1	2.040	1.770	4.080	6.880	3.350	15.92	2.880	3.090	1.380	58.62	100
2	2.050	1.990	2.980	5.030	4.130	16.45	3.240	3.760	1.810	58.55	100
3	2.950	2.100	1.740	3.930	3.600	15.48	2.850	4.420	2.130	60.81	100
4	1.770	1.590	2.160	2.450	2.190	9.410	2.770	3.020	1.790	72.85	100
5	4.570	2.400	2.530	3.580	2.170	11.55	4.050	5.460	2.670	61.02	100
6	2.630	2.450	3.880	3.530	4.050	10.73	1.770	7.420	2.490	61.05	100
7	2.940	2.420	3.330	4.590	2.820	12.37	1.480	3.790	2.440	63.82	100
8	4.170	6.240	3.830	6.180	3.420	14.66	2.820	3.420	2.710	52.55	100
9	2.740	2.220	2.430	3.570	2.810	7.120	1.600	2.470	1.020	**74.01**	100

B. Price Decreases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	6.960	1.960	2.720	4.290	4.090	11.48	3.320	2.990	2.860	59.33	100
1	11.37	2.700	2.570	3.800	3.930	11.63	5.830	6.720	6.160	45.29	100
2	11.43	10.79	3.560	3.460	4.810	9.180	7.020	6.120	4.870	38.76	100
3	8.190	11.66	7.210	5.930	4.890	8.020	5.030	5.330	4.890	38.85	100
4	7.010	7.060	8.680	9.800	4.910	6.750	4.850	5.690	3.400	41.84	100
5	9.600	8.280	9.740	11.11	9.830	8.050	3.950	5.800	4.170	29.46	100
6	5.930	6.240	7.470	8.290	9.830	14.66	4.420	4.380	3.490	35.29	100
7	4.590	4.490	4.210	6.530	7.850	12.17	23.04	4.170	2.960	29.99	100
8	4.790	4.210	4.830	6.920	8.140	14.60	10.06	12.37	4.970	29.12	100
9	4.730	4.550	4.800	4.620	9.030	9.330	6.640	7.410	4.090	**44.81**	100

Table 3d'. 10-State Markov Chain Transition Probability Matrix for Price Increases and Decreases by Last Digit Conditional on Price Change, from Starting Last Digit to Ending Last Digit (Dominick's; Regular Prices, No-Inflation Periods; Expanded Sample)

A. Price Increases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	2.970	2.040	3.630	3.550	4.240	15.91	2.150	2.330	1.310	61.87	100
1	2.740	1.660	3.990	7.180	3.920	16.12	3.010	3.310	1.490	56.59	100
2	2.480	1.330	2.730	4.650	3.900	17.30	3.200	3.840	2.010	58.56	100
3	4.280	1.950	2.740	5.450	4.080	17.09	2.850	4.600	1.870	55.09	100
4	1.920	1.200	2.390	2.670	2.380	10.03	2.520	3.260	1.510	72.11	100
5	5.810	2.470	2.300	2.990	2.270	13.63	4.460	5.390	2.860	57.81	100
6	3.450	2.530	3.710	3.150	3.520	10.59	1.660	5.570	2.250	63.56	100
7	3.520	2.810	4.220	3.910	2.400	14.78	1.700	3.710	2.290	60.67	100
8	4.680	4.500	4.300	6.990	2.800	16.98	3.120	3.380	3.020	50.24	100
9	2.900	2.370	2.540	3.520	2.730	7.970	1.750	2.550	1.170	**72.49**	100

B. Price Decreases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	8.020	2.570	3.580	5.380	4.260	11.14	4.140	3.760	2.840	54.31	100
1	9.030	3.220	3.010	4.190	4.590	12.03	6.020	7.590	8.140	42.16	100
2	10.84	7.340	4.410	3.890	6.440	11.26	6.600	7.420	5.040	36.77	100
3	6.920	9.910	7.700	6.700	3.580	8.960	4.810	7.200	5.190	39.03	100
4	6.590	7.360	8.540	8.470	5.570	8.570	4.700	4.950	4.020	41.23	100
5	9.460	8.080	9.140	10.53	8.220	8.600	4.060	6.020	4.740	31.16	100
6	5.190	6.200	7.220	8.370	9.560	14.30	4.140	4.720	3.690	36.63	100
7	3.910	4.210	4.920	6.770	6.500	15.95	15.96	5.240	3.750	32.80	100
8	6.640	4.340	6.060	7.190	6.470	16.21	8.930	9.420	5.600	29.14	100
9	4.270	4.200	4.250	4.450	7.930	9.070	5.870	7.340	3.670	**48.94**	100

Table 4a’. Probability that a New Price Ends with 9

(Dominick’s; All Prices; Regular Prices; Regular Prices, Inflation Periods; Regular Prices, No-Inflation Periods; Expanded Sample)

	All price changes	Regular price changes	Regular price changes, Inflation periods	Regular price changes, No-inflation periods
Sales Price Indicator	-0.29*** (0.0006)	N/A		
Price Level	0.12*** (0.0002)	0.12*** (0.0003)	0.12*** (0.0002)	0.12*** (0.0003)
Price Change	-0.11*** (0.0005)	-0.17*** (0.0010)	-0.11*** (0.0005)	-0.17*** (0.0010)
Price Decrease	**-0.11***** **(0.0007)**	**-0.45***** **(0.0012)**	**-0.11***** **(0.0007)**	**-0.45***** **(0.0012)**
Previous 9-Ending	**0.28***** **(0.0005)**	**0.20***** **(0.0010)**	**0.28***** **(0.0005)**	**0.20***** **(0.0010)**
Constant	-0.06*** (0.0006)	-0.18*** (0.0012)	-0.06*** (0.0006)	-0.18*** (0.0012)
Observations	24,863,575	6,209,919	24,863,575	6,209,919

Notes: The table reports the results of a probit regression for the probability that a new price ends with 9. Standard errors are reported in parentheses. *** $p < 1\%$

Table 5a’. Probability of Price Increases and Decreases Relative to Price Remaining Unchanged (Dominick’s; All Prices; Regular Prices; Regular Prices, Inflation Periods; Regular Prices, No-Inflation Periods; Expanded Sample)

	All prices		Regular prices		Regular prices, Inflation periods		Regular prices, No-Inflation Period	
	Price Decreases	Price Increases	Price Decreases	Price Increases	Price Decreases	Price Increases	Price Decreases	Price Increases
Sale Price Indicat in Previous Week	0.39*** (0.001)	3.09*** (.0008)	N/A					
Previous 9-Endi	**-0.15*** (.0007)**	**-0.31*** (.0008)**	**-0.39*** (0.001)**	**-0.87*** (0.001)**	**-038*** (0.002)**	**-0.90*** (0.002)**	**-0.41*** (0.002)**	**-0.83*** (0.002)**
Absolute Value of the Percentage Change in the Wholesale Price	7.43*** (0.004)	7.46*** (0.004)	5.00*** (0.005)	5.12 (0.005)	4.82*** (0.006)	4.95*** (0.006)	5.28 *** (0.008)	5.36*** (0.008)
Price Level	-0.14 *** (0.0003)	0.09*** (0.0002)	-0.06*** (0.0004)	0.10*** (0.0003)	-0.08*** (0.0006)	0.10*** (0.0004)	-0.04*** (0.0007)	0.10*** (0.0005)
Constant	-1.69*** (0.0007)	-3.12*** (0.0009)	-2.85*** (0.001)	-2.80*** (0.001)	-2.77*** (0.002)	-2.77*** (0.001)	-2.96*** (0.002)	-2.84*** (0.002)
χ^2	94,439,718		68,466,467		39,732,553		28,732,914	
Observations	$2.84\text{x}10^7$		$2.33\text{x}10^7$		$1.33\text{x}10^7$		$1.00\text{x}10^7$	

Notes: The table reports estimation results of a SURE regression of the probability that the corresponding digit will change conditional on a price change. Standard errors are reported in parentheses. *** $p < 1\%$.

Table 6a’. The Size of 9-Ending Price Changes

(Dominick’s; All Prices; Regular Prices; Regular Prices, Inflation Periods; Regular Prices, No-Inflation Periods; Expanded Sample)

	All prices	Regular prices	Regular prices, Inflation periods	Regular prices, No-Inflation Period
Previous 9-Ending	**0.02*** (0.0001)**	**0.02*** (0.0002)**	**0.02*** (0.0002)**	**0.02*** (0.0002)**
Previous 9-Ending × Price Decrease	**0.01*** (0.0001)**	**-0.01*** (0.0002)**	**-0.01*** (0.0002)**	**-0.01*** (0.0003)**
Price Level	-0.008*** (0.00002)	-0.006*** (0.00004)	-0.006*** (0.000005)	-0.006*** (0.00006)
Absolute Value of the Percentage Change in the Wholesale Price	0.50*** (0.0002)	0.57*** (0.0003)	0.58*** (0.0004)	0.55*** (0.0005)
Sale Price Indicator in Previous Week	0.07*** (0.00008)			
Sale Price Indicator	-0.01*** (0.00009)			
Constant	0.13*** (0.0001)	0.10*** (0.0001)	0.10*** (0.0002)	0.09*** (0.0002)
R^2	0.26	0.34	0.33	0.35
Observations	24,349,085	6,172,998	3,648,778	2,524,020

Notes: The table reports estimation results of a linear regression of the percentage price change, conditional on the price changing. Standard errors are reported in parentheses. *** $p < 1\%$.

Discussion of Tables 3a''–6a''

Using Dominick's sale indicator variable might lead to erroneous results because according to Peltzman (2000), and also as mentioned in the Dominick's Data Manual (2013, p. 10), the sale indicator variable is not complete. We therefore run all the tests and analyses again, this time using a sale filter as suggested by Nakamura and Steinsson (2008, 2011). In this appendix, we discuss the results when we use observations on the actual transaction prices (81,982,683 observations, same as we report in the paper and in Tables 3a–6a). In the next section we discuss the results when we use the expanded dataset (94,695,300 observations).

Sale filters are procedures for identifying V-shaped sales. Nakamura and Steinsson (2008, 2011) offer two such filters, Filter A and Filter B. Filter B identifies a price as a sale price when it identifies instances in which the price decreases and then bounces back up to the same pre-sale price. Filter A identifies a price as sale price when it identifies instances in which the price decreases and then bounces back up to a price that is equal or higher than the pre-sale price.

Below, we chose to use Filter A. We made this choice for three reasons. First, according to the Dominick's sale indicator variable, post-sale prices are occasionally higher than the pre-sale prices. Second, Anderson et al. (2015b) find that sales are sometimes used to mask upcoming price increases and, consequently, post-sale prices are occasionally higher than the pre-sale prices. Third, Filter A is more general than Filter B and it was used in other studies as well (e.g., Knotek 2010, Chakraborty et al. 2015).

Using sale filters has significant drawbacks, because first, sale filters cannot identify sales if the sales either do not have the expected V-shape or if the sales last longer than the defined period. Second, sale prices may identify regular price changes as sale prices when several regular price changes occur within a short period. Third, sale filters might also miss sale prices if some observations on previous or future prices are missing (Nakamura and Steinsson, 2008). We nevertheless use the sale filter to identify the sale prices because of the possibility that there are systematic errors in the Dominick's sale indicator variable.

In applying the sale filter, we assume that sales do not last more than one month. We therefore define a price as a sale price if the price first decreases, stays at the low level for up to four-weeks and then bounces back to a price that is equal or higher than the pre-sale price (Knotek, 2010). It turns out that the sale dummy that we construct using this filter is strongly correlated with (but is not identical to) Dominick's sale indicator variable (r = 0.54).

Tables 3a"–3d" present the transition probability matrix by last digit for price increases and decreases conditional on a price change. Table 3a" uses the actual transaction prices and is the same as Table 3 in the paper. It is included here to facilitate comparisons. Tables 3b", 3c" and 3d"' present the results for regular prices, for regular prices in inflation periods, and for regular prices in no-inflation periods, respectively.

According to Table 3b", for regular prices the probability that a 9-ending price will increase to a 9-ending price is 51.15%, while the probability that a 9-ending price will decrease to a 9-ending price is 50.84%.

There are similar differences in both inflation (51.62% vs. 51.11%, respectively) and no-inflation periods (50.48% vs. 50.46%, respectively). These differences are smaller than the ones we find when we use the Dominick's sale indicator variable (Table 3b–3d) and also when we use the actual transaction prices (Table 3a", same as Table 3 in the paper).

Nevertheless, the differences we find are in the predicted direction. Further, looking at all price changes in Table 3b", we find that 49% of the post-increase prices are 9-ending. The corresponding figure for price decreases is 43%. The figures for regular prices in inflation periods (Table 3c") and for regular prices (Table 3d") are similar: 49% and 48% of the post-increase prices in the inflation sample of regular prices and in the no-inflation sample of regular prices, respectively, are 9-ending. Only 42% and 43% of the post-decrease prices in the inflation sample of regular prices and in the no-inflation sample of regular prices, respectively, are 9-ending.

Thus, we find that when we use the sale filter, the differences between the likelihoods that a regular 9-ending price will increase and decrease to a 9-ending price are smaller than when we use the Dominick's sale indicator variable. Nevertheless, we still find significantly more rigidity upward than downward for 9-ending prices.

In Table 4a", we estimate the probability that a post-change price will be 9-ending conditional on a price change. The first column presents the results for the actual transaction prices, the second presents the results for regular prices, the third presents the results for regular prices in inflation periods, and the fourth column presents the results for regular prices in no-inflation periods.

We find, consistent with the results reported in the paper, that 9-endingprices are likely to remain 9-ending after a price change. The coefficients of the 9-ending dummy in all four columns are positive, suggesting that for both regular prices and for the actual transaction prices (which include the sale prices), and in both inflation and no-inflation periods, the likelihood that a pre-change 9-ending price will change to a 9-ending price is greater than the likelihood that a price with another ending will change to a 9-ending price. Further, the size of the coefficients is similar in all four columns (ranging from 0.26 to 0.28) and is similar to the coefficient reported in Table 4 in the paper (0.26).

More importantly, we find that the coefficient of price decreases is negative and significant in all four columns. In Column 1 (all actual transaction prices) it is –0.11, in Column 2 (regular prices) it is –0.22, in Column 3 (regular prices, inflation period) it is –0.19, and in Column 4 (regular prices, no-inflation period) it is –0.23.

Thus, we find that the probability that a post-change price will be 9-ending is significantly smaller when the change is a price decrease than when the change is a price increase. Furthermore, *the asymmetry in the likelihood that a price will be 9-ending for price increases vs. price decreases is greater when we use data on regular prices than when we use data on the actual transaction prices (i.e., when sale prices are included).*

In Table 5a", we report the results of a multinomial-logit regression of the likelihood that a price will either increase or decrease relative to remaining unchanged. The left-most panel presents the results for the actual transaction prices, the next panel presents the results for regular prices, the penultimate panel presents the results for regular prices in inflation periods, and the right-most panel presents the results for regular prices in no-inflation periods.

Similar to the findings we report in the paper, we find that in all four panels, a 9-ending price is less likely to increase than other prices. Prices that end in 9 are also less likely to decrease than other prices, but they are not as rigid downward as they are upward. In addition, we find that the coefficient of the 9-ending dummy in the price increase column of the first panel (actual transaction prices) is –0.39. In panels 2, 3, and 4 (regular prices, regular prices in inflation periods, and regular prices in no-inflation periods) the equivalent figures are –0.56, –0.57, and –0.55, respectively, i.e., greater than in the first panel. In the price decrease regressions, we find that the coefficient of the 9-ending dummy are –0.15, –0.15, –0.16, and –0.15, in the four columns, respectively. *Thus, we find that the asymmetry in the rigidity of 9-ending prices is greater for regular prices than for the actual transaction prices.*

In Table 6a", we compare the size of price changes when prices increase and decrease. The columns of the table report the results for the actual transaction prices, for regular prices, for regular prices in inflation periods, and for regular prices in no-inflation periods.

The results in the first column (same as in Table 6 in the paper) suggest that in case of the actual transaction prices (which include the sale prices), when 9-ending prices increase, the expected change in the price is about 4% greater than the expected change in the prices with other endings. The negative sign of the interaction term between price-decreases and the 9-ending dummy suggests that when 9-ending prices decrease, the expected change is only 1% larger (4% – 3% = 1%) than the expected change in prices with other endings.

When we exclude the sale and the bounce-back prices (Column 2), we find that when 9-ending prices increase, the expected change in the price is about 7% greater than the expected change in prices with other endings. The expected decrease in 9-ending prices is a little smaller than the expected change in other prices (7% – 8% = –1%). The results presented in Columns 3–4 (regular prices in inflation periods, and regular prices in no-inflation periods) are similar to the results in Column 2.

We therefore find that whether we include sales or not, and whether we focus on inflation periods or on no-inflation periods, when 9-ending prices increase, the expected price change is greater than the expected price change when prices with other endings change. This is consistent with the finding above that 9-ending prices are more rigid upward than prices with other endings: if prices change only infrequently, the when they do change, the changes are expected to be relatively large. At the same time, because 9-ending prices are less rigid downward than upward, their decreases will not necessarily be larger than the decreases in prices ending with other digits. The finding that the expected price changes are slightly smaller when 9-ending prices decrease than when prices with other endings decrease, is perhaps an outcome of the retailers using signals other than 9-endings to inform consumers about price cuts.

Table 3a". 10-State Markov Chain Transition Probability Matrix for Price Increases and Decreases by Last Digit Conditional on Price Change, from Starting Last Digit to Ending Last Digit (Dominick's; Actual Transaction Prices)

A. Price Increases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	5.560	4.900	5.850	5.040	5.850	13.84	3.540	3.470	2.090	49.86	100
1	3.800	2.510	6.430	8.010	4.420	15.45	3.350	3.480	1.830	50.71	100
2	4.390	2.880	3.770	6.970	5.600	15.79	3.910	4.020	2.430	50.25	100
3	5.590	2.650	2.360	5.410	6.190	15.54	4.270	5.240	3.160	49.59	100
4	3.950	2.090	2.740	2.750	3.110	12.30	4.810	4.370	2.430	61.45	100
5	8.170	3	2.920	3.470	2.620	12.85	5.960	6.630	4.030	50.35	100
6	5.180	3.250	4.660	3.720	4.550	9.890	2.650	9.320	4	52.79	100
7	5.510	3.770	4.240	4.580	3.180	12.41	2.130	4.880	4.080	55.22	100
8	6.840	6.140	4.550	6.390	3.620	13.67	3.170	3.250	3.720	48.66	100
9	6.660	4.070	3.880	4.210	4.350	7.780	2.480	3.220	1.700	**61.65**	100

B. Price Decreases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	10.18	3	3.300	5.210	4.180	10.68	5.490	3.770	3.120	51.06	100
1	12.52	2.730	3.610	4.260	4.030	8.180	6.010	5.110	5.700	47.86	100
2	14.32	7.220	3.500	3.230	4.720	7.310	9.050	5.240	3.270	42.14	100
3	10.24	9.390	5.670	5.810	3.920	6.760	5.260	5.400	3.940	43.61	100
4	12.63	4.730	5.720	6.600	4.910	5.910	6.570	3.980	2.390	46.56	100
5	11.33	5.610	6.170	8.050	6.340	7.830	5.690	5.680	3.280	40.01	100
6	9.360	5.400	5.470	7.330	10.73	9.270	4.730	3.850	2.770	41.08	100
7	7.060	3.810	4.180	6.350	9.610	10.57	11.81	4.430	2.180	40.02	100
8	7.780	3.610	4.710	6.980	9.650	12.89	9.970	8.380	4.210	31.82	100
9	8.650	3.080	2.670	3.980	6.200	6.440	5.910	4.460	2.060	**56.55**	100

Table 3b''. 10-State Markov Chain Transition Probability Matrix for Price Increases and Decreases by Last Digit Conditional on Price Change, from Starting Last Digit to Ending Last Digit (Dominick's; Regular Prices; Sale Filter)

A. Price Increases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	8.99	5.51	5.75	5.45	5.70	16.85	3.36	3.69	2.05	42.64	100
1	4.10	2.17	7.20	8.96	4.92	17.99	3.58	3.56	1.82	45.69	100
2	5.56	2.01	2.90	7.63	5.62	17.42	3.49	4.16	2.70	48.51	100
3	7.12	2.92	2.81	4.51	7.29	17.04	4.77	6.46	3.21	43.85	100
4	5.49	2.25	2.40	2.42	2.62	13.74	5.44	5.05	2.64	57.95	100
5	12.16	3.42	3.03	3.75	2.28	10.61	8.42	8.96	5.09	42.29	100
6	7.64	4.16	3.27	3.84	3.35	8.77	2.40	13.48	4.43	48.67	100
7	6.97	4.54	3.80	5.24	2.62	11.44	2.06	4.01	5.22	54.09	100
8	9.21	6.19	4.32	6.84	3.37	14.42	3.22	3.27	3.17	45.98	100
9	11.76	5.67	5.25	5.14	5.49	8.19	2.52	3.27	1.57	**51.15**	100

B. Price Decreases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	9.42	2.48	3.57	5.02	4.10	12.01	4.35	3.47	2.77	52.80	100
1	9.95	2.50	2.72	4.88	4.28	11.09	5.47	6.70	5.38	47.03	100
2	11.19	7.23	4.25	3.49	4.86	10.47	5.47	5.45	3.70	43.90	100
3	9.24	10.95	6.74	5.27	3.60	8.58	4.69	5.67	4.59	40.66	100
4	9.25	5.59	6.94	6.94	4.70	6.96	3.72	4.24	2.62	49.04	100
5	5.50	3.76	4.20	52.38	4.04	4.41	2.24	3.20	2.16	18.12	100
6	7.43	5.84	5.71	7.69	10.78	12.39	3.90	4.15	3.54	38.56	100
7	5.71	4.29	4.82	7.30	9.37	14.61	9.52	4.72	2.97	36.69	100
8	6.50	3.91	5.22	7.32	9.47	17.77	9.75	9.59	3.69	26.78	100
9	6.97	3.48	3.62	4.30	7.37	7.90	5.76	6.14	3.62	50.84	100

Table 3c''. 10-State Markov Chain Transition Probability Matrix for Price Increases and Decreases by Last Digit Conditional on Price Change, from Starting Last Digit to Ending Last Digit (Dominick's; Regular Prices, Inflation Periods; Sale Filter)

A. Price Increases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	9.43	5.60	6.03	5.48	5.69	15.48	3.53	3.99	2.20	42.58	100
1	3.95	2.21	7.21	8.96	4.53	18.52	3.42	3.27	1.72	46.22	100
2	5.31	1.95	2.92	7.66	5.62	17.79	3.63	4.04	2.47	48.61	100
3	6.41	2.84	2.06	3.61	7.52	17.49	5.38	6.49	3.63	44.56	100
4	5.51	2.29	2.12	2.14	2.37	13.85	5.80	4.94	2.77	58.22	100
5	11.14	3.42	3.00	4.05	2.15	9.99	8.02	8.96	4.93	44.35	100
6	7.70	4.16	3.22	3.92	3.14	8.62	2.47	15.33	4.85	46.60	100
7	7.18	4.35	3.62	5.69	2.62	10.98	2.11	3.74	5.52	54.20	100
8	9.43	6.83	4.00	6.34	3.33	13.53	2.98	3.32	2.82	47.43	100
9	11.91	5.68	5.23	4.97	5.53	7.87	2.40	3.24	1.55	**51.62**	100

B. Price Decreases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	9.36	2.33	2.87	4.20	4.17	12.66	3.00	3.13	3.00	54.36	100
1	13.46	2.95	3.09	5.74	4.94	14.11	6.36	8.38	6.46	34.50	100
2	11.70	7.98	3.70	3.42	5.09	8.97	5.59	4.74	3.96	44.84	100
3	10.25	10.47	6.77	4.80	3.56	8.26	4.66	5.62	4.07	41.53	100
4	9.44	5.59	7.56	6.49	4.52	6.21	3.66	4.60	2.50	49.44	100
5	10.77	7.05	8.08	9.52	8.09	8.10	4.19	5.86	3.65	34.69	100
6	8.29	5.81	5.58	7.66	10.88	12.33	3.93	3.58	3.16	38.76	100
7	6.33	4.49	4.56	7.35	9.94	13.95	10.52	4.48	2.39	35.98	100
8	6.42	4.00	4.42	6.89	9.77	17.30	9.39	10.61	3.66	27.54	100
9	7.18	3.43	3.60	4.20	5.98	8.09	5.98	6.14	3.12	51.11	100

Table 3d''. 10-State Markov Chain Transition Probability Matrix for Price Increases and Decreases by Last Digit Conditional on Price Change, from Starting Last Digit to Ending Last Digit (Dominick's; Regular Prices, No-Inflation Periods; Sale Filter)

A. Price Increases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	8.32	5.38	5.32	5.41	5.71	18.95	3.12	3.24	1.81	42.73	100
1	4.32	2.12	7.20	8.95	5.51	17.21	3.83	4.01	1.97	44.88	100
2	5.91	2.10	2.86	7.60	5.61	16.90	3.29	4.33	3.03	48.36	100
3	8.03	3.02	3.78	5.67	7.00	16.47	4.00	6.42	2.67	42.93	100
4	5.47	2.19	2.80	2.80	2.96	13.60	4.96	5.20	2.46	57.56	100
5	12.55	3.16	2.83	3.07	2.28	10.59	8.29	8.26	4.91	44.06	100
6	7.56	4.15	3.35	3.72	3.64	8.98	2.30	10.88	3.85	51.56	100
7	6.70	4.78	4.03	4.66	2.63	12.04	2.00	4.37	4.83	53.95	100
8	8.89	5.25	4.81	7.59	3.41	15.75	3.58	3.18	3.70	43.83	100
9	11.54	5.64	5.29	5.37	5.44	8.65	2.69	3.31	1.59	**50.48**	100

B. Price Decreases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	17.39	4.92	8.63	11.34	7.38	20.27	9.08	7.25	4.48	9.25	100
1	8.88	10.50	3.12	5.37	4.83	10.96	6.11	6.80	5.77	45.43	100
2	10.49	2.15	5.02	3.59	4.54	12.51	5.30	6.42	3.33	42.61	100
3	8.01	4.57	6.69	5.84	3.65	8.96	4.73	5.74	5.23	39.59	100
4	8.95	15.02	5.93	7.68	4.99	8.18	3.81	3.65	2.81	48.41	100
5	9.91	1.82	7.75	10.42	7.05	8.68	4.28	6.32	4.68	33.73	100
6	6.37	28.13	2.99	7.98	10.96	12.86	3.97	5.12	4.22	39.46	100
7	4.85	4.12	5.19	7.23	8.57	15.53	8.14	5.04	3.78	37.67	100
8	6.62	7.25	6.28	7.88	9.07	18.39	10.23	8.24	3.73	25.77	100
9	6.67	0.17	3.65	4.44	7.68	7.62	5.43	6.13	4.36	**50.46**	100

Table 4a''. Probability that a New Price Ends with 9

(Dominick's; Actual Transaction Prices; Regular Prices; Regular Prices, Inflation Periods; Regular Prices, No-Inflation Periods; Sale Filter)

	Actual transaction price changes	Regular price changes	Regular price changes, Inflation periods	Regular price changes, No-inflation periods
Sale Filter Indicator	0.24*** (0.0007)	N/A		
Price Level	0.11*** (0.0002)	0.11*** (0.0003)	0.09*** (0.0005)	0.12*** (0.0004)
Price Change	-0.13*** (0.0005)	-0.20*** (0.0007)	-0.17*** (0.001)	-0.23*** (0.001)
Price Decrease	**-0.11***** **(0.0007)**	**-0.22***** **(0.001)**	**-0.19***** **(0.002)**	**-0.23***** **(0.001)**
Previous 9-Ending	**0.26***** **(0.0006)**	**0.27***** **(0.0009)**	**0.28***** **(0.001)**	**0.26***** **(0.001)**
Constant	-0.30*** (0.0008)	-0.26*** (0.001)	-0.25*** (0.002)	0.26*** (0.001)
Observations	20,839,462	7,865,307	3,242,665	4,622,642

Notes: The table reports the results of a probit regression for the probability that a new price ends with 9. Standard errors are reported in parentheses. *** $p < 1\%$

Table 5a''. Probability of Price Increases and Decreases Relative to Price Remaining Unchanged (Dominick's; Actual Transaction Prices; Regular Prices; Regular Prices, Inflation Periods; Regular Prices, No-Inflation Periods; Sale Filter)

	Actual transaction prices		Regular prices		Regular prices, Inflation periods		Regular prices, No-Inflation Period	
	Price Decreases	Price Increases	Price Decreases	Price Increases	Price Decreases	Price Increases	Price Decreases	Price Increases
Sale Filter Indicator	1.06*** (0.001)	3.93*** (0.0009)	N/A					
Previous 9-Ending	**-0.15*** (0.0008)**	**-0.39 (0.0009)**	**-0.15*** (0.001)**	**-0.56*** (0.001)**	**-0.16*** (0.002)**	**-0.57*** (0.001)**	**-0.15*** (0.002)**	**-0.55*** (0.002)**
Absolute Value of the Percentage Change in the Wholesale Price	7.93*** (0.004)	7.30*** (0.005)	6.75*** (0.005)	5.92*** (0.005)	6.68*** (0.006)	5.87*** (0.006)	6.86*** (0.008)	6.09*** (0.008)
Price Level	-0.14*** (0.0003)	0.11*** (0.0002)	-0.05*** (0.0004)	0.10*** (0.0003)	-0.05*** (0.0005)	0.11*** (0.0004)	-0.05*** (0.0006)	0.10*** (0.0004)
Constant	-1.76*** (0.0008)	-2.81*** (0.0009)	-2.87*** (0.001)	-2.71*** (0.001)	-2.86*** (0.002)	-2.70*** (0.001)	-2.89*** (0.002)	-2.73*** (0.002)
χ^2	2.74×10^7		3.62×10^7		$2..08\times10^7$		1.54×10^7	
Observations	81,734,333		66,689,125		38,706,365		27,982,760	

Notes: The table reports estimation results of a SURE regression of the probability that the corresponding digit will change conditional on a price change. Standard errors are reported in parentheses. *** $p < 1\%$.

Table 6a''. The Size of 9-Ending Price Changes

(Dominick's; Actual Transaction Prices; Regular Prices; Regular Prices, Inflation Periods; Regular Prices, No-Inflation Periods; Sale Filter)

	Actual transaction prices	Regular prices	Regular prices, Inflation periods	Regular prices, No-Inflation Period
Previous 9-Ending	**0.04*** (0.0003)**	**0.07*** (0.0006)**	**0.07*** (0.0009)**	**0.06*** (0.0005)**
Previous 9-Ending × Price Decrease	**-0.03*** (0.0003)**	**-0.08*** (0.0006)**	**-0.08*** (0.001)**	**-0.07*** (0.0006)**
Price Level	-0.0005*** (0.00007)	0.007*** (0.0001)	0.007*** (0.0002)	0.007*** (0.0001)
Absolute Value of the Percentage Change in the Wholesale Price	0.56*** (0.0005)	0.63*** (0.001)	0.65*** (0.002)	0.61*** (0.0009)
Sale Filter Indicator in Previous Week	-0.04*** (0.0002)	N/A		
Sale Filter Indicator	0.07*** (0.0002)			
Constant	0.13*** (0.0003)	0.10*** (0.0005)	0.09*** (0.0007)	0.10*** (0.0004)
R^2	0.07	0.05	0.04	0.13
Observations	20,601,077	7,719,952	4,537,952	3,182,219

Notes: The table reports estimation results of a linear regression of the percentage price change, conditional on the price changing. Standard errors are reported in parentheses. *** $p < 1\%$.

Discussion of Tables 3a'''– 6a'''

Our last set of robustness tests for Dominick's data uses the expanded set of observations (94,695,300 observations) combined with the sale filter for identifying sales. As discussed above, we use same sale filter A of Nakamura and Steinsson (2008, 2011).

The results of this set of tests are likely to be less reliable than the other tests run because using the sale filter in combination with the interpolation procedure we employ to address the problem of missing observations might lead to errors in the identification of sales.

The correlation between the sale filter and the Dominick's sale indicator variable in this sample, 0.51, is indeed a little lower than in our main sample of the actual transaction prices, 0.54. Nevertheless, we proceed with the tests for completeness. In addition, we would like to show that our results are not driven by a combination of missing observations and a misspecification of the sales dummy.

Tables 3a'''–3d''' present the transition probability matrix by last digit for price increases and decreases conditional on a price change. The figures in Table 3a''' are based on the analysis all prices in the expanded dataset (including sale prices) and are identical to those in Table 3a'. The figures in Table 3b''' are based on the analyses of regular prices. The figures in Table 3c''' are based on the analyses of regular prices in inflation periods. Table 3d''' presents the results for regular prices in no-inflation periods.

The results suggest that increasing the sample size by interpolating the missing observations and using a sale filter rather than the Dominick's sale indicator variable do not affect the main results that we report in the paper. According to the figures in Tables 3b''', 3c''', and 3d''', the probability that a post-increase price will be 9-ending if the pre-increase price was 9-ending are 65.58%, 66.09% and 64.83%, respectively. The corresponding figures when 9-ending prices decrease are 58.33%, 58.56% and 58.13%, respectively. We therefore find that prices are more likely to be 9-ending following a price increase than following a price decrease.

In Table 4a''', we estimate the probability that a post-change price will be 9-ending conditional on a price change. The first column presents the results for the all prices in the expanded dataset, the second presents the results for regular prices, the third presents the results for regular prices in inflation periods, and the fourth column presents the results for regular prices in no-inflation periods.

We find, consistent with the results we report in the paper, that the coefficients of 9-endings in all four regressions are in the range of 0.26–0.30, suggesting that when 9-ending prices change, they are more likely to change to 9-ending prices than when prices with other endings change. The main finding, however, is that the probability that a post-change price will be 9-ending is significantly smaller following a price decrease than following a price increase. Further, *this probability is smaller for regular prices than for the actual transaction prices* (which also include the sale prices). The coefficient of price decreases is –0.12 in Column 1 (for the actual transaction prices) and it increases in absolute value to –0.33, –0.34, and –0.31, in Columns 2, 3, and 4 (for regular prices, for regular prices in inflation periods, and for regular prices in no-inflation periods), respectively.

In Table 5a''', we report the results of a multinomial-logit regression of the likelihood that a price will either increase or decrease relative to remaining unchanged. The left-most panel presents the results for all prices in the expanded dataset, the next panel presents the results for regular prices, the penultimate panel presents the results for regular prices in inflation periods, and the right-most panel presents the results for regular prices in no-inflation periods.

Similar to the findings we report in the paper, we find that in all four columns, a 9-ending price is less likely to increase than other prices. Prices that end in 9 are also less likely to decrease than other prices, but they are not as rigid downward as they are upward.

Further, for price increases, the coefficient of 9-ending is –0.48 when we use all prices (which also include the sale prices, Panel 1). The corresponding coefficients are –0.64, –0.65, and –0.63 (for regular prices, for regular prices in inflation periods, and for regular prices in no-inflation periods, Panels 2, 3, and 4), respectively.

For price decreases, the coefficient of 9-ending is –0.14 when we use all prices (which also include the sale prices, Panel 1). The corresponding coefficients are –0.17 for regular prices, –0.18 for regular prices in inflation periods, and –0.17 for regular prices in no-inflation periods. *Thus, not only do we find that there is asymmetry in the upward and downward rigidity of 9-ending prices, but also that the asymmetry is more pronounced for regular prices than for all prices* (i.e. sale prices included).

In Table 6a''', we compare the size of price changes when prices increase and decrease. The table columns present the results for all prices in the expanded dataset, for regular prices, for regular prices in inflation periods, and for regular prices in no-inflation periods.

We find that when we use all prices (Column 1), there is no asymmetry in the size of 9-ending price increases and decreases. The coefficient of the interaction term between 9-ending and price decreases is 0.0001 and it is not statistically significant.

This is similar to our other results using the expanded dataset, in Table 6a', where we find that the coefficient of the interaction between price increases and 9-ending is positive. This result therefore seems to be an outcome of the interpolation procedure that we employ.

When we exclude the sales (Columns 2, 3, and 4), we find that the coefficient of 9-ending is positive and significant, ranging from 0.03 to 0.04, suggesting that when a 9-ending price increases, the change is about 3%–4% greater than when prices with other endings change. The coefficient of the interaction term between 9-ending and price decreases is –0.02 in all three columns (2, 3, and 4) suggesting that when 9-ending prices decrease, the change is only 1%–2% larger than when prices with other endings decrease (3% – 2% = 1%, 4% – 2% = 2%).

The results in Columns 2, 3, and 4 are therefore consistent with our hypothesis that if 9-ending prices change less frequently than prices with other endings, then when they do change, they should change by more than prices with other endings. Since 9-ending prices are more rigid upward than downward, we should expect that the difference in the size of the price changes will be greater for price increases than for price decreases, which is what we find, at least for regular prices.

Table 3a’’’. 10-State Markov Chain Transition Probability Matrix for Price Increases and Decreases by Last Digit Conditional on Price Change, from Starting Last Digit to Ending Last Digit (Dominick’s; All Prices; Expanded Sample)

A. Price Increases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	4.670	4.240	5.130	4.620	5.320	13.16	3.180	3.200	1.850	54.63	100
1	3.800	1.980	6.020	8.100	4.260	15.08	3.210	3.470	1.750	52.33	100
2	4.240	2.670	3.010	6.760	5.430	15.61	3.730	4.070	2.270	52.21	100
3	5.410	2.490	2.320	4.430	5.880	15.52	4.050	5.320	2.950	51.62	100
4	3.690	1.910	2.550	2.720	2.540	11.43	4.400	4.070	2.200	64.50	100
5	7.850	2.750	2.710	3.550	2.480	10.95	5.630	6.500	3.730	53.85	100
6	4.930	3.100	4.350	3.750	4.260	9.780	2.150	9.160	3.750	54.78	100
7	5.170	3.420	3.950	4.740	3.020	12.29	1.960	3.710	3.750	57.98	100
8	6.610	5.960	4.280	6.440	3.460	13.88	3.120	3.410	3.240	49.62	100
9	5.990	3.510	3.420	4.010	3.910	7.350	2.180	3.010	1.500	**65.13**	100

B. Price Decreases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	9.070	3.050	3.230	5.270	4.230	10.74	5.310	3.710	3.050	52.33	100
1	12.26	2.460	3.540	4.240	4.050	8.180	6.020	5.130	5.630	48.50	100
2	14.04	6.970	3.250	3.250	4.810	7.340	8.750	5.320	3.210	43.06	100
3	10.09	9.440	5.420	5.550	4.010	6.800	5.150	5.570	3.930	44.04	100
4	12.58	4.630	5.600	6.520	4.540	5.650	6.170	3.820	2.290	48.19	100
5	11.64	5.590	6.080	7.880	6.230	7.860	5.520	5.780	3.250	40.17	100
6	9.450	5.430	5.470	7.280	10.77	9.340	4.020	3.750	2.790	41.71	100
7	7.050	3.780	4.140	6.230	9.250	10.51	11.70	4.290	2.180	40.87	100
8	7.660	3.530	4.600	6.840	9.420	12.87	9.980	8.410	4.210	32.50	100
9	8.770	2.920	2.550	3.690	6.060	6.150	5.420	4.230	1.900	**58.31**	100

Table 3b’’’. 10-State Markov Chain Transition Probability Matrix for Price Increases and Decreases by Last Digit Conditional on Price Change, from Starting Last Digit to Ending Last Digit (Dominick’s; Regular Prices; Sale Filter; Expanded Sample)

A. Price Increases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	7.15	3.52	3.90	4.36	4.37	13.74	1.58	2.81	1.58	56.04	100
1	5.40	2.05	5.91	8.83	4.43	16.23	3.18	3.58	1.66	48.74	100
2	5.35	1.78	2.73	6.95	5.25	16.38	3.27	4.21	2.25	51.82	100
3	6.39	2.44	2.54	4.81	5.95	15.67	4.01	6.07	2.76	49.37	100
4	4.69	1.82	2.08	2.48	2.68	10.99	4.21	3.98	2.13	64.93	100
5	10.29	2.72	2.52	3.71	2.09	10.82	6.53	7.54	3.91	49.88	100
6	6.82	3.50	2.90	3.93	3.21	9.05	2.03	11.10	3.64	53.83	100
7	5.98	3.64	3.23	5.31	2.52	11.17	1.79	4.31	4.06	58.00	100
8	8.04	5.61	3.74	6.64	3.16	14.41	3.10	3.72	3.30	48.28	100
9	7.27	3.28	3.23	3.72	6.23	6.23	6.23	1.67	2.45	62.17	100

B. Price Decreases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	9.75	3.40	3.34	4.90	4.10	11.56	2.55	3.45	2.55	52.35	100
1	6.39	1.76	1.80	3.16	2.95	6.88	3.43	4.17	3.43	31.47	100
2	11.06	6.65	4.32	3.60	5.30	9.71	3.44	5.57	3.44	44.74	100
3	9.86	10.19	5.62	5.53	4.04	8.11	4.34	5.82	4.34	41.77	100
4	9.95	4.97	6.00	6.61	5.17	6.20	2.36	4.04	2.36	50.47	100
5	11.79	6.43	6.84	8.82	6.70	8.75	3.74	6.21	3.74	36.11	100
6	8.27	5.50	5.34	7.45	10.41	11.03	3.38	3.94	3.38	40.64	100
7	6.32	3.97	4.54	6.68	8.51	12.68	2.88	5.19	2.88	39.84	100
8	6.87	3.49	4.81	7.39	9.22	15.57	4.39	8.83	4.39	29.65	100
9	7.67	3.46	3.41	3.92	3.96	6.57	1.76	2.58	1.08	65.58	100

Table 3c’’’. 10-State Markov Chain Transition Probability Matrix for Price Increases and Decreases by Last Digit Conditional on Price Change, from Starting Last Digit to Ending Last Digit (Dominick’s; Regular Prices, Inflation Periods; Sale Filter; Expanded Sample)

A. Price Increases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	7.53	3.57	4.04	4.35	4.40	12.64	1.69	3.05	1.69	56.07	100
1	5.24	2.16	5.94	8.86	4.18	16.37	3.03	3.36	1.63	49.22	100
2	5.11	1.75	2.89	7.02	5.30	16.26	3.36	4.12	2.03	52.16	100
3	5.98	2.38	1.93	4.11	6.19	15.59	4.45	6.14	3.11	50.13	100
4	4.78	1.91	1.85	2.30	2.59	10.99	4.54	3.80	2.17	65.06	100
5	9.74	2.73	2.53	4.14	2.12	10.32	6.48	7.67	3.85	50.43	100
6	6.32	3.57	2.71	4.25	3.15	8.81	2.11	12.48	3.96	52.63	100
7	6.03	3.49	2.95	5.85	2.60	10.36	1.79	4.17	4.35	58.40	100
8	8.49	6.43	3.53	6.24	3.31	12.64	3.02	3.51	3.03	49.80	100
9	7.80	3.44	3.38	3.92	1.68	6.12	1.68	2.56	1.05	66.09	100

B. Price Decreases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	9.60	3.18	2.58	4.21	4.31	11.92	2.74	3.22	2.74	53.95	100
1	10.44	2.68	2.51	4.50	4.19	10.43	5.58	6.26	4.84	48.58	100
2	11.47	7.44	3.85	3.63	5.40	8.82	5.75	4.83	3.61	45.20	100
3	10.72	9.70	5.65	5.27	4.07	7.78	4.89	5.63	3.88	42.42	100
4	10.60	4.85	6.55	6.40	4.82	5.77	4.06	4.36	2.28	50.30	100
5	12.45	6.22	6.70	8.73	6.94	8.46	4.50	5.92	3.33	36.76	100
6	9.25	5.70	5.26	7.57	10.54	10.93	4.20	3.61	3.15	39.77	100
7	6.67	4.14	4.44	6.99	8.69	11.80	10.42	5.06	2.55	39.23	100
8	7.10	3.53	3.96	7.25	9.64	14.80	9.96	9.94	4.07	29.75	100
9	9.01	2.69	2.67	3.36	4.64	6.40	4.64	4.39	2.09	58.56	100

Table 3d’’’. 10-State Markov Chain Transition Probability Matrix for Price Increases and Decreases by Last Digit Conditional on Price Change, from Starting Last Digit to Ending Last Digit (Dominick’s; Regular Prices, No-Inflation Periods; Sale Filter; Expanded Sample)

A. Price Increases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	6.57	3.45	3.69	4.38	4.33	15.42	1.42	2.44	1.42	55.98	100
1	5.63	1.89	5.86	8.78	4.78	16.02	3.39	3.87	1.71	48.07	100
2	5.65	1.82	2.79	6.84	5.16	16.51	3.14	4.32	2.54	51.23	100
3	6.90	2.51	3.31	5.72	5.64	15.77	3.46	5.99	2.31	48.40	100
4	4.57	1.70	2.39	2.72	2.79	11.00	3.77	4.22	2.08	64.76	100
5	11.01	2.71	2.51	3.14	2.07	11.47	6.60	7.36	3.98	49.16	100
6	7.51	3.41	3.17	3.49	3.29	9.37	1.92	9.18	3.18	55.49	100
7	5.92	3.83	3.59	4.61	2.41	12.24	1.79	4.48	3.68	57.46	100
8	7.43	4.53	4.03	7.16	2.96	16.77	3.21	4.00	3.66	46.25	100
9	7.49	3.49	3.45	3.95	1.89	7.22	1.89	2.61	1.12	64.83	100

B. Price Decreases

From \ To	0	1	2	3	4	5	6	7	8	9	Total
0	9.98	3.70	4.42	5.88	3.81	11.05	2.27	3.79	2.27	50.06	100
1	8.68	2.66	3.04	5.20	4.90	10.47	6.23	6.42	5.71	46.68	100
2	10.52	5.59	4.94	3.55	5.17	10.90	5.42	6.56	3.20	44.14	100
3	8.73	10.83	5.59	5.85	4.01	8.54	4.50	6.08	4.95	40.92	100
4	8.93	5.17	5.13	6.93	5.71	6.89	4.50	3.53	2.47	50.73	100
5	10.95	6.70	7.02	8.94	6.39	9.11	4.75	6.58	4.27	35.28	100
6	6.88	5.21	5.46	7.29	10.23	11.17	3.81	4.41	3.69	41.86	100
7	5.91	3.77	4.73	6.32	8.37	14.07	8.14	4.09	3.37	41.23	100
8	6.56	3.43	5.89	7.56	8.66	16.52	9.50	7.65	4.78	29.45	100
9	7.64	2.97	2.94	3.68	4.64	6.54	4.64	4.76	1.95	58.13	100

Table 4a’’’. Probability that a New Price Ends with 9

(Dominick’s; All Prices; Regular Prices; Regular Prices, Inflation Periods; Regular Prices, No-Inflation Periods; Sale Filter; Expanded Sample)

	All price changes	Regular price changes	Regular price changes, Inflation periods	Regular price changes, No-inflation periods
Sale Filter Indicator	-0.30*** (0.0006)	N/A		
Price Level	0.11*** (0.0002)	0.13*** (0.0003)	0.14*** (0.0003)	0.11*** (0.0004)
Price Change	-0.10*** (0.0005)	-0.18*** (0.0006)	-0.20*** (0.0008)	-0.15*** (0.0009)
Price Decrease	**-0.12***** **(0.0007)**	**-0.33***** **(0.001)**	**-0.34***** **(0.001)**	**-0.31***** **(0.001)**
Previous 9-Ending	**0.26***** **(0.0005)**	**0.29***** **(0.0008)**	**0.28***** **(0.001)**	**0.30***** **(0.001)**
Constant	-0.08*** (0.0006)	-0.15*** (0.0009)	-0.16*** (0.001)	-0.15*** (0.001)
Observations	24,587,238	10,940,295	6,412,853	4,527,442

Notes: The table reports the results of a probit regression for the probability that a new price ends with 9. Standard errors are reported in parentheses. *** $p < 1\%$

Table 5a’’’. Probability of Price Increases and Decreases Relative to Price Remaining Unchanged (Dominick’s; All Prices; Regular Prices; Regular Prices, Inflation Periods; Regular Prices, No-Inflation Periods; Sale Filter; Expanded Sample)

	All prices		Regular prices		Regular prices, Inflation periods		Regular prices, No-Inflation Periods	
	Price Decreases	Price Increases	Price Decreases	Price Increases	Price Decreases	Price Increases	Price Decreases	Price Increases
Sale Filter Indicator i Previous Week	1.00*** (0.001)	3.78*** (0.001)	N/A					
Previous 9-Ending	**-0.14*** (0.007)**	**-0.48*** (0.0008)**	**-0.17*** (0.001)**	**-0.64*** (0.0009)**	**-0.18*** (0.001)**	**-0.65*** (0.001)**	**-0.17*** (0.002)**	**-0.63*** (0.001)**
Absolute Value of the Percentage Change in the Wholesale Price	7.58*** (0.004)	7.78*** (0.004)	6.56*** (0.004)	6.56*** (0.004)	6/46*** (0.005)	6.46*** (0.005)	6.73*** (0.007)	6.71*** (0.007)
Price Level	-0.13*** (0.0003)	0.12*** (0.0002)	-0.05*** (0.0003)	0.11*** (0.0002)	-0.05*** (0.0004)	0.12*** (0.0003)	-0.04*** (0.0005)	0.11*** (0.0003)
Constant	-1.71*** (0.0007)	-2.69*** (0.0008)	-2.63*** (0.001)	-2.59*** (0.0008)	-2.60*** (0.001)	-2.58*** (0.001)	-2.66*** (0.002)	-2.60*** (0.001)
χ^2	2.86×10^7		5.16×10^7		3.02×10^7		2.14×10^7	
Observations	94,439,718		78,595,860		45,535,728		33,060,132	

Notes: The table reports estimation results of a SURE regression of the probability that the corresponding digit will change conditional on a price change. Standard errors are reported in parentheses. *** $p < 1\%$.

Table 6a’’’. The Size of 9-Ending Price Changes

(Dominick’s; All Prices; Regular Prices; Regular Prices, Inflation Periods; Regular Prices, No-Inflation Periods; Sale Filter; Expanded Sample)

	All prices	Regular prices	Regular prices, Inflation periods	Regular prices, No-Inflation Periods
Previous 9-Ending	**0.03*** (0.0001)**	**0.03*** (0.0001)**	**0.04*** (0.0002)**	**0.03*** (0.0002)**
Previous 9-Ending × Price Decrease	**0.0001 (0.0001)**	**-0.02*** (0.0001)**	**-0.02*** (0.0002)**	**-0.02*** (0.0002)**
Price Level	-0.008*** (0.0001)	-0.006*** (0.00003)	-0.006*** (0.00004)	-0.005*** (0.00005)
Absolute Value of the Percentage Change in the Wholesale Price	0.50*** (0.0002)	0.57*** (0.0002)	0.57*** (0.0003)	0.56*** (0.0004)
Sale Filter Indicator in Previous Week	0.06*** (0.00009)	N/A		
Sale Filter Indicator	-0.03*** (0.00009)			
Constant	0.15*** (0.00009)	0.13*** (0.0001)	0.13*** (0.0001)	0.13*** (0.0002)
R^2	0.26	0.35	0.35	0.36
Observations	24,349,085	10,819,038	6,347,206	4,471,832

<u>Notes</u>: The table reports estimation results of a linear regression of the percentage price change, conditional on the price changing. Standard errors are reported in parentheses. *** p < 1%.

Appendix E. Robustness Check: Probability of Price Increases and Decreases Relative to Price Remaining Unchanged without Excluding the Outlier Observations on Wholesale Prices (Dominick's Data)

In the paper, we estimate the regression of the probability of price increases and decreases (Table 6) after excluding the outlier observations on changes in the wholesale prices, where we define outliers as wholesale price changes in excess of 200%.

As a robustness check, below we report the estimation results of the same regression without excluding the outliers. To make the results comparable with the robustness tests and analyses discussed in Appendix D, as well as with the results reported in Table 5 in the paper, we use both the actual transaction price dataset and the expanded dataset. For each dataset and for each method of sale identification (Dominick's sale indicator variable and Nakamura and Steinsson's sale filter, as discussed in Appendix D), we estimate all the regressions four times: (1) using all observations, (2) using the observations on regular prices, (3) using the observations on regular prices in inflation periods, and (4) using observations on regular prices in no-inflation periods. The results of these tests are presented in Tables 5b–5b'''.

The first panel of Table 5b presents the results when we use the actual transaction prices, i.e., the same dataset as we use in the paper. The results suggest that when we do not exclude the outliers, the effects of changes in the wholesale prices on the likelihood of price changes are small and their statistical significance is lower than in the paper. The coefficients of the wholesale price variable are 0.0003 ($p < 0.01$) and 0.00003 ($p < 0.05$) in the price decrease and the price increase regressions, respectively. In Table 5 in the paper, the equivalent values are 8.23 and 7.33 ($p < 0.01$ in both cases).

However, the values of the coefficient of 9-ending dummy are hardly affected by the inclusion of the outlier wholesale price observations. The coefficients of 9-ending dummy is –0.12 ($p < 0.01$) and –0.40 ($p < 0.01$) in the price decrease and the price increase regressions, respectively. For comparison, the equivalent values in Table 5 are –0.17 ($p < 0.01$) and –0.44 ($p < 0.01$).

Thus, the inclusion of the outlier observations on wholesale prices does not affect the coefficient of the 9-ending dummy. Regardless of whether or not we include the outliers, 9-ending prices are more rigid than other prices both upward and downward, but they are significantly more rigid upward than downward.

When we exclude the sales observations, and consider only the regular prices (panels 2, 3, and 4) we find that the effects of the wholesale prices are even smaller than when we use the observations on the actual transaction prices. In all three price increase regressions, the effect of the wholesale price variable is statistically insignificant.

Importantly, however, the coefficients of the 9-ending dummy are not affected much by the removal of the outlier wholesale price observations. We find, as in Table 5a (Appendix D), that when we exclude the sale prices and consider only regular prices, 9-ending prices are more rigid relative to other prices both upward and downward than when we use the actual transaction prices. The difference between the upward and downward rigidity, however, is kept. The coefficients of 9-ending in the price increase regressions are –0.91, –0.94, and –0.85 for regular prices, for regular prices in inflation periods, and for regular prices in no-inflation periods, respectively. The equivalent values in the price decreases regressions are less than half as large in absolute values, –0.35, –0.33, and –0.38, respectively.

Table 5b' presents the results for the expanded (interpolated) dataset. When we use all prices (which include sale prices), we find that the interpolation procedure we employ to handle the missing observations and thus expand the dataset, has two effects. First, the addition of observations diminishes the effect of the outlier wholesale price observations and consequently, the effects of changes in the wholesale price on the likelihood of price changes are larger than in Table 5b.

Second, the interpolation introduces spurious price changes and, therefore, the measured difference between the likelihood that a 9-ending price and a price with a different ending will change is reduced. We still find, however, that 9-ending prices are significantly more rigid than other prices both upward and downward, but more importantly, that 9-ending prices are more rigid upward than downward. The coefficients of 9-ending in the price decrease and price increase regressions are –0.10 and –0.22, respectively.

When we limit the analyses to regular prices, we find again that the rigidity of 9-ending prices relative to prices with other endings is more pronounced than when we use the sample that includes sale prices. We also find that the difference between the upward and downward rigidity of 9-ending prices is greater than in the sample that includes sale prices. The coefficients of 9-ending price in the price decrease regressions are –0.37, –0.25 and –0.41 for regular prices, for regular prices in inflation periods, and for regular prices in no-inflation periods, respectively. The corresponding figures in the price increase regressions are, in absolute terms, more than twice as large, –0.88, –0.60 and –0.88, respectively.

Table 5b" presents the results for the actual transaction prices (same as in the paper) and the sale filter of Nakamura and Steinsson (2008, 2011) to identify sale prices. We find that using the sale filter does not have any noticeable effect on the coefficients of the wholesale prices in comparison to the figures reported in Table 5b. The coefficients in all regressions are small, and in the price increase regressions in Panels 3 and 4, they are statistically insignificant.

In the actual transaction prices panel (Panel 1), we find that the coefficients are similar to the ones we find when we use the Dominick's sale indicator variable. The coefficient of 9-ending prices in the price decrease (increase) regression is –0.12 (–0.35) compared to –0.12 (–0.40) in Panel 1 of Table 5b.

At the same time, both the upward and the downward rigidities of 9-ending prices are smaller for regular prices when we use the sale filter instead of the Dominick's sale indicator variable to identify and exclude the observations on sale prices. The coefficients of 9-ending in the price decrease (increase) regressions are –0.20 (–0.54), –0.21 (–0.56) and –0.19 (–0.54) for regular prices, for regular prices in inflation periods, and for regular prices in no-inflation periods, respectively. This is compared to the figures we report in Table 5b: –0.35 (–0.91), –0.33 (–0.94) and –0.38 (–0.85) in the price decrease (increase) regressions for regular prices, for regular prices in inflation periods, and for regular prices in no-inflation periods, respectively.

Nevertheless, we find that using the sale filter does not change our main result: 9-ending prices are significantly more rigid than prices ending with other digits both upward and downward. Moreover, the upward rigidity is significantly greater than the downward rigidity. Thus, the main results remain qualitatively unchanged whether we use Nakamura and Steinsson’s sale filter or the Dominick's sale indicator variable to identify sales.

Table 5b''' presents the results when we use the expanded (interpolated) dataset along with the sale filter to identify sales. Similar to what we report in Table 5b', we find that when we use the expanded dataset, the effect of the outlier observations on wholesale prices changes have a smaller effect than when we use the dataset of the actual transaction prices. The coefficients of the change in the wholesale prices are 0.59 (0.80), 0.80 (0.96), and 0.59 (0.80), for price decrease (increase) regressions, for regular prices, for regular prices in inflation periods, and for regular prices in no-inflation periods, respectively. The corresponding figures in Table 5b’’ are 0.0003 (0.00005), 0.0004 (8.23×10^{-6}), and 0.0003 (0.00002), respectively.

However, the use of the expanded dataset and the sale filter do not affect qualitatively the main results reported in the paper. The figures in Panel 1 (all prices, which include sales), indicate that 9-ending prices are more rigid both downward and upward than prices that end with other digits. In addition, the coefficient in the price increase regression –0.34, is three times larger in absolute value than the coefficient in the price decrease regression (–0.11).

The differences between the upward and downward rigidities are even more pronounced for regular prices. The coefficients of 9-ending in the price decrease regressions in Columns 2, 3, and 4 (regular prices, regular prices in inflation periods, and regular prices in no-inflation periods) are –0.18, –0.18 and –0.17, respectively. The corresponding coefficients in the price increase regressions, –0.73, –0.73, –0.71, respectively, are more than four time as large in absolute value.

The results of the robustness tests discussed in this appendix, therefore suggest that an inclusion or an exclusion of the outlier wholesale price changes do not affect any of the main conclusions we draw in the paper. 9-ending prices are more rigid than prices that end with other digits both upward and downward, and the upward rigidity is greater than the downward rigidity. This is true for both for the transaction prices and for regular prices, regardless of whether or not the sample includes sale prices or not.

Table 5b. Probability of Price Increases and Decreases Relative to Price Remaining Unchanged

(Dominick's; Actual Transaction Prices; Regular Prices; Regular Prices, Inflation Periods; Regular Prices, No-Inflation Periods)

	Actual transaction prices		Regular prices		Regular prices, Inflation periods		Regular prices, No-Inflation Period	
	Price Decreases	Price Increases	Price Decreases	Price Increases	Price Decreases	Price Increases	Price Decreases	Price Increases
Sale Price Indicator in Previous Week	0.45*** (0.001)	3.04*** (0.0008)	N/A					
Previous 9-Ending	**-0.12****** **(0.0007)**	**-0.40****** **(0.0008)**	**-0.35****** **(0.001)**	**-0.91****** **(0.001)**	**-0.33****** **(0.002)**	**-0.94****** **(0.002)**	**-0.38****** **(0.002)**	**-0.85****** **(0.002)**
Absolute Value of the Percentage Change in the Wholesale Price	0.0003*** (5.06×10^{-6})	0.00003** (0.0001)	0.0003*** (5.48×10^{-6})	9.13×10^{-6} (0.00002)	0.0005*** (0.00001)	-0.00001 (0.0005)	0.0003*** (9.51×10^{-6})	0.00003 (0.00003)
Price Level	-0.15*** (0.0003)	0.09*** (0.0002)	-0.07*** (0.0005)	0.09*** (0.0003)	-0.09*** (0.0006)	0.09*** (0.005)	-0.05*** (0.0008)	0.10*** (0.0005)
Constant	-1.48*** (0.0008)	-2.85*** (0.0009)	-2.73*** (0.001)	-2.68*** (0.001)	-2.65*** (0.002)	-2.66*** (0.001)	-2.83*** (0.002)	-2.73*** (0.002)
χ^2	1.85×10^{7}		6.02×10^{6}		3.86×10^{6}		2.22×10^{6}	
Observations	81,982,683		58,677,364		34,211,984		24,465,380	

Notes: The table reports estimation results of a Multinomial-logit model for the probability of a price decrease and increase relative to the prices remaining unchanged. Standard errors are reported in parentheses.
*** $p < 1\%$. ** $p < 5\%$

Table 5b'. Probability of Price Increases and Decreases Relative to Price Remaining Unchanged

(Dominick's; All Prices; Regular Prices; Regular Prices, Inflation Periods; Regular Prices, No-Inflation Periods; Expanded Sample)

	All prices		Regular prices		Regular prices, Inflation periods		Regular prices, No-Inflation Period	
	Price Decreases	Price Increases	Price Decreases	Price Increases	Price Decreases	Price Increases	Price Decreases	Price Increases
Sale Price Indicator in Previous Week	0.32*** (0.001)	3.74*** (0.0008)	N/A					
Previous 9-Ending	**-0.10***** **(0.0007)**	**-0.22***** **(0.0007)**	**-0.37***** **(0.001)**	**-0.88***** **(0.001)**	**-0.25***** **(0.002)**	**-0.60***** **(0.001)**	**-0.41***** **(0.005)**	**-0.88***** **(0.002)**
Absolute Value of the Percentage Change in the Wholesale Price	0.68*** (0.002)	0.79*** (0.002)	0.65*** (0.004)	1.18*** (0.003)	1.11*** (0.004)	1.12*** (0.004)	1.73*** (0.005)	1.98*** (0.005)
Price Level	-0.12*** (0.0002)	0.08*** (0.0002)	-0.06*** (0.0004)	0.11 (0.0003)	-0.05*** (0.0005)	0.07*** (0.0004)	-0.04*** (0.0007)	0.11*** (0.0004)
Constant	1.53*** (0.0007)	-2.56*** (0.0008)	-2.73*** (0.001)	-2.60*** (0.001)	-2.80*** (0.002)	-2.71*** (0.001)	-2.83*** (0.002)	-2.68*** (0.002)
χ^2	1.94×10^7		1.27×10^7		7.42×10^6		7.72×10^6	
Observations	94,681,575		68,529,665		39,766,815		28,762,850	

Notes: The table reports estimation results of a Multinomial-logit model for the probability of a price decrease and increase relative to the prices remaining unchanged. Standard errors are reported in parentheses.
*** $p < 1\%$.

Table 5b". Probability of Price Increases and Decreases Relative to Price Remaining Unchanged

(Dominick's; Actual Transaction Prices; Regular Prices; Regular Prices, Inflation Periods; Regular Prices, No-Inflation Periods; Sale Filter)

	Actual transaction prices		Regular prices		Regular prices, Inflation periods		Regular prices, No-Inflation Period	
	Price Decreases	Price Increases	Price Decreases	Price Increases	Price Decreases	Price Increases	Price Decreases	Price Increases
Sale Price Indicator Previous Week	0.90*** (0.001)	3.79*** (0.001)	N/A					
Previous 9-Ending	**-0.12***** **(0.0007)**	**-0.35***** **(0.0008)**	**-0.20***** **(0.001)**	**-0.54***** **(0.001)**	**-0.21***** **(0.001)**	**-0.56***** **(0.001)**	**-0.19***** **(0.002)**	**-0.54***** **(0.002)**
Absolute Value of the Percentage Change in the Wholesale Price	0.0003*** (5.08×10^{-6})	0.00004*** (0.00001)	0.0003*** (7.12×10^{-6})	0.00005** (0.00002)	0.0004*** (0.00001)	8.23×10^{-6} (0.0003)	0.0003*** (0.00001)	0.00002 (0.00004)
Price Level	-0.15*** (0.0003)	0.11*** (0.002)	-0.05*** (0.0003)	0.11*** (0.0003)	-0.05*** (0.0005)	0.12*** (0.0003)	-0.05*** (0.0006)	0.11*** (0.0004)
Constant	-1.47*** (0.0008)	-2.61*** (0.0009)	-2.51*** (0.001)	-2.56*** (0.0009)	-2.54*** (0.001)	-2.54*** (0.001)	-2.58*** (0.002)	-2.58*** (0.001)
χ^2	2.16×10^{7}		4.34×10^{6}		2.61×10^{6}		1.71×10^{6}	
Observations	81,982,683		66,844,240		38,796,790		28,047,450	

Notes: The table reports estimation results of a Multinomial-logit model for the probability of a price decrease and increase relative to the prices remaining unchanged. Standard errors are reported in parentheses.
*** $p < 1\%$. ** $p < 5\%$

Table 5b'''. Probability of Price Increases and Decreases Relative to Price Remaining Unchanged

(Dominick's; All Prices; Regular Prices; Regular Prices, Inflation Periods; Regular Prices, No-Inflation Periods; Sale Filter; Expanded Sample)

	All prices		Regular prices		Regular prices, Inflation periods		Regular prices, No-Inflation Period	
	Price Decreases	Price Increases	Price Decreases	Price Increases	Price Decreases	Price Increases	Price Decreases	Price Increases
Sale Price Indicator i Previous Week	0.94*** (0.0007)	4.81*** (0.001)	N/A					
Previous 9-Ending	**-0.11***** **(0.0007)**	**-0.34***** **(0.0008)**	**-0.18***** **(0.001)**	**-0.73***** **(0.0009)**	**-0.18***** **(0.001)**	**-0.73***** **(0.001)**	**-0.17***** **(0.002)**	**-0.71***** **(0.001)**
Absolute Value of the Percentage Change in the Wholesale Price	0.71*** (0.002)	0.80*** (0.002)	0.59*** (0.002)	0.80*** (0.002)	0.80*** (0.003)	0.96*** (0.003)	0.59*** (0.003)	0.80*** (0.003)
Price Level	-0.12*** (0.0002)	0.10*** (0.0002)	-0.05*** (0.0003)	0.16*** (0.0002)	-0.05*** (0.0004)	0.16*** (0.0003)	-0.04*** (0.0005)	0.15*** (0.0003)
Constant	-1.52*** (0.0007)	-2.30*** (0.0008)	-2.41*** (0.001)	-2.37*** (0.0008)	-2.38*** (0.001)	-2.37*** (0.001)	-2.45*** (0.002)	-2.39*** (0.001)
χ^2	2.14×10^7		1.95×10^7		1.26×10^7		8.43×10^6	
Observations	94,681,575		78,725,589		45,607,335		33,118,254	

Notes: The table reports estimation results of a Multinomial-logit model for the probability of a price decrease and increase relative to the prices remaining unchanged. Standard errors are reported in parentheses.

*** p < 1%. ** p< 5%

Appendix F. Robustness Check: Comparison of the Average Size of Price Changes without Excluding the Outlier Observations on Wholesale Prices (Dominick's Data)

In the paper, we estimate the regression of the size of price changes (Table 6) after excluding the outlier observations on changes in the wholesale prices, where we define outliers as wholesale price changes in excess of 200%.

As a robustness check, below we report the estimation results of the same regression without excluding the outliers. To make the results comparable with the robustness tests and analyses discussed in Appendix D, as well as with the results reported in Table 6 in the paper, we use both the actual transaction price dataset and the expanded dataset. For each dataset and for each method of sale identification (Dominick's sale indicator variable and the sale filter, discussed in appendix D), we estimate all the regressions four times: (1) using all the observations, (2) using the observations on regular prices, (3) using the observations on regular prices in inflation periods, and (4) using observations on regular prices in no-inflation periods. The results of these tests are presented in Tables 6b–6b'''.

Table 6b reports the results when we use the actual transaction prices (same as in the paper) and the Dominick's sale indicator variable to identify sales. Table 6b' presents the results for the expanded dataset (94,695,300 observations) and the Dominick's sale indicator variable to identify sales. Table 6b'' reports the results for the actual transaction prices and the sale filter to identify sales. Table 6b''' presents the results when we use the expanded dataset and the sale filter to identify sales.

As in the paper, we measure both the changes in the wholesale prices and the changes in the retail prices in percentages, to avoid giving greater (lower) weight to the more (less) expensive items. We use the absolute value of the percentage change which we calculate by dividing the absolute value of the price change by the pre-change price..

We find that when we do not exclude the outliers, the coefficient of wholesale prices is smaller compared to the results when we exclude the outliers. This, however, does not affect the main results qualitatively. In all the regressions, we find that the coefficient of 9-ending is positive, suggesting that when 9-ending prices increase they increase by more than other prices. We also find that the interaction between 9-ending dummy and price decreases is negative. Thus, when 9-ending prices decrease, the size of the decrease is smaller than when 9-ending prices increase.

In addition, we find that these effects hold true both for the actual transaction prices and for regular prices. We also find that these results hold in both inflation periods and in no-inflation periods.

Starting with Table 6b (which uses the same dataset as the paper), we find that in the first column (for the actual transaction prices, which include the sale prices), the coefficient of the wholesale prices is 6.59×10^{-7}, compared with $\beta = 0.55$ in Table 6 in the paper. Thus, when we do not exclude the outlier observations on the wholesale price changes, the effect of wholesale price changes on retail price changes is very small.

However, the coefficient of 9-ending is 0.05, similar to 0.06 in Table 6 in the paper. The coefficient of the interaction term between 9-ending and price decreases is –0.05, close to –0.07 in Table 6 in the paper. Thus, both in the paper and in these robustness tests, we find that, as we hypothesize, 9-ending prices change by more when they increase than when prices with other endings increase. We also find that when 9-ending prices decrease, the expected change is not different, or is even smaller, than the expected change when prices with other endings decrease, as may be expected if 9-ending prices are not more rigid downward than other prices.

The results for regular prices, in column 2 (i.e., when we exclude sales), and in inflation and no-inflation periods (columns 3 and 4) are similar to the results reported in the first column. In all four columns, the coefficient of the percentage change in the wholesale price is significant, but quantitatively very small (ranging from 1.47×10^{-6} to 2.32×10^{-5}). At the same time, the coefficient of 9-ending falls in the range of 0.04–0.06, while the interactions between 9-ending and price decreases are negative and significant with values ranging between –0.05 and –0.06.

Thus, as in the first column, we find that when 9-ending prices increase, the expected change is greater than when prices with other endings increase. When 9-ending prices decrease, however, the expected change is not different, or is even smaller than when prices with other endings change.

When we use the expanded dataset (see Table 6b'), the interpolation procedure adds more observations on price changes and therefore, the effect of the outlier wholesale price changes is diminished. Consequently, the coefficient of the wholesale price change is 0.09 when we use all prices (Column 1). When we remove sales and thus use only regular prices, the estimated coefficients are 0.18, 0.30 and 0.14, for regular prices, for regular prices in inflation periods, and for regular prices in no-inflation periods, respectively.

As to the effect of 9-endings, we find again, similar to what we report in Table 6a', that the expansion of the dataset, which adds many small price changes, yields a coefficient of 0.04 for all prices (Column 1, which include the sale prices), 0.03 for regular prices (Column 2), 0.02 for regular prices in inflation periods (Column 3), and 0.04 for regular prices in no-inflation periods (Column 4). These values are smaller than 0.06, which is the value of the corresponding estimate in Table 6 in the paper.

The coefficients of price decreases are –0.03, –0.03, –0.02 and –0.03 in Columns 1, 2, 3 and 4 (all prices, regular prices, regular prices in inflation periods and regular prices in no-inflation periods), respectively. Thus, when 9-ending prices decrease, the expected change is not different and perhaps is even smaller than when prices with other endings change.

According to the figures in Table 6b" (which is based on the same dataset as in the paper, using sale filter to identify sale prices), the coefficient of 9-ending are 0.04, 0.05, 0.05, and 0.05 in Columns 1, 2, 3 and 4 (for actual transaction prices, regular prices, regular prices in inflation periods, and regular prices in no-inflation periods), respectively. These results are similar to the results we report in Table 6b, where we use the Dominick's indicator variable to identify sale prices.

The corresponding coefficients of the interaction term between 9-ending and price decreases are negative and significant in all four columns. Their values are –0.01, –0.06, –0.06, –0.06. Thus, when 9-ending prices decrease, the expected change is smaller than when they increase. This is consistent with 9-ending prices being more rigid upward than downward and, therefore, when they increase, they change by more than when they decrease.

According to the figures in Table 6b''' (which is based on the expanded dataset, using sale filter to identify sale prices), the coefficient of 9-ending are 0.03, 0.04, 0.04, and 0.03, in Columns 1, 2, 3 and 4, respectively. These results are similar to the results we report in Table 6b', where we use the Dominick's indicator variable to identify the sale prices.

The corresponding coefficients of the interaction term between 9-ending and price decreases are negative and significant in all four columns. Their values are –0.02, –0.05, –0.05, and –0.05. Thus, when 9-ending prices decrease, the expected change is smaller than when 9-ending prices increase. This is consistent with 9-ending prices being more rigid upward than downward and, therefore, they change by more when they increase than when they decrease.

Table 6b. The Size of 9-Ending Price Changes

(Dominick's; Actual Transaction Prices; Regular Prices; Regular Prices, Inflation Periods; Regular Prices, No-Inflation Periods)

	Actual transaction prices	Regular prices	Regular prices, Inflation periods	Regular prices, No-Inflation Periods
Previous 9-Ending	**0.05*** (0.0003)**	**0.05*** (0.0009)**	**0.04*** (0.001)**	**0.06*** (0.001)**
Previous 9-Ending × Price Decrease	**-0.05*** (0.0003)**	**-0.05*** (0.001)**	**-0.05*** (0.002)**	**-0.06*** (0.001)**
Price Level	0.0004*** (0.00007)	-0.002*** (0.0002)	-0.002*** (0.0004)	-0.002*** (0.0003)
Absolute Value of the Percentage Change in the Wholesale Price	6.59×10^{-7}*** (3.18×10^{-8})	1.76×10^{-6}*** (3.18×10^{-7})	2.32×10^{-5}*** (1.70×10^{-6})	1.47×10^{-6}*** (1.31×10^{-7})
Sale Price Indicator in Previous Week	0.04*** (0.0002)	N/A		
Sale Price Indicator	0.006*** (0.0002)			
Constant	0.18*** (0.002)	0.14*** (0.0007)	0.14*** (0.001)	0.13*** (0.0008)
R^2	0.005	0.0008	0.0005	0.002
Observations	20,839,462	5,069,160	3,017,423	2,051,737

Notes: The table reports estimation results of a linear regression of the percentage price change, conditional on the price changing. Standard errors are reported in parentheses. *** $p < 1\%$.

Table 6b’. The Size of 9-Ending Price Changes

(Dominick’s; All Prices; Regular Prices; Regular Prices, Inflation Periods; Regular Prices, No-Inflation Periods, Expanded Sample)

	All prices	Regular prices	Regular prices, Inflation periods	Regular prices, No-Inflation Periods
Previous 9-Ending	**0.04*** (0.0002)**	**0.03*** (0.0003)**	**0.02*** (0.0004)**	**0.04*** (0.006)**
Previous 9-Ending × Price Decrease	**-0.03*** (0.0002)**	**-0.03*** (0.0004)**	**-0.02*** (0.0004)**	**-0.03*** (0.0007)**
Price Level	-0.002*** (0.00004)	-0.004*** (0.00009)	-0.005*** (0.0001)	-0.003*** (0.0002)
Absolute Value of the Percentage Change in the Wholesale Price	0.09*** (0.00006)	0.18*** (0.0002)	0.30*** (0.0003)	0.14*** (0.0002)
Sale Price Indicator in Previous Week	0.05*** (0.0001)	N/A		
Sale Price Indicator	0.006*** (0.0001)			
Constant	0.17*** (0.0002)	0.13*** (0.0003)	0.12*** (0.0003)	0.13*** (0.0005)
R^2	0.09	0.15	0.22	0.13
Observations	24,578,539	6,255,500	3,675,932	2,549,568

Notes: The table reports estimation results of a linear regression of the percentage price change, conditional on the price changing. Standard errors are reported in parentheses. *** $p < 1\%$.

Table 6b''. The Size of 9-Ending Price Changes

(Dominick's; Actual Transaction Prices; Regular Prices; Regular Prices, Inflation Periods; Regular Prices, No-Inflation Periods; Sale Filter)

	Actual transaction prices	Regular prices	Regular prices; Inflation periods	Regular prices, No-Inflation Periods
Previous 9-Ending	**0.04*** (0.0003)**	**0.05*** (0.0006)**	**0.05*** (0.0009)**	**0.05*** (0.0006)**
Previous 9-Ending × Price Decrease	**-0.01*** (0.0003)**	**-0.06*** (0.0006)**	**-0.06*** (0.001)**	**-0.06*** (0.0006)**
Price Level	-0.0009*** (0.00007)	0.007*** (0.0001)	0.008*** (0.0002)	0.007*** (0.0001)
Absolute Value of the Percentage Change in the Wholesale Price	6.60×10^{-7}*** (3.18×10^{-8})	5.32×10^{-7}*** (4.48×10^{-8})	5.03×10^{-7}*** (5.50×10^{-8})	1.08×10^{-6}*** (1.22×10^{-7})
Sale Filter Indicator in Previous Week	0.05*** (0.0002)	N/A		
Sale Filter Indicator	-0.05*** (0.0002)			
Constant	0.19*** (0.0003)	0.17*** (0.0005)	0.17*** (0.0007)	0.17*** (0.0005)
R^2	0.008	0.002	0.001	0.004
Observations	20,839,462	7,865,307	4,622,642	3,242,665

Notes: The table reports estimation results of a linear regression of the percentage price change, conditional on the price changing. Standard errors are reported in parentheses. *** $p < 1\%$.

Table 6b'''. The Size of 9-Ending Price Changes

(Dominick's; All Prices; Regular Prices; Regular Prices, Inflation Periods; Regular Prices - No-Inflation Periods; Sale Filter; Expanded Sample)

	All prices	Regular prices	Regular prices, Inflation periods	Regular prices, No-Inflation Periods
Previous 9-Ending	**0.03*** (0.0002)**	**0.04*** (0.0003)**	**0.04*** (0.0003)**	**0.03*** (0.0004)**
Previous 9-Ending × Price Decrease	**-0.02*** (0.0002)**	**-0.05*** (0.0003)**	**-0.05*** (0.0003)**	**-0.05*** (0.0005)**
Price Level	-0.003*** (0.00004)	0.002*** (0.00006)	0.002*** (0.0008)	0.002*** (0.0001)
Absolute Value of the Percentage Change in the Wholesale Price	0.09*** (0.00006)	0.09*** (0.00008)	0.09*** (0.0001)	0.09*** (0.0001)
Sale Filter Indicator in Previous Week	-0.04*** (0.0001)	N/A		
Sale Filter Indicator	0.05*** (0.002)			
Constant	0.19*** (0.0001)	0.18*** (0.0002)	0.18*** (0.0003)	0.18*** (0.0003)
R^2	0.10	0.09	0.08	0.11
Observations	24,578,539	10,937,145	6,410,852	4,526,293

Notes: The table reports estimation results of a linear regression of the percentage price change, conditional on the price changing. Standard errors are reported in parentheses. *** $p < 1\%$.

Appendix G. Likelihood of Changes in the Right-Most Digit in Dominick's Data

In the paper, we show in Table 4 that the probability that a 9-ending price will change to a 9-ending price is greater when the 9-ending price increases than when it decreases. Here we explore further the effect of 9-endings on the likelihood of a change in the right-most digit when a price changes. For this we estimate a SURE regression of the likelihood that the left-most, the middle, and the right-most digits will be adjusted when a price changes. It consists of a system of three equations, one for each of the probabilities that the right-most/middle/left-most digit will change, respectively. The dependent variables are dummy variables which equal 1 if the right-most/middle/left-most digit changes, respectively, and 0 otherwise.

The main explanatory variables are *previous 9-ending* to test the hypothesis that the probability the right-most digit will change is smaller when the right-most digit is 9 than when it is a different digit, and an interaction between *previous 9-ending* and *price decrease* to test the hypothesis that 9-ending prices are more likely to change after a price decrease than after a price increase. We use the same control variables as we used to estimate the regression of the likelihood that a post-change price will be 9-ending (Table 4 in the paper).

To facilitate comparisons with the results of the other robustness tests for Dominick's data as well as with the results reported in the paper, we use both the data on the actual transaction prices (same as in the paper) and the expanded dataset. We also estimate separate regressions for regular prices, for regular prices in inflation periods, and for regular prices in no-inflation periods. Finally, we use both the Dominick's sale indicator variable as well as the sale filter of Nakamura and Steinsson (2008, 2011) to identify sales.

Table 12a reports the results for the actual transaction prices data and the Dominick's sale indicator variable to identify sales. Table 12a' reports the results for the expanded data and the Dominick's sale indicator variable to identify sales. Table 12a'' reports the results for the actual transaction prices data and the sale filter to identify sales. Table 12a''' reports the results for the expanded data and the sale filter to identify sales.

The first panel of Table 12a reports the results when we use all observations, including sales, of the actual transaction prices. Thus, this panel uses the same data that we use in the paper.

In this panel, the coefficient of *previous 9-ending* in the right most digit regression is negative (β = –0.53, $p \leq 0.01$) whereas its interaction with *price-decreases* is positive (β = 0.06, $p \leq 0.01$). However, the coefficients of *previous 9-ending* in the left-most (β = 0.24, $p \leq 0.01$) and middle–digit regressions (β = 0.25, $p \leq 0.01$) are positive, while their interaction with price-decreases are negative (β = –0.20, $p \leq 0.01$, and β = –0.23, $p \leq 0.01$, respectively).

Together, these results suggest that when a *9-ending* prices increase, the right-most digits are less likely to change but the left-most and the middle digits are more likely to change, compared to prices that end with other digits. When 9-ending prices decrease, however, the right-most digits are more flexible, while the left-most and middle digits are less likely to change compared to the prices that end with other digits.

The other panels in the table present the results for regular prices, for regular prices in inflation periods, and for regular prices in no-inflation periods. The results are similar to the result in the first panel. According to the figures in the three panels, when 9-

ending prices increase, the coefficient of the right-most digit is –0.47. Thus, when 9-ending prices increase, the right-most digit is significantly less likely to change than when prices with other endings change.

At the same time, the coefficients of the interaction term between 9-ending and price decrease in the right-most digit columns are negative and their absolute sizes are larger than when we use all prices (ranging from 0.13 to 0.18, compared to 0.06 in Panel 1). The results therefore suggest that when we use regular prices, there is a greater difference between the upward rigidity of a 9-ending price’s right-most digit and its downward rigidity.

The results presented in the other robustness tests, in Tables 12a’–12a’’’, are very similar. In all three tables we find that when we use the actual transaction prices (Table 12a’’) or all prices (Tables 12a’ and 12a’’’), the coefficients of 9-ending in the right-most digit regressions are in the range of –0.53 and –0.59. The coefficients of the interaction term between 9-ending and price-decrease are in the range of 0.06 and 0.08.

When we exclude sales, the coefficients of 9-ending in the right-most digit regressions are in the range of –0.43 and –0.59. The coefficients of the interaction term between 9-ending and price-decrease are in the range of 0.03 and 0.28. Thus, in all tables we find that when 9-ending prices increase, the right-most digit is less likely to change than when prices with other endings increase. In most cases we also find that the difference between the rigidity of the right-most digit when 9-ending prices increase and decrease is greater when we use only observations on regular prices than when we use observations on all prices, including sale prices.

Table 12a. Probability of the Price Digits Adjusting

(Dominick's; Actual Transaction Prices; Regular Prices; Regular Prices, Inflation Periods; Regular Prices, No-Inflation Periods)

	Actual transaction price changes			Regular price changes		
	Left-Most Digit	Middle Digit	Right-Most Digit	Left-Most Digit	Middle Digit	Right-Most Digit
Sale Price Indicator	-0.08*** (0.0002)	0.05*** (0.0002)	0.02*** (0.0002)	N/A		
Price Change	-0.02*** (0.0002)	-0.04*** (0.0002)	0.02*** (0.0002)	-0.03*** (0.0004)	-0.09*** (0.0004)	0.04*** (0.0004)
Price Decrease	0.09*** (0.0004)	0.10*** (0.0003)	0.03*** (0.0003)	0.11*** (0.0006)	0.16*** (0.0006)	0.003*** (0.0001)
Price Level	0.007*** (0.00007)	0.06*** (0.00006)	-0.03*** (0.00006)	-0.005*** (0.0001)	0.08*** (0.0001)	-0.03*** (0.0001)
Previous 9-Ending	0.24*** (0.0003)	0.25*** (0.0002)	**-0.53***** **(0.0002)**	0.23*** (0.0005)	0.40*** (0.0005)	**-0.47***** **(0.0005)**
Previous 9-Ending × Price Decrease	-0.20*** (0.0004)	-0.23*** (0.0004)	**0.06***** **(0.0004)**	-0.23*** (0.0008)	-0.45*** (0.0008)	**0.16***** **(0.0004)**
Constant	0.26*** (0.0003)	0.44*** (0.00002)	0.97*** (0.0002)	0.19*** (0.0005)	0.32*** (0.0005)	0.98*** (0.0004)
Observations	20,839,462			5,069,160		
R-squared	0.04	0.10	0.29	0.03	0.16	0.21
	Regular price changes, Inflation periods			Regular price changes; No-Inflation Periods		
Price Change	-0.04*** (0.0005)	-0.10*** (0.0005)	0.04*** (0.0005)	-0.02*** (0.0006)	-0.08*** (0.0006)	0.03*** (0.0005)
Price Decrease	0.11*** (0.0008)	0.16*** (0.0008)	0.006*** (0.0006	0.13*** (0.0009)	0.17*** (0.0009)	-0.003*** (0.0008)
Price Level	-0.005*** (0.0002)	0.08*** (0.0002)	-0.03*** (0.0002)	-0.004*** (0.0002)	0.08*** (0.0002)	-.02*** (0.0002)
Previous 9-Ending	0.24*** (0.0007)	0.40*** (0.0007)	**-0.47***** **(0.0006)**	0.21*** (0.0009)	0.39*** (0.0008)	**-0.47***** **(0.0008)**
Previous 9-Ending × Price Decrease	-0.25*** (0.001)	-0.45*** (0.001)	**0.18***** **(0.0009)**	-0.21*** (0.001)	-0.44*** (0.001)	**0.13***** **(0.001)**
Constant	0.19*** (0.0006)	0.31*** (0.0006)	0.97*** (0.0006)	0.19*** (0.0008)	0.34*** (0.0007)	0.98*** (0.0007)
Observations	3,097,053			2,102,183		
R-squared	0.04	0.16	0.21	0.03	0.16	0.22

Notes: The table reports estimation errors are reported in parentheses. *** p < 1%.

Table 12a’. Probability of the Price Digits Adjusting

(Dominick’s; All Prices; Regular Prices; Regular Prices, Inflation Periods; Regular Prices, No-Inflation Periods; Expanded Sample)

	All price changes			Regular price changes		
	Left-Most Digit	Middle Digit	Right-Most Digit	Left-Most Digit	Middle Digit	Right-Most Digit
Sale Price Indicator	0.08*** (0.0002)	.0.03*** (0.0002)	0.05*** (0.0002)	N/A		
Price Change	-0.01*** (0.0002)	-0.04*** (0.0001)	0.02*** (0.0001)	-0.01*** (0.0004)	-0.08*** (0.0003)	0.04*** (0.0003)
Price Decrease	0.10*** (0.0003)	0.10*** (0.0003)	-0.02*** (0.0003)	0.12*** (0.0006)	0.16*** (0.0005)	0.004*** (0.0005)
Price Level	0.01*** (0.0006)	0.06*** (0.00005)	-0.03*** (0.00005)	0.002*** (0.0001)	0.07*** (0.0001)	-0.03*** (0.0001)
Previous Price Ending in 9	0.25*** (0.0003)	0.25*** (0.0002)	**-0.59***** **(0.0002)**	0.21*** (0.0005)	0.37*** (0.0005)	**-0.55***** **(0.0004)**
Previous Price Ending in 9 × Price Decrease	-0.22*** (0.0004)	-0.24*** (0.0003)	**0.07***** **(0.0003)**	-0.22*** (0.0007)	-0.43*** (0.0007)	**0.17***** **(0.0006)**
Constant	0.26*** (0.0002)	0.49*** (0.0002)	1.00*** (0.0002)	0.19*** (0.0004)	0.38*** (0.0004)	1.01*** (0.0004)
Observations	24,587,283			6,227,901		
R-squared	0.05	0.10	0.35	0.03	0.17	0.30
	Regular price changes, Inflation periods			Regular price changes, No-Inflation Periods		
Price Change	-0.02*** (0.0005)	-0.08*** (0.0004)	0.04*** (00004)	-0.009*** (0.0005)	-0.07*** (0.0004)	0.04*** (0.0005)
Price Decrease	0.12*** (0.0008)	0.15*** (0.0007)	0.004*** (0.0006)	0.14*** (0.0009)	0.16*** (0.0008)	0.003*** (0.0008)
Price Level	0.002*** (0.0002)	0.07*** (0.0001)	-0.03*** (0.0001)	0.003*** (0.0002)	0.07*** (0.0002)	-0.03*** (0.0002)
Previous 9-Ending	0.21*** (0.006)	0.37*** (0.0006)	**-0.56***** **(0.0006)**	0.20*** (0.0008)	0.37*** (0.0007)	**-0.54***** **(0.0007)**
Previous 9-Ending × Price Decrease	-0.23*** (0.001)	-0.43*** (0.0009)	**0.20***** **(0.0008)**	-0.20*** (0.001)	-0.42*** (0.001)	**0.14***** **(0.001)**
Constant	0.19*** (0.0006)	0.37*** (0.0005)	1.02*** (0.0005)	0.18*** (0.0007)	0.39*** (0.0006)	1.00*** (0.0006)
Observations	3,677,512			2,550,389		
R-squared	0.03	0.16	0.30	0.03	0.17	0.30

Notes: The table reports estimation results of a SURE regression of the probability that the corresponding digit will change conditional on a price change. Standard errors are reported in parentheses. *** $p < 1\%$.

Table 12a''. Probability of the Price Digits Adjusting

(Dominick's; Actual Transaction Prices; Regular Prices; Regular Prices, Inflation Periods; Regular Prices, No-Inflation Periods; Sale Filter)

	Actual transaction price changes			**Regular price changes**		
	Left-Most Digit	Middle Digit	Right-Most Digit	Left-Most Digit	Middle Digit	Right-Most Digit
Sale Filter Indicator	0.03*** (0.0003)	0.04*** (0.0002)		N/A		
Price Change	-0.02*** (0.0002)	-0.04*** (0.0002)	0.02*** (0.0002)	-0.04*** (0.0003)	-0.05*** (0.0002)	0.03*** (0.0002)
Price Decrease	0.12*** (0.0004)	0.11*** (0.0003)	-0.06*** (0.0003)	0.18*** (0.0005)	0.17*** (0.0005)	0.005*** (0.0005)
Price Level	0.007*** (0.0007)	0.06*** (0.00006)	-0.03*** (0.00006)	0.14*** (0.0001)	0.05*** (0.0001)	-0.03*** (0.0001)
Previous 9-Ending	0.24*** (0.0003)	0.25*** (0.0003)	**-0.53***** **(0.0002)**	0.22*** (0.0005)	0.29*** (0.0004)	**-0.44***** **(0.0004)**
Previous 9-Ending × Price Decrease	-0.20*** (0.0004)	-0.23*** (0.0004)	**0.06***** **(0.0004)**	-0.20*** (0.0007)	-0.26*** (0.0006)	**0.03***** **(0.0006)**
Constant	0.27*** (0.0003)	0.44*** (0.0002)	0.97*** (0.0002)	0.19*** (0.0004)	0.40*** (0.0004)	0.93*** (0.0004)
Observations	20,839,462			7,865,307		
R-squared	0.04	0.10	0.30	0.05	0.09	0.21
	Regular price changes, Inflation periods			**Regular price changes, No-Inflation Periods**		
Price Change	-0.04*** (0.0003)	-0.05*** (0.0003)	0.03*** (0.0003	-0.04*** (0.0004)	-0.05*** (0.0004)	0.03*** (0.0003)
Price Decrease	0.17*** (0.0007)	0.17*** (0.0007)	0.007*** (0.0006)	0.19*** (0.0008)	0.18*** (0.0008)	0.003*** (0.0007)
Price Level	0.02*** (0.0001)	0.05*** (0.0001)	-0.03*** (0.0001)	0.008*** (0.0002)	0.05*** (0.0002)	-0.03*** (0.0002)
Previous 9-Ending	0.23*** (0.0006)	0.30*** (0.0006)	**-0.43***** **(0.0006)**	0.21*** (0.0007)	0.28*** (0.0007)	**-0.45***** **(0.0006)**
Previous 9-Ending × Price Decrease	-0.21*** (0.0009)	-0.26*** (0.0008)	**0.04***** **(0.0008)**	-0.20*** (0.001)	-0.27*** (0.001)	**0.28***** **(0.001)**
Constant	0.17*** (0.0005)	0.39*** (0.0005)	**0.93***** **(0.00005)**	0.20*** (0.0006)	0.41*** (0.0006)	**0.94***** **(0.0006)**
Observations	4,622,642			3,242,665		
R-squared	0.05	0.09	0.21	0.04	0.09	0.22

Notes: The table reports estimation results of a SURE regression of the probability that the corresponding digit will change conditional on a price change. Standard errors are reported in parentheses. *** $p < 1\%$.

Table 12a’’’. Probability of the Price Digits Adjusting

(Dominick’s; All Prices; Regular Prices; Regular Prices, Inflation Periods; Regular Prices, No-Inflation Periods; Sale Filter; Expanded Sample)

	All price changes			Regular price changes		
	Left-Most Digit	Middle Digit	Right-Most Digit	Left-Most Digit	Middle Digit	Right-Most Digit
Sale Filter Indicator	0.01*** (0.0002)	-0.02*** (0.0002)	0.07*** (0.0002)	N/A		
Price Change	-0.009*** (0.0002)	-0.04*** (0.0001)	0.03*** (0.0002)	-0.02*** (0.0002)	-0.03*** (0.0002)	0.04*** (0.0002)
Price Decrease	0.14*** (0.0004)	0.13*** (0.0003)	-0.05*** (0.0003)	0.19*** (0.0005)	0.16*** (0.0004)	0.004*** (0.0004)
Price Level	0.01*** (0.00007)	0.06*** (000005)	-0.03*** (0.00005)	0.02*** (0.00009)	0.04*** (0.00007)	-0.03*** (0.00007)
Previous 9-Ending	0.26*** (0.0003)	0.26*** (0.0002)	**-0.59***** **(0.0002)**	0.24*** (0.0004)	0.29*** (0.0003)	**-0.59***** **(0.0003)**
Previous 9-Ending × Price Decrease	-0.22*** (0.0004)	-0.24*** (0.0003)	**0.08***** **(0.0003)**	-0.26*** (0.0006)	-0.28*** (0.0005)	**0.09***** **(0.0005)**
Constant	0.27*** (0.0002)	0.50*** (0.0002)	1.01*** (0.0002)	0.21*** (0.0004)	0.52*** (0.0003)	1.01*** (0.0003)
Observations	24,587,238			10,940,295		
R-squared	0.04	0.10	0.35	0.05	0.10	0.34
	Regular price changes, Inflation periods			Regular price changes, No-Inflation Periods		
Price Change	-0.02*** (0.0003)	0.04*** (0.0001)	0.04*** (0.0002)	-0.02*** (0.0003)	-0.03*** (0.0003)	-0.03*** (0.0001)
Price Decrease	0.19*** (0.0007)	0.15*** (0.0005)	0.006*** (0.0005)	0.19*** (0.0007)	0.17*** (0.0006)	0.04*** (0.0003)
Price Level	0.02*** (0.0001)	0.04*** (0.0009)	-0.04*** (0.00009)	0.02*** (0.0001)	0.04*** (0.0001)	0.002*** (0.0006)
Previous 9-Ending	0.25*** (0.0005)	0.29*** (0.0004)	**-0.59***** **(0.0004)**	0.23*** (0.0006)	0.29*** (0.0005)	**-0.58***** **(0.0005)**
Previous 9-Ending × Price Decrease	-0.27*** (0.0008)	-0.28*** (0.0006)	**0.09***** **(0.0006)**	-0.25*** (0.0009)	-0.30*** (0.0008)	**0.08***** **(0.0008)**
Constant	0.21*** (0.0005)	0.52*** (0.0004)	**1.02***** **(0.0004)**	0.21*** (0.0006)	0.51*** (0.0005)	**1.01***** **(0.0005)**
Observations	6,412,853			4,527,442		
R-squared	0.05	0.10	0.35	0.04	0.11	0.34

Notes: The table reports estimation results of a SURE regression of the probability that the corresponding digit will change conditional on a price change. Standard errors are reported in parentheses. *** $p < 1\%$

Appendix H. The Level of 9-Ending Prices vs. Non 9-Ending Prices in Dominick's Data

The finding that retailers are more likely to set 9-ending prices after price increases than after price decreases implies that the average 9-ending prices could be higher than the average non 9-ending prices.[3] Schindler (2001), using a different and substantially smaller dataset, reports findings that are consistent with this hypothesis.

To test this hypothesis, we compare the average of 9-ending prices with the average of non 9-ending prices in each of the 29 categories in the Dominick's dataset. The results are summarized in Table 13a below.

The first three columns of the table report the averages of 9- and non 9-ending prices in each category along with the difference between the averages. A positive difference indicates that the average level of the 9-ending prices is higher than the average level of the non 9-ending prices.

Using this simple comparison of averages, we find that in 21 of the 29 categories, the average 9-ending price is higher than the average non 9-ending price. This result is therefore consistent with the hypothesis that the tendency to set 9-ending prices after price increases leads to the 9-ending prices being, on average, higher than the non 9-ending prices, for a set of similar goods.

When we compare the category averages, however, we do not control for heterogeneity across goods and/or across prices within each category. We therefore estimate for each category a fixed effects regression. The dependent variable in each regression is the price and the independent variable is a dummy variable which equals one if the price is 9-ending and zero otherwise. The regression also includes fixed effects for SKUs and a linear time trend to control for inflation and for the possibility that there might be changes in the pricing strategy over the sample period (not reported to save space).

We find that in 25 of the 29 categories, the coefficient of 9-ending is positive. Thus, when we control for heterogeneity between goods, we find even stronger evidence that 9-ending prices tend to be more expensive than non 9-ending prices. These results

[3] We thank the anonymous referee for suggesting this idea.

suggest that the rigidity of 9-ending prices together with the greater prevalence of 9-endings after price increases than after price decreases has an effect on the price level.

Table 13a. Comparing the Level of 9-Ending and Non 9-Ending Prices: Averages (LHS) and Fixed-Effects Regression (RHS) - Dominick's

Category	Averages			Fixed-Effects Regression	Number of Observations
	9-endings	Non 9-endings	Difference		
Analgesics	**5.32** **(2.387)**	4.30 (1.980)	1.22***	0.77*** (0.003)	3,060,150
Bath soaps	3.15 (3.147)	**3.24** **(2.312)**	-0.09***	0.31*** (0.005)	418,097
Beer	5.68 (2.691)	**5.83** **(2.945)**	-0.15***	-0.10*** (0.010)	1,970,266
Bottled juices	**2.27** **(0.977)**	2.22 (0.955)	0.05***	0.08*** (0.0008)	4,325,024
Cereals	3.08 (0.767)	**3.14** **(0.761)**	-0.06***	0.01*** (0.0006)	4,751,202
Cheese	**2.51** **(1.257)**	2.18 (0.955)	0.33***	0.35*** (0.002)	1,578,562
Cigarettes	**11.94** **(8.827)**	6.89 (7.499)	5.05***	4.43*** (0.018)	1,810,615
Cookies	2.05 (0.604)	**2.21** **(0.961)**	-0.16***	-0.04*** (0.0007)	7,635,071
Crackers	**2.08** **(0.574)**	1.90 (0.526)	0.18***	0.04*** (0.0007)	2,245,703
Canned soups	**1.21** **(0.499)**	1.09 (0.530)	0.12***	0.08*** (0.0004)	5,5551,684
Dish detergents	**2.36** **(0.928)**	2.30 (0.843)	0.06***	0.12*** (0.001)	2,183,582
Front end candies	**0.74** **(0.196)**	0.53 (0.222)	0.21***	0.19*** (0.0002)	4,475,750
Frozen dinners	2.33 (0.840)	**2.42** **(0.947)**	-0.09***	0.03*** (0.001)	1,654,053
Frozen entrees	**2.34** **(0.950)**	2.32 (1.217)	0.02***	-0.04*** (0.0008)	7,232,080
Frozen juices	1.32 (0.375)	**1.44** **(0.507)**	-0.12***	-0.10*** (0.0005)	2,387,420
Fabric Softeners	**2.88** **(1.604)**	2.73 (1.182)	0.15***	0.25*** (0.002)	2,296,612
Grooming products	**3.02** **(1.393)**	2.42 (1.597)	0.60***	0.49*** (0.002)	4,065,694
Laundry detergents	**5.76** **(3.302)**	5.10 (2.880)	0.66***	0.71*** (0.004)	3,303,174
Oat meals	2.65 (0.666)	**2.66** **(0.655)**	-0.01***	0.02*** (0.003)	981,263
Paper towels	**1.69** **(1.749)**	1.30 (0.905)	0.39***	0.47*** (0.003)	948,871
Refrigerated juices	**2.28** **(0.885)**	2.19 (0.943)	0.09***	0.08*** (0.001)	2,182,989
Soft drinks	**2.53** **(1.913)**	1.43 (1.457)	1.00***	0.54*** (0.001)	10,807,191
Shampoos	**3.00** **(1.897)**	2.44 (1.242)	0.56***	0.27*** (0.002)	4,676,790
Snack Crackers	**2.20** **(0.574)**	2.12 (0.628)	0.08***	0.12*** (0.0007)	3,515,192
Soaps	2.13 (0.898)	**2.52** **(1.496)**	-0.39***	0.54*** (0.002)	1,835,196
Tooth brushes	**2.21**	2.08	0.13***	0.02***	1,854,983

	(0.860)	(0.824)		(0.001)	
Canned tuna	**1.99** **(1.153)**	1.63 (0.955)	0.36***	0.22*** (0.001)	2,430,558
Tooth paste	**2.53** **(0.996)**	2.25 (0.608)	0.28***	0.008*** (0.0007)	3,003,392
Toilet paper	**2.50** **(1.852)**	1.64 (1.726)	0.86***	0.67*** (0.003)	1,159,016

Notes: The averages columns give the average 9-ending prices and of non 9-ending prices in each category. The boldface numerals indicate the higher average price in each category. The difference column gives the difference between the average 9-ending price and the average non 9-ending price. In the averages columns, the standard deviations are reported in parentheses. All the differences between the averages of the 9-ending and the non 9-ending prices are statistically significant, $p < 0.01$. The FE regression column presents the results of fixed effects regressions. The regressions were estimated for each category separately. The dependent variable in each regression is the prices of every SKU in every week in each shop. The independent variable is a dummy for 9-ending price. The regressions also include a linear time trend to control for inflation and fixed effects for SKUs (not reported). The 9-ending dummy therefore captures the difference between 9-ending prices and non 9-ending prices after controlling for the heterogeneity between SKUs within each category and for inflation. *** $p < 0.01$**.** Robust standard deviations are in parentheses.

Appendix I. Robustness checks with Israeli ELI-CPI data

The Israeli Entry Level Item (ELI)-CPI monthly data cover the period from January 2002 to December 2013. During this period, the average annual inflation rate was moderate, about 2.29%. Nevertheless, to check that our results are not driven by inflation nor by changes in the pricing strategy over the sample period, we include a linear time trend in the regressions we estimate using the Israeli data. The results are presented in Tables 8a–10a.

In addition, we use a sale filter, similar to the one we use in Appendix D to identify sales (Nakamura and Steinsson 2008, 2011). Since sales rarely last more than one month, we categorize prices as sale prices if the price in week t is below the price in week $t-1$ and the price in week $t+1$ is equal, or greater than the price in week $t-1$.

Using the resulting sale filter, we estimate all the regressions again using the Israeli data after excluding the observations on sale prices and the prices following sales (i.e., bounce-back prices), i.e., in these analyses we use only regular prices. The results are presented in Tables 8a'–10a'.

Table 8a presents the results of estimating the probability that a post-change price will be 9-ending, conditional on a price change. We find that when we include the time trend, the coefficient of the price level becomes insignificant, suggesting that during the sample period there were changes in the likelihood that a good with a high price will be 9-ending.

The coefficient of 9-ending is positive and significant, 1.00, while the coefficient of price decreases is negative and significant, –0.10. It follows therefore that controlling for possible changes in the pricing strategies does not affect the finding that retailers are more likely to set a 9-ending price after a price change if the pre-change price is 9-ending than if the price ends in other digits. More importantly, we find that retailers are less likely to set the new prices to end with 9 after price decreases than after price increases.

Table 9a presents the results of a regression of the probability of price increases and decreases relative to price remaining unchanged. Again, we find that when we include the time trend, there are changes in the signs of the coefficients of the price level compared to the results without the time trend (Table 9 in the paper). The coefficient estimates of price level in Table 9a are 0.003 and –0.004 (both significant at 1%), for price increases and price decreases, respectively. In Table 9 (in the paper), the corresponding figures are –0.008 and 0.003 (both significant at 1%). It seems therefore that over the period there were changes in the likelihood that prices with different price levels will change, and some of these changes are captured by the time trend.

The results for the 9-ending prices remain quantitatively unchanged. The coefficient of 9-ending in the price decrease regression is –0.17 while the coefficient of 9-ending in the price increase regression is –0.29. Prices that end in 9 are therefore less likely to change than other prices both upward and downward but they are significantly more rigid upward than downward ($\chi^2 = 16.56, p < 0.01$).

Table 10a presents the results of the analyses of the size of 9-ending price changes. The coefficient of 9-ending is 0.04 while the coefficient of the interaction between 9-ending and price decreases is –0.09. We therefore find that, similar to what we report in the paper, when 9-ending prices increase, they increase by more than other prices. When 9-ending prices decrease, however, they change by less than other prices.

Table 8a' presents the results of the regression of the likelihood that a price will be 9-ending following a price change when we exclude sale prices and the prices following sales (i.e., bounce-back prices), i.e., when we use regular prices. We find that the likelihood that a post-change price will be 9-ending is significantly higher if the pre-change price is 9-ending than if the pre-change price ends with a different digit (β = 1.02, $p < 0.01$). The likelihood that a price will be 9-ending is smaller after price decreases than after price increases (β = –0.06, $p < 0.01$).

Therefore, similar to what we find when we use the actual transaction prices, when we focus on regular prices we find that when retailers change 9-ending prices, the post-change prices tend to be 9-ending. We also find that when prices decrease, the post-change prices are less likely to be 9-ending than when the prices increase.

Table 9a' presents the results of the regression of the likelihood that a price will increase and decrease relative to price remaining unchanged for regular prices, i.e., when we exclude the sale prices and the prices following the sales. We find again that the likelihood that a 9-ending price will increase (β = –0.26, $p < 0.01$) is smaller than the probability that it will decrease (β = –0.22, p < 0.01). The difference is smaller than when we use the dataset of the actual transaction prices, but it is still statistically significant ($\chi^2 = 3.85, p < 0.05$).

Table 10a' presents the results of the size of 9-ending price changes for regular prices. We find that the coefficient of 9-ending is 0.02, while the coefficient of the interaction between 9-ending and price decreases is –0.04 (both significant at 1%). Together, these results suggest that when 9-ending prices increase, the size of the change is larger than when non 9-ending prices change. When 9-ending prices decrease, the size of the change is smaller (2% – 4% = –2%) than when non 9-ending prices change. This is consistent with the hypothesis that because 9-ending prices are more rigid upward than prices that end with other digits, they change by more than other prices when they do increase. However, because 9-ending prices are less rigid downward than upward, we don’t expect that the size of the change when 9-ending prices decrease will necessarily be different than the size of changes in prices that end with other digits. The finding that 9-ending prices change by less than other prices downward could be due to retailers using signals other than 9-endings to inform consumers about price cuts.

Table 8a. Probability that the New Price Ends with 9 – Israeli Supermarkets and Drugstores

Price Level	0.0002 (0.0003)
Price Change	0.00009 (0.0004)
Price Decrease	**–0.10 (0.012)*****
Previous 9-Ending	**1.00 (0.012)*****
Time trend	0.0002 (5.06×10^{-6}) ***
Constant	–3.34 (0.107)***
Observations	59,855

Notes: Results of a probit regression of the probability of a new price ending in 9 conditional on a price change. The regression also includes category fixed effects and for the 7 districts of Israel (not reported). Robust standard errors are reported in parentheses. *** $p < 0.01$

Table 9a. Probability of Price Increases and Decreases Relative to Price Remaining Unchanged - Israeli Supermarkets and Drugstores

	Price Decreases	Price Increases
Previous 9-Ending	**–0.17 (0.018)*** **	**–0.29 (0.150)*** **
Price Level	0.003 (0.0003)***	–0.004 (0.0004)***
Time Trend	–0.0001 (6.21×10^{-6})***	–0.000006 (5.52×10^{-6})***
Constant	–0.17 (0.1380)	–0.04 (0.114)
χ^2	$2.77\text{x}10^5$	
Observations	190,807	

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

Table 10a. The Size of 9-Ending Price Change – Israeli Supermarkets and Drugstores

Previous 9-ending	**0.04 (0.006)*** **
Previous 9-ending×price-decrease	**–0.09 (0.006)*** **
Price Level	0.0007 (0.0001)***
Time Trend	0.00001 (1.91×10^{-6})***
Constant	–0.12 (0.042)***
R^2	0.05
Observations	59,855

Notes: The table reports estimation results of a linear regression of the size of the percentage price change, conditional on price change. Robust standard errors in parentheses. *** $p < 1\%$.

Table 8a'. Probability that the New Price Ends with 9 – Israeli Supermarkets and Drugstores (Regular Prices; Sale Filter)

Price Level	0.0002 (0.0003)
Price Change	0.0002 (0.0003)
Price Decrease	**-0.06***** **(0.01)**
Previous 9-Ending	**1.02***** **(0.015)**
Time trend	0.0002*** (5.71×10^{-6})
Constant	-3.17*** (0.120)
Observations	46,642

Notes: Results of a probit regression of the probability of a new price ending in 9 conditional on a price change. The regression also includes category fixed effects and for the 7 districts of Israel (not reported). Robust standard errors are reported in parentheses. *** $p < 0.01$

Table 9a'. Probability of Price Increases and Decreases Relative to Price Remaining Unchanged - Israeli Supermarkets and Drugstores (Regular Prices; Sale Filter)

	Price Decreases	Price Increases
Previous 9-Ending	**-0.22*** (0.020)**	**-0.26*** (0.02)**
Price Level	-0.006*** (0.0006)	0.004*** (0.0003)
Time Trend	-0.0001*** (7.05×10^{-6})	-0.00007*** (6.06×10^{-6})
Constant	-0.35** (0.156)	-0.22* (0.124)
χ^2	24,119.84	
Observations	177,579	

Notes: The table reports estimation results of a Multinomial-logit model for the probability of a price decrease and increase relative to the prices remaining unchanged. Standard errors are reported in parentheses. The asterisks indicate statistical significance as follows: *** $p < 1\%$. ** $p < 5\%$. * $p < 10\%$

Table 10a'. The Size of 9-Ending Price Change – Israeli Supermarkets and Drugstores
(Regular Prices: Sale Filter)

Previous 9-ending	**0.02***** **(0.004)**
Previous 9-ending×price-decrease	**-0.04***** **(0.0004)**
Price Level	0.0005*** (0.00008)
Time Trend	3.70×10^{-6}*** (1.38×10^{-6})
Constant	0.005 (0.030)
R^2	0.08
Observations	46,642

Notes: The table reports estimation results of a linear regression of the size of the percentage price change, conditional on price change. Robust standard errors in parentheses. *** p < 1%.

Appendix J. Probability of a Correct Response – Lab Experiment

Linear Probability Model with Random Effects

In Table 1 in the manuscript, we present and discuss the coefficient estimates of only the key variables of interest. Below, in Table 1A, we present the full set of results of estimating the probability of a correct response in the lab experiment using a linear probability model with random effects (standard errors clustered at the participant level). We also present the results of several robustness tests. In Table 1B, we present the results of estimating a linear probability model regression with fixed effects (standard errors clustered at the participant level). In Table 1C, we present the results of estimating a pooled linear probability model (standard errors clustered at the participant level). In Table 1D, we present the results of estimating a probit model of the probability of correct response.[4]

Linear Probability Model with Fixed Effects

In the first column of the fixed effects regression in Table 1B, we find that 9-endings have a negative and significant effect on the likelihood that a participant gives a correct answer ($\beta = -0.007, p < 0.01$). In Column (2), where we add controls, we find that the negative effect of 9-endings is present only in the sample of price comparisons: the coefficient of the main effect of 9-ending ($\beta = -0.001, p > 0.10$), which measures the effect of 9-endings in the compare-numbers treatment, is small and not statistically significant. The coefficient of the interaction of price-comparison and 9-ending ($\beta = -0.01, p < 0.05$), however, is negative and statistically significant, suggesting that when at least one of the prices is 9-ending, participants are about 1% less likely to give a correct answer.

[4] In the initial version of the manuscript, we primarily used the probit model to estimate the probabilities of correct response. However, following the suggestion of one of the anonymous reviewers and the editor, we switched to the linear probability model. We therefore include the probit model estimates in the appendix, so that the reader can see both methods and their results, which not surprisingly, are fully consistent with each other.

If 9-endings signal low prices, then they should affect response accuracy only if they appear in the higher of the two prices compared. To test this, we split the price condition sample in two. Subsample 1 (2) includes the trials in which the prices compared were equal to (different from) each other. We estimate a separate model for each. We do not expect 9-endings to affect comparison accuracy in subsample 1 because if one price ends with 9, both prices end with 9. In subsample 2, 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 subsample 2, therefore, we include in the regression the dummy *bigger-9-ending* (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* will be negative. We include also all the controls as in regressions discussed in section 3.1.2, with the exception of the location variables and their interactions because of multicollinearity in subsample 1. We report the estimation results in Table 1B, columns (3) and (4).

In both subsamples, the coefficient of *9-ending* is insignificant. Thus, when prices are equal or when the smaller price ends with 9, 9-endings do not affect comparison accuracy (subsample 1: $\beta = -0.007$, $p > 0.10$; subsample 2: $\beta = 0.02$, $p > 0.10$). In subsample 2, however, the coefficient of *bigger-9-ending* is negative and significant ($\beta = -0.04$, $p < 0.05$). Thus, if the bigger price is 9-ending, participants are more likely to erroneously identify it as the smaller of the two prices, in comparison to a situation where it ends with a different digit.

Linear Probability Model

In the first column of the OLS regression in Table 1C, we find that 9-endings have a negative and significant effect on the likelihood that a participant gives a correct answer ($\beta = -0.006, p < 0.01$). In Column (2), where we add controls, we find that the negative effect of 9-endings is present only in the price comparison treatment: the coefficient of the main effect of 9-ending ($\beta = -0.001, p > 0.10$), which measures the effect of 9-endings in the number-comparison treatment, is not statistically significant. The coefficient of the interaction of price-comparison and 9-ending ($\beta = -0.01, p < 0.10$), however, is negative and with statistical significance just above 5%, suggesting that when at least one of the prices is 9-ending, participants are about 1% less likely to give a correct answer.

If 9-endings signal low prices, then they should affect response accuracy only if they appear in the higher of the two prices compared. To test this, we split the price condition sample into two. Subsample 1 (2) includes the trials in which the prices compared were equal to (different from) each other. We estimate a separate model for each. We do not expect 9-endings to affect comparison accuracy in subsample 1 because in that sample, if one price ends with 9, both prices end with 9. In subsample 2, 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 subsample 2, therefore, we include in the regression the dummy *bigger-9-ending* (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* will be negative. We include also all the controls as in the regressions discussed in section 3.1.2, with the exception of the location variables and their interactions because of multicollinearity in subsample 1. We report the estimation results in Table 1C, columns (3) and (4).

In both subsamples, the coefficient of *9-ending* is insignificant. Thus, when prices are equal or when the smaller price ends with 9, 9-endings do not affect comparison accuracy (subsample 1: $\beta = -0.01$, $p > 0.10$; subsample 2: $\beta = 0.02$, $p > 0.10$). In subsample 2, however, the coefficient of *bigger-9-ending* is negative and significant ($\beta = -0.03$, $p < 0.05$). Thus, if the bigger price is 9-ending, participants are more likely to erroneously identify it as the smaller of the two prices, in comparison to the situation where it ends with a different digit.

Thus, all the linear probability regression models, whether we use OLS, random effects, or fixed effects, give very similar results. In all cases, both the size of the coefficients and their statistical significance are almost identical.

Probit Model

In Table 1D, we report the results of a probit regression model. In column (1), we find that 9-endings have a negative and significant effect on the likelihood that a participant gives a correct answer ($\beta = -0.06, p < 0.01$). In Column (2), where we add controls, we find that the negative effect of 9-endings is present only in the price comparison condition: The coefficient of the main effect of 9-ending ($\beta = -0.02, p > 0.10$), which measures the effect of 9-endings in the number comparison condition, is not statistically significant. The coefficient of the interaction of price-comparison and 9-ending ($\beta = -0.07, p < 0.10$), however, is negative and marginally statistically significant, suggesting that when at least one of the prices is 9-ending, participants are about 1% less likely to give a correct answer.

In addition, when we use probit regression, the coefficients of the location dummies and their interactions with *find-small* and *price-comparison* provide further evidence on the effect of 9-endings on price comparisons. In both *find-large* and *find-small* number conditions, comparison accuracy is affected by the location of the different digit. Participants are most (least) accurate if the numbers differ in their left-most (right-most) digit.[5] In price comparisons, however, the 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.[6] Thus, in both *find-large* and *find-small* number conditions, as well as in the *find-large* price condition, participants compare numbers digit-by-digit. In the cognitively demanding *find-small* price condition, however, participants seem to use a different cognitive process, since the location of the different digit has only a small effect on the probability of an error. Our results above suggest that one such cognitive process is using 9-endings as a heuristic for low prices.

If 9-endings signal low prices, then they should affect response accuracy only if they appear in the higher of the two prices compared. To test this, we split the price condition sample in two. Subsample 1 (2) includes the trials in which the prices compared equal (differ from) each other. We estimate a separate model for each. We do not expect 9-endings to affect comparison accuracy in subsample 1 because if one price ends with 9, both prices end with 9. In subsample 2, we expect that 9-endings will have a negative

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[5] 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.

[6] 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.

effect on the comparison accuracy when the bigger price ends with 9 but not when the smaller price ends with 9. In subsample 2, therefore, we include in the regression the dummy *bigger-9-ending* (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* will be negative. We include also all the controls as in section 3.1.2, except the location variables and their interactions because of multicollinearity in subsample 1. We report the estimation results in Table 1D, columns (3) and (4).

In both subsamples, the coefficient of *9-ending* is insignificant. Thus, when prices are equal or when the smaller price ends with 9, 9-endings do not affect comparison accuracy (subsample 1: $\beta = -0.09$, $p > 0.10$; subsample 2: $\beta = 0.14$, $p > 0.10$). In subsample 2, however, the coefficient of *bigger-9-ending* is negative and significant ($\beta = -0.26$, $p < 0.01$). Thus, if the bigger price is 9-ending, participants are more likely to erroneously identify it as the smaller of the two prices, in comparison to the situation where it ends with a different digit.

Table 1A. Probability of a Correct Response – Lab Experiment (Random Effects)

	All observations		Observations on Equal Prices	Observations on Unequal Prices
	(1)	(2)	(3)	(4)
9-Ending	−0.01*** (0.002)	−0.001 (0.004)	−0.007 (0.007)	0.02 (0.015)
Price-Comparison×9-Ending		−0.01** (0.005)		
Bigger-9-Ending				−0.04** (0.016)
Right-Most	−0.10*** (0.017)	−0.08*** (0.022)		
Middle	−0.08*** (0.017)	−0.05** (0.023)		
Left-Most	−0.07*** (0.018)	−0.04* (0.020)		
Digit-Difference		0.004*** (0.0006)		0.005*** (0.001)
Price-Comparison	0.004 (0.025)	0.03 (0.029)		
Find-Small	−0.08*** (0.025)	0.006 (0.038)	0.005 (0.023)	−0.10* (0.055)
3-Digits	−0.001 (0.025)	0.03 (0.023)	−0.007 (0.018)	0.001 (0.039)
Price-Comparison×Find Small		−0.04 (0.055)		
Price-Comparison×3 Digit		−0.02 (0.038)		
Three-Digits×Find Small		−0.002 (0.069)	−0.06 (0.052)	−0.01 (0.080)
Price-Comparisons×3-Digits×Find-Small		−0.02 (0.095)		
Price-Comparison×Low-Shopping-Freq.		−0.11 (0.079)		
Find-Small×Right-Most		−0.11** (0.049)		
Find-Small×Middle		−0.13** (0.052)		
Find-Small×Left-Most		−0.13** (0.052)		
Price-Comparison×Right-Most		0.01 (0.027)		
Price-Comparison×Middle		0.004 (0.029)		
Price-Comparison×Left-Most		0.02 (0.016)		
Price-Comparison×Find-		0.08		

Small×Right-Most		(0.066)		
Price-Comparison×Find-Small×Middle		0.08 (0.068)		
Price-Comparison×Find-Small×Left-Most		0.05 (0.070)		
0-Ending		0.01*** (0.004)	0.01** (0.007)	0.004 (0.007)
Price-Comparison×0-Ending		−0.003 (0.007)		
Female		0.03 (0.028)	−0.02 (0.022)	0.04 (0.040)
Low Shopping Frequency		−0.03 (0.048)	0.01 (0.019)	−0.19 (0.080)
Low Shopping Frequency×Price-Comparison		−0.11 (0.079)		
Constant	0.99*** (0.020)	0.94*** (0.028)	0.97*** (0.021)	0.92*** (0.033)
Number of Observations	55,346	55,346	5,982	20,905
χ^2	100.4***	196.2***	10.3	51.3***

Notes: The table reports estimation results of a linear model with random effects for the probability of a correct response. The dependent variable is *accurate*, a dummy that equals 1 if the answer is correct and 0 otherwise (average = 0.89). The independent variables are: 9-ending dummy that equals 1 if at least one of the prices/numbers ends in 9; Price-comparison dummy for treatments in which the participants were asked to compare prices (rather than numbers); Bigger 9-ending dummy for 9-endings appearing in the bigger of the two prices compared; Right most dummy that equals 1 if the two prices/numbers differed in their right-most digit; Middle dummy that equals 1 if the two prices/numbers differed in their middle digit(s); Left most dummy that equals 1 if the two prices/numbers differed in their left-most digit (the base group in all three cases when the prices/numbers were equal); Find-small dummy for treatments where the participants were asked to identify the smaller (rather than the larger) of the prices /numbers; Three digits dummy for treatments where the participants were asked to compare 3-digit prices /numbers (rather than 4 digits prices/numbers); Zero-ending dummy that equals 1 if at least one of the prices/numbers ends in zero; Female dummy for women; Low shopping frequency dummy for participants that report shopping once a month or less; and all the interaction of price-comparison, find-small and 3-digits. Column (1) uses all observations. Column (2) uses observations on equal prices. Column (3) uses observations on unequal prices. * $p <$ 10%, ** $p <$ 5%, and *** $p <$ 1%. Standard errors, clustered at the participant level, are reported in parentheses.

Table 1B. Probability of a Correct Response – Lab Experiment (Fixed Effects)

	All observations		Observations on Equal Prices	Observations on Unequal Prices
	(1)	(2)	(3)	(4)
9-Ending	−0.007*** (0.002)	−0.001 (0.004)	−0.007 (0.007)	0.02 (0.015)
Price-Comparison×9-Ending		−0.01** (0.005)		
Bigger-9-Ending				−0.04** (0.016)
Right-Most	−0.10*** (0.017)	−0.08*** (0.022)		
Middle	−0.08*** (0.017)	−0.05** (0.023)		
Left-Most	−0.07*** (0.018)	0.039* (0.020)		
Digit-Difference		0.004*** (0.0006)		0.005*** (0.001)
Find-Small×Right-Most		−0.11** (0.049)		
Find-Small×Middle		−0.13** (0.052)		
Find-Small×Left-Most		−0.13** (0.052)		
Price-Comparison×Right-Most		0.01 (0.027)		
Price-Comparison×Middle		0.004 (0.029)		
Price-Comparison×Left-Most		0.02 (0.027)		
Price-Comparison×Find-Small×Right-Most		0.08 (0.066)		
Price-Comparison×Find-Small×Middle		0.08 (0.066)		
Price-Comparison×Find-Small×Left-Most		0.05 (0.070)		
0-Ending		0.01*** (0.004)	0.01** (0.007)	0.004 (0.007)
Price-Comparison×0-Ending		−0.003 (0.007)		
Constant	0.99*** (0.020)	0.95*** (0.013)	0.94*** (0.002)	0.87*** (0.003)
Number of Observations	55,346	55,346	5,982	20,905

F	24.3***	10.7***	3.3**	8.7***

Notes: The table reports estimation results of a linear model with fixed effects for the probability of a correct response. The dependent variable is accurate, a dummy that equals 1 if the answer is correct and 0 otherwise (average = 0.89). The independent variables are: 9-ending dummy that equals 1 if at least one of the prices/numbers ends in 9; Price-comparison dummy for treatments in which the participants were asked to compare prices (rather than numbers); Bigger 9-ending dummy for 9-endings appearing in the bigger of the two prices compared; Right most dummy that equals 1 if the two prices/numbers differed in their right-most digit; Middle dummy that equals 1 if the two prices/numbers differed in their middle digit(s); Left most dummy that equals 1 if the two prices/numbers differed in their left-most digit (the base group in all three cases when the prices/numbers were equal); Find-small dummy for treatments where the participants were asked to identify the smaller (rather than the larger) of the prices /numbers; Three digits dummy for treatments where the participants were asked to compare 3-digit prices /numbers (rather than 4 digits prices/numbers); Zero-ending dummy that equals 1 if at least one of the prices/numbers ends in zero; Female dummy for women; Low shopping frequency dummy for participants that report shopping once a month or less; and all the interaction of price-comparison, find-small and 3-digits. Column (1) uses all observations. Column (2) uses observations on equal prices. Column (3) uses observations on unequal prices. * $p < 10\%$, ** $p < 5\%$, and *** $p < 1\%$. Standard errors, clustered at the participant level, are reported in parentheses.

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

	All observations		Observations on Equal Prices	Observations on Unequal Prices
	(1)	(2)	(3)	(4)
9-Ending	−0.006*** (0.003)	−0.001 (0.004)	−0.01 (0.008)	0.02 (0.017)
Price-Comparison×9-Ending		−0.01* (0.005)		
Bigger-9-Ending				−0.03** (0.017)
Right-Most	−0.10*** (0.016)	−0.08*** (0.019)		
Middle	−0.08*** (0.017)	−0.04** (0.020)		
Left-Most	−0.07*** (0.017)	−0.03* (0.020)		
Digit-Difference		0.003*** (0.0007)		0.005*** (0.001)
Price-Comparison	0.007 (0.025)	0.03 (0.029)		
Find-Small	−0.08*** (0.026)	0.003 (0.039)	0.003 (0.023)	−0.10* (0.055)
3-Digits	−0.001 (0.025)	0.03 (0.023)	−0.01 (0.018)	0.003 (0.039)
Price-Comparison×Find Small		−0.04 (0.056)		
Price-Comparison×3 Digit		−0.02 (0.038)		
Three-Digits×Find Small		−0.001 (0.069)	−0.06 (0.052)	−0.01 (0.080)
Price-Comparisons×3-Digits×Find-Small		−0.02 (0.005)		
Price-Comparison×Low-Shopping-Freq.		−0.11 (0.078)		
Find-Small×Right-Most		−0.10** (0.047)		
Find-Small×Middle		−0.13** (0.051)		
Find-Small×Left-Most		−0.12** (0.050)		
Price-Comparison×Right-		0.01 (0.025)		

Most				
Price-Comparison×Middle		−0.001 (0.027)		
Price-Comparison×Left-Most		0.006 (0.025)		
Price-Comparison×Find-Small×Right-Most		0.08 (0.062)		
Price-Comparison×Find-Small×Middle		0.08 (0.067)		
Price-Comparison×Find-Small×Left-Most		0.05 (0.068)		
0-Ending		0.01*** (0.005)	0.02** (0.007)	0.008 (0.007)
Price-Comparison×0-Ending		−0.001 (0.007)		
Female		0.03 (0.028)	−0.02 (0.022)	0.03 (0.039)
Low Shopping Frequency		−0.03 (0.048)	0.01 (0.018)	−0.19 (0.080)
Low Shopping Frequency× Price-Comparison		−0.11 (0.079)		
Constant	0.99*** (0.020)	0.93*** (0.028)	0.97*** (0.021)	0.93*** (0.033)
Number of Observations	55,346	55,346	5,982	20,905
F	100.4***	6.7***	10.3	51.3***

Notes: The table reports estimation results of a linear model for the probability of a correct response. The dependent variable is accurate, a dummy that equals 1 if the answer is correct and 0 otherwise (average = 0.89). The independent variables are: 9-ending dummy that equals 1 if at least one of the prices/numbers ends in 9; Price-comparison dummy for treatments in which the participants were asked to compare prices (rather than numbers); Bigger 9-ending dummy for 9-endings appearing in the bigger of the two prices compared; Right most dummy that equals 1 if the two prices/numbers differed in their right-most digit; Middle dummy that equals 1 if the two prices/numbers differed in their middle digit(s); Left most dummy that equals 1 if the two prices/numbers differed in their left-most digit (the base group in all three cases when the prices/numbers were equal); Find-small dummy for treatments where the participants were asked to identify the smaller (rather than the larger) of the prices /numbers; Three digits dummy for treatments where the participants were asked to compare 3-digit prices /numbers (rather than 4 digits prices/numbers); Zero-ending dummy that equals 1 if at least one of the prices/numbers ends in zero; Female dummy for women; Low shopping frequency dummy for participants that report shopping once a month or less; and all the interaction of price-comparison, find-small and 3-digits. Column (1) uses all observations. Column (2) uses observations on equal prices. Column (3) uses observations on unequal prices. * $p < 10\%$, ** $p < 5\%$, and *** $p < 1\%$. Standard errors, clustered at the participant level, are reported in parentheses.

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

	All observations		Observations on Equal Prices	Observations on Unequal Prices
	(1)	(2)	(3)	(4)
9-Ending	−0.06*** (0.021)	–0.02 (0.030)	–0.09 (0.078)	0.14 (0.090)
Price-Comparison×9-Ending		–0.07* (0.042)		
Bigger-9-Ending		–0.26*** (0.087)		–0.26*** (0.087)
Right-Most	−0.82*** (0.029)	–0.72*** (0.058)		
Middle	−0.68*** (0.027)	–0.46*** (0.056)		
Left-Most	−0.61*** (0.029)	–0.38*** (0.062)		
Digit-Difference		0.03*** (0.005)		0.04*** (0.008)
Price-Comparison	0.005 (0.081)	–0.03** (0.208)		
Find-Small	−0.32*** (0.088)	0.41 (0.181)		
3-Digits	0.005 (0.081)	0.12 (0.203)	0.32 (0.253)	–0.31 (0.196)
Price-Comparison×Find Small		–0.32 (0.252)	–0.20 (0.840)	0.04 (0.227)
Price-Comparison×3 Digit		–0.10 (0.297)		
Three-Digits×Find Small		0.03 (0.251)		
Price-Comparisons×3-Digits×Find-Small		–0.19 (0.371)	–0.53 (0.366)	–0.15 (0.304)
Price-Comparison×Low-Shopping-Freq.		–0.46** (0.195)		
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)	0.20 (0.109)	0.03 (0.055)
Price-Comparison×0-Ending		–0.04 (0.068)		
Female		0.14 (0.091)	–0.13 (0.195)	0.14 (0.166)
Low Shopping Frequency		–0.16 (0.134)	–0.11 (0.236)	–0.78*** (0.206)
Low Shopping Frequency× Price-Comparison		–0.46** (0.195)		
Constant	2.24*** (0.093)	1.92 (0.161)***	2.03*** (0.224)	1.55*** (0.191)
Number of Observations	55,346	55,346	5,982	20,905
χ^2	905.3***	1127***	11.44	67.02***

Notes: The table reports estimation results of a probit model for the probability of a correct response. The dependent variable is accurate, a dummy that equals 1 if the answer is correct and 0 otherwise (average = 0.89). The independent variables are: 9-ending dummy that equals 1 if at least one of the prices/numbers ends in 9; Price-comparison dummy for treatments in which the participants were asked to compare prices (rather than numbers); Bigger 9-ending dummy for 9-endings appearing in the bigger of the two prices compared; Right most dummy that equals 1 if the two prices/numbers differed in their right-most digit; Middle dummy that equals 1 if the two prices/numbers differed in their middle digit(s); Left most dummy that equals 1 if the two prices/numbers differed in their left-most digit (the base group in all three cases when the prices/numbers were equal); Find-small dummy for treatments where the participants were asked to identify the smaller (rather than the larger) of the prices /numbers; Three digits dummy for treatments where the participants were asked to compare 3-digit prices /numbers (rather than 4 digits prices/numbers); Zero-ending dummy that equals 1 if at least one of the prices/numbers ends in zero; Female dummy for women; Low shopping frequency dummy for participants that report shopping once a month or less; and all the interaction of price-comparison, find-small and 3-digits. Column (1) uses all observations. Column (2) uses observations on equal prices. Column (3) uses observations on unequal prices. * p < 10%, ** p < 5%, and *** p < 1%. Standard errors are reported in parentheses.

Appendix K. Probability of a Correct Response – Field Study

<u>Linear Probability Model with Random Effects</u>

In Table 2 in the manuscript, we present and discuss the coefficient estimates of only the key variables of interest. Below, in Table 2A, we present the full set of results of estimating the probability of a correct response in the field study using a linear probability model with random effects (standard errors clustered at the participant level). We also present the results of several robustness tests. In Table 2B, we present the results of estimating a linear probability model with fixed effects (standard errors clustered at the participant level). In Table 2C, we present the results of estimating a pooled linear probability model (the standard errors clustered at the participant level). In Table 2D, we present the results of estimating a probit model to estimate the probability of correct response.

In column (1) of Table 2A, we find that the coefficient of 9-ending is negative and significant ($\beta_1 = -0.08, p < 0.01$), suggesting that shoppers at supermarkets are affected by 9-endings in the same way as in the lab. The shoppers, however, do not process price information from left to right: the coefficient of right-most ($\gamma_1 = 0.005, p > 0.10$) is larger than the coefficient of left-most ($\gamma_3 = -0.11, p < 0.01$), which in turn is larger than the coefficient of middle ($\gamma_2 = -0.39, p < 0.01$). These results hold when we add further controls, as the figures in column (2) show. In columns (3) and (5), we present the results of the same regression when we split the data in two: column (3) presents the results of a regression when we use the sample of price decreases and column (5) presents the results when we use the sample of price increases. We find that 9-endings have an effect only in the sample of price increases. The coefficient is negative ($\beta_1 = -0.11, p < 0.05$), suggesting that 9-endings reduce the likelihood that consumers will notice price increases.

In Columns (3) and (5) we split the 9-ending dummy into three: *from-9-to-9* (1 if 9-

ending price changed to 9-ending price, and 0 otherwise), *from-9-to-other* (1 if 9-ending price changed to non 9-ending price, and 0 otherwise), and *from-other-to-9* (1 if non 9-ending price changed to 9-ending price, and 0 otherwise). We find that *from-other-to-9* has a negative and significant effect in the sample of price increases ($\beta = -0.22, p < 0.01$). It seems, therefore, that 9-endings reduce the likelihood of recalling price increases mostly because consumers recall the previous prices as high and the current one as low.

Linear Probability Model with Fixed Effects

In column (1) of Table 2B, which presents the results of a fixed effects regression, we find that the coefficient of 9-endings is negative and significant ($\beta_1 = -0.07, p < 0.01$), suggesting that shoppers at supermarkets are affected by 9-endings in the same way as in the lab. At the same time, however, it appears that shoppers do not process price information from left to right: the coefficient of right-most ($\gamma_1 = 0.003, p > 0.10$) is larger than the coefficient of left-most ($\gamma_3 = -0.11, p < 0.01$), which in turn is larger than the coefficient of middle ($\gamma_2 = -0.33, p < 0.01$).

In columns (3) and (5), we present the results of the same regression when we split the data into two: column (3) presents the results of a regression when we use the sample of price decreases, which column (5) presents the results when we use the sample of price increases. We find that in none of the samples 9-endings have a statistically significant effect, although the coefficient in the sample of price increases is larger in absolute value than in the sample of price decreases (-0.08 vs. -0.04). Thus, even though the results are not strong, it seems that 9-endings have a bigger effect in the sample of price increases than in the sample of price decreases.

Further evidence on the effect of 9-endings on the recall accuracy of price increases is presented in columns (4) and (6), where we split the 9-ending dummy into three dummies: *from-9-to-9* (1 if 9-ending price changed to 9-ending price, and 0 otherwise), *from-9-to-other* (1 if 9-ending price changed to non 9-ending price, and 0 otherwise), and *from-other-to-9* (1 if non 9-ending price changed to 9-ending price, and 0 otherwise). We find that *from-other-to-9* has a negative and significant effect in the sample of price increases ($\beta = -0.17, p < 0.01$). It seems, therefore, that 9-endings reduce the likelihood of accurately recalling price increases mostly because consumers recall the previous prices as high and the current price as low.

Linear Probability Model

In column (1) of Table 2C, where we present the results of an OLS regression with clustered standard errors, we find that the coefficient of 9-endings is negative and significant ($\beta_1 = -0.08, p < 0.01$), suggesting that shoppers at supermarkets are affected by 9-endings in the same way as in the lab. The shoppers, however do not process price information from left to right: the coefficient of right-most ($\gamma_1 = 0.0005, p > 0.10$) is larger than the coefficient of left-most ($\gamma_3 = -0.11, p < 0.01$), which in turn is larger than the coefficient of middle ($\gamma_2 = -0.43, p < 0.01$). These results hold when we add further controls in column (2).

In Columns (3) and (5) we present the results of the same regression after splitting the data into two: column (3) presents the results of a regression when we use the sample of price decreases, and column (5) presents the results when we use the sample of price increases. We find that 9-endings have an effect only in the sample of price increases. The coefficient is negative ($\beta_1 = -0.16, p < 0.01$), suggesting again that 9-endings reduce the likelihood that consumers will accurately recall price increases.

In columns (4) and (6), we split the 9-ending dummy into three dummies: *from-9-to-9* (1 if 9-ending price changed to 9-ending price, and 0 otherwise), *from-9-to-other* (1 if 9-ending price changed to non 9-ending price, and 0 otherwise), and *from-other-to-9* (1 if non 9-ending price changed to 9-ending price, and 0 otherwise). We find that *from-other-to-9* has a negative and significant effect in the sample of price increases ($\beta = -0.27, p < 0.01$). It seems, therefore, that 9-endings reduce the likelihood of recalling price increases mostly because consumers recall the previous prices as high and the current price as low.

Probit Model

In column (1) of Table 2D, where we present the results of estimating a probit regression, we find that the coefficient of 9-endings is negative and significant ($\beta_1 = -0.27, p < 0.01$), suggesting that shoppers at supermarkets are affected by 9-endings in the same way as in the lab. However, they do not process price information from left to right: the coefficient of right-most ($\gamma_1 = 0.03, p > 0.10$) is larger than the coefficient of left-most ($\gamma_3 = -0.40, p < 0.01$), which in turn is larger than the coefficient of middle ($\gamma_2 = -1.26, p < 0.01$). These results hold also when we add further controls in Column (2).

In columns (3) and (5), we present the results of the same regression after splitting the data into two: column (3) presents the results of a regression when we use the sample of price decreases, and Column (5) presents the results when we use the sample of price increases. We find that 9-endings have an effect only in the sample of price increases. The coefficient is negative ($\beta_1 = -0.28, p < 0.01$), suggesting that 9-endings reduce the likelihood that consumers will notice price increases.

In columns (4) and (6), we split the 9-ending dummy into three: *from-9-to-9* (1 if 9-ending price changed to 9-ending price, and 0 otherwise), *from-9-to-other* (1 if 9-ending price changed to non 9-ending price, and 0 otherwise), and *from-other-to-9* (1 if non 9-ending price changed to 9-ending price, and 0 otherwise). We find that *from-other-to-9* has a negative and significant effect in the sample of price increases ($\beta = -0.51, p < 0.05$). It seems, therefore, that 9-endings reduce the likelihood of accurately recalling price increases mostly because consumers recall the previous prices as high and the current one as low.

Table 2A. Probability of a Correct Response – Field Study (Random Effects)

	All Observations		Price Decreases		Price Increases	
	(1)	(2)	(3)	(4)	(5)	(6)
9-Ending	−0.08*** (0.015)	−0.07*** (0.015)	−0.01 (0.057)		−0.11** (0.051)	
From 9 to 9				−0.06 (0.080)		−0.05 (0.061)
From other to 9				−0.01 (0.090)		−0.22*** (0.073)
From 9 to other				−0.09 (0.097)		0.05 (0.074)
Right-Most	0.005 (0.018)	0.10*** (0.020)	0.11** (0.045)	0.11** (0.047)	0.15*** (0.039)	0.16*** (0.040)
Middle	−0.39*** (0.027)	−0.20*** (0.028)	−0.45*** (0.051)	−0.44*** (0.054)	−0.08* (0.046)	−0.12** (0.050)
Left–Most	−0.11*** (0.021)	0.09*** (0.025)	−0.01 (0.037)	−0.01 (0.038)	0.11*** (0.033)	0.11*** (0.032)
0-Ending		−0.09* (0.052)	−0.06 (0.268)	−0.10 (0.270)	−0.09 (0.076)	−0.09 (0.074)
Female		0.04 (0.026)	0.02 (0.041)	0.02 (0.041)	0.05 (0.052)	0.05 (0.051)
Ultra-Religious Consumer		0.06** (0.024)	0.17*** (0.051)	0.18*** (0.051)	0.11* (0.066)	0.10 (0.065)
Academic Degree		0.02 (0.024)	-0.0002 (0.042)	0.001 (0.042)	0.12** (0.055)	0.12** (0.055)
More than One Trip a Week		0.08*** (0.023)	0.01*** (0.039)	0.10*** (0.039)	0.07 (0.053)	0.07 (0.053)
More than NIS 300/Shopping Trip		−0.09*** (0.022)	−0.09** (0.040)	−0.08** (0.039)	−0.08 (0.050)	−0.08 (0.050)
Older than 55		−0.09** (0.043)	−0.05 (0.066)	−0.05 (0.067)	−0.12 (0.094)	−0.12 (0.092)
Price Increase		−0.33*** (0.038)				
Price Decrease		−0.36*** (0.036)				
Previous Price		−0.001 (0.001)	-0.001 (0.001)	−0.001 (0.001)	0.001 (0.002)	0.001 (0.002)
Relative Size of the Price Change		0.09** (0.045)	0.34*** (0.086)	0.35*** (0.089)	0.03 (0.051)	0.001 (0.053)

Intercept	0.76*** (0.016)	0.76*** (0.030)	0.42*** (0.087)	0.45*** (0.095)	0.28*** (0.087)	0.28*** (0.091)
Number of Observations	6,031	6,031	581	581	639	639
χ^2	354.7***	640.0***	562.8***	560.7***	124.5***	135.3***

Notes: The table reports estimation results of linear models with random effects of the probability of a correct response. The dependent variable is *accurate*, a dummy that equals 1 if the answer is correct and 0 otherwise (average = 0.65). The independent variables are: 9-ending dummy that equals 1 if at least one of the prices/numbers ends in 9; From 9 to 9 dummy that equals 1 if the previous price ended in 9 and the current one ends in 9; From other to 9 dummy that equals 1 if the previous price did not end in 9 and the current one does; From 9 to other dummy that equals 1 if the previous price ended in 9 and the current does not; Right most dummy that equals 1 if the two prices/numbers differed in their right-most digit; Middle dummy that equals 1 if the two prices/numbers differed in their middle digit(s); Left most dummy that equals 1 if the two prices/numbers differed in their left-most digit (the base group in all three cases when the prices/numbers were equal); Female dummy for women; Ultra-Religious Consumer dummy for consumers that identify themselves as orthodox Jews; Academic degree dummy for consumers with at least one academic degree; More than one trip a week dummy for consumers that report making more than one shopping trip a week; More than NIS 300/shopping trip dummy for consumers that report spending on average more than NIS 300 (69 dollars) per shopping trip; Older than 55 dummy for consumers 55 or older; Price increase dummy for a price that has increased relative to the price in the previous week; Price decrease dummy for a price that has decreased relative to the price in the previous week; Previous price which is the price of the good in the previous week; and Relative size of the price change which is the absolute percentage change in the price relative to the previous week. Column (1) uses all observations. Columns (2) and (3) use only observations on price increases. Column (2) uses one dummy, *9-ending*, to control for 9-ending prices. Column (3) splits the *9-ending* dummy into three dummies (*from 9 to 9*, *from other to 9*, and *from 9 to other*). Columns (4) and (5) are similar to (2) and (3) but for price decreases. * p < 10%, ** p < 5%, and *** p < 1%. Standard errors, clustered at the participant level, are reported in parentheses.

Table 2B. Probability of a Correct Response – Field Study (Fixed Effects)

	All Observations		Price Decreases		Price Increases	
	(1)	(2)	(3)	(4)	(5)	(6)
9-Ending	−0.07*** (0.015)	−0.06*** (0.015)	−0.04 (0.070)		−0.08 (0.058)	
From 9 to 9				−0.08 (0.084)		−0.04 (0.065)
From other to 9				−0.04 (0.097)		−0.17*** (0.080)
From 9 to other				−0.06 (0.093)		0.05 (0.090)
Right-Most	0.003 (0.017)	0.09*** (0.020)	0.15** (0.059)	0.15** (0.060)	0.11*** (0.042)	0.13*** (0.044)
Middle	−0.38*** (0.028)	−0.18*** (0.029)	0.001 (0.074)	−0.01*** (0.077)	−0.02 (0.051)	−0.07 (0.058)
Left–Most	−0.11*** (0.021)	0.09*** (0.025)	−0.005 (0.001)	−0.01 (0.047)	0.09** (0.036)	0.09*** (0.035)
0-Ending		−0.09* (0.053)	−0.35 (0.350)	−0.37 (0.349)	−0.0002 (0.076)	−0.01 (0.084)
Price Increase		−0.35*** (0.038)				
Price Decrease		−0.37*** (0.037)				
Previous Price		−0.001 (0.001)	-0.002 (0.001)	−0.002 (0.001)	0.00003 (0.002)	-3.21×10^{-6} (0.002)
Relative Size of the Price Change		0.09* (0.047)	0.17* (0.097)	0.18* (0.100)	−0.14** (0.068)	−0.16** (0.073)
Intercept	0.76*** (0.012)	0.78*** (0.014)	0.36*** (0.073)	0.38*** (0.074)	0.39*** (0.067)	0.38*** (0.070)
Number of Observations	6,031	6,031	581	581	639	639
F	75.1***	46.2***	3.8***	3.0***	3.3***	2.9***

Notes: The table reports estimation results of linear models with fixed effects of the probability of a correct response. The dependent variable is *accurate*, a dummy that equals 1 if the answer is correct and 0 otherwise (average = 0.65). The independent variables are: 9-ending dummy that equals 1 if at least one of the prices/numbers ends in 9; From 9 to 9 dummy that equals 1 if the previous price ended in 9 and the current one ends in 9; From other to 9 dummy that equals 1 if the previous price did not end in 9 and the current one does; From 9 to other dummy that equals 1 if the previous price ended in 9 and the current does not; Right most dummy that equals 1 if the two prices/numbers differed in their right-most digit; Middle dummy that equals 1 if the two prices/numbers differed in their middle digit(s); Left most dummy that equals 1 if the two prices/numbers differed in their left-most digit (the base group in all three cases when the prices/numbers were equal); Female dummy for women; Ultra-Religious Consumer dummy for consumers that identify themselves as orthodox Jews; Academic degree dummy for consumers with at least one academic degree; More than one trip a week dummy for consumers that report making more than one shopping trip a week; More than NIS 300/shopping trip dummy for consumers that report spending on average more than NIS 300 (69 dollars) per shopping trip; Older than 55 dummy for consumers 55 or older; Price increase dummy for a price that has increased relative to the price in the previous week; Price decrease dummy for a price that has decreased relative to the price in the previous week; Previous price which is the price of the good in the previous week; and Relative size of the price change which is the absolute percentage change in the price relative to the previous week. Column (1) uses all observations. Columns (2) and (3) use only observations on price increases. Column (2) uses one dummy, *9-ending*, to control for 9-ending prices. Column (3) splits the *9-ending* dummy into three dummies (*from 9 to 9*, *from other to 9*, and *from 9 to other*). Columns (4) and (5) are similar to (2) and (3) but for price decreases. * $p < 10\%$, ** $p < 5\%$, and *** $p < 1\%$. Standard errors, clustered at the participant level, are reported in parentheses.

Table 2C. Probability of a Correct Response – Field Study (OLS)

	All Observations		Price Decreases		Price Increases	
	(1)	(2)	(3)	(4)	(5)	(6)
9-Ending	−0.08*** (0.019)	−0.08*** (0.017)	−0.01 (0.057)		−0.16*** (0.055)	
From 9 to 9				−0.06 (0.084)		−0.07 (0.066)
From other to 9				−0.03 (0.095)		−0.27*** (0.084)
From 9 to other				−0.09 (0.105)		0.13* (0.077)
Right-Most	0.0005 (0.018)	0.09*** (0.021)	0.10** (0.044)	0.10** (0.047)	0.15*** (0.045)	0.16*** (0.044)
Middle	−0.43*** (0.025)	−0.25*** (0.029)	−0.50*** (0.050)	−0.49*** (0.053)	−0.10* (0.056)	−0.15** (0.058)
Left–Most	−0.11*** (0.024)	0.07*** (0.025)	−0.01 (0.037)	−0.01 (0.037)	0.13*** (0.037)	0.13*** (0.037)
0-Ending		−0.12** (0.054)	−0.08 (0.261)	−0.11 (0.265)	−0.16* (0.086)	−0.17** (0.084)
Female		0.06* (0.030)	0.02 (0.041)	0.01 (0.042)	0.06 (0.053)	0.06 (0.051)
Ultra-Religious Consumer		0.05* (0.026)	0.17*** (0.051)	0.15*** (0.052)	0.09* (0.073)	0.08 (0.072)
Academic Degree		0.02 (0.028)	-0.0002 (0.042)	0.003 (0.043)	0.12** (0.061)	0.12** (0.060)
More than One Trip a Week		0.06** (0.028)	0.01*** (0.039)	0.08*** (0.038)	0.01 (0.059)	0.01 (0.059)
More than NIS300.00 per Shopping Trip		−0.11*** (0.026)	−0.09** (0.040)	−0.08** (0.039)	−0.07 (0.053)	−0.07 (0.052)
Older than 55		−0.10**	−0.04	−0.04	−0.14	−0.13

		(0.054)	(0.062)	(0.062)	(0.090)	(0.086)
Price Increase		−0.31*** (0.040)				
Price Decrease		−0.32*** (0.037)				
Previous Price		−0.0004 (0.0007)	-0.0004 (0.001)	−0.0003 (0.001)	0.0002 (0.002)	0.001 (0.002)
Relative Size of the Price Change		0.11** (0.042)	0.38*** (0.089)	0.39*** (0.092)	0.09* (0.051)	0.03 (0.055)
Intercept	0.78*** (0.015)	0.77*** (0.039)	0.48*** (0.083)	0.51*** (0.094)	0.35*** (0.097)	0.33*** (0.102)
Number of Observations	6,031	6,031	581	581	639	639
F	125.7***	56.8***	39.7***	35.9***	10.6***	10.1***

Notes: The table reports estimation results of linear models of the probability of a correct response. The dependent variable is *accurate*, a dummy that equals 1 if the answer is correct and 0 otherwise (average = 0.65). The independent variables are: 9-ending dummy that equals 1 if at least one of the prices/numbers ends in 9; From 9 to 9 dummy that equals 1 if the previous price ended in 9 and the current one ends in 9; From other to 9 dummy that equals 1 if the previous price did not end in 9 and the current one does; From 9 to other dummy that equals 1 if the previous price ended in 9 and the current does not; Right most dummy that equals 1 if the two prices/numbers differed in their right-most digit; Middle dummy that equals 1 if the two prices/numbers differed in their middle digit(s); Left most dummy that equals 1 if the two prices/numbers differed in their left-most digit (the base group in all three cases when the prices/numbers were equal); Female dummy for women; Ultra-Religious Consumer dummy for consumers that identify themselves as orthodox Jews; Academic degree dummy for consumers with at least one academic degree; More than one trip a week dummy for consumers that report making more than one shopping trip a week; More than NIS 300/shopping trip dummy for consumers that report spending on average more than NIS 300 (69 dollars) per shopping trip; Older than 55 dummy for consumers 55 or older; Price increase dummy for a price that has increased relative to the price in the previous week; Price decrease dummy for a price that has decreased relative to the price in the previous week; Previous price which is the price of the good in the previous week; and Relative size of the price change which is the absolute percentage change in the price relative to the previous week. Column (1) uses all observations. Columns (2) and (3) use only observations on price increases. Column (2) uses one dummy, *9-ending*, to control for 9-ending prices. Column (3) splits the *9-ending* dummy into three dummies (*from 9 to 9*, *from other to 9*, and *from 9 to other*). Columns (4) and (5) are similar to (2) and (3) but for price decreases. * p < 10%, ** p < 5%, and *** p < 1%. Standard errors, clustered at the participant level, are reported in parentheses.

Table 2D. Probability of a Correct Response – Field Study (Probit)

	(1)	(2)	(3)	(4)	(5)	(6)
9-Ending	−0.27*** (0.046)	–0.25*** (0.05)	–0.17 (0.23)		–0.28*** (0.05)	
From 9 to 9				−0.36 (0.285)		−0.26 (0.249)
From other to 9				−0.19 (0.327)		−1.00*** (0.353)
From 9 to other				−0.39 (0.394)		0.06 (0.338)
Right-Most	0.03 (0.056)	0.39*** (0.07)	0.53** (0.22)	0.54*** (0.231)	0.27*** (0.07)	0.80*** (0.195)
Middle	−1.26*** (0.065)	–0.68 *** (0.08)	–2.46*** (0.34)	−0.41*** (0.342)	–0.27*** (0.10)	−0.60*** (0.221)
Left–Most	−0.40*** (0.066)	0.37*** (0.09)	0.05 (0.24)	0.03 (0.242)	0.47*** (0.12)	0.60*** (0.179)
0-Ending		–0.32 (0.18)	–0.25 (0.80)	−0.39 (0.821)	–0.23 (0.19)	−0.35 (0.391)
Female		0.08 (0.06)	0.30 (0.24)	0.14 (0.241)	0.08 (0.07)	0.27 (0.266)
Ultra-Religious Consumer		0.20 ** (0.10)	0.70*** (0.26)	0.70*** (0.261)	0.01 (0.10)	0.46 (0.313)
Academic Degree		0.07 (0.09)	–0.03 (0.22)	−0.01 (0.229)	0.05 (0.09)	0.57** (0.253)
More than One Trip a Week		0.26 *** (0.08)	0.58** (0.24)	0.58** (0.246)	0.28*** (0.09)	0.34 (0.261)
More than NIS 300/Shopping Trip		–0.33 *** (0.08)	–0.42* (0.23)	−0.43* (0.229)	–0.31*** (0.09)	−0.34 (0.240)
Older than 55		–0.31 ** (0.14)	–0.23 (0.37)	−0.23 (0.371)	–0.33** (0.15)	−0.58 (0.412)
Price Increase		–1.19 *** (0.11)			–1.41*** (0.13)	
Price Decrease		–1.30 *** (0.11)				
Previous Price		–.004* (0.002)	–0.009 (0.009)	−0.01 (0.009)	–0.005** (0.002)	0.004 (0.010)
Relative Size of the Price Change		0.30* (0.16)	2.30*** (0.64)	2.34*** **(0.644)**	0.28* (0.16)	0.02 (0.261)
Intercept	0.85*** (0.054)	0.85*** (0.11)	–0.63 (0.44)	−0.37 (0.457)	0.88*** (0.12)	−1.08** (0.445)
Number of Observations	6,031	6,031	581	581	639	639
χ^2	528.5***	657.1***	76.1***	77.0***	379.0***	59.2***

Notes: The table reports estimation results of probit models of the probability of a correct response. The dependent variable is *accurate*, a dummy that equals 1 if the answer is correct and 0 otherwise (average = 0.65). The independent variables are: 9-ending dummy that equals 1 if at least one of the prices/numbers ends in 9; From 9 to 9 dummy that equals 1 if the previous price ended in 9 and the current one ends in 9; From other to 9 dummy that equals 1 if the previous price did not end in 9 and the current one does; From 9 to other dummy that equals 1 if the previous price ended in 9 and the current does not; Right most dummy that equals 1 if the two prices/numbers differed in their right-most digit; Middle dummy that equals 1 if the two prices/numbers differed in their middle digit(s); Left most dummy that equals 1 if the two prices/numbers differed in their left-most digit (the base group in all three cases when the prices/numbers were equal); Female dummy for women; Ultra-Religious Consumer dummy for consumers that identify themselves as orthodox Jews; Academic degree dummy for consumers with at least one academic degree; More than one trip a week dummy for consumers that report making more than one shopping trip a week; More than NIS 300/shopping trip dummy for consumers that report spending on average more than NIS 300 (69 dollars) per shopping trip; Older than 55 dummy for consumers 55 or older; Price increase dummy for a price that has increased relative to the price in the previous week; Price decrease dummy for a price that has decreased relative to the price in the previous week; Previous price which is the price of the good in the previous week; and Relative size of the price change which is the absolute percentage change in the price relative to the previous week. Column (1) uses all observations. Columns (2) and (3) use only observations on price increases. Column (2) uses one dummy, *9-ending*, to control for 9-ending prices. Column (3) splits the *9-ending* dummy into three dummies (*from 9 to 9*, *from other to 9*, and *from 9 to other*). Columns (4) and (5) are similar to (2) and (3) but for price decreases. * p < 10%, ** p < 5%, and *** p < 1%. Standard errors, clustered at the participant level, are reported in parentheses.

Appendix L. Asymmetric Rigidity of 9-Endings – Dominick's

Probit Model

In the paper, we test for the asymmetric rigidity of 9-ending prices. In this appendix we present three robustness checks for the results that we report. Table 4A presents the results of a probit regression of the probability that a post-change price is 9-ending. The dependent variable is the same as in the paper: It is a dummy that equals 1 if the post change price is equal to 1 and 0 otherwise. The main independent variables is *price decrease* (1= price cut, and 0 otherwise). We expect the coefficient of this variable to be negative, suggesting that prices are more likely to be 9-ending following a price increase than following a price decrease. The other controls are: *previous 9-ending* (1 if the pre-change price is 9-ending, and 0 otherwise), price change (the absolute difference between the post- and pre-change prices), and price level, defined as the price without the penny-digit.

We find that the coefficient of price decreases is negative and significant ($\beta = -0.15, p < 0.01$). Thus, the probit results confirm the OLS results presented in the paper. 9-endings are more common following price increases than following price decreases.

OLS Model – Regular Prices

In Table 4B we report the results of an OLS regression, similar to the one we estimate in the paper of the probability that a post change price is 9-ending. However, in this regression we use only observations on regular prices. That is, we drop all observations if the pre or post change prices are sale prices (using the Dominick's sale indicator). We find that the coefficient of price decreases is negative and significant ($\beta = -0.14, p < 0.01$). Further, the value we get in this regression is larger than the one we report in the paper: When we use all the observations we find that the coefficient of price decreases is -0.06. Thus, the asymmetry in the rigidity of the likelihood that a price will be 9-ending seems to be more pronounced for regular prices than for sale prices.

OLS Model – Regular Prices using a Sale Filter

In Table 4C we report the results of an OLS regression, similar to the one we estimate in the paper of the probability that a post change price is 9-ending. However, in this regression we use only observations on regular prices, by using a sale filter to identify sales.[7] That is, we drop all observations if the pre or post change prices are sale prices according to the sale filter we employ. We find that the coefficient of price decreases is negative and significant ($\beta = -0.03, p < 0.01$). Thus, we find that the asymmetry in the likelihood that a price will be 9-ending is also present when we use a sale filter to remove sales from the data.

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[7] Sale filters are procedures for identifying V-shaped sales. We use Nakamura and Steinsson (2008, 2011) Filter A which identifies a price as sale price when it identifies instances in which the price decreases and then bounces back up to a price that is equal or higher than the pre-sale price. See also the discussion of sale filters in Appendix D.

Table 4A. Probability that a New Price Ends with 9 – Dominick's – Probit

Price Decrease	−0.15 (0.010)***
Previous 9-Ending	0.22 (0.012)***
Price Level	0.07 (0.006)***
Price Change	0.002 (0.0001)***
Constant	−0.19 (0.018)***
Number of Observations	20,839,462

Notes: The table reports the results of a probit regression of the probability that a new price ends with 9. The dependent variable is a dummy that equals 1 if the post change price is 9-ending and zero otherwise. The average of the dependent variable is 0.54. Price decrease is a dummy that equals 1 if the price change is a price decrease. Previous 9-ending is a dummy that equals 1 if the pre-change price was 9-ending. Price change is the absolute value size of the price change. The regression also includes store dummies. *** $p < 1\%$. Standard errors, clustered at the UPC level, are reported in parentheses.

Table 4B. Probability that a New Price Ends with 9 – Dominick's – Regular prices

Price Decrease	−0.14 (0.004)***
Previous 9-Ending	0.03 (0.006)***
Price Level	0.02 (0.002)***
Price Change	0.001 (0.00006)***
Constant	0.39 (0.007)***
Number of Observations	5,199,236

Notes: The table reports the results of a linear regression of the probability that a new price ends with 9. The dependent variable is a dummy that equals 1 if the post change price is 9-ending and zero otherwise. The average of the dependent variable is 0.46. Price decrease is a dummy that equals 1 if the price change is a price decrease. Previous 9-ending is a dummy that equals 1 if the pre-change price was 9-ending. Price change is the absolute value size of the price change. The regression also includes store dummies. *** $p < 1\%$. Standard errors, clustered at the UPC level, are reported in parentheses.

Table 4C. Probability that a New Price Ends with 9 – Dominick's – Regular Prices Using a Sale Filter

Price Decrease	−0.03 (0.003)***
Previous 9-Ending	0.10 (0.004)***
Price Level	0.03 (0.002)***
Price Change	0.0006 (0.00004)***
Constant	0.39 (0.005)***
Number of Observations	7,865,307

Notes: The table reports the results of a linear regression of the probability that a new price ends with 9. The dependent variable is a dummy that equals 1 if the post change price is 9-ending and zero otherwise. The average of the dependent variable is 0.46. Price decrease is a dummy that equals 1 if the price change is a price decrease. Previous 9-ending is a dummy that equals 1 if the pre-change price was 9-ending. Price change is the absolute value size of the price change. The regression also includes store dummies. *** $p < 1\%$. Standard errors, clustered at the UPC level, are reported in parentheses.

Appendix M. Asymmetric Rigidity of 9-Ending Prices – Dominick's

In the paper, we report that 9-ending prices are more rigid upward than downward. In this appendix, we report the results of three robustness checks. For the first robustness check, we estimate the regression when we include all observations, including the observations on outlier values of the percentage change in the wholesale prices. For the second, we use a sample that is restricted to regular prices, by removing observations of sale prices, using the Dominick's sale indicator. For the third, we use a sample that is restricted to regular prices, by removing observations of sale prices, using a sale filter to identify sales.

For all three tests, we use multinomial-logit regression, similar to the one estimated in the paper (results reported in Table 5). The dependent variable is an index variable that equals 0/1/2 if the price remained-unchanged/decreased/increased, respectively. The main independent variable is *previous 9-ending*, which controls for the effect of 9-endings on price rigidity. The other controls are the price level (price minus the penny digit), the absolute value of the percentage change in the wholesale price, $\lfloor (w_t - w_{t-1})/w_{t-1} \rfloor$, and a dummy for sale price in the previous week (1 if the price was a sale price, and 0 otherwise).

<u>Multinomial Logit Regression Including Outliers</u>

Table 5A reports the estimation results when we include all observations, including observations where the wholesale price changed, according to the data, by more than 200%. We find that 9-ending prices are less likely to decrease than the prices with other endings ($\beta = -0.12, p < 0.01$), as well as less likely to increase than prices with other endings ($\beta = -0.39, p < 0.01$).

The difference between the coefficient of price increase and decrease is statistically significant ($\chi^2 = 330.7, p < 0.01$). We therefore conclude that even if we include the outlier observations of the wholesale prices, we still find that 9-ending prices are significantly more rigid upward than downward.

<u>Multinomial Logit Regression – Regular Prices</u>

Table 5B reports the estimation results when we use the sample of regular prices. To obtain the sample, we remove observations if the price is a sale price or if the price in the previous week was a sale price (using the Dominick's sale indicator). We find that 9-ending prices are less likely to decrease than prices with other endings ($\beta = -0.50, p < 0.01$), as well as less likely to increase than prices with other endings ($\beta = -1.94, p < 0.01$).

The difference between the coefficient of price increase and decrease is statistically significant ($\chi^2 = 1110.9, p < 0.01$). We therefore conclude that even when we restrict the sample to regular prices, we still find asymmetry in the rigidity of 9-ending prices. We therefore conclude that the asymmetric rigidity we report in the paper is not driven by sale prices.

Multinomial Logit Regression – Regular Prices using a Sale Filter

Table 5C reports the estimation results when we use the sample of regular prices. To obtain the sample, we remove observations if the price is a sale price or if the price in the previous week was a sale price (using a sale filter to identify sales).[8] We find that 9-ending prices are less likely to decrease than prices with other endings ($\beta = -0.10, p < 0.01$), as well as less likely to increase than prices with other endings ($\beta = -0.39, p < 0.01$).

The difference between the coefficient of price increase and decrease is statistically significant ($\chi^2 = 321.5, p < 0.01$). We therefore conclude that even when we restrict the sample to regular prices using a sale filter, we still find asymmetry in the rigidity of 9-ending prices. We therefore conclude that the asymmetric rigidity we report in the paper is not driven by sale prices.

[8] Sale filters are procedures for identifying V-shaped sales. We use Nakamura and Steinsson (2008, 2011) Filter A which identifies a price as sale price when it identifies instances in which the price decreases and then bounces back up to a price that is equal or higher than the pre-sale price. See also the discussion of sale filters in Appendix D.

Table 5A. Probability of Price Increases and Decreases Relative to Price Remaining Unchanged – Dominick's – Including all observations on wholesale prices

	Price Decreases	Price Increases
Previous 9-Ending	−0.12*** (0.017)	−0.39*** (0.013)
Absolute Value of the Percentage Change in the Wholesale Price	0.0002*** (0.00003)	2.85×10^{-6} (0.00002)
Sale Price Indicator in Previous Week	0.48*** (0.015)	3.049*** (0.015)
Price Level	−0.15*** (0.012)	0.08 (0.006)
Constant	−1.39*** (0.031)	−2.815*** (0.020)
χ^2	117,714.2	
Number of Observations	81,982,683	

Notes: The table reports estimation results of a Multinomial-logit model of the probability of a price decrease and increase relative to the prices remaining unchanged. The dependent variable is an index variable, which equals 0/1/2 if the price has remained unchanged/decreased/increased. Previous 9-ending is a dummy that equals 1 if the pre-change price was 9-ending. The absolute value of the percentage change in the wholesale Price is the absolute percentage change in the wholesale price. Sale price indicator in previous week is a dummy that is equal to 1 if the good was on sale in the previous week. Price level is equal to the price minus the penny digit. The regression also includes store dummies. *** $p < 1\%$. Standard errors, clustered at the UPC level, are reported in parentheses.

Table 5B. Probability of Price Increases and Decreases Relative to Price Remaining Unchanged – Dominick's – Regular prices

	Price Decreases	Price Increases
Previous 9-Ending	−0.50*** (0.022)	−1.94*** (0.020)
Absolute Value of the Percentage Change in the Wholesale Price	0.0003*** (0.00004)	4.78×10^{-6} (0.00002)
Price Level	−0.07*** (0.008)	0.09*** (0.006)
Constant	−2.55*** (0.028)	−2.56 (0.023)
χ^2	29,185.0	
Number of Observations	57141084	

Notes: The table reports estimation results of a Multinomial-logit model of the probability of a price decrease and increase relative to the prices remaining unchanged. The dependent variable is an index variable, which equals 0/1/2 if the price has remained unchanged/decreased/increased. Previous 9-ending is a dummy that equals 1 if the pre-change price was 9-ending. The absolute value of the percentage change in the wholesale Price is the absolute percentage change in the wholesale price. Sale price indicator in previous week is a dummy that is equal to 1 if the good was on sale in the previous week. Price level is equal to the price minus the penny digit. The regression also includes store dummies. *** $p < 1\%$. Standard errors, clustered at the UPC level, are reported in parentheses.

Table 5C. Probability of Price Increases and Decreases Relative to Price Remaining Unchanged – Dominick's – Regular Prices Using a Sale Filter

	Price Decreases	Price Increases
Previous 9-Ending	−0.10*** (0.021)	-0.39*** (0.025)
Absolute Value of the Percentage Change in the Wholesale Price	11.22*** (0.261)	5.13*** (0.240)
Price Level	−0.05*** (0.008)	0.11*** (0.010)
Constant	−2.86*** (0.028)	-3.18*** (0.027)
χ^2	33,648.1	
Number of Observations	66,689,125	

Notes: The table reports estimation results of a Multinomial-logit model of the probability of a price decrease and increase relative to the prices remaining unchanged. The dependent variable is an index variable, which equals 0/1/2 if the price has remained unchanged/decreased/increased. Previous 9-ending is a dummy that equals 1 if the pre-change price was 9-ending. The absolute value of the percentage change in the wholesale Price is the absolute percentage change in the wholesale price. Sale price indicator in previous week is a dummy that is equal to 1 if the good was on sale in the previous week. Price level is equal to the price minus the penny digit. The regression also includes store dummies. *** p < 1%. Standard errors, clustered at the UPC level, are reported in parentheses.

Appendix N. Asymmetry in the Size of Price Changes – Dominick's

In this appendix, we report the results of three robustness checks for the results reported in Table 6 in the paper. First, we present the results of estimating regression (5), when we do not remove outlier observations of the wholesale prices. Second, we report the result of estimating regression (5) when we use only observations on regular prices using Dominick's sale indicator dummy to remove sale prices. Third, we report the result of estimating regression (5) when we again use only observations on regular prices, but this time using a sale filter to remove sale prices.

<u>OLS Regression, Including Outlier Observations</u>

Table 6A reports the results when use all the observations, including those with outlier values of the changes in the wholesale prices. The dependent variable is the *absolute percentage price change*. The independent variables are *previous 9-ending* (a dummy that equals 1 if the pre-change price was 9-ending), and its interaction with *price decrease* (a dummy for price cuts), *price level* (the price minus the penny digit), the *absolute value of the percentage change in the wholesale price*, dummies for *sale prices in the current* and *previous week*, and *store* dummies.

We find that when 9-ending price increase, they change by more than other prices ($\beta = 0.05, p < 0.01$). When they decrease, they change by less than other prices ($\beta = -0.05, p < 0.01$). Therefore, including the values of outlier observations of the wholesale prices does not change the main results we report in the paper.

<u>OLS Regression – Regular Prices</u>

Table 6B reports the results when we use only observations on regular prices, by removing the observations on sale prices in the current or previous week (using the Dominick's sale indicator). The dependent variable is the *absolute percentage price* *change*. The independent variables are *previous 9-ending* (a dummy that equals 1 if the pre-change price was 9-ending), and its interaction with *price decrease* (a dummy for price cuts), *price level* (the price minus the penny digit), *absolute value of the percentage change in the wholesale price*, dummies for *sale prices in the current* and *previous week*, and *store* dummies.

We find that when 9-ending price increase, they change by more than other prices ($\beta = 0.05, p < 0.01$). When they decrease, they change by less than other prices ($\beta = -0.07, p < 0.01$). We therefore conclude that the asymmetry in the size of the price changes we report in the paper is not driven by sale prices.

OLS Regression – Regular Prices – Using a Sale Filter

Table 6C reports the results when we use only observations on regular prices, by using a sale filter to identify sales.[9] That is, we drop all observations if the pre or post change prices are sale prices according to the sale filter we employ. The dependent variable is the *absolute percentage price change*. The independent variables are *previous 9-ending* (a dummy that equals 1 if the pre-change price was 9-ending), and its interaction with *price decrease* (a dummy for price cuts), *price level* (the price minus the penny digit), *absolute value of the percentage change in the wholesale price*, dummies for *sale prices in the current* and *previous week*, and *store* dummies.

[9] Sale filters are procedures for identifying V-shaped sales. We use Nakamura and Steinsson (2008, 2011) Filter A which identifies a price as sale price when it identifies instances in which the price decreases and then bounces back up to a price that is equal or higher than the pre-sale price. See also the discussion of sale filters in Appendix D.

We find that when 9-ending price increase, they change by more than other prices ($\beta = 0.07, p < 0.01$). When they decrease, they change by less than other prices ($\beta = -0.08, p < 0.01$). We therefore conclude that the asymmetry in the size of the price changes we report in the paper is not driven by sale prices, also when use a sale filter to remove sales from the data.

Table 6A. The Size of 9-Ending Price Change – Dominick's – Including all observations on wholesale prices

Previous 9-Ending	0.05*** (0.003)
Previous 9-Ending × Price-Decrease	−0.05*** (0.002)
Price Level	0.0005 (0.001)
Absolute Value of the Percentage Change in the Wholesale Price	6.25×10^{-7}*** (2.19×10^{-7})
Sale Price Indicator in Previous Week	0.04*** (0.002)
Sale Price Indicator	0.006*** (0.002)
Constant	0.17*** (0.005)
R^2	0.07
Number of Observations	20,839,462

Notes: The table reports estimation results of a linear regression of the percentage price change, conditional on the price changing. The dependent variable is the absolute percentage price change. The average value of the dependent variable is 0.22. The independent variables are *previous 9-ending* (a dummy which equals 1 if the pre change price was 9-ending), *price-decrease* (a dummy that equals 1 if the price change is a price decrease), the *absolute value of the percentage change in the wholesale price*, *sale price indicator in previous week* (a dummy that equals 1 if the good was on sale in the previous week), *sale price indicator* (a dummy that equals 1 if the good was on sale in the week of the observation), and store dummies. *** $p < 0.01\%$. Standard errors, clustered at the UPC level, are reported in parentheses.

Table 6B. The Size of 9-Ending Price Change – Dominick's – Regular Prices

Previous 9-Ending	0.05*** (0.006)
Previous 9-Ending × Price-Decrease	−0.07*** (0.003)
Price Level	0.0009 (0.001)
Absolute Value of the Percentage Change in the Wholesale Price	0.71*** (0.058)
Constant	0.08*** (0.005)
R^2	0.03
Number of Observations	5,142,841

Notes: The table reports estimation results of a linear regression of the percentage price change, conditional on the price changing. The dependent variable is the absolute percentage price change. The average value of the dependent variable is 0.22. The independent variables are *previous 9-ending*, a dummy which equals 1 if the pre change price was 9-ending, *price-decrease*, a dummy that equals 1 if the price change is a price decrease, the *absolute value of the percentage change in the wholesale price*, *sale price indicator in previous week*, a dummy that equals 1 if the good was on sale in the previous week, *sale price indicator*, a dummy that equals 1 if the good was on sale in the week of the observation and store dummies. *** $p < 0.01\%$. Standard errors, clustered at the UPC level, are reported in parentheses.

Table 6C. The Size of 9-Ending Price Change – Dominick's – Regular prices only using a sale filter

Previous 9-Ending	0.07 (0.004)***
Previous 9-Ending × Price-Decrease	−0.08 (0.002)***
Price Level	0.007 (0.0009)***
Absolute Value of the Percentage Change in the Wholesale Price	0.63 (0.025)***
Constant	0.09 (0.004)***
R^2	0.05
Number of Observations	7,719,952

Notes: The table reports estimation results of a linear regression of the percentage price change, conditional on the price changing. The dependent variable is the absolute percentage price change. The average value of the dependent variable is 0.22. The independent variables are *previous 9-ending*, a dummy which equals 1 if the pre change price was 9-ending, *price-decrease*, a dummy that equals 1 if the price change is a price decrease, the *absolute value of the percentage change in the wholesale price*, *sale price indicator in previous week*, a dummy that equals 1 if the good was on sale in the previous week, *sale price indicator*, a dummy that equals 1 if the good was on sale in the week of the observation and store dummies. *** p < 0.01%. Standard errors, clustered at the UPC level, are reported in parentheses.

Appendix O. **Share of 9-Endings in Regular Prices and in Sale Prices – Dominick's**

In Panel A of Table 14A we present the percentages of 9-ending prices in regular prices and in sale prices, where we use Dominick's sale index dummy to identify sales (left hand side panel) and a sale filter (right hand side panel) of Nakamura and Steinsson (2008, 2011).[10] We find that in both panels, the percentage of 9-endings is higher in the sample of regular prices than in the sample of sale prices: When we use the Dominick's sale index dummy (sale filter), the percentage of 9-endings in the regular data is 65.33% (64.02%) compared to 48.75% (47.47%) in the sale prices.

In Panel B we report the results when we extrapolate the data by assuming that if a price is missing, then the price is equal to the price in the previous week. The results are similar. When we use the Dominick's sale index dummy (sale filter), the percentage of 9-endings in the regular data is 67.00% (65.44%), compared to 49.67% (48.68%) in the sale prices.

[10] See also the discussion of sale filters in Appendix D.

Table 14A. Share of 9-Endings in Regular Prices and in Sale Prices – Dominick's.

A. Actual transaction price data			
Dominick's sale indicator variable		Sale filter	
Regular prices	Sale prices	Regular prices	Sale prices
65.33% *N* = 66,837,776	48.75% *N* = 15,144,907	64.02% *N* = 73,277,007	47.47% *N* = 8,705,676
B. Expanded (interpolated) price data			
Dominick's sale indicator variable		Sale filter	
Regular prices	Sale prices	Regular prices	Sale prices
67.00% *N* = 77,304,915	49.67% *N* = 17,390,385	65.44% *N* = 85,522,297	48.68% *N* = 9,173,003

Appendix P. Asymmetric Rigidity of 9-Endings – Israeli Supermarkets and Drugstores

In the paper, we estimate a linear model of the probability that following a price change, the new price ends with 9. In this appendix, we present two robustness tests. First, we present the results of a probit regression. Second, we present the results after we exclude sale prices, which we define using a sale filter (Nakamura and Steinsson, 2008).

Probit Model

In column (1) of Table 8A, we report the estimation results when the only dependent variable is a dummy for price decreases. The regression (as well as the next regression presented in column (2)) also includes dummy controls for *product categories* and for the 7 *districts* of Israel.

We find that the coefficient of price decreases is negative and significant ($\beta = -0.07, p < 0.01$). Therefore, the main result we report in the paper, that 9-endings are less common after price decreases than after price increases, holds also when we estimate the model using probit.

In column (2), we add further controls: *previous 9-ending*, a dummy that equals 1 if the pre-change price was 9-ending, *price level* defined as the price without the penny digit, and the absolute size of the *price change*. We find that the effect of price decreases increases slightly when we add the controls ($\beta = -0.10, p < 0.01$).

We therefore conclude that the finding that 9-endings are less common following price decreases than price increases is robust to the estimation procedure we use.

Linear Probability Model – Regular Prices

In Table 8B we report the results after we use a sale filter to remove observations on sale prices.[11] Sale filters are procedures for identifying V-shaped sales. Nakamura and Steinsson (2008, 2011) offer two such filters, Filter A and Filter B. Filter B identifies a price as a sale price when it identifies instances in which the price decreases and then bounces back up to the same pre-sale price. Filter A identifies a price as sale

[11] See also the discussion of sale filters in Appendix D.

price when it identifies instances in which the price decreases and then bounces back up to a price that is equal or higher than the pre-sale price.

Below, we chose to use Filter A. We made this choice for three reasons. First, according to the Dominick's sale indicator variable, post-sale prices are occasionally higher than the pre-sale prices. Second, Anderson et al. (2015b) find that sales are sometimes used to mask upcoming price increases and, consequently, post-sale prices are occasionally higher than the pre-sale prices. Third, Filter A is more general than Filter B and it was used in other studies as well (e.g., Knotek 2010, Chakraborty et al. 2015).

The results reported in the table are, therefore, for the sample of regular prices. In column (1), we report the results where the only dependent variables are the dummy for *price decrease* and dummies for *product categories* and for the 7 *districts* of Israel. We find that the estimation results are similar to the results we report in the paper: the coefficient of *price-decrease* is negative and significant ($\beta = -0.02, p < 0.05$). Therefore, 9-endings are about 2% less likely following price decreases than following price increases.

In column (2), we add further controls. The results remain similar: 9-endings are still about 2% ($\beta = -0.02, p < 0.05$) less likely following price decreases than following price increases.

Table 8A. Probability that a New Price Ends with 9 – Israeli Supermarkets and Drugstores (Probit)

	(1)	(2)
Price Decrease	−0.07*** (0.019)	−0.10*** (0.024)
Previous 9-Ending		1.13*** (0.038)
Price Level		0.0007** (0.0007)
Price Change		0.00003 (0.0003)
Constant	0.15*** (0.027)	−0.45*** (0.031)
χ^2	6,390.8***	15,105.3***
Number of Observations	59,852	58,385

Notes: The table presents the estimation results of a probit regression of the probability that a new price ends in 9, conditional on a price change. The average of the dependent variable is 0.68. *Price decrease* is a dummy that equals 1 if a price change is a decrease. *Previous 9-ending* is a dummy that equals 1 if the pre-change price was 9-ending. *Price level* is the price without the penny digit. *Price change* is the absolute value of the size (in NIS) of the price change. The regression also includes fixed effects for *categories* and for the 7 *districts* of Israel (not reported). ** $p < 0.05$, *** $p < 0.01$. Robust standard errors, clustered at the product category level, are reported in parentheses.

Table 8B. Probability that a New Price Ends with 9 – Israeli Supermarkets and Drugstores – Regular Prices

	(1)	(2)
Price Decrease	−0.02** (0.007)	−0.02** (0.008)
Previous 9-Ending		0.41*** (0.012)
Price Level		0.0002 (0.0003)
Price Change		-2.59×10^{-6} (0.0002)
Constant	0.57*** (0.008)	0.34*** (0.011)
R^2	0.11	0.25
Number of Observations	46,642	46,642

Notes: The table presents the estimation results of a linear regression of the probability that a new price ends in 9, conditional on a price change. The average of the dependent variable is 0.68. *Price decrease* is a dummy that equals 1 if a price change is a decrease. *Previous 9-ending* is a dummy that equals 1 if the pre-change price was 9-ending. *Price level* is the price without the penny digit. *Price change* is the absolute value of the size (in NIS) of the price change. The regression also includes fixed effects for *categories* and for the 7 *districts* of Israel (not reported). ** $p < 0.05$, *** $p < 0.01$. Robust standard errors, clustered at the product category level, are reported in parentheses.

Appendix Q. Asymmetry in the Rigidity of Price Endings – Dominick's and Israeli Supermarkets and Drugstores

To show graphically that a price ending is more rigid upward than downward, we present the probability that the price with a given ending will end with the same digit following a price increase and following a price decrease. Figure 1A depicts these probabilities for Dominick's data, while Figure 1B depicts the same for the Israeli supermarket and drugstore data.

Several observations follow from these figures.

First, in both datasets, we find asymmetric adjustment of 9-endings. In both datasets, we are more likely to see 9-endings after a price increase than after a price decrease. In the US, the figures are 61.65% after a price increase, and 56.55% after a price decrease. In Israel, the figures are 83.2% after a price increase, and 81.6% after a price decrease.

Second, the figures draw our attention to two other endings, 0-ending and 5-endings, which are not the focus of current study. Here, several observations stand out.

First, in the Israeli price data, the probability that 0-ending will remain 0-ending and 5-ending will remain 5-ending after a price change, are quite high, around 50%, suggesting that although 9-endings are the most rigid endings in Israel as in the US, in Israel 0-endings and 5-endings are quite rigid as well.

Second, the probability that 0-ending will remain 0-ending after a price change in Israel far exceeds the probability found in the US data. The probability that 0-ending will remain 0-ending, after a price increase (decrease) in the US, is 5.6% (10.2%). The same probability for the Israeli data is 46.2% (50.3%).

Third, the probability that 5-ending will remain 5-ending after a price change in Israel far exceeds the probability found in the US data. The probability that 5-ending will remain 5-ending, after a price increase (decrease) in the US, is 12.9% (7.8%). The same probability for the Israeli data is 50.0% (55.2%).

Fourth, there is a difference in the asymmetry of price ending rigidity between the US and Israel, when we consider 0- and 5-endings. In the US data, 5-endings are more rigid upwards than downwards, similar to 9-endings. In the Israeli data, 5-endings are more rigid downwards than upwards. As to 0-endings, according to the figures, in both datasets, 0-endings are more rigid downwards than upwards.

These findings about 0-endings and 5-endings are interesting and demand further attention. For example, they suggest that 5-endings are perhaps used by U.S. shoppers also as a signal of low/discount/sale price, but not by Israeli shoppers. These and other related issues are beyond the scope of this paper.

The overall conclusion, however, is unchanged. Because of the overrepresentation of 9-endings in both datasets (62% and 65.5% in Dominick's and in the Israeli data, respectively), their asymmetric upward rigidity is of particular interest because potentially they can have macroeconomic significance, as discussed in the conclusions of the paper.

Figure 1A. Probability that a Price with a Given End-Digit Will End with the Same Digit Following a Price Increase and Decrease – Dominick's

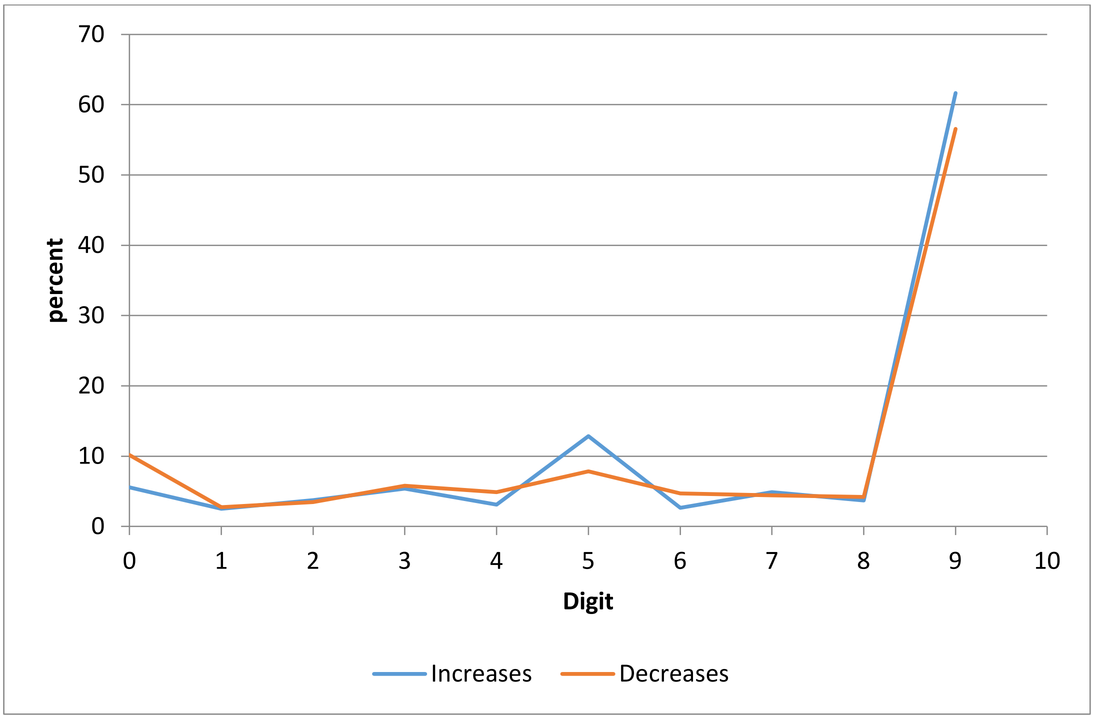
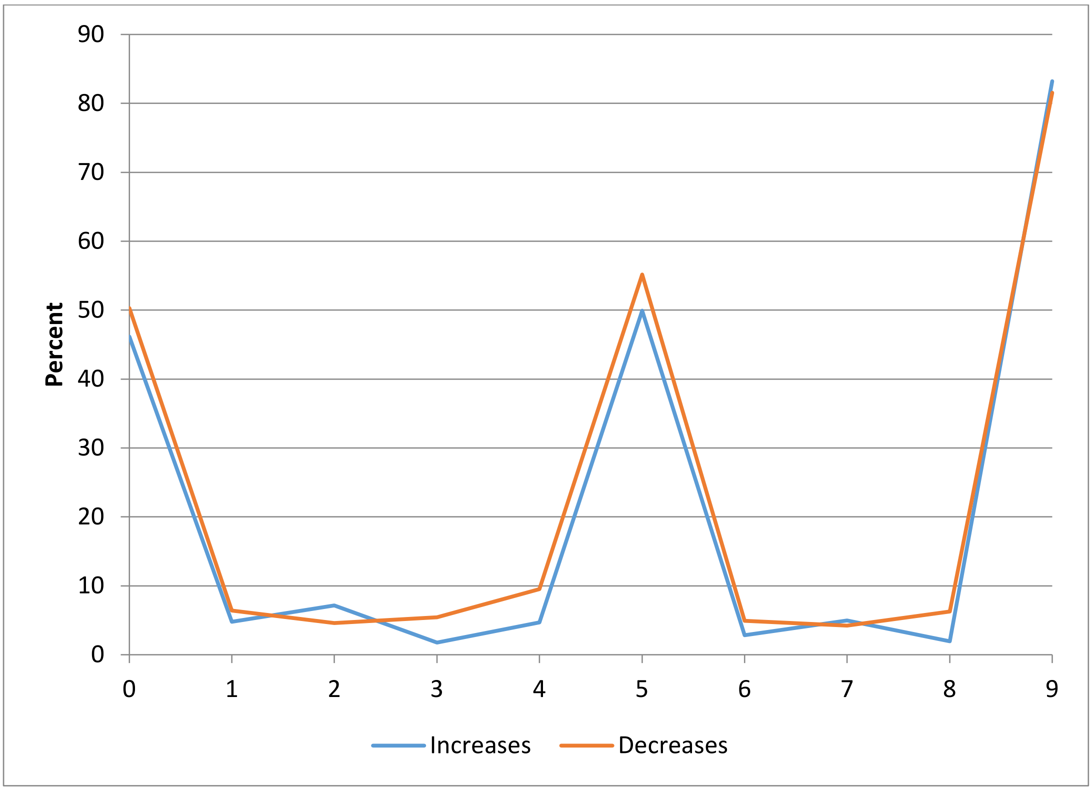


Figure 1B. Probability that a Price with a Given End-Digit Will End with the Same Digit Following a Price Increase and Decrease – Israeli Supermarkets and Drugstores



Appendix R. Asymmetric Rigidity of 9-Ending Prices: Regular Prices – Israeli Supermarkets and Drugstores

In the paper, we report that in the Israeli data, as in the US data, 9-ending prices are more rigid upward than downward. In this appendix, we assess whether this result holds for regular prices also. We therefore remove observations on sale prices, which we identify using a sale filter (Nakamura and Steinsson, 2008).[12]

We then estimate a multinomial-logit regression where the dependent variable takes on the values 0/1/2 if the price has remained unchanged/decreased/increased, respectively. The independent variables are *previous 9-ending*, which equals 1 if the pre-change price was 9-ending, and 0 otherwise, and *price level*, which is the price minus the penny digit. The estimation results are reported in Table 9A.

The coefficient of *previous 9-ending* suggests that 9-endings are more rigid upwards ($\beta = -0.32, p < 0.01$) than downwards ($\beta = -0.30, p < 0.05$). The difference, however, is not statistically significant (χ^2 = 0.27, p > 0.10).

The insignificant effect, however, may be due to the fact that sale filters are an imperfect proxy for sales. In addition, the monthly data we use is not ideal for identifying the effect of sale prices. We therefore suggest giving a greater weight to the results we report in the paper using the entire dataset than to the results of this restricted sample.

[12] See the discussion of sale filters in Appendix D.

Table 9A. Probability of Price Increases and Decreases Relative to Price Remaining Unchanged - Israeli Supermarkets and Drugstores – Regular Prices

	Price Decreases	Price Increases
Previous 9-Ending	−0.30*** (0.048)	−0.32*** (0.036)
Price Level	−0.006*** (0.002)	0.003*** (0.0008)
Constant	−2.04*** (0.080)	−1.48*** (0.36)
χ^2	28,559.3	
Number of Observations	177,579	

The table reports the estimation results of a multinomial-logit regression of the probability of a price decrease and increase relative to the price remaining unchanged. The dependent variable is an index variable, which equals 0/1/2 if the price has remained unchanged/decreased/increased, respectively. *Previous 9-ending* is a dummy that equals 1 if the pre-change price was 9-ending. *Price level* is the price without the penny digit. The regression also includes dummies for product categories and for the 7 *districts* of Israel (not reported to save space). *** $p < 0.01$. Robust standard errors, clustered at the product category level, are reported in parentheses.

Appendix S. Asymmetry in the Size of Price Change: Regular Prices – Israeli Supermarkets and Drugstores

In this appendix, we show that the results we obtain in the paper for the asymmetry in the size of price changes hold also after we remove observations on sale prices, which we identify using a sale filter (Nakamura and Steinsson, 2008). [13]

The results are reported in Table 10A. We find that the coefficient of *previous 9-ending* is positive and significant ($\beta = 0.03, p < 0.01$). Its interaction with *price decrease*, however, is negative ($\beta = -0.04, p < 0.05$). Therefore, the results we report in the paper hold also for the sample of regular prices. When 9-endings increase, they change by more than the average price change. When they decrease, they change by less than the average price change. Thus, as we hypothesize in the paper, the changes when 9-endings increase are larger than the changes when they decrease.

[13] See the discussion of sale filters in Appendix D.

Table 10A. The Size of 9-Ending Price Change – Israeli Supermarkets and Drugstores – Regular Prices

Previous 9-Ending	0.03 (0.006)***
Previous 9-Ending×Price-Decrease	–0.04 (0.010)***
Price Level	0.0006 (0.0002)***
Constant	0.07 (0.007)***
R^2	0.08
Number of Observations	46,642

Notes: The table reports estimation results of a linear regression of the percentage price change, conditional on price change. The average value of the dependent variable is 0.23. *Previous 9-ending* is a dummy that equals 1 if the pre-change price was 9-ending. *Price-decrease* is a dummy that equals 1 if the price change is a decrease. *Price level* is the price without the penny digit. The regression also includes dummies for product *categories* and for the 7 *districts* of Israel (not reported to save space). *** $p < 0.01$. Robust standard errors, clustered at the product category level, are reported in parentheses.

Appendix T. 9-Ending Price Increases and Consumer Inattention - Dominick's and Israeli Supermarkets and Drugstores

Dominick's

A possible rival explanation for our findings in the lab and field studies is that consumers are inattentive to increases in 9-ending prices. If 9-ending prices increase by less than prices with other endings, this could explain consumers' inattention to increases in 9-ending prices. Indeed, since processing price information is cognitively demanding and time-consuming, consumers may have incentive to ignore price change information, if they expect that the change is small.[14]

To explore this possibility, we check whether 9-ending price increases are smaller than the increases of prices with other endings. For this we estimate two linear regressions:

$$price\text{-}increase_{ijt} = \alpha + \beta 9\text{-}ending_{ijt} + X_{ijt}\gamma + u_i \qquad (6)$$

In the first regression, price-increase is measured in absolute terms (in dollars) of good *i* in store *j* in week *t*, and in the second, it is measured in relative terms, $(p_t - p_{t-1})/p_{t-1}$. The main independent variable is 9-ending, which equals 1 if the price is 9-ending and 0 otherwise. The matrix of controls *X* includes dummies for the store, the year, and the UPC (not reported to save space).

The results are summarized in Table 15A. Column (1) reports the results when the dependent variable is the absolute price increase, while column (2) reports the results when the dependent variable is the relative price increase.

In both columns, we find that the coefficient of 9-ending is positive and significant. In the regression of absolute price changes, the coefficient is 0.014 ($p < 0.01$) suggesting that when a new price is set at 9-ending, the expected price increase is 1.4 cents larger than when the price is set at a different ending. In the regression of relative price changes, the coefficient is 0.015 ($p < 0.01$), suggesting that when a new price is set at

[14] We thank an anonymous reviewer for this suggestion.

9-ending, the expected price increase is 1.5 percent larger than when the price is set at a different ending.

Thus, both regressions suggest that when a new price is set at a 9-ending, the increase is larger than when a new price is set at some other ending. Therefore, if anything, consumers have incentives to pay more attention to prices that end with 9 than prices that end with other digits, counter to the above rival hypothesis.

Israeli Supermarkets and Drugstores

Table 15B reports the results when we estimate the regression using the Israeli data. As further controls, we use dummies for product categories and for the year. We cluster the standard errors at the product category level.

We find that when we use the absolute price changes, the coefficient of 9-endings is positive, but statistically insignificant ($\beta = 0.31, p > 0.10$). When we use relative price changes, the coefficient of 9-endigns is negative, but again, it is statistically insignificant ($\beta = -0.01, p > 0.10$). Therefore, the results of the Israeli data suggest that when a price increases and the new price is set at a 9-ending, the price increase is not different than when the price is set at some other ending. Thus, in Israel, consumers have a similar incentive to process and pay attention to price change information whether the price ends with 9 or not.

Table 15A. The Size of Price Increases – Dominick's

	Absolute Price Increases (1)	Relative Price Increases (2)
9-ending	0.014*** (0.005)	0.015*** (0.003)
Constant	0.40*** (0.009)	0.33*** (0.052)
F	65.9	80.5
Number of Observations	10,934,191	

Notes: The table reports the estimation results of a linear regression, where dependent variable is price increase. In column (1), the dependent variable is absolute price increase, while in column (2), it is the relative (percentage) price increase. The independent variable is *9-ending* dummy, which equals 1 if the post-increase price is 9-ending, 0 otherwise. The controls include dummies for the store, the year, and the UPC. *** $p < 0.01$. Robust standard errors, clustered at the product category level, are reported in parentheses.

Table 15B. The Size of Price Increases – Israeli Supermarkets and Drugstores

	Absolute Price Increases (1)	Relative Price Increases (2)
9-ending	0.31 (0.721)	−0.01 (0.012)
Constant	2.51 (0.201)***	0.09 (0.023)***
F	189.6	14.4
Number of Observations	33,756	

Notes: The table reports the estimation results of a linear regression, where dependent variable is price increase. In column (1), the dependent variable is absolute price increase, while in column (2), it is the relative (percentage) price increase. The independent variable is 9-ending dummy, which equals 1 if the post-increase price is 9-ending, 0 otherwise. The controls include dummies for the store, the year, and the UPC. *** $p < 0.01$. Robust standard errors, clustered at the product category level, are reported in parentheses.

Appendix U. Asymmetric Rigidity of Non-9-Endings

In the paper, we show that 9-endings are more rigid upward than downward. It is of interest to check if this property is specific to 9-endings, or perhaps, there are other price endings with a similar property.[15]

To explore this question, we estimate a linear probability model of the likelihood that a price ends with digit *m* = 0, 1, …, 8. Thus, we estimating regression (3) in the paper, for each ending *m* = 0, 1, … , 8. In each regression, the dependent variable is a dummy end_m that equals 1 if the penny digit of the post-change price is *m* and 0 otherwise. The main independent variable is *price decrease* (1 = price decrease, and 0 otherwise). The other controls are *previous m-ending* (1 if the pre-change price is *m*-ending, and 0 otherwise), *price change* (the absolute difference between the post- and pre-change prices), *price level* (the price without the penny-digit) and *store* dummies (not reported to save space). Table 16A reports the estimation results.

According to the figures in the table, there are only two endings that are less likely following a price decrease than following a price increase: *m* = 2 and *m* = 5. All the other endings are more common following price decreases than following price increases, because the coefficient estimates for *price decrease* in the corresponding regressions are all positive. This positive effect is expected because if 9-endings are more common following price increases than following price decreases, then some other endings have to exhibit the opposite pattern.

Of the two endings that are more common following price decreases than following price increases, 2-ending quantitatively exhibits only a weak difference ($\beta = -0.004, p < 0.01$). This effect is an order of magnitude smaller than the effect of 9-ending prices ($\beta = -0.06$), which we report in the paper.

The other ending that is more likely after price decreases than after price increases is 5. The coefficient of price decreases ($\beta = -0.03, p < 0.01$) suggests that 5 endings are 3% less likely following a price decrease than following a price increase. It is interesting that prices that end in 5 show a pattern that is similar to 9-ending prices, because 5 is also known to be a psychological price point (Schindler and Kirby 1997). Thus, it may be that setting 5-ending prices more frequently following price increases

[15] We thank an anonymous reviewer for this suggestion.

than following price decreases is part of Dominick’s pricing strategy (as discussed in Appendix Q), but this is beyond the scope of the current paper.

Table 16A. Probability that a New Price Ends with m = 0, 1, …, 8 – Dominick's

	New *m*-Endings								
	0	1	2	3	4	5	6	7	8
Price Decrease	0.03*** (0.002)	0.003*** (0.0007)	−0.004*** (0.001)	0.003*** (0.001)	0.02*** (0.001)	−0.03*** (0.002)	0.03*** (0.001)	0.006*** (0.001)	0.001** (0.0006)
Previous *m*-Ending	−0.03*** (0.003)	−0.02*** (0.001)	−0.01*** (0.001)	−0.004 (0.002)	−0.02*** (0.001)	−0.004 * (0.002)	−0.02*** (0.001)	-0.01 (0.002)	0.009*** (0.002)
Price Level	−0.009*** (0.0008)	0.0009*** (0.0003)	−0.0006 (0.0004)	−0.003*** (0.0003)	−0.003*** (0.0004)	−0.004*** (0.0007)	−0.006*** (0.0004)	-0.001 (0.0003)	-0.002 (0.0002)
Price Change	0.0006*** (0.00003)	−0.0002*** (7.31×10^{-6})	−0.0002*** (6.91×10^{-6})	−0.0002*** (6.00×10^{-6})	−0.0002*** (8.26×10^{-6})	−0.0003*** (0.00001)	−0.0001 (6.63×10^{-6})	-0.0002 (6.56×10^{-6})	-0.0001 (4.76×10^{-6})
Constant	0.05*** (0.002)	0.05*** (0.001)	0.05*** (0.002)	0.06*** (0.001)	0.06*** (0.002)	0.13*** (0.003)	0.05*** (0.001)	0.06*** (0.001)	0.03*** (0.0009)
R^2	0.02	0.004	0.003	0.004	0.005	0.01	0.01	0.005	0.003
Number of Observations	20,839,462								

Notes: The table reports the results of a linear regression for the probability that a new price ends with the digit m (m = 0, 1, …, 8). The dependent variable is a dummy that equals 1 if the post change price is m-ending and zero otherwise. Price decrease is a dummy that equals 1 if the price change is a price decrease. Previous m-ending is a dummy that equals 1 if the pre-change price was m-ending. Price change is the absolute price change. The regression also includes store dummies. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors, clustered at the UPC level, are reported in parentheses.

Appendix V. Inflation and No-Inflation Periods – Dominick's

To test the robustness of the results to variation in inflation, we separate the Dominick's data into two sub-samples: A sample of no-inflation periods, and a sample of inflation periods. Following Chen et al. (2008) and Levy et al. (2011), we classify observations as belonging to the inflation period sample if they were collected in a month with a positive CPI inflation, and to the no-inflation period otherwise.

We then estimate the regressions we estimated in the paper again, once using the sample of no-inflation periods and once using the sample of inflation periods.

Rigidity of 9-Endings

Table 4D present the results of a linear regression of the probability that a post-change price is 9-ending when we use only data from no inflation periods. The dependent variable is the same as in the paper: It is a dummy that equals 1 if the post- change price is equal to 1 and 0 otherwise. The main independent variables is *price decrease* (1 = price cut, and 0 otherwise). We expect the coefficient of this variable to be negative, suggesting that prices are more likely to be 9-ending following a price increase than following a price decrease. The other controls are: *previous 9-ending* (1 if the pre-change price is 9-ending, and 0 otherwise), *price change* (the absolute difference between the post- and pre-change prices), and *price level*, defined as the price without the penny-digit.

We find that the coefficient of price decreases is negative and significant ($\beta = -0.05, p < 0.01$). In Table 4E, we report the results of a similar regression, using only observation from the inflation periods. We find that the coefficient of price decreases is negative and significant ($\beta = -0.07, p < 0.01$). Thus, in both inflation and no-inflation periods, we find similar to we report in the paper, that 9-endings are less common following price decreases than price increases.

Rigidity of 9-Ending Prices

Tables 5D and 5E report the results of a multinomial-logit regression of the probability that a price will increase, decrease or remain unchanged. Table 5D reports the results when we include only observations from no-inflation periods, and Table 5E reports the results when we use only observations from inflation periods.

The dependent variable is an index variable, which equals 0/1/2 if the price has remained unchanged/decreased/increased, respectively. We use *previous 9-ending* to control for the effect of 9-endings on price rigidity, expecting its effect on the likelihood of price increases to be negative but less so on the likelihood of price decreases. We also include the *absolute value of the % change in wholesale price*, a dummy for *sale price in the previous week* (1 if the price was a sale price, and 0 otherwise), because sale prices are temporary and thus they are more likely to change than regular prices, *price level* (defined as the price without the penny digit), and store dummies. It turns out that some changes in the wholesale price are suspiciously large. We therefore drop 238,279 observations with wholesale price changes of 200% or more.

The results summarized in Table 5D (no-inflation periods) show that the effect of previous 9-ending on price increases and decreases are both negative ($\beta = -0.38$, $p < 0.01$, and $\beta = -0.15$, $p < 0.01$, respectively), implying that 9-ending prices are more rigid than other prices. What is more important, however, is that the difference in their magnitude is sizeable and statistically significant ($\chi^2 = 196.9$, $p < .01$), which confirms that 9-ending prices are more rigid upward than downward.

The results reported in Table 5E (inflation periods) are qualitatively similar. The effect of *previous 9-ending* on price increases and decreases are both negative (β = –0.47, $p < 0.01$, and β = –0.20, $p < 0.01$, respectively), implying that 9-ending prices are more rigid than other prices. What is more important again, is that the difference in their magnitude is sizeable and statistically significant (χ^2 = 325.4, $p < 0.01$), which confirms that 9-ending prices are more rigid upward than downward.

Thus, the results we report in the paper regarding the differences in the upward and downward rigidity of 9-endings, are similar to the results we obtain when we estimate separately the regressions using the observations from periods of no-inflation and inflation.

Tables 6D and 6E report the results of regressions similar to the ones reported in Table 6 in the paper. Table 6D reports the results when we use only data from no-inflation periods. Table 6E reports the results when we use only observations from inflation periods.

Size of 9-Ending Price Change

Table 6D reports the results when use only observations from no-inflation periods. The dependent variable is the *absolute percentage price change*. The independent variables are *previous 9-ending* (a dummy that equals 1 if the pre-change price was 9-ending), and its interaction with *price decrease* (a dummy for price cuts), *price level* (the price minus the penny digit), the *absolute value of the percentage change in the wholesale price*, dummies for *sale prices in the current* and *previous week*, and *store* dummies.

We find that when 9-ending prices increase, they change by more than other prices ($\beta = 0.05, p < 0.01$). When they decrease, they change by less than other prices ($\beta = -0.07, p < 0.01$).

Table 6E reports the results when we use only observations from inflation-periods. The dependent variable is the *absolute percentage price change*. The independent variables are *previous 9-ending* (a dummy that equals 1 if the pre-change price was 9-ending) and its interaction with *price decrease* (a dummy for price cuts), *price level* (the price minus the penny digit), *absolute value of the percentage change in the wholesale price*, dummies for *sale prices in the current* and *previous week*, and *store* dummies.

We find that when 9-ending price increase, they change by more than other prices ($\beta = 0.05, p < 0.01$). When they decrease, they change by less than other prices ($\beta = -0.06, p < 0.01$). Therefore, the conclusions we draw in the paper are robust to separating the data into inflation and no-inflation periods.

Table 4D. Probability that a New Price Ends with 9 – Dominick's – No-Inflation Periods

Price Decrease	−0.05 (0.004)***
Previous 9-Ending	0.09 (0.005)***
Price Level	0.02 (0.002)***
Price Change	0.0008 (0.00005)***
Constant	0.43 (0.007)***
Number of Observations	8,010,913

Notes: The table reports the results of a linear regression for the probability that a new price ends with 9. The dependent variable is a dummy that equals 1 if the post change price is 9-ending and zero otherwise. The average of the dependent variable is: 0.54. Price decrease is a dummy that equals 1 if the price change is a price decrease. Previous 9-ending is a dummy that equals 1 if the pre-change price was 9-ending. Price change is the absolute value size of the price change. The regression also includes store dummies. * $p < 10\%$, ** $p < 5\%$, and *** $p < 1\%$. Standard errors, clustered at the UPC level, are reported in parentheses.

Table 4E. Probability that a New Price Ends with 9 – Dominick's – Inflation Periods

Price Decrease	−0.07 (0.004) ***
Previous 9-Ending	0.08 (0.005)***
Price Level	0.03 (0.002)***
Price Change	0.0008 (0.00004)***
Constant	0.43 (0.007)***
Number of Observations	12,828,549

Notes: The table reports the results of a linear regression for the probability that a new price ends with 9. The dependent variable is a dummy that equals 1 if the post change price is 9-ending and zero otherwise. The average of the dependent variable is: 0.54. Price decrease is a dummy that equals 1 if the price change is a price decrease. Previous 9-ending is a dummy that equals 1 if the pre-change price was 9-ending. Price change is the absolute value size of the price change. The regression also includes store dummies. * $p < 10\%$, ** $p < 5\%$, and *** $p < 1\%$. Standard errors, clustered at the UPC level, are reported in parentheses.

Table 5D. Probability of Price Increases and Decreases Relative to the Price Remaining Unchanged – Dominick’s – No-Inflation Periods

	Price decreases	Price increases
Previous 9-Ending	−0.15 (0.017)***	−0.38 (0.014) ***
Absolute Value of % Change in Wholesale Price	8.24 (0.134)***	7.48 (0.129) ***
Sale Price Indicator in Previous Week	0.33 (0.017)***	2.90 (0.017)***
Price Level	−0.15 (0.011)***	0.07 (0.006)***
Constant	−1.72 (0.030)***	−3.01 (0.019)***
χ^2	87,289.5	
N	33,622,460	

The table reports estimation results of a multinomial-logit probability model of a price decrease/increase relative to the prices remaining unchanged. The dependent variable is an index variable and equals 0/1/2 if the price has remained unchanged/decreased/increased. The controls are *Previous 9-ending* (1 if the price was 9-ending), *Absolute value of % change in wholesale price*, *Sale price indicator in previous week* (1 if it was on sale), *Price level* (price minus the penny digit) and store dummies. *** $p < 1\%$. Standard errors, clustered at the UPC level, are reported in parentheses.

Table 5E. Probability of Price Increases and Decreases Relative to the Price Remaining Unchanged – Dominick's –Inflation Periods

	Price decreases	Price increases
Previous 9-Ending	−0.20 (0.0167)***	−0.47 (0.014)***
Absolute Value of % Change in Wholesale Price	8.26 (0.130)***	7.32 (0.124)***
Sale Price Indicator in Previous Week	0.42 (0.016)***	0.08 (0.006)***
Price Level	−0.15 (0.012)***	3.16 (0.016)***
Constant	−1.56 (0.031)***	−2.95 (0.021)***
χ^2	120,639.2	
N	4,8111,873	

The table reports estimation results of a multinomial-logit probability model of a price decrease/increase relative to the prices remaining unchanged. The dependent variable is an index variable and equals 0/1/2 if the price has remained unchanged/decreased/increased. The controls are *Previous 9-ending* (1 if the price was 9-ending), *Absolute value of % change in wholesale price*, *Sale price indicator in previous week* (1 if it was on sale), *Price level* (price minus the penny digit) and store dummies. *** $p < 1\%$. Standard errors, clustered at the UPC level, are reported in parentheses.

Table 6D. The Size of 9-Ending Price Change – Dominick's – No-Inflation Periods

Previous 9-Ending	0.05 (0.003)***
Previous 9-Ending × Price-Decrease	−0.07 (0.003)***
Price Level	0.002 (0.001)
Absolute Value of the Percentage Change in the Wholesale Price	0.53 (0.017)***
Sale Price Indicator in Previous Week	0.03 (0.003)***
Sale Price Indicator	0.005 (0.003)*
Constant	0.13 (0.004)***
R^2	0.10
Number of Observations	7,902,082

Notes: The table reports estimation results of a linear regression of the percentage price change, conditional on the price changing. The dependent variable is the absolute percentage price change. The average value of the dependent variable is 0.22. The independent variables are *previous 9-ending* (a dummy which equals 1 if the pre change price was 9-ending), *price-decrease* (a dummy that equals 1 if the price change is a price decrease), the *absolute value of the percentage change in the wholesale price*, *sale price indicator in previous week* (a dummy that equals 1 if the good was on sale in the previous week), *sale price indicator* (a dummy that equals 1 if the good was on sale in the week of the observation) and store dummies. *** p < 1%. Standard errors, clustered at the UPC level, are reported in parentheses.

Table 6E. The Size of 9-Ending Price Change – Dominick's – Inflation Periods

Previous 9-Ending	0.05 (0.003)***
Previous 9-Ending × Price-Decrease	−0.06 (0.003)***
Price Level	−0.0002 (0.0009)
Absolute Value of the Percentage Change in the Wholesale Price	0.56 (0.023)***
Sale Price Indicator in Previous Week	0.04 (0.003)***
Sale Price Indicator	0.0005 (0.002)
Constant	0.13 (0.005)
R^2	0.05
Number of Observations	12,698,995

Notes: The table reports estimation results of a linear regression of the percentage price change, conditional on the price changing. The dependent variable is the absolute percentage price change. The average value of the dependent variable is 0.22. The independent variables are *previous 9-ending*, a dummy which equals 1 if the pre change price was 9-ending, *price-decrease*, a dummy that equals 1 if the price change is a price decrease, the *absolute value of the percentage change in the wholesale price*, *sale price indicator in previous week*, a dummy that equals 1 if the good was on sale in the previous week, *sale price indicator*, a dummy that equals 1 if the good was on sale in the week of the observation and store dummies. *** $p < 1\%$. Standard errors, clustered at the UPC level, are reported in parentheses.

Appendix W. The Effect of 9-Endings on Price- and Number-Comparisons, with the Main Controls Only – Lab Experiment

In the paper, we estimate Table 1 using a full set of controls. These included dummies for 9- and 0- endings, for the different treatments, for participants' characteristics, for the location of the digits that differed between the two prices/numbers compared, and for the difference between the prices.

In this appendix, we present two robustness tests of regression (1), when we use only controls for 9- and 0-endings. In the first, we use random effects to control for the correlation between answers given by the same participant, while in the second we use fixed effects. The estimation results are given in Table 1E for random effects, and in Table 1F for fixed effects.

Random Effects

In the first column of Table 1E, we report the results when the only controls are *9-ending*, *0-ending* and the interactions between *9-edning* and *0-ending* and price treatments. We find that when we do not control for the different treatments, *9-ending* has a marginally negative effect in both the number and the price conditions ($\beta = -0.01, p < 0.1$); the interaction between *9-ending* and price (vs. number) comparison is negative but not statistically significant ($\beta = -0.01, p > 0.1$). *0-ending* has a positive effect in both the number and price conditions ($\beta = 0.02, p < 0.01$); the interaction between *0-ending* and price (vs. number) comparison is negative but not statistically significant ($\beta = -0.01, p > 0.1$).

Thus, when we do not control for differences between the conditions, we find no significant differences in the effects of 9-endings between the price and number conditions. Rather, we find a similar, negative, effect of *9-ending* on the accuracy in both conditions.

In columns (2) and (3), we use only observations on prices, and we separate the observations into two samples: The sample of equal prices and the sample of unequal prices. We expect 9-endings to have no effect in the first sample because in that sample, if one price is 9-ending, so is the other. In the sample of unequal prices, we expect 9-endings to have no effect on the likelihood of a correct response when the smaller price is 9-ending, but to have a negative effect when the higher price is 9-ending. Indeed, if participants treat 9-endings as a signal for low prices, they might mistakenly identify a high 9-ending price as a low price.

We find that the coefficient of *9-ending* in the second column (equal prices) is indeed statistically not significant ($\beta = -0.01, p > 0.10$). It is also statistically not significant in the column 3 of unequal prices ($\beta = 0.02, p > 0.10$). However, as we hypothesize, the coefficient of *greater 9-ending* is negative and statistically significant ($\beta = -0.04, p < 0.05$).

Fixed Effects

In Table 1F, we report the results when we use fixed effects instead of random effects. The estimation results are virtually identical to those we find using random effects. We therefore conclude that even when we do not fully control for the differences between the different experimental conditions, we still find that the participants are less likely to correctly identify the bigger/smaller of the two prices compared when one of the prices is 9-ending, and particularly when it is the bigger price that is 9-ending.

Table 1E. Probability of a Correct Answer – Lab Experiment – Random Effects.

	(1) All observations	(2) Equal prices	(3) Unequal prices
9-Ending	−0.01 (0.003)*	−0.01 (0.007)	0.02 (0.015)
Price Comparison×9-Ending	−0.01 (0.005)		
Bigger-9-Ending			−0.04 (0.016)**
0-ending	0.02 (0.005)***	0.01 (0.007)**	0.02 (0.007)
Price Comparison×0-Ending	−0.01 (0.008)		
Constant	0.89 (0.013)***	0.93 (0.014)***	0.88 (0.021)***
N	55,346	5982	20,905
χ^2	50.6	6.9	16.9

The table reports estimation results of a linear model with random effects for the probability of a correct answer. The dependent variable is the *accurate* dummy (1 if the answer is correct, 0 otherwise). Its average equals 0.89. The independent variables are the dummies 9-*ending* (1 if at least one of the prices compared ends in 9), *Price-comparison* (1 if participants had to compare prices), *Bigger* 9-*ending* (if the bigger of the two prices/numbers compared ends with 9, 0-*ending* (1 if at least one of the prices/numbers compared ended in zero). Standard errors, clustered at the participant level, are reported in parentheses. Column (1) uses all observations. Column (2) uses observations on equal prices. Column (3) uses observations on unequal prices. * p < 10%, ** p < 5%, and *** p < 1%.

Table 1F. Probability of a Correct Answer – Lab Experiment – Fixed Effects.

	(1) All observations	(2) Equal prices	(3) Unequal prices
9-Ending	−0.01 (0.003)*	−0.01 (0.007)	0.02 (0.015)
Price Comparison×9-Ending	−0.01 (0.005)		
Bigger-9-Ending			−0.04 (0.016)**
0-ending	0.02 (0.005)***	0.01 (0.007)**	0.02 (0.007)
Price Comparison×0-Ending	−0.01 (0.008)		
Constant	0.89 (0.001)***	0.94 (0.002)***	0.88 (0.001)***
N	55,346	5982	20,905
F	12.6	3.3	5.6

The table reports estimation results of a linear model with fixed effects for the probability of a correct answer. The dependent variable is the *accurate* dummy (1 if the answer is correct, 0 otherwise). Its average equals 0.89. The independent variables are the dummies 9-*ending* (1 if at least one of the prices compared ends in 9), *Price-comparison* (1 if participants had to compare prices), *Bigger* 9-*ending* (if the bigger of the two prices/numbers compared ends with 9, 0-*ending* (1 if at least one of the prices/numbers compared ended in zero). Standard errors, clustered at the participant level, are reported in parentheses. Column (1) uses all observations. Column (2) uses observations on equal prices. Column (3) uses observations on unequal prices. * p < 10%, ** p < 5%, and *** p < 1%.

Appendix X. Consumers' Sample – Field Study

In the paper, we report the results of a field study in which we asked consumers, as they were exiting supermarkets, about their recollection of price changes. Given the nature of this type of surveys, we could not compile a precise list of customers who declined to take part in the survey. We also do not have any socio-demographic information about those who declined to participate and, consequently, we cannot compare their socio-demographic background to the background of those who agreed to take part in the survey.

As a token of appreciation, we gave each participant a chocolate bar. That could potentially cause selection bias. First, a chocolate bar cannot match the opportunity cost and the time value of many (working) adults, and thus it could be that our sample is not a good representative of people in that group. Second, it could be that the chocolate bar was particularly attractive to consumers shopping with families (kids).

Despite these possible selection biases, we believe that our sample nevertheless, is a fair representation of the population we study. First, the average age of the participants in our sample, 40, is a little above the median age in the three cities where we sampled the population (Holon, Petah-Tiquah and Rehovot), 33. This difference is expected, as participants in our survey were all adult consumers.

Second, the percentage of academics in our survey is 31%, slightly below the average percentage in the three cities we study, 33%.[16] The average family size in our sample is 4.2, higher than the average in the population, 3.7. This, however, is likely because

[16] Source: Israel Central Bureau of Statistics at: www.cbs.gov.il/publications13/1530/pdf/tab01_01.pdf. Last accessed: May 26, 2018.

members of larger families are more likely to shop more frequently in these supermarkets.[17]

Thus, although we cannot completely rule out the possibility of a selection bias in our sample, we believe that our sample is a reasonably good representation of the population studied.

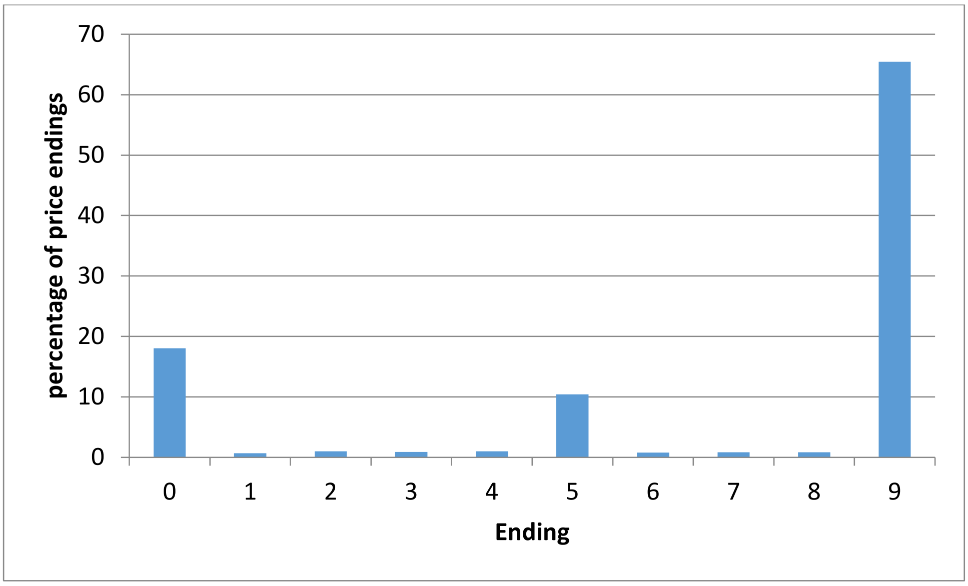
[17] Source: Israel Central Bureau of Statistics at: www.cbs.gov.il/www/hodaot2015n/11_15_039b.doc (in Hebrew). Last accessed: May 26, 2018.

Appendix Y. Frequency Distribution of the Last Digit – Israeli Supermarkets and Drugstores

The frequency distribution of the last digit in the Israeli supermarket and drugstore price data is shown in Figure 2A. As indicated in the paper, in section 3.4, these are monthly data, covering the period January 2002–December 2013, and include 190,807 observations on prices for goods in 99 product categories.

As the figure indicates, 9 is the most frequent price ending, comprising about 66% of the prices. 0 is the next popular price ending, comprising about 18% of the prices, followed by 5 ending, which comprises about 10% of the prices. The remaining endings are quite rare, each comprising 1% or less of the prices.

Figure 2A. Frequency Distribution of the Last Digit in the Israeli Supermarket and Drugstore Prices, Monthly, January 2002–December 2013

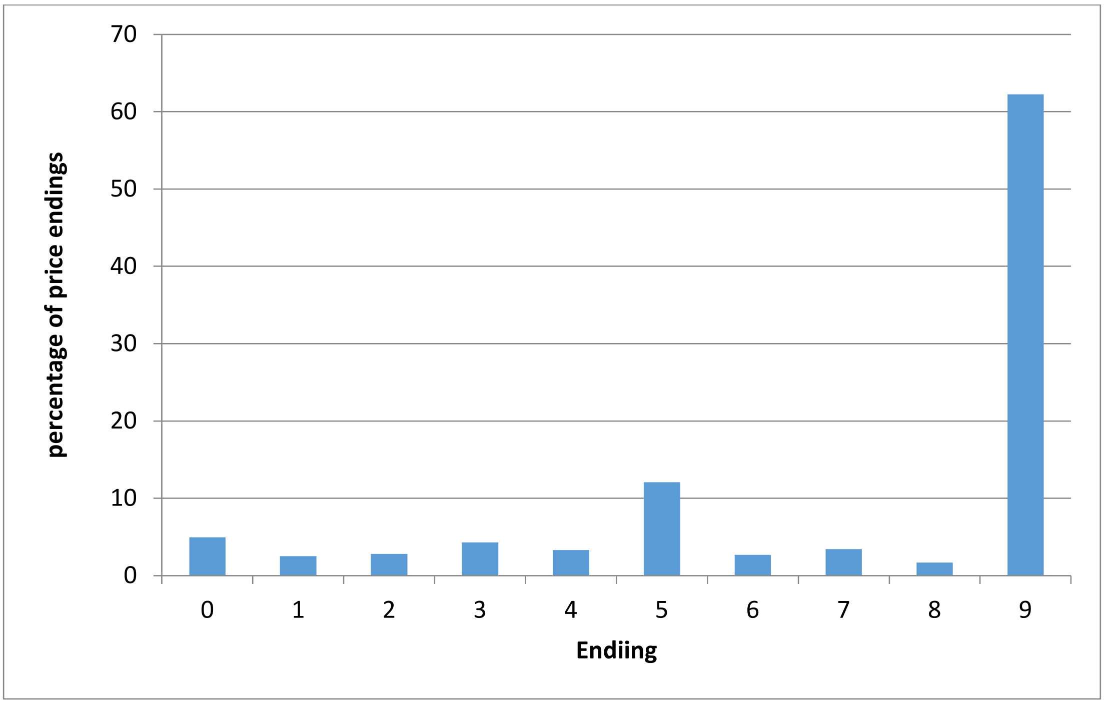


Appendix Z. Frequency Distribution of the Last Digit – Dominick's

The frequency distribution of the last digit in the Dominick's price data is shown in Figure 2B. As indicated in the paper, in section 3.3, these are weekly data, covering the period September 14 1989 – May 8, 1997, and include 98,691,750 weekly price observations for 18,037 products in 29 product categories.

As the figure indicates, 9 is the most frequent price ending, comprising about 62% of the prices. 5 is the next popular price ending, comprising about 12% of the prices, followed by 0 ending, which comprises about 5% of the prices. The remaining endings are less common, each comprising 2%–4% of the prices.

Figure 2B. Frequency Distribution of the Last Digit in the Dominick's Prices, Weekly, September 14 1989–May 8, 1997



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