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"PRICE POINTS AND PRICE RIGIDITY"

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Price Points and Price Rigidity

Abstract

We offer new evidence on the link between price points and price rigidity using two datasets. One is a large weekly transaction price dataset, covering 29 product categories over an eight-year period from a large U.S. supermarket chain. The other is from the Internet, and includes daily prices over a two-year period for 474 consumer electronic goods covering ten product categories, from 293 different Internet retailers. Across the two datasets, we find that (i) 9 is the most frequently used price-ending for the penny, dime, dollar and the ten-dollar digits, (ii) the most common price changes are in multiples of dimes, dollars, and ten-dollars, (iii) 9-ending prices are at least 24% (and as much as 73%) less likely to change in comparison to prices ending with other digits, and (iv) the average size of the price change is higher if the price ends with 9 in comparison to non-9-ending prices. This link between price points and price rigidity is robust across a wide range of prices, products, product categories, and retail formats. We offer a behavioral explanation for the findings.

"Thus, the natural question is whether standard statistical tests can be used to determine their [price points] relevance for price rigidity."

Anil Kashyap (1995, p. 266)

I. Introduction

The recent expansion in the popularity of new Keynesian ideas has led a growing number of economists to recognize the importance of understanding the sources of nominal price rigidity.[1] One of the recent additions to the list of existing theories of price rigidity is Kashyap's (1995) *price point theory*, which Blinder, et al. (1998) list among the leading twelve theories of price rigidity. According to the authors (p. 26), practitioners' "…belief in pricing points is part of the folklore of pricing…" Consistent with this observation, they offer evidence from interviews on the importance of price points. For example, in their study of 200 large U.S. firms, they find that 88% of the firms that operate in the retail industry report substantial importance of psychological price points in their pricing decisions.[2] Similarly, Kashyap (1995) observes that mail-order catalog prices have the tendency to be "stuck" at certain ending prices. He concludes that the existing theories of price rigidity are unable to explain the specific form of price rigidity he finds. As an alternative explanation he offers the idea of price points, which according to Kashyap has been suggested by the pricing managers of the mail order companies.

As Blinder, et al. (1998) note, however, a major difficulty with price point theory is that not much is known about the actual practical importance of price points and their relationship to price rigidity. Price points, although of interest by themselves (e.g., Landsburg, 1995), will be particularly important for macroeconomics if they can be shown to contribute to price rigidity, across a wide selection of products and retailers. Although the existing literature in economics and marketing offers growing evidence on the use of price points, there is a lack of direct evidence on the link between price points and price rigidity. Indeed, the literature documenting a link between price points and price rigidity using the U.S. data is limited to Blinder, et al.'s (1998) interview study and Kashyap's (1995) study of catalogue prices. Kashyap emphasizes the need for more direct evidence, stating that—"The overall evidence on price points suggests that they may influence price adjustment, but this dataset is not very well suited to establishing their importance. A study focusing on more goods … would have much more power to determine the significance of price points".

We fill this gap in the literature by offering new evidence on the relationship between price points and price rigidity using two large datasets. One is a large weekly price dataset,

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[1] See, for example, Blinder, et al. (1998), Carlton (1986), Cecchetti (1986), Caplin (1993), Warner and Barsky (1995), Lach and Tsiddon (1996), Slade (1998), Ball and Romer (1990, 2003), Davis and Hamilton (2004), Fisher and Konieczny (2000, 2006), Konieczny and Skrzypacz (2005), and Rotemberg (1987, 2005). For recent surveys, see Willis (2003) and Wolman (2007).

[2] See also the studies of the European Central Bank's Inflation Persistence Network, as summarized in Fabiani, et al. (2006).

covering 29 product categories over an eight-year period from a major Midwestern U.S. supermarket chain. The dataset includes actual transaction prices, as recorded by the stores' scanners. The second dataset comes from the Internet and includes daily prices over a two-year period for 474 consumer electronic goods with a wide range of prices, such as music CDs, digital cameras, DVD players, notebook PCs, etc., from 293 different e-retailers. Taken together, the two datasets cover a diverse set of products, a wide range of prices, different retail formats, retailers and time periods.

We find that across the two datasets, 9 is the most popular price point for the penny, dime, dollar and the ten-dollar digits. To explore the link between price points and price rigidity, we examine the patterns of price changes. We find that the most common price changes are in multiples of dimes, dollars, and ten-dollar increments—an outcome that is consistent with efforts to keep the terminal digits at 9. Given the particular significance of 9-ending prices in our data, we econometrically estimate the probability of a price change and find that 9-ending prices are at least 24% (and as much as 73%) less likely to change in comparison to prices ending with other digits. We also find that the average size of change of 9-ending prices are systematically larger, in comparison to non-9-ending prices. These findings underscore the extent of the retail price rigidity that is created by 9-ending price points.

To make sense of these findings, we offer a behavioral explanation. We suggest that 9-ending prices can be the outcome of firms' optimal reaction to consumers' inattention. Consumers may find it rational to be inattentive to the rightmost digits of retail prices because they face large amounts of information which are costly to gather and process, and have time, and information processing capacity constraints. In response to this inattentiveness, firms may find it profitable to set those digits to the highest possible number, 9. Our findings, thus, suggest that price points are a substantial source of retail price rigidity in the datasets we study, and that consumer inattention offers a plausible behavioral explanation for the use of price points and their link to price rigidity.

The rest of the paper is organized as follows. We describe the two datasets in Section II. In Section III, we document the popularity of 9-endings by assessing the frequency distribution of price-endings in the two datasets. In Section IV, we examine the frequency distribution of price changes by size and assess the extent to which they preserve the 9-endings. In Section V, we estimate econometrically the effect of 9-endings on the retail price rigidity. In Section VI, we study the link between price points and the size of price changes. In Section VII, we offer a consumer-based explanation for the 9-ending pricing and price rigidity patterns we find. We conclude in Section VIII by summarizing the findings and discussing their potential implications.

II. Two Datasets

The most obvious prediction of Kashyap's (1995) price point theory is that price points should be most important to firms in retailing selling mostly to consumers (Blinder, et al 1998, Stahl 2006). We examine retail prices from two large datasets. One is Dominick's weekly retail transaction price data for 29 product categories over an eight-year period. The other contains daily prices from the Internet on 474 products varying from music CDs, to DVDs, to hard disks, and to notebook PCs. The two datasets combined cover a wide variety of products, a wide price range, and different retail formats. In addition, although Dominick's is a grocery chain where prices are mostly set on a chain-wide basis, our Internet data come from 293 different retailers presumably employing different pricing-decision models. Our use of two datasets allows us to draw general conclusions that are not specific to a retail format, retailer, product, or price range.

Dominick's is a large supermarket chain in the Chicago metropolitan area, operating about 100 stores with a market share of about 25%. The data consist of up to 400 weekly observations of retail prices in 29 different product categories, covering the period from September 14, 1989 to May 8, 1997. The prices are the actual transaction prices as recorded by the chain's scanners. If an item was on sale, then the price data we have reflect the sale price. In the analysis described below, we use all the data from all stores, a total of over 98 million weekly price observations. Dominick's data also contains a binary variable indicating whether a given product on a given week was on sale or on promotion. We use this information to estimate a probabilistic model of the likelihood of price changes. See Chevalier, et al. (2003) for more details about these data. Table 1 presents descriptive statistics for the Dominick's price data.

The Internet data were obtained through the use of a price information gathering agent. It was programmed to download price data from BizRate.com (www.BizRate.com), a popular price comparison site, from 3:00 a.m. to 5:00 a.m. From a list of products available at BizRate.com, we generated a large sample of product IDs using stratified proportionate random sampling (Wooldridge, 2002). The software agent then automatically built a panel of selling prices given the product IDs.[3] The resulting dataset consists of 743 daily price observations for 474 personal electronic products in ten product categories, from 293 different Internet-based retailers, over a period of more than two years from March 26, 2003 to April 15, 2005. The categories include

[3] Sometimes the Internet-based sellers' (especially small firms') Web sites were inaccessible or the required price information was not available. Some prices, therefore, are missing in our original dataset. We used the following procedure to handle such missing data. If 10% or more observations were missing for a product in a store, then that series was excluded from the data altogether. If less than 10% of the data was missing, then we examined if the prices for the day before and the day after were the same. If they were the same, then the software agent automatically filled in for the missing data with that price. Otherwise, the agent filled in for the missing data with the price for the day after. Although we recognize that this is an arbitrary procedure, there are only 0.075% missing prices in the entire dataset, and thus missing data are unlikely to affect our results significantly.

music CDs, movie DVDs, video games, notebook PCs, personal digital assistants (PDAs), computer software, digital cameras and camcorders, DVD players, PC monitors, and hard drives.[4] In total, the Internet data contains over 2.5 million daily price observations. Table 2 presents descriptive statistics for the Internet price data.

III. Evidence on the Popularity of 9-Ending Prices

"I asked the best economist I know, at least for such things—my wife, if she recalled a price not ending in a 9 at our local grocery store. Not really, she said. Maybe sometimes there are prices ending in a 5, but not really."

Jurek Konieczny (2003), Discussant Comments at the CEU Conference

We begin by presenting results on the frequency distribution of price-endings in the two datasets. In the analysis of Dominick's data, our focus is on 9¢ and 99¢ price-endings because the overwhelming majority of the prices in retail grocery stores are well below $10.00.[5] In the Internet data, the prices range from $5.49 to $6,478.00, with the average prices in different categories spanning $12.90 to $1,694.58. In the Internet data, therefore, given the wider price range, we study not only 9¢ and 99¢ price-endings, but also other 9-ending prices in both the cents and the dollars digits, including $9, $9.99, $99, and $99.99.

In Figure 1, we report the frequency distribution of the last digit for the entire Dominick's dataset. If a digit's appearance as a price-ending was random, then with ten possible endings, we should see 10% of the prices ending with each. As the figure indicates, however, about 65% of the prices end with 9. The next most popular price-ending is 5, accounting for about 11% of all price endings. Only a small proportion of the prices ends with the other digits. The pattern is very similar at the category level, with 9 as the most popular price-ending for all categories except cigarettes.[6, 7]

Next, we consider the frequency distribution of the last two digits. With two digits, there

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[4] We selected these categories because they are the most popular categories on the Internet. In addition, the products in these categories are sold by a large number of stores. For example, in the category of digital cameras, "Canon-EOS Digital Rebel XT" is sold by 63 stores. The selection of products was random. For example, in the category of DVDs, we chose products from multiple sub-categories (e.g., action, drama, comedy, children, etc.). Similarly, in the music CDs category, we chose from many different sub-categories (e.g., blues, jazz, country, heavy metal, etc.). However, in some categories (e.g., notebook PCs, hard drives, PDAs), we included all the products available. In other categories (e.g., DVD players, digital cameras, PC monitors, software, video games), we randomly chose products from all sub-categories. For example, in DVD players, we chose half of the products from standard DVD players while the other half came from the more expensive DVD/VCR combo players. In digital cameras and camcorders, we chose half from regular digital cameras while the other half came from digital camcorders. In PC monitors, we chose half from CRT and flat CRT models, and the other half from LCD and TFT. In the software category, we chose products from multiple genres of software (e.g., educational software, operating systems, programming software, utility software, etc.). Similarly, in video games, we included multiple genres (adventure, action, sports, etc.). See Figures R8a–R8i in the Reviewer's Appendix for sample price series.

[5] Indeed, according to Dutta, et al. (1999) and Levy, et al. (1997, 1998), the average price of an item in large U.S. supermarket chains during 1991–92 was about $1.70. According to Bergen, et al. (2007), the figure increased to $2.08 by 2001.

[6] To save space, most of figures and tables on individual product categories are included in a separate Reviewer's Appendix to this paper. We shall note that the results for individual product categories are similar to the aggregate results we report here.

[7] The products in the Beer and Cigarettes categories in the Dominick's data are subject to various tax rules and other government regulations that could potentially skew the results. We, therefore, do not discuss their results.

are 100 possible endings, 00¢, 01¢, …, 98¢, and 99¢. Thus, with a random distribution, the probability of each ending is only 1%. According to Figure 2, however, most prices end with either 09¢, 19¢, …, or 99¢. This is not surprising since 9 is the dominant single-digit ending. But of these, more than 15% of the prices end with 99¢. In contrast, only 4% to 6% of the prices end with 09¢, 19¢, …, and 89¢, each. We found a similar pattern for individual categories.[8]

Figure 3 displays the frequency distribution of the last digit in the Internet data. 9 is the most popular terminal digit (33.4%), followed by 0 (24.1%), and 5 (17.4%). The frequency distribution of the last two digits exhibits a similar pattern, with 99¢ as the most popular price-ending (26.7%), followed by 00¢ (20.3%), 95¢ (13.8%), and 98¢ (4.8%). See Figure 4.

As mentioned above, the Internet dataset also includes some high-price product categories, which allows us to examine price-endings in dollar digits as well. In Figure 5, therefore, we present the frequency distribution of the last dollar digit in the Internet data. According to the figure, 9 is the most popular ending for the dollar digit, with $9 price-endings over-represented with 36.1%, followed by $4 price-endings with 9.9%, and $5 price-endings with 9.2%. A similar pattern emerges for the last two dollar digits as indicated by Figure 6. Not surprisingly, the last two dollar digits of most prices contain 9, such as $99, $89, and $09. But more prices end with $99 than any other 9 price-endings. Moreover, almost 10% end with $99 among the 100 possible dollar endings (i.e., $0 through $99).

We also examined the frequency distribution of the last three digits of prices in the Internet data.[9] According to Table 3, $9.99 is the most popular ending for the last three digits (13.2%), followed by $9.00 (10.0%), and $9.95 (4.9%).[10] When we examine the last four digits of the prices (last column of Table 4), $99.99 is the most popular ending for the last four digits (3.47%), followed by $99.00 (3.46%), and $19.99 (2.16%).[11]

In the Internet data, three individual product categories with low average prices exhibit some variation in price endings.[12] For example, for the dollar-digit, $3, $4 and $5 price-endings are the most common for CDs and DVDs because prices of CDs and DVDs are often between $13 and $16. Also, the $99 and $99.99 endings are not common in those two categories and the

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[8] With the exception of five categories (canned tuna, cigarettes, front-end-candies, oatmeal, and paper towels), the 99¢ ending prices are the most common than other two-digit ending prices. Even in the five categories where the 99¢ ending is not the most popular, it is still very common and ranks within the top five price-endings among the 100 possible endings. See Figures R2a–R2c in the Reviewer's Appendix.

[9] So far we have used figures to present some of the results. However the results on the use of 9 for the last three and four digits in the Internet data, and some of the results in Section IV on price changes in the Internet data, are presented only in tables, as they are too numerous to be plotted .

[10] Note that there are 1,000 possible endings here.

[11] Note that there are 10,000 possible endings here.

[12] For results on individual product categories in the Internet data, see the Reviewer's Appendix, where Figures R3 and R4 show the frequency distribution of the last cent-digit and last two cent-digits, while Figures R5 and R6 show the frequency distribution of the last dollar-digit and last two dollar-digits.

category of video games (see Table 4), because the average prices in these categories are far less than $100 (i.e., $13.46 for CDs, $27.43 for DVDs, and $30.83 for video games). It isn't surprising, therefore, that we do not see a lot of 9-endings for the dollar and ten-dollar digits in those product categories.

To summarize, in both datasets, 9 is the most popular terminal digit overall. But the popularity of 9 is not limited to the penny digit. Rather, it is present in the dime, dollar, and ten-dollar digits too. The fact that our data include a variety of products with wide-ranging prices and different retail formats, further underscores the use of 9 as a terminal digit in our datasets.

IV. Frequency Distribution of Price Changes by Size

Having documented the dominance of 9 as the terminal digit in both datasets, we next focus on the relationship between 9-ending and price rigidity. As Kashyap (1995) points out, the frequency distributions of price points will be of particular interest to macroeconomists and monetary economists if they have dynamic consequences. Our goal is to assess to what extent the specific price point, 9, that we have identified may be contributing to the retail price rigidity.

Figure 7 displays the frequency distribution of price changes in Dominick's data. Although the actual price changes occasionally go over $1, these are few. We thus limit the analysis to price changes of up to $1. According to the figure, the most common price changes, in fact, over 35% of the price changes are multiples of 10 cents.[13]

In the Internet data, the observed price range is much wider and consequently we observe a much wider range for price changes. The price changes vary in magnitude from 1¢ to $1,568, but the most common changes are in multiples of dollars—and consequently, in multiples of dimes. As shown in Table 5, among the top ten most common changes in this dataset, eight are multiples of dollars, and nine are multiples of dimes. The only exception is 1¢ which ranks tenth. Thus, similar to Dominick's dataset, the sizes of Internet price changes are such that they preserve the 9-endings.

Because of the wider range of price changes found in the Internet data, the ten most common price changes account for less than 30% of all price changes. As an alternative way to identify the prevalence of price changes in multiples of dimes, dollars, and tens of dollars, we categorize price changes based on how many digits in a price are affected by a price change (i.e., whether it affects the penny digit only, the penny and dime digits, or the penny, dime and dollar digits, etc.). For example, if we focus on price changes affecting the penny digit only, we can

[13] Category level data indicate some cross-category variation, although in general they are consistent with the above finding. That is, in most categories, price changes in multiples of 10 cents are more common than other price changes. See Figures R7a–R7c in the Reviewer's Appendix.

group all possible price changes into ten categories: those that change a price by 0¢, 1¢, …, 9¢. In the first group will be price changes in multiples of dimes (excluding 0¢ where a price does not change); in the second group, 1¢, 11¢, …, 91¢, $1.01, …., etc. Similarly, we can group price changes into 100 groups based on how they affect the penny and the dime digits, one of which will be the category into which all price changes in multiples of dollars fall (again, excluding 0¢ where price does not change). Finally, we can group price changes into 1,000 groups based on how they affect the penny, dime and dollar-digits, one of which will be the category into which all price changes in tens of dollars fall (again excluding 0¢, where price does not change).

When we categorize price changes in this manner, we find that price changes in multiples of dimes are the most frequent among the ten possible changes to the penny digit, accounting for 55.12% of all price changes. In addition, we find that among the 100 possible changes to the penny and dime digits, the most popular ones are multiples of dollars, which account for more than 42.86% of all changes. Finally, among the 1,000 possible changes to the last three digits, multiples of ten dollars are the most common, accounting for 9.60% of all changes. Similar results are obtained for individual product categories. Changes in multiples of dimes and in multiples of dollars are the most common for all ten product categories in our dataset. Changes in multiples of ten dollars are the most common for seven product categories (video games, software, PDAs, DVD players, PC monitors, digital cameras, and notebook PCs).[14] Based on the above results, we conclude that when prices change, they most often change in multiples of dimes, multiples of dollars, or in multiples of tens of dollars. Consequently, the terminal digits are kept at 9 even after a price change. This indicates that terminal prices are “stuck” at 9.

V. The Effect of Price Points on Price Rigidity

To explore the contribution of 9-ending prices to price rigidity, we use a binomial logit model to estimate the price change probabilities. A logit model maintains logical consistency with the estimation of a 0/1 dependent variable, and provides an effective means to gauge the marginal effects via the odds ratio (Agresti, 2002; Greene, 2003; Hosmer and Lemeshow, 2000). The model which we estimate using the method of maximum likelihood is given by

$$(1) \qquad ln\,(q/(1-q)) = a + bD_{9\text{-}Ending} + cD_{Sale} + e_t,$$

where q is the probability of a price change, $D_{9\text{-}Ending}$ is a *9-Ending* dummy variable which equals 1 if the price ends with 9 (i.e., *9¢-Ending* or *99¢-Ending*) and 0 otherwise, and D_{Sale} is a *Sale* dummy variable which equals 1 if the product is on sale and 0 otherwise. The regression

[14] For hard drives, changes in multiples of ten dollars are the fourth most popular category. For CDs and DVDs, they are <u>not</u> ranked in the top 20, because the prices for both products are low and thus the price changes rarely reach $10.

equation includes the *Sale* dummy because, according to Schindler (2006) and Anderson and Simester (2003), prices ending with 9 may be related to sales, and sale prices are more likely to change than regular prices.[15] Indeed, if we consider a sample series of Frozen Concentrate Orange Juice, Heritage House, 12 oz. (UPC = 3828190029 from Store No. 78), which is plotted in Figure 8, it is clear that sale prices are always reversed, unless there is a change in the list price, which is rare. For example, in the sample of 400 observations shown in this figure, there are only about fourteen to sixteen changes in the list price. By including the *Sale* dummy, we account for any potential effect of sales when estimating price change probabilities. We estimated the model using the method of maximum likelihood.

The estimation results for Dominick's data are reported in Table 6. In the table, we report the estimated coefficient of each dummy along with the odds ratio that the estimated coefficients imply. For *all 27 product categories*, the coefficient estimate on the *9-Ending* dummy is negative, and the coefficient estimate on the *Sale* dummy is positive as expected (all p-values < 0.0001). The odds ratios, which equal $e^{Coefficient}$, are all smaller than 1 for the *9-Ending* dummy, indicating that prices that end with 9¢ are less likely to change than prices that do not end with 9¢. On average, prices that end with 9¢ are more than 40% less likely to change than prices that do not end with 9¢. Not surprisingly, sale prices are about 65 times more likely to change than regular prices.

We obtain similar results for the 99¢-ending prices. The coefficient estimate on the *99¢-Ending* dummy is negative and significant for *all 27 product categories*, as shown in Table 6. The odds ratios indicate that prices that end with 99¢ are 24% less likely to change than prices that do not end with 99¢. Also, all product categories showed positive and significant coefficients on the *Sale* dummy, and sale prices are about 67 times more likely to change than regular prices.

Next, we estimate the same logit regression model for the Internet data, but now we use 9¢, 99¢, \$9, \$9.99, \$99, and \$99.99, in turn, as the independent variable. We did not include a *Sale* dummy in these regressions as such information was not available in our data.[16] The results of the logit regression for each independent variable are reported in Table 7. Similar to what we found with Dominick's data, 9-ending prices are less likely to change than other prices. Overall, 9¢-ending prices are 31.90%, 99¢-ending prices 44.59%, \$9-ending prices 45.89%, \$99-ending

[15] Our test here is a conservative one, because according to Dominick's website, "this [sales] variable is not set by Dominick's on consistent basis (i.e., if the variable is set it indicates a promotion, if it is not set, there might still be a promotion that week)" (gsbwww.uchicago.edu/kilts/research/db/dominicks/movement).

[16] We should note, however, that the internet price series seem to have far fewer sales and promotional price discounts. Indeed, inspection of the internet price series suggests that in our internet data there are not many cases of temporary price decreases which are reversed after two-three weeks. See, for example, some sampled series shown in Figures R8a-R8j, which are included in the Referee Appendix.

prices 59.74%, $9.99-ending prices 58.90%, and $99.99-ending prices are 72.87%, less likely to change than other prices. We obtained similar results for each product category. Although music CDs and video games showed some unexpected results, in 95% of all possible cases in the category-level analyses, the effect of 9 price-endings on the probability of price changes is negative and significant. Thus, we find that prices tend to be "stuck" at 9-endings, making them more rigid: 9-ending prices are 24% to 73% less likely to change than non-9-ending prices.

VI. The Effect of Price Points on the Size of Price Change

"… if pricing points inhibit price changes, then they might also be expected to affect the sizes of price increases. Specifically if prices that are at price points are fixed longer than other prices, then any subsequent price adjustments might be expected to be larger than average."

Anil Kashyap (1995, p. 267)

If 9-ending prices are less likely to change in comparison to non-9-ending prices, then the average size of change of 9-ending prices should be larger when they do change, in comparison to non-9-ending prices. This assumes that the cost of a price change is the same regardless of the price ending, which is indeed the case according to the menu cost estimates of Levy, et al. (1997, 1998) and Dutta, et al. (1999) for large U.S. supermarket and drugstore chains.

In Tables 8 and 9, we report the average size of price changes for 9¢-ending and non-9¢-ending prices, and for 99¢ and non-99¢-ending prices, respectively, in the Dominick's data. According to Table 8, in 23 of the 27 categories, the average change is indeed higher for 9¢-ending prices. The exceptions are the categories of frozen dinners, frozen entrees, and frozen juices (perhaps because they have short expiration periods), and front-end candies. Across all product categories, the average price change is 47¢ if the price ends with 9¢, in contrast to 37¢ change when it does not end with 9¢, a 27% difference.

The findings obtained for the 99¢-ending prices are even stronger. According to Table 9, in 26 of the 27 categories (frozen entrees being the only exception), the average change is higher for 99¢-ending prices. The differences for individual categories are also bigger here in comparison to Table 8. Across all product categories, the average price change is 57¢ if the price ends with 99¢, in contrast to 42¢ change when it does not end with 99¢, a 35% difference.

In Tables 10–15, we report the findings for the Internet data. Because of the wider price range, we consider here price endings with 9¢, 99¢, $9, $9.99, $99, and $99.99, as before. The results are as follows. For 9¢-ending prices (Table 10): in 8 out of the 10 categories (the exceptions being PDAs and Notebooks PCs), the average size of the price change is higher by about 12% if the price ends with 9¢ in comparison to non-9¢ ending prices. For 99¢-ending prices (Table 11): in 9 out of the 10 categories (the exception being PDAs), the average size of the price change is higher by about 29% if the price ends with 99¢ in comparison to non-99¢-ending prices. For \$9-ending prices (Table 12): in 9 out of the 10 categories (the exception being Music CDs), the average size of the price change is higher by about 97% if the price ends with \$9 in comparison to non-\$9-ending prices. For \$9.99-ending prices (Table 13): in all 10 categories, the average size of the price change is higher by about 53% if the price ends with \$9.99 in comparison to non-\$9.99-ending prices. For \$99-ending prices (Table 14): in all 8 categories (the categories of Music CDs and Video Games contain no prices with \$99-ending), the average size of the price change is higher by about 165% if the price ends with \$99 in comparison to non-\$99-ending prices. For \$99.99-ending prices (Table 15): in all 8 categories (the categories of Music CDs and Video Games contain no prices with \$99.99-ending), the average size of the price change is higher by about 150% if the price ends with \$99.99 in comparison to non-\$99.99-ending prices.

Thus, the results are very robust in the Internet data as well: in 52 of the 56 cases, the average size of the price change is higher if the price ends with a 9-ending price point. Moreover, in many individual cases the differences in the size of price changes are quite substantial. For example, for 9¢ price-endings, the average price changes of the 9¢-ending and non-9¢-ending prices are \$1.30 and \$1.01, respectively, a difference of about 30%. In some cases, the differences are even larger. These findings, which are all statistically significant at the $p < 0.0001$ level, are consistent with our predictions: because 9-ending prices are less likely to change, the average size of the change of 9-ending prices are systematically larger when they do change, in comparison to non-9-ending prices. These findings further underscore the extent of the retail price rigidity that is created by 9-ending price points.

VII. Making Sense of Ignoring Cents – Rational Inattention

"Buyers may use rules of thumb when searching for items and comparing prices… If firms are aware of this tendency by consumers, they may set prices so as to exploit the use of the rules."

Anil Kashyap (1995, p. 266)

"Why are so many items sold for \$2.99 and so few for \$3.00? There is an enormous temptation to attribute this phenomenon-to a mild form of irrationality in which consumers notice only the first digit of the price and are lulled into thinking that \$2.99 is 'about \$2.00' instead of 'about \$3.00.' In fact, this explanation seems so self-evident that even many economists believe it. For all I know, they could be right. Perhaps someday a careful analysis of such behavior will form the basis for a modified economics in which people are assumed to depart from rationality in certain systematic ways."

Steven Landsburg (1995, p. 15)

Having documented overwhelming popularity of 9-ending price points in our two datasets, and having demonstrated that the price points lead to a substantial degree of price rigidity, we next want to try and explain these findings. As Kashyap (1995) notes, the existing literature does not offer a "tight" theoretical explanation for the popularity of price points and for their link to price rigidity. We hope to fill this gap in the literature by offering a behavioral explanation which builds on the emerging literature on rational inattention.

The frequent use of 9-ending price points and their link to price rigidity may be an outcome of firms' optimal reaction to consumers' rational inattention to the rightmost digits of prices. The need for rational inattention by consumers arises for at least two reasons. First, consumers face huge amounts of information, which is costly to gather, absorb, and process. Second, they have time, resource, and cognitive information processing-capacity constraints.[17] In Sims' (1998, pp. 320–321) words, "Because individuals have many things to think about and limited time, they can devote only limited intellectual resources to … data-gathering and analysis. We know from personal experience that many data that we could look up daily, and that are in principle relevant to our optimal economic decision-making, do not in fact influence our behavior ..."

Consumers with limited time and cognitive information processing-capacity constraints often need to assess and compare the prices of dozens and sometimes hundreds of products. They are likely to use time-saving devices, such as rules-of-thumb, as suggested by Kashyap (1995). They also may rationally choose to ignore some price information. Specifically, we argue that the benefit of paying attention to each additional digit of a price declines as we move from left to right in the price digits.[18] On the other hand, since people process multi-digit numeric information, including prices, from left to right (Schindler and Kirby, 1997; Hinrichs, et al. 1982; Poltrock and Schwartz, 1984; and Lambert, 1975), the effort they need to recognize, process, and recall numeric information increases as the number of digits increases. Thus, the marginal cost of processing each additional digit increases.[19] The marginal benefit of the last digit is the lowest but its marginal cost is the highest, making it the least valuable among all digits. The last digit, thus, will offer the time-constrained consumer the lowest *net* marginal value giving him an incentive to ignore it.[20] A price-setter that knows that her customers will

[17] These constraints have been explored by many authors in economics and marketing, under the labels of *thinking costs* (Shugan 1980), *reoptimization costs* (Roufagalas 1994), *information processing costs* (Sims 1998), *information gathering costs* (Ball and Mankiw 1994; Ball 2000; Zbaracki, et al. 2004), *decision-making costs* that result from either costs of acquiring information or costs of reoptimization (Mankiw and Reis 2002; Ball, et al. 2005; Reis 2006a and 2006b; Zbaracki, et al. 2004), or *limited channel capacity* for absorbing information (Woodford 2003; Adam 2004; Sims 1998, 2003). See also Akerlof, et al. (2000), Ameriks, et al. (2003, 2004), Rotemberg (2003, 2005), Klenow and Willis (2006), and Knotek (2006b).

[18] This is known as *the place-value principle* (Debaene, 1997). For example, each one of the three digits that make up number 999 signifies different magnitude because of their different location in the number, even though the three digits are identical. This principle applies only to Arabic numerals. It does not apply, for example to Roman numerals.

[19] This argument holds even if the marginal cost remains constant because marginal benefit certainly declines as we move from left to right.

[20] This is consistent with recent laboratory experiment findings that people tend to drop the rightmost digit in processing price information (Bizer and Schindler, 2005). This kind of selective consumer inattention to price information is consistent with evidence from surveys of consumer behavior in this industry (*Progressive Grocer,* November 1974, p. 39 and *Progressive Grocer,* February 1964, pp. C104–C106, as cited by Gabor and Granger (1961) and Carlton and Perloff (2000)). This behavior is

ignore the last digit will have incentive to make it as high as possible, setting it to 9. Rational consumers expect this and thus 9-ending will be an equilibrium outcome (Basu, 1997).[21]

This is illustrated in Figure 9. Under rational inattention, there will be a range of inattention along the demand curve. In this price range, say ±10¢, consumers are inattentive and thus they do not respond to price changes. The optimal pricing strategy in this case will be to set the price at the highest point in the vertical segment of the demand curve, which will be 9.[22]

According to the above argument, consumers' incentive to be attentive increases and therefore, the optimality of the use of the 9 digit decreases as we move from the rightmost digits to the left in the price. This implies that we should still see more 99¢ endings than 89¢, 79¢, …, 09¢ endings among the rightmost two digits, but that the dominance of 99¢ over 89¢, 79¢, etc. should be weaker than the dominance of 9¢ over 8¢, 7¢, and so on. This process will continue towards the dollar-digit as well as the ten-dollar digit. Indeed, this is what we observe in both Dominick's data (65% for 9¢ vs. 15% for 99¢) and our Internet data (31.9% for 9¢, 26.3% for 99¢, 13.5% for $9.99, and 3.9% for $99.99).

Now consider the implications of rational inattention for price rigidity. Rational inattention suggests that there will be a discontinuity in price adjustment within the range of rational inattention. When changes in market conditions are not large enough to warrant a price change larger than the range of inattention based on the ignored digit, firms might rationally choose not to respond. For example, when the price-setter is facing a price change decision that requires a price increase from $1.79 to $1.80, the increase will not be optimal if the customers ignore the last digit and perceive the change to be bigger (i.e., as a 10¢ increase) than it actually is. Similarly, a price decrease from $1.79 to $1.78 will have no effect on the quantity demanded if consumers ignore the last digit. Thus, 9¢-ending prices will lead to price rigidity.

However, when a price change is justified, then the price-setter will have incentive to make price changes in multiples of 10¢. For example, a firm that faces a series of 1¢ cost increases may not change its price for many periods, but when the firm does react, it may increase the price by 10¢, even though the cost increase in that particular period was only 1¢. The implication is that the store could change the price from $1.79 to $1.89, instead of to $1.80, without any additional cost, but with much higher benefit. That would be true even in a world

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consistent also with the marketing literature on "just noticeable differences" in consumer behavior (Monroe, 1970, 2001), where consumers do not react to small price changes because they do not "notice" them (Kalyanaram and Little 1994).

[21] We shall note that the optimality of inattention to last digit for processing numeric information under time constraints will not necessarily extend to other settings. For example, the strategy of ignoring the last digit or the last two digits will not be very efficient in processing such numeric information as phone numbers, social security numbers, etc.

[22] Consistent with this idea is a recent study by Levy, et al. (2006), which also uses the Dominick's data, and documents asymmetric price adjustment "in the small." The authors report more frequent "small" price increases than decreases, for price changes of up to about 10¢. After ruling out standard models of price adjustment or inflation as explanation, they argue that the asymmetry might be due to rational inattention.

with costs of price adjustment (Mankiw 1985) because of the largely fixed nature of such costs (Levy, et al. 1997, 1998; Dutta, et al. 1999). This seems to capture the ideas proposed by Kashyap (1995), Konieczny (2003), and Konieczny Skrzypacz (2003), and offers a plausible resolution to the puzzle posed by Landsburg (1995). The empirical findings we reported in Section IV are consistent with these predictions.

VIII. Discussion and Conclusion

To our knowledge, this is the first study that directly examines the effect of price points on price rigidity across a broad range of product categories, price levels, and retailers, in traditional retailing and Internet-based selling formats, using individual product level transaction price data from the U.S. To briefly summarize our findings, we find that 9-ending prices are at least 24% (and as much as 73%) less likely to change compared to non-9-ending prices. Further, most common price changes occur in multiples of dimes and dollars, which preserve the terminal digits at 9. Also, the size of the price changes is larger for 9-ending than non-9-ending prices.

Thus, in both datasets, 9-ending prices form a substantial barrier to retail price changes. These findings are quite robust, occurring in both datasets, with a wide range of prices, products, retail formats, retailers and even time periods. The findings lend support to the price point theory of price rigidity, as suggested by Kashyap (1995), and further explored by Blinder, et al. (1998) using survey methods.

In our data, 9 is the most popular terminal digit overall, consistent with the findings reported by Friedman (1967).[23] The existing empirical evidence, however, suggests that price points may vary across countries.[24] For example, Konieczny and Skrzypacz (2003, 2004) note that 9-ending prices are particularly popular in the U.S., Canada, Germany, and Belgium, but they are scarce in Spain, Italy, Poland, and Hungary, where *round prices* are more common.[25] In Asian countries (Malaysia, Hong Kong, Singapore, Japan, and China), Heeler and Nguyen (2001) find an unusual over-representation of 8-endings.[26] Knotek (2004, 2006a) focuses on

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[23] Landsburg (1995) describes the historical origins of 9-ending prices. See also Ginzberg (1936).

[24] We are unlikely to see 9-ending prices in certain settings. For example, imagine the patients' reaction if the dentist tells them that "A tooth filling costs $79.99. It's today's Special!"

[25] See Fengler and Winter (2001), Ratfai (2003), and Mostacci and Sabbatini (2003).

[26] According to Heeler and Nguyen (2001), in the Chinese culture, numbers have special significance and symbolism. Even the sounds of the numbers can suggest good or bad luck. For example, the number 8 represents luck to Cantonese Chinese because it sounds like *multiply* or *get rich* (*fa* in Cantonese). In Japan, 8 also has great symbolic significance because the writing of the number 8 looks like a mountain ("八"), and thus the number 8 signifies *growth* and *prosperity*. Heeler and Nguyen (2001) find that close to 50% of restaurant menu prices sampled in Hong Kong had 8-endings, which they refer to as "happy endings." Also, a *Time Magazine* article (Rawe 2004) reports that at the casino of a recently-built $240 million hotel, Sands Macao in Macao, China, the slot machines' winning trios of 7's have been replaced with trios of 8's. The cross-cultural importance of numbers is not limited to "happy endings." For example, according to Mirhadi (2000), when the Masquerade Tower was added to Hotel Rio

other types of pricing practices: the common use of round prices, which he terms "convenient prices." Their use reduces the amount of the change used in a transaction. Levy and Young (2004) report that the Coca Cola Company held the nominal price of its drink fixed for almost 70 years at 5¢, also a "convenient price." These and other pricing practices, and their economic significance, need to be explored further.[27]

The phenomenon of 9-ending prices has received considerable attention in the marketing literature, where most studies explain the 9-ending pricing phenomena on psychological grounds. For example, according to Nagle and Holden (1995, p. 300), buyers perceive the 9-ending prices "… as significantly lower than the slightly higher round numbers that they approximate." As another example, Schindler and Kirby (1997) posit that consumers might perceive a 9-ending price as a round-number price with a small amount given back.[28]

We suggest that consumers' *rational* inattention and firms' reactions to it can offer a plausible explanation for our findings. The existing studies that employ the idea of rational inattention all focus on macro issues, such as monetary policy, inflation dynamics, etc. As far as we know, this is the first paper that extends the idea of rational inattention to the study of individual price dynamics.

Our findings also may have potential macroeconomic implications. We typically do not consider nominal magnitudes to be as important as real magnitudes for optimal decision-making. Yet, our results imply decision rules by customers and firms that may affect both price points and price adjustments. In such situations, the nominal magnitude of numeric information attached to economic quantities may matter.

There are a variety of macroeconomic settings where these insights on price points, price rigidity and rational inattention might be relevant. For example, dropping the smallest currency unit has been a recent topic of debate in the U.S. and Europe.[29] The smallest currency unit

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in Las Vegas in 1997, the architects decided to skip the 40th to the 49th floors because the Arabic numeral "4" in Chinese sounds similar to the word "death." The elevators in the building went directly from the 39th floor to the 50th floor.

[27] Additional analyses (not reported here to save space) show that 9 is indeed more rigid than any other digit in our datasets. Other popular digits in our data (e.g., 5), do not consistently lead to more price rigidity, and even when they do, the rigidity associated with them is considerably less compared to that associated with 9.

[28] Other theories argue that sellers like to give change or that buyers like to receive a change. It has been suggested also that 9-ending prices may be interpreted as discount prices and thus are indicative of good bargains. Finally some authors note the cognitive accessibility of certain numbers, such as 0 and 5, to explain pricing points. See Shapiro (1968) and Monroe (1990) for reviews of earlier literature. Basu (1997, 2006), Anderson and Simester (2003), and Ruffle and Shtudiner (2006) provide reviews of more recent literature.

[29] *USA Today* has reported that "France, Spain and Britain quit producing low-denomination coins in recent decades because production costs kept going up while the coins' purchasing power went down" (Copeland 2001). More recently, it has been reported that in many European Union countries which have adopted the Euro, the public—including buyers and sellers—seems to be exhibiting resistance to the use of 1-cent and 2-cent denomination coins. This is due to the inconvenience their use entails. The *International Herald Tribune* reports that these coins are "small, nearly valueless—and a nuisance to millions of Europeans. The tiny denomination 1- and 2-cent Euro coins are annoying shoppers and disrupting business from Paris to Milan" (Pfanner 2002, p. 1). The argument here seems to resemble the arguments made in the context of the "1¢ nuisance" cost caused by the need to obtain a one-cent stamp to be added to the standard first-class mail stamp after each upward adjustment in the price of

might define the price ranges of customer inattention. This appears to be true in the case of products that are sold through automated devices, such as soda and candy bar vending machines, parking meters, coin-operated laundry machines, etc.[30]

As another example, the common use of 9-endings, and more generally the popularity of price points have recently received a considerable attention in public discussions in several European Union countries in the context of the conversion of prices from local currencies to the Euro. The concern was about the possibility that retailers may have acted opportunistically by rounding their prices upward after conversion to the Euro in their attempt to preserve the price points.[31] The idea of rational inattention and our findings reported here along with the findings reported by Levy, et al. (2006) about the presence of asymmetry in "small" price adjustments in various datasets suggests that more research is needed on these and other related issues.

Future work might study this phenomenon across other products, industries, retailers, and countries. Such studies will help test the generalizability of our results, and uncover the boundaries of our reasoning. In fact, recent work from the European Union seems to indicate that prices set at price points tend to be more rigid in their contexts as well (e.g., Dhyne, et al. 2006).

We conclude by suggesting that the Internet, along with the techniques developed in the information systems disciplines, offer many opportunities to improve our understanding of price setting, price points, and price rigidity. The Internet provides a unique technological context for the micro-level study of price setting behavior and strategies (Bergen, et al. 2005). The ability to access transaction price data using software agents allows us to explore pricing and price adjustment patterns at low costs at a previously unimaginable level of microeconomic detail. It allows empirical research methods (e.g., *massive quasi-experimental data mining methods*), to take advantage of natural experiments in the real world (e.g., Kauffman and Lee, 2007; Kauffman and Wood, 2007a, 2007b). With the expanding retail activities on the Internet, and new techniques and tools that have become available, we expect such opportunities to increase further in the future.

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first-class mail by 1¢ in the U.S. (Rubin 1999). In 2001, Rep. Jim Kolbe (R-Arizona) introduced the "Legal Tender Modernization Act," to make the U.S. penny obsolete. According to that bill, checks were to be written to the exact amount, but merchants were to be required to round up or down to the nearest nickel on cash purchases. The bill was defeated. Previous attempts made in 1990 and 1996 also died in Congress (Copeland 2001). Elimination of pennies in cash transactions and rounding prices to the nearest nickel was also earlier discussed for price-setting in the U.S. House of Representative Gift Shop (Office of the Inspector General 1995).

[30] See Bils and Klenow (2004), Levy and Young (2004), and Campbell and Eden (2005).

[31] See, for example, Ehrmann (2005) and Hoffmann and Kurz-Kim (2006), and the studies cited therein.

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Table 1. Descriptive Statistics for Weekly Retail Price Observations in Dominick's Data

Category	Number of Observations	Number of Products	Number of Stores	Mean Price	Std. Dev.	Min. Price	Max. Price
Analgesics	3,040,159	638	93	$5.18	$2.36	$0.47	$23.69
Bath Soap	418,087	579	93	$3.16	$1.60	$0.47	$18.99
Bathroom Tissue	1,149,953	127	93	$2.10	$1.68	$0.25	$11.99
Beer	1,966,139	787	89	$5.69	$2.70	$0.99	$26.99
Bottled Juice	4,294,956	506	93	$2.24	$0.97	$0.32	$8.00
Canned Soup	5,504,477	445	93	$1.13	$0.49	$0.23	$5.00
Canned Tuna	2,382,969	278	93	$1.80	$1.07	$0.22	$12.89
Cereals	4,707,750	489	93	$3.12	$0.76	$0.25	$7.49
Cheeses	6,752,297	657	93	$2.42	$1.12	$0.10	$16.19
Cigarettes	1,801,440	793	93	$7.69	$7.90	$0.59	$25.65
Cookies	7,568,399	1,124	93	$2.10	$0.63	$0.25	$8.79
Crackers	2,228,265	330	93	$2.01	$0.57	$0.25	$6.85
Dish Detergent	2,164,726	287	93	$2.34	$0.90	$0.39	$7.00
Fabric Softeners	2,278,536	318	93	$2.82	$1.45	$0.10	$9.99
Front-End-Candies	4,437,054	503	93	$0.61	$0.24	$0.01	$6.99
Frozen Dinners	1,654,049	266	93	$2.37	$0.89	$0.25	$9.99
Frozen Entrees	7,172,065	898	93	$2.33	$1.06	$0.25	$15.99
Frozen Juices	2,368,129	175	93	$1.39	$0.45	$0.22	$6.57
Grooming Products	4,065,657	1,381	93	$2.94	$1.37	$0.49	$11.29
Laundry Detergents	3,277,439	581	93	$5.61	$3.22	$0.25	$24.49
Oatmeal	981,034	96	93	$2.65	$0.66	$0.49	$5.00
Paper Towels	940,740	163	93	$1.50	$1.41	$0.31	$13.99
Refrigerated Juices	2,166,726	225	93	$2.24	$0.91	$0.39	$7.05
Shampoos	4,676,362	2,930	93	$2.95	$1.79	$0.27	$29.99
Snack Crackers	3,487,548	420	93	$2.18	$0.57	$0.10	$8.00
Soaps	1,835,196	334	93	$2.51	$1.48	$0.10	$10.99
Soft Drinks	10,741,661	1,608	93	$2.34	$1.89	$0.10	$26.02
Toothbrushes	1,839,530	491	93	$2.18	$0.85	$0.39	$9.99
Toothpastes	2,981,513	608	93	$2.43	$0.89	$0.31	$10.99
Total	**98,691,750**	**18,037**	**93**	**$2.59**	**$2.16**	**$0.01**	**$29.99**

Note: The table covers the entire weekly price data from the Dominick's in its 93 stores for a period of 400 weeks from September 14, 1989 to May 8, 1997. The data are available at: gsbwww.uchicago.edu/kilts/research/db/dominicks/.

Table 2. Descriptive Statistics for the Daily Price Observations in the Internet Data

Category	Number of Observations	Number of Products	Number of Retailers	Mean Price	Std. Dev.	Min. Price	Max. Price
Music CDs	302,914	46	15	$13.46	$3.50	$3.99	$26.98
Movie DVDs	447,519	49	22	$27.42	$26.70	$4.95	$144.99
Video Games	244,625	49	38	$30.83	$12.57	$4.90	$57.99
Software	382,297	48	83	$294.07	$417.60	$4.95	$5,695.00
Hard Drives	263,244	46	73	$330.67	$556.29	$39.00	$3,670.98
PDAs	148,731	45	92	$346.60	$193.24	$32.99	$956.95
DVD Players	220,236	49	104	$369.51	$247.75	$57.99	$1,489.00
PC Monitors	319,369	51	87	$682.89	$659.13	$85.78	$3,010.41
Digital Cameras	247,917	46	143	$760.12	$688.76	$175.95	$6,000.00
Notebook PCs	79,386	45	45	$1,666.68	$475.80	$699.00	$3,199.00
Total	**2,656,238**	**474**	**293**	**$337.06**	**$536.13**	**$3.99**	**$6,000.00**

Note: The table covers 743 daily price observations from March 26, 2003 to April 15, 2005, from the Internet retailers. The retailers have many different product categories (e.g., Amazon.com sells books, CDs, DVDs, computer products and electronics, etc.). Consequently, the sum of the number of retailers in each product category will not necessarily be consistent with the total number of stores in all product categories. In addition, some retailers do not have all products (e.g., in our sample, Amazon has 15 music CDs while Barnes & Noble has 20). Also, the length of individual product's price time series varies due to different life cycle of products. Thus, the number of observations in the Music CDs category, for example, 302,914, is less than total available combinations (i.e., 46x15x743 = 512,670.)

Table 3. Top 10 Highest Frequencies of Last Three Digits of Prices in the Internet Data

Rank	CDs	DVDs	Video Games	SW	PDAs	Hard Drives	DVD Players	PC Monitors	Digital Cameras	Notebook PCs	Total
1	**$4.99**	**$9.99**	**$9.99**	**$9.00**	**$9.00**	**$9.99**	**$9.99**	**$9.00**	**$9.99**	**$9.00**	**$9.99**
	7.76%	5.13%	37.78%	11.55%	23.43%	8.97%	23.13%	16.60%	23.58%	48.43%	13.17%
2	**$2.99**	**$4.99**	**$9.82**	**$9.95**	**$9.99**	**$9.00**	**$9.00**	**$9.99**	**$9.00**	**$9.99**	**$9.00**
	5.20%	4.89%	4.51%	11.49%	15.21%	6.18%	10.74%	8.99%	21.60%	16.62%	9.98%
3	**$3.99**	**$3.99**	**$8.95**	**$9.99**	**$9.95**	**$9.95**	**$9.95**	**$9.95**	**$9.95**	**$9.95**	**$9.95**
	4.35%	2.78%	3.62%	7.72%	5.26%	4.41%	5.77%	4.03%	8.76%	5.01%	4.86%
4	$1.99	$0.99	$7.99	$5.00	$8.00	$5.00	$9.97	$5.00	$5.00	$9.98	$4.99
	4.22%	2.72%	3.35%	4.53%	3.09%	3.44%	5.39%	3.42%	5.19%	3.28%	3.24%
5	$3.98	$5.99	$4.99	$0.00	$5.00	$4.99	$9.90	$0.00	$8.00	$5.00	$5.00
	3.26%	2.65%	3.20%	3.40%	2.74%	2.57%	4.85%	2.80%	2.80%	2.49%	2.48%
6	$5.99	$2.99	$9.95	$8.00	$4.99	$2.00	$5.00	$5.95	$4.99	$7.00	$2.99
	2.96%	2.57%	2.85%	2.84%	2.48%	2.26%	4.13%	2.41%	2.37%	1.73%	1.46%
7	$9.99	$6.99	$9.88	$4.95	$0.00	$7.00	$4.99	$0.95	$7.00	$4.00	$8.95
	2.43%	2.37%	2.76%	2.73%	1.85%	2.16%	3.24%	2.33%	2.26%	1.64%	1.45%
8	$4.98	$5.98	$8.99	$8.95	$4.95	$6.00	$8.00	$2.95	$0.00	$4.95	$8.00
	2.40%	2.34%	2.72%	2.53%	1.69%	2.14%	2.26%	2.26%	1.85%	1.00%	1.44%
9	$7.99	$1.98	$6.99	$2.00	$8.95	$8.99	$9.96	$8.95	$9.98	$7.99	$7.99
	2.26%	2.08%	2.04%	2.21%	1.68%	2.10%	2.21%	2.05%	1.56%	0.97%	1.43%
10	$8.99	$7.99	$6.95	$7.00	$5.99	$3.00	$9.94	$6.95	$9.90	$5.99	$4.95
	2.11%	2.07%	1.79%	2.15%	1.47%	2.02%	1.51%	1.98%	1.44%	0.95%	1.42%

Note: Each cell contains the last three digits of prices and their proportions in the product category. Bold-marked prices in the first three rows indicate that they are in the top three frequent price endings in each category. The rightmost column includes all categories. The figures in each column are ordered from the most frequent ending to the least frequent ending.

Table 4. Top 10 Highest Frequencies of Last Four Digits of Prices in the Internet Data

Rank	CDs	DVDs	Video Games	SW	PDAs	Hard Drives	DVD Players	PC Monitors	Digital Cameras	Notebook PCs	Total
1	**$14.99**	**$09.99**	**$19.99**	**$99.00**	**$49.00**	**$29.99**	**$99.99**	**$99.00**	**$99.99**	**$99.00**	**$99.99**
	7.48%	2.66%	14.34%	3.54%	5.77%	1.30%	7.87%	5.98%	13.51%	27.47%	3.47%
2	**$12.99**	**$13.99**	**$29.99**	**$99.95**	**$99.00**	**$59.99**	**$49.99**	**$99.99**	**$99.00**	**$49.00**	**$99.00**
	4.90%	2.56%	10.47%	3.46%	5.76%	1.27%	3.72%	3.78%	9.02%	9.29%	3.46%
3	**$11.99**	**$14.99**	**$49.99**	**$99.99**	**$99.99**	**$09.99**	**$19.99**	**$49.00**	**$99.95**	**$99.99**	**$19.99**
	4.00%	2.31%	9.05%	3.33%	4.82%	1.09%	2.90%	1.89%	3.26%	8.00%	2.16%
4	$13.99	$15.99	$39.99	$89.95	$59.00	$49.99	$99.00	$49.99	$49.99	$79.00	$49.99
	3.57%	2.14%	3.21%	1.71%	2.44%	1.01%	2.35%	1.72%	3.18%	3.04%	2.00%
5	$13.98	$15.98	$19.82	$49.95	$79.00	$59.00	$69.99	$29.00	$49.00	$99.98	$29.99
	3.26%	2.03%	2.74%	1.50%	2.44%	0.91%	2.30%	1.62%	3.15%	2.84%	1.55%
6	$15.99	$10.99	$18.95	$79.95	$49.99	$99.99	$49.00	$39.00	$29.00	$29.00	$49.00
	2.43%	1.83%	2.11%	1.37%	2.41%	0.86%	1.87%	1.35%	1.99%	2.84%	1.43%
7	$14.98	$11.98	$19.88	$19.00	$19.00	$79.99	$79.99	$59.00	$79.99	$29.99	$14.99
	2.40%	1.44%	1.99%	1.35%	2.00%	0.86%	1.83%	1.27%	1.81%	2.17%	1.40%
8	$10.99	$10.95	$17.99	$79.00	$19.99	$39.99	$39.99	$19.00	$79.00	$30.00	$99.95
	1.89%	1.40%	1.33%	1.14%	1.59%	0.83%	1.65%	1.07%	1.62%	1.89%	1.09%
9	$15.18	$16.99	$48.95	$89.00	$29.99	$79.00	$29.00	$69.00	$39.00	$19.99	$09.99
	1.89%	1.39%	1.28%	1.1%	1.41%	0.73%	1.64%	1.04%	1.34%	1.55%	0.97%
10	$7.99	$17.99	$49.95	$19.95	$39.00	$39.00	$79.00	$79.00	$69.00	$49.99	$79.00
	1.85%	1.34%	1.24%	1.05%	1.34%	0.71%	1.62%	1.00%	1.32%	1.53%	0.87%

Note: Each cell contains the last four digits of prices and their proportions in the product category. Bold-marked prices in the first three rows indicate that they are in the top three frequent price endings in each category. The rightmost column includes all categories.

Table 5. Top 10 Highest Frequencies of Price Changes in the Internet Data

Rank	CDs	DVDs	Video Games	SW	PDAs	Hard Drives	DVD Players	PC Monitors	Digital Cameras	Notebook PCs	Total	3 Categories Removed
1	**$1.00**	**$1.00**	**$10.00**	**$1.00**	**$10.00**	**$1.00**	**$10.00**	**$1.00**	**$10.00**	**$50.00**	**$1.00**	**$1.00**
	10.26%	7.73%	11.44%	6.78%	7.54%	10.03%	4.46%	3.29%	8.09%	11.30%	6.74%	5.63%
2	**$0.10**	**$0.20**	**$1.00**	**$2.00**	**$5.00**	**$2.00**	**$20.00**	**$2.00**	**$20.00**	**$100.00**	**$2.00**	**$2.00**
	6.77%	3.42%	9.82%	5.15%	4.41%	7.54%	3.95%	3.29%	5.89%	7.63%	4.49%	4.66%
3	**$2.00**	**$2.00**	**$5.00**	**$5.00**	**$2.00**	**$3.00**	**$30.00**	**$10.00**	**$4.00**	**$200.00**	**$10.00**	**$10.00**
	5.22%	3.40%	7.40%	4.11%	4.02%	5.55%	2.70%	3.27%	3.46%	3.97%	3.24%	4.31%
4	$0.20	$0.01	$2.00	$10.00	$1.00	$4.00	$5.00	$3.00	$5.00	$20.00	$3.00	$3.00
	3.59%	2.34%	5.57%	3.76%	3.41%	4.00%	2.51%	3.02%	3.44%	3.05%	3.09%	3.60%
5	$0.01	$0.09	$20.00	$3.00	$20.00	$5.00	$1.00	$5.00	$2.00	$10.00	$5.00	$5.00
	3.46%	2.30%	4.69%	3.56%	3.24%	3.98%	2.13%	2.23%	3.28%	2.44%	2.72%	3.38%
6	$0.50	$0.10	$3.00	$4.00	$30.00	$10.00	$3.00	$4.00	$6.00	$60.00	$4.00	$4.00
	2.45%	2.29%	4.25%	3.04%	2.57%	2.83%	2.13%	1.91%	3.28%	2.14%	2.30%	2.90%
7	$0.06	$3.00	$3.06	$20.00	$3.00	$6.00	$4.00	$6.00	$50.00	$30.00	$20.00	$20.00
	2.06%	2.21%	2.64%	2.44%	2.35%	2.10%	1.95%	1.83%	2.97%	1.98%	1.80%	2.56%
8	$0.14	$0.30	$0.11	$6.00	$6.00	$7.00	$2.00	$20.00	$1.00	$40.00	$6.00	$6.00
	1.88%	1.79%	2.05%	2.19%	2.29%	1.84%	1.57%	1.61%	2.87%	1.83%	1.55%	2.18%
9	$0.02	$0.08	$18.00	$0.01	$4.00	$8.00	$6.00	$30.00	$30.00	$150.00	$0.10	$30.00
	1.69%	1.31%	1.61%	2.03%	1.90%	1.08%	1.51%	1.54%	2.87%	1.83%	1.38%	1.50%
10	$0.30	$0.50	$7.00	$8.00	$15.00	$20.00	$50.00	$7.00	$3.00	$70.00	$0.01	$7.00
	1.69%	1.26%	1.39%	1.54%	1.79%	1.06%	1.51%	1.44%	2.64%	1.68%	1.38%	1.47%

Note: The rightmost column shows the results after three product categories (CDs, DVDs, and video games) are left out. Bold-marked prices in the first three rows indicate that they are in the top three frequent price changes in each category.

Table 6. Results of the Logit Regression (Equation 1) Estimation for Dominick's Data

	9¢-Ending				99¢-Ending			
	D_9 (9-Ending = 1)		D_{Sale} (Sale = 1)		D_{99} (9-Ending = 1)		D_{Sale} (Sale = 1)	
1. Category	**Coeff.**	**O/R**	**Coeff.**	**O/R**	**Coeff.**	**O/R**	**Coeff.**	**O/R**
Analgesics	– 0.6781	0.51	3.9829	52.63	– 0.1847	0.83	3.9805	52.63
Bath Soap	– 0.8155	0.44	4.6464	100.00	– 0.2273	0.80	4.7925	125.00
Bathroom Tissues	– 0.5036	0.60	3.6723	40.00	– 0.3426	0.71	3.6795	40.00
Bottled Juices	– 0.2891	0.75	4.1268	62.50	– 0.2042	0.81	4.1422	62.50
Canned Soup	– 0.1112	0.89	4.6189	100.00	– 0.1629	0.85	4.6238	100.00
Canned Tuna	– 0.5331	0.59	4.5788	100.00	– 0.4714	0.62	4.5281	90.91
Cereals	– 0.2558	0.77	4.7368	111.11	– 0.1603	0.85	4.7239	111.11
Cheeses	– 0.9142	0.40	3.8187	45.45	– 0.6098	0.54	3.8378	45.45
Cookies	– 0.8173	0.44	4.1490	62.50	– 0.1876	0.83	4.2162	66.67
Crackers	– 0.4412	0.64	4.0389	55.56	– 0.0441	0.96	4.1185	62.50
Dish Detergent	– 0.6283	0.53	4.7074	111.11	– 0.6024	0.55	4.7350	111.11
Fabric Softeners	– 0.3779	0.69	4.6161	100.00	– 0.1980	0.82	4.5797	100.00
Front-end-candies	– 0.4477	0.64	4.8119	125.00	– 1.3781	0.25	4.8630	125.00
Frozen Dinners	– 0.5808	0.56	3.5407	34.48	– 0.4377	0.65	3.7235	41.67
Frozen Entrees	– 0.5642	0.57	3.2641	26.32	– 0.1291	0.88	3.4461	31.25
Frozen Juices	– 0.2451	0.78	3.9482	52.63	– 0.1008	0.90	3.9182	50.00
Grooming Products	– 0.9030	0.41	3.3588	28.57	– 0.2406	0.79	3.6612	38.46
Laundry Detergents	– 0.5783	0.56	4.1731	66.67	– 0.1446	0.87	4.1543	62.50
Oatmeal	– 0.5805	0.56	4.1839	66.67	– 0.2548	0.78	4.1707	66.67
Paper Towels	– 0.5186	0.60	4.3241	76.92	– 0.1546	0.86	4.2669	71.43
Refrigerated Juices	– 0.5042	0.60	3.6385	38.46	– 0.2908	0.75	3.6428	38.46
Shampoos	– 0.7868	0.46	3.1548	23.26	– 0.2957	0.74	3.3005	27.03
Snack Crackers	– 0.8517	0.43	3.8756	47.62	– 0.3930	0.68	4.1214	62.50
Soaps	– 0.6709	0.51	4.2641	71.43	– 0.3583	0.70	4.2807	71.43
Soft Drinks	– 0.6709	0.51	4.2641	71.43	– 0.3583	0.70	4.2807	71.43
Tooth Brushes	– 0.3154	0.73	3.6447	38.46	– 0.0709	0.93	3.6285	37.04
Tooth Pastes	– 0.2343	0.79	3.7560	43.48	– 0.2760	0.76	3.7405	41.67
Average		0.59		64.90		0.76		66.83

Note: D_9 (or D_{99}) is 9-ending dummy variable, which equals 1 if the price ends with 9 (or 99) and 0 otherwise. D_{Sale} is a sale dummy, which equals 1 if the product is on sale in the given week and 0 otherwise. All *p*-values are less than 0.0001. The average odds ratios (O/R) reported in the last row of the table are the simple averages of the odds ratios for each product category.

Table 7. Results of Logit Regression (Equation 1) Estimation for the Internet Data

Category	9¢-Endings	99¢-Endings	$9-Endings	$99-Endings	$9.99-Endings	$99.99-Endings
Music CDs	-0.0743** (0.9284)	-0.5085*** (0.6014)	*-0.0174* (0.9827)		-0.4283** (0.6516)	
Movie DVDs	-0.5036*** (0.6043)	-0.6154*** (0.5404)	-0.2596*** (0.7714)		-0.7835*** (0.4568)	
Video Games	*0.1087** (1.1148)	*0.0558* (1.0573)	-0.2951*** (0.7445)		-0.2779*** (0.7574)	
Software	-0.3011*** (0.7400)	-0.4889*** (0.6133)	-0.6148*** (0.5407)	-1.0667*** (0.3441)	-0.9012*** (0.4061)	-1.3153*** (0.2684)
PDAs	-0.2553*** (0.7747)	-0.3586*** (0.6986)	-0.4654*** (0.6279)	-0.7911*** (0.4533)	-0.5418*** (0.5817)	-1.1819*** (0.3067)
Hard Drives	-0.2806*** (0.7553)	-0.3698*** (0.6909)	-0.4711*** (0.6243)	-0.6199*** (0.5380)	-0.6796*** (0.5068)	-0. 5254*** (0. 5913)
DVD Players	-0.4939*** (0.6102)	-0.5763*** (0.5620)	-0.6695*** (0.5120)	-0.6790*** (0. 5071)	-0.6389*** (0.5279)	-0.8103*** (0.4447)
PC Monitors	-0.2729*** (0.7612)	-0.4617*** (0.6302)	-0.5507*** (0.5766)	-0.8433*** (0.4303)	-0.8375*** (0.4328)	-1.2927*** (0.2745)
Digital Cameras	-0.4389*** (0.6447)	-0.4933*** (0.6106)	-0.5297*** (0.5888)	-1.1229*** (0.3253)	-0.5879*** (0.5500)	-1.4480*** (0.2350)
Notebook PCs	-0.5566*** (0.5731)	-0.8885*** (0.4113)	-1.0680*** (0. 3437)	-0.7654*** (0. 4652)	-0.9528*** (0.3856)	-1.1891*** (0.3045)
Total	-0.3690*** (0.6914)	-0.5703*** (0.5653)	-0.6472*** (0.5235)	-1.0179*** (0.3613)	-0.8761*** (0.4164)	-1.3528*** (0.2585)

Note: Each cell contains a coefficient and odds ratio in parenthesis; significance levels: *** < 0.01, ** < 0.05, * < 0.10. The estimated coefficients in *italics* indicate unsupportive results.

Table 8. Average Size of Price Change in Dominick's Data: 9¢-Ending vs. Non-9¢-Ending Prices

	9¢-Ending		**Non-9¢-Ending**				
Category	**Mean Price Change**	**Sample Size**	**Mean Price Change**	**Sample Size**	**Corr.**	**t-Stat**	***p*-Value**
Analgesics	$0.7625	367,969	$0.4672	102,550	0.173	76.47	0.000
Bath Soap	$0.5786	58,735	$0.5473	18,298	0.019	64.41	0.000
Bathroom Tissues	$0.2499	156,863	$0.2260	184,414	0.031	210.19	0.000
Bottled Juices	$0.3121	457,490	$0.2650	583,025	0.060	255.92	0.000
Canned Soup	$0.2196	304,439	$0.1948	741,357	0.033	162.99	0.000
Canned Tuna	$0.1946	170,023	$0.1421	281,703	0.091	268.59	0.000
Cereals	$0.5010	271,757	$0.4701	494,597	0.027	-153.45	0.000
Cheeses	$0.2943	872,489	$0.2128	1,039,738	0.122	505.32	0.000
Cookies	$0.4947	1,135,112	$0.3656	709,697	0.129	359.98	0.000
Crackers	$0.2964	283,278	$0.2366	279,353	0.098	317.30	0.000
Dish Detergent	$0.2798	240,532	$0.2119	183,222	0.133	392.69	0.000
Fabric Softeners	$0.3955	212,288	$0.2597	191,319	0.168	210.90	0.000
*Front-end-candies**	*$0.1454*	*137,453*	*$0.2164*	*385,234*	*-0.113*	*86.40*	*0.000*
*Frozen Dinners**	*$0.5008*	*230,423*	*$0.5452*	*336,201*	*-0.033*	*-109.08*	*0.000*
*Frozen Entrees**	*$0.7031*	*883,284*	*$0.7551*	*1,183,557*	*-0.029*	*-432.43*	*0.000*
*Frozen Juices**	*$0.2567*	*301,114*	*$0.2816*	*395,344*	*-0.029*	*203.22*	*0.000*
Grooming Products	$0.6285	1,017,513	$0.4849	287,969	0.085	266.89	0.000
Laundry Detergents	$0.9036	446,767	$0.5548	210,342	0.194	-103.55	0.000
Oatmeal	$0.4239	72,753	$0.4115	107,971	0.012	-8.37	0.000
Paper Towels	$0.1913	109,596	$0.1702	152,846	0.030	205.91	0.000
Refrigerated Juices	$0.3780	405,144	$0.2987	418,402	0.115	243.81	0.000
Shampoos	$1.4476	1,916,061	$1.0888	238,976	0.065	-440.40	0.000
Snack Crackers	$0.3251	488,341	$0.2903	405,005	0.047	371.01	0.000
Soaps	$0.3147	180,935	$0.1700	190,632	0.218	280.21	0.000
Soft Drinks	$1.0409	4,614,455	$0.6155	1,219,151	0.140	-311.91	0.000
Tooth Brushes	$0.5063	350,705	$0.3653	123,840	0.191	376.47	0.000
Tooth Pastes	$0.4255	468,688	$0.3497	291,045	0.108	340.88	0.000
Total	$0.7452	16,154,207	$0.4033	10,755,788	0.181	-44.00	0.000
Average	$0.4730		$0.3777				
Median	$0.3955		$0.2987				

Note: Categories with unsupportive results are indicated by * and *italic.* **Corr.** is the correlation between 9-ending prices and the size of price change. ***p*-Value** is a significance level derived from a paired-sample t-test. Cross-category paired t-tests showed that the price changes are of a larger magnitude when prices end with 9 (t_{26} = 3.911, p = .001).

Table 9. Average Size of Price Change in Dominick's Data: 99¢-Ending vs. Non-99¢-Ending Prices

	99¢-Ending		Non-99¢-Ending				
Category	**Mean Price Change**	**Sample Size**	**Mean Price Change**	**Sample Size**	**Corr.**	**t-Stat**	***p*-Value**
Analgesics	$0.8931	106,038	$0.6415	$0.8931	0.149	-424.68	0.000
Bath Soap	$0.7149	15,608	$0.5346	$0.7149	0.102	-130.63	0.000
Bathroom Tissues	$0.3302	36,944	$0.2257	$0.3302	0.085	-159.40	0.000
Bottled Juices	$0.3760	104,451	$0.2756	$0.3760	0.077	-397.80	0.000
Canned Soup	$0.2703	56,527	$0.1981	$0.2703	0.048	-378.08	0.000
Canned Tuna	$0.3303	19,566	$0.1543	$0.3303	0.128	-246.09	0.000
Cereals	$0.6374	56,437	$0.4686	$0.6374	0.080	-602.23	0.000
Cheeses	$0.3563	160,237	$0.2403	$0.3563	0.097	-557.70	0.000
Cookies	$0.5612	270,448	$0.4251	$0.5612	0.099	-707.64	0.000
Crackers	$0.4902	62,297	$0.2489	$0.4902	0.165	-292.33	0.000
Dish Detergent	$0.3273	52,117	$0.2397	$0.3273	0.113	-211.97	0.000
Fabric Softeners	$0.5585	62,370	$0.2896	$0.5585	0.241	-237.44	0.000
Front-end-candies	$0.2326	11,923	$0.1969	$0.2326	0.019	-405.47	0.000
Frozen Dinners	$0.5585	56,617	$0.5237	$0.5585	0.016	-449.31	0.000
*Frozen Entrees**	*$0.7229*	*188,496*	*$0.7339*	*$0.7229*	*-0.004*	*-1002.78*	*0.000*
Frozen Juices	$0.2794	67,862	$0.2699	$0.2794	0.007	-279.32	0.000
Grooming Products	$0.6756	247,298	$0.5785	$0.6756	0.054	-595.05	0.000
Laundry Detergents	$1.1475	158,974	$0.6785	$1.1475	0.239	-527.15	0.000
Oatmeal	$0.5420	12,921	$0.4068	$0.5420	0.068	-261.98	0.000
Paper Towels	$0.3555	15,137	$0.1682	$0.3555	0.126	-158.70	0.000
Refrigerated Juices	$0.4874	101,063	$0.3168	$0.4874	0.162	-447.38	0.000
Shampoos	$1.6000	503,157	$1.3492	$1.6000	0.062	-987.01	0.000
Snack Crackers	$0.3673	97,690	$0.3022	$0.3673	0.055	-403.24	0.000
Soaps	$0.3907	43,874	$0.2203	$0.3907	0.166	-176.49	0.000
Soft Drinks	$1.2138	1,385,935	$0.8704	$1.2138	0.118	-1370.09	0.000
Tooth Brushes	$0.5972	108,407	$0.4317	$0.5972	0.215	-351.86	0.000
Tooth Pastes	$0.5097	117,086	$0.3758	$0.5097	0.141	-457.98	0.000
Total	$0.9156	4,119,480	$0.5532	$0.9156	0.143	-2494.28	0.000
Average	$0.5750		$0.4209				
Median	$0.5097		$0.3168				

Note: Categories with unsupportive results are indicated by * and *italic*. **Corr.** is the correlation between 9-ending prices and the size of price change. ***p*-Value** is a significance level derived from a paired-sample t-test. Cross-category paired t-tests showed that the price changes are of a larger magnitude when prices end with 9 ($t_{26} = 7.657$, $p = .000$).

Table 10. Average Size of Price Change in Internet Data: 9¢-Ending vs. Non-9¢-Ending Prices

Category	9¢-Ending Mean Price Change	9¢-Ending Sample Size	Non-9¢-Ending Mean Price Change	Non-9¢-Ending Sample Size	Corr.	t-Stat	*p*-Value
Music CDs	$1.30	2,268	$1.01	2,352	0.097	29.45	0.000
Movie DVDs	$2.71	2,813	$1.68	5,888	0.122	40.16	0.000
Video Games	$8.12	832	$6.95	532	0.075	34.55	0.000
Software	$14.94	778	$13.51	4,751	0.014	27.60	0.000
*PDAs**	*$22.30*	*355*	*$25.86*	*1,436*	*-0.039*	*28.88*	*0.000*
Hard Drives	$27.65	1,435	$14.29	5,517	0.097	25.10	0.000
DVD Players	$36.02	383	$28.43	1,210	0.065	24.07	0.000
PC Monitors	$41.35	809	$28.45	5,150	0.072	37.83	0.000
Digital Cameras	$45.76	852	$36.97	3,018	0.046	30.60	0.000
*Notebook PCs**	*$86.42*	*92*	*$97.58*	*563*	*-0.031*	*19.57*	*0.000*
Total*	*$16.08*	*10,617*	*17.87*	*30.417*	*-0.016*	*69.30*	*0.000*
Average	$28.66		$25.47				
Median	$25.00		$20.00				

Note: Categories with unsupportive results are indicated by * and *italic.* **Corr**. is the correlation between 9-ending prices and the size of price change. ***p*-Value** is a significance level derived from a paired-sample t-test. Cross-category paired t-tests showed that the price changes are of a larger magnitude when prices end with 9 ($t_9 = 1.324$, $p = .10$).

Table 11. Average Size of Price Change in Internet Data: 99¢-Ending vs. Non-99¢-Ending Prices

Category	99¢-Ending Mean Price Change	99¢-Ending Sample Size	Non-99¢-Ending Mean Price Change	Non-99¢-Ending Sample Size	Corr.	t-Stat	*p*-Value
Music CDs	$1.95	1,142	$0.89	3,478	0.305	43.25	0.000
Movie DVDs	$3.39	1,532	$1.72	7,169	0.160	43.81	0.000
Video Games	$8.45	744	$6.72	620	0.113	34.96	0.000
Software	$16.58	553	$13.39	4,976	0.026	27.69	0.000
*PDAs**	*$23.74*	*300*	*$25.44*	*1,491*	*-0.017*	*28.92*	*0.000*
Hard Drives	$30.28	1,083	$14.60	5,869	0.102	25.17	0.000
DVD Players	$39.32	329	$27.90	1,264	0.093	24.10	0.000
PC Monitors	$48.86	544	$28.33	5,415	0.096	37.89	0.000
Digital Cameras	$47.53	852	$36.78	3,018	0.054	30.62	0.000
Notebook PCs	$103.15	64	$95.24	591	0.019	19.58	0.000
Total	$20.59	7,056	$16.75	33,978	0.029	69.68	0.000
Average	$32.33		$25.10				
Median	$27.00		$20.00				

Note: Categories with unsupportive results are indicated by * and *italic.* **Corr.** is the correlation between 9-ending prices and the size of price change. ***p*-Value** is a significance level derived from a paired-sample t-test. Cross-category paired t-tests showed that the price changes are of a larger magnitude when prices end with 9 ($t_9 = 3.148$, $p = .006$).

Table 12. Average Size of Price Change in Internet Data: $9-Endings vs. Non-$9-Endings

	$9-Ending		Non-$9-Ending				
Category	**Mean Price Change**	**Sample Size**	**Mean Price Change**	**Sample Size**	**Corr.**	**t-Stat**	***p*-Value**
*Music CDs**	*$1.04*	*587*	*$1.17*	*4,033*	*-0.030*	*45.25*	*0.000*
Movie DVDs	$3.20	926	$1.87	7,775	0.104	45.20	0.000
Video Games	$9.01	659	$6.41	705	0.172	35.40	0.000
Software	$20.38	1,347	$11.56	4,182	0.104	27.42	0.000
PDAs	$31.66	710	$20.88	1,081	0.144	28.72	0.000
Hard Drives	$19.88	1,169	$16.47	5,783	0.023	25.14	0.000
DVD Players	$42.22	641	$22.21	952	0.197	23.97	0.000
PC Monitors	$53.71	1,436	$22.74	4,523	0.216	37.74	0.000
Digital Cameras	$48.29	1,899	$29.86	1,971	0.117	30.41	0.000
Notebook PCs	$126.22	344	$62.61	311	0.254	19.52	0.000
Total	$33.13	9,718	$12.53	31,316	0.175	69.50	0.000
Average	$38.56		$19.58				
Median	$26.00		$18.70				

Note: Categories with unsupportive results are indicated by * and *italic.* **Corr.** is the correlation between 9-ending prices and the size of price change. ***p*-Value** is a significance level derived from a paired-sample t-test. Cross-category paired t-tests showed that the price changes are of a larger magnitude when prices end with 9 ($t_9 = 2.598$, $p = .01$).

Table 13. Average Size of Price Change in Internet Data: $9.99-Endings vs. Non-$9.99-Endings

	$9.99-Ending		Non-$9.99-Ending				
Category	**Mean Price Change**	**Sample Size**	**Mean Price Change**	**Sample Size**	**Corr.**	**t-Stat**	***p*-Value**
Music CDs	$2.52	76	$1.13	4,544	0.118	52.01	0.000
Movie DVDs	$5.82	188	$1.93	8,513	0.143	47.19	0.000
Video Games	$9.62	433	$6.75	931	0.176	36.21	0.000
Software	$22.93	186	$13.39	5,343	0.047	27.82	0.000
PDAs	$26.86	170	$24.97	1,621	0.015	29.02	0.000
Hard Drives	$32.40	335	$16.27	6,617	0.062	25.32	0.000
DVD Players	$48.23	219	$27.40	1,374	0.144	24.16	0.000
PC Monitors	$72.98	247	$28.35	5,712	0.145	37.95	0.000
Digital Cameras	$53.91	566	$36.34	3,304	0.079	30.67	0.000
Notebook PCs	$110.03	47	$94.93	608	0.031	19.59	0.000
Total	$36.24	2,467	$16.20	38,567	0.095	70.15	0.000
Average	$38.53		$25.15				
Median	$29.60		$20.60				

Note: Categories with unsupportive results are indicated by * and *italic.* **Corr.** is the correlation between 9-ending prices and the size of price change. ***p*-Value** is a significance level derived from a paired-sample t-test. Cross-category paired t-tests showed that the price changes are of a larger magnitude when prices end with 9 ($t_9 = 3.224$, $p = .005$).

Table 14. Average Size of Price Change in Internet Data: $99-Endings vs. Non-$99-Endings

	$99-Ending		Non-$99-Ending				
Category	**Mean Price Change**	**Sample Size**	**Mean Price Change**	**Sample Size**	**Corr.**	**t-Stat**	***p*-Value**
Music CDs	N/A	0	$1.15	4,620			NA
Movie DVDs	$6.47	60	$1.98	8,641	0.094	47.40	0.000
Video Games	N/A	0	$7.66	1,669			NA
Software	$23.09	251	$13.26	5,278	0.056	27.80	0.000
PDAs	$46.75	122	$23.57	1,669	0.160	29.08	0.000
Hard Drives	$26.70	137	$16.85	6,815	0.024	25.36	0.000
DVD Players	$58.98	132	$27.66	1,461	0.173	24.21	0.000
PC Monitors	$98.11	332	$26.19	5,627	0.269	37.96	0.000
Digital Cameras	$85.88	476	$32.32	3,394	0.224	30.70	0.000
Notebook PCs	$144.42	161	$80.24	494	0.221	19.57	0.000
Total	$71.83	1,671	$15.10	39,363	0.224	70.26	0.000
Average	$61.30		$23.09				
Median	$52.90		$20.20				

Note: Categories with unsupportive results are indicated by * and *italic*. **Corr.** is the correlation between 9-ending prices and the size of price change. ***p*-Value** is a significance level derived from a paired-sample t-test. Cross-category paired t-tests showed that the price changes are of a larger magnitude when prices end with 9 ($t_7 = 3.598$, $p = .004$).

Table 15. Average Size of Price Change in Internet Data: $99.99-Endings vs. Non-$99.99-Endings

	$99.99-Ending		Non-$99.99-Ending				
Category	**Mean Price Change**	**Sample Size**	**Mean Price Change**	**Sample Size**	**Corr.**	**t-Stat**	***p*-Value**
Music CDs	N/A	0	$1.15	4,620			NA
Movie DVDs	$12.01	24	$1.99	8,677	0.133	47.50	0.000
Video Games	N/A	0	$7.66	1,364			NA
Software	$20.06	37	$13.66	5,492	0.014	27.87	0.000
PDAs	$30.80	24	$25.04	1,757	0.021	29.10	0.000
Hard Drives	$34.75	36	$16.95	6,916	0.023	25.38	0.000
DVD Players	$73.51	56	$28.68	1,537	0.166	24.24	0.000
PC Monitors	$112.24	64	$29.31	5,895	0.139	37.98	0.000
Digital Cameras	$83.74	139	$37.24	3,731	0.110	30.75	0.000
Notebook PCs	$144.12	17	$94.73	638	0.063	19.60	0.000
Total	$70.56	407	$16.87	40,627	0.106	70.33	0.000
Average	$63.90		$25.64				
Median	$54.10		$20.00				

Note: Categories with unsupportive results are indicated by * and *italic*. **Corr.** is the correlation between 9-ending prices and the size of price change. ***p*-Value** is a significance level derived from a paired-sample t-test. Cross-category paired t-tests showed that the price changes are of a larger magnitude when prices end with 9 ($t_7 = 3.390$, $p = .006$).

Figure 1. Frequency Distribution of the Last Digit in the Dominick's Data

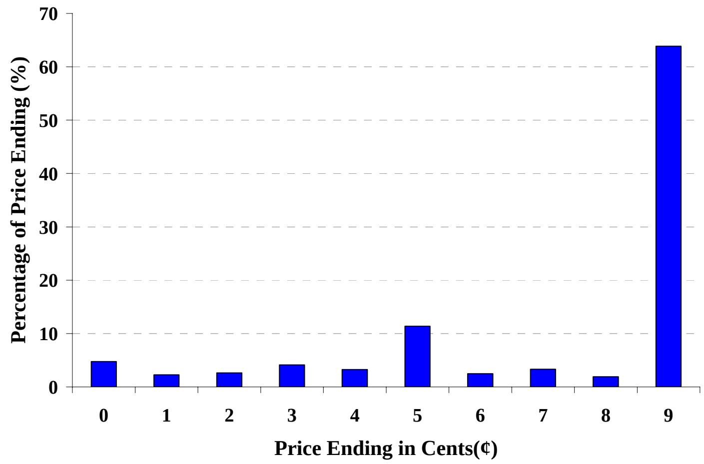


Figure 2. Frequency Distribution of the Last Two Digits in the Dominick's Data

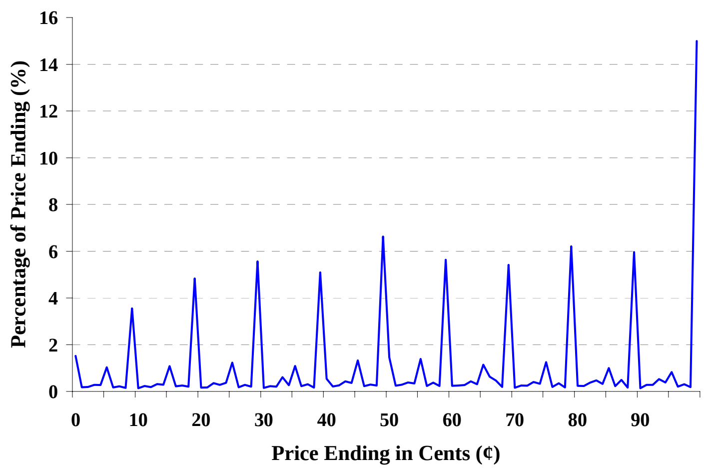


Figure 3. Frequency Distribution of the Last Digit in the Internet Data

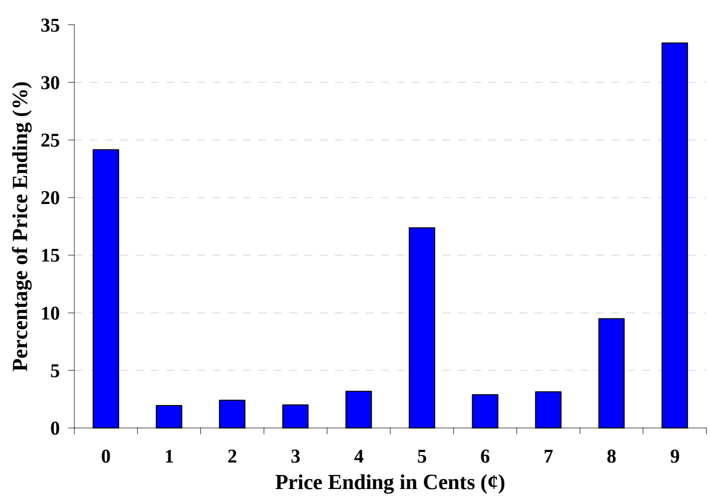


Figure 4. Frequency Distribution of the Last Two Digits in the Internet Data

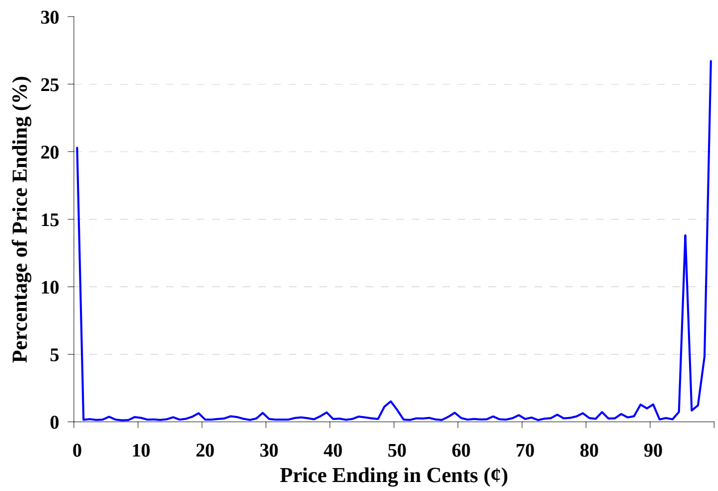


Figure 5. Frequency Distribution of the Last Dollar Digit in the Internet Data

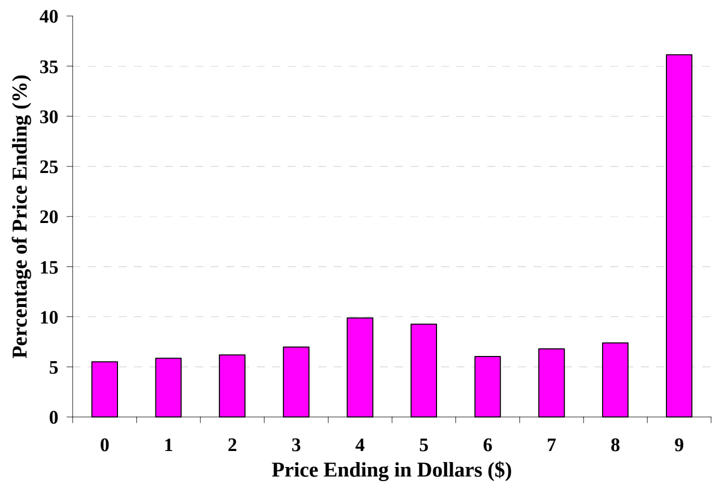


Figure 6. Frequency Distribution of the Last Two Dollar Digits in the Internet Data

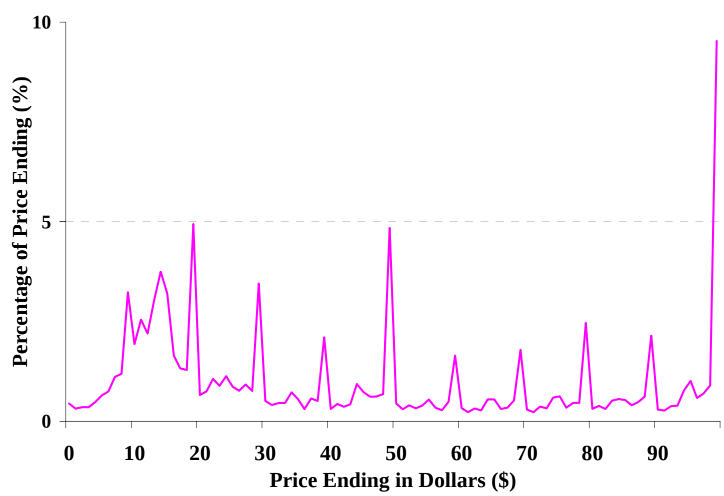


Figure 7. Frequency Distribution of the Price Changes in the Dominick's Data

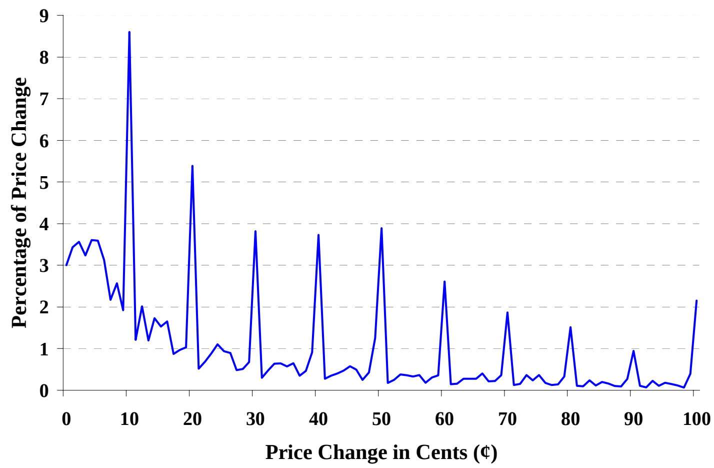


Figure 8. Price of Frozen Concentrate Orange Juice, Heritage House, 12 oz (UPC = 3828190029, Store No. 78), September 14, 1989 – May 8, 1997

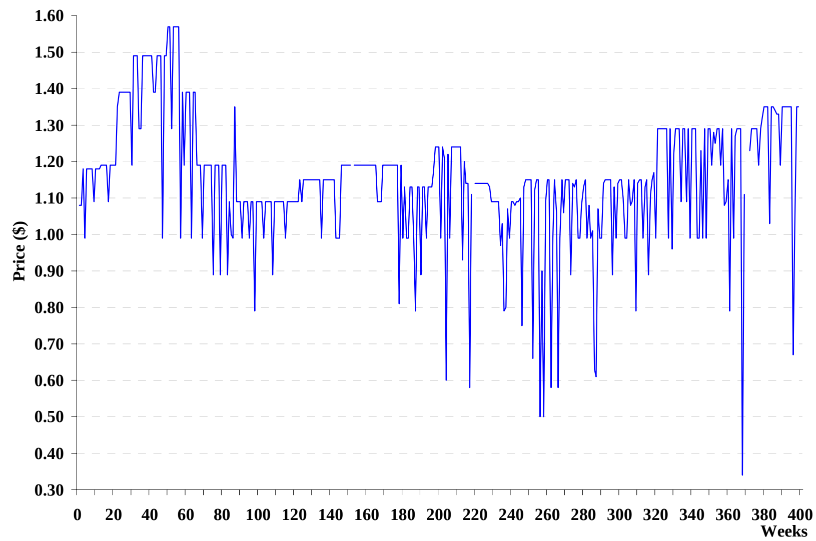
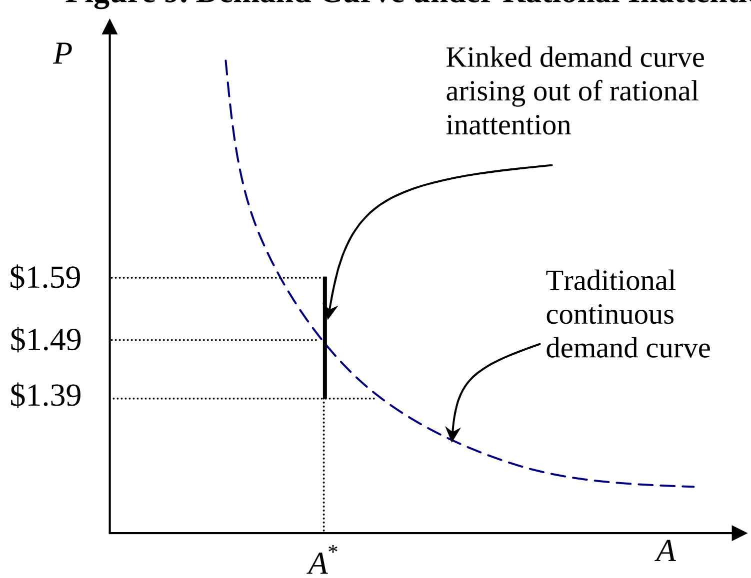


Figure 9. Demand Curve under Rational Inattention



Reviewer's Appendix

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A. Results on Price Endings for Individual Product Categories in Dominick's and Internet Data

Similar to the aggregate results reported in the paper, the following figures show that 9¢ and 99¢ are the most popular price-endings for most of the individual product categories in both Dominick's data and our Internet data.

B. Results on Price Changes for Individual Product Categories in Dominick's Data

Similar to the aggregate results reported in the paper and the results for individual product categories in our Internet data in Table 5, the following figures show that price changes in multiples of dimes are most common among all price changes in Dominick's data.

C. Sample Price Series for Our Internet data

The following figures provide sample price series for ten randomly selected products, one from each of the ten product categories in our Internet data. All data are for 743 days in the period from March 26, 2005 to April 15, 2005.

Figure R1a. Frequency Distribution of the Last Digit by Product Category - Dominick's

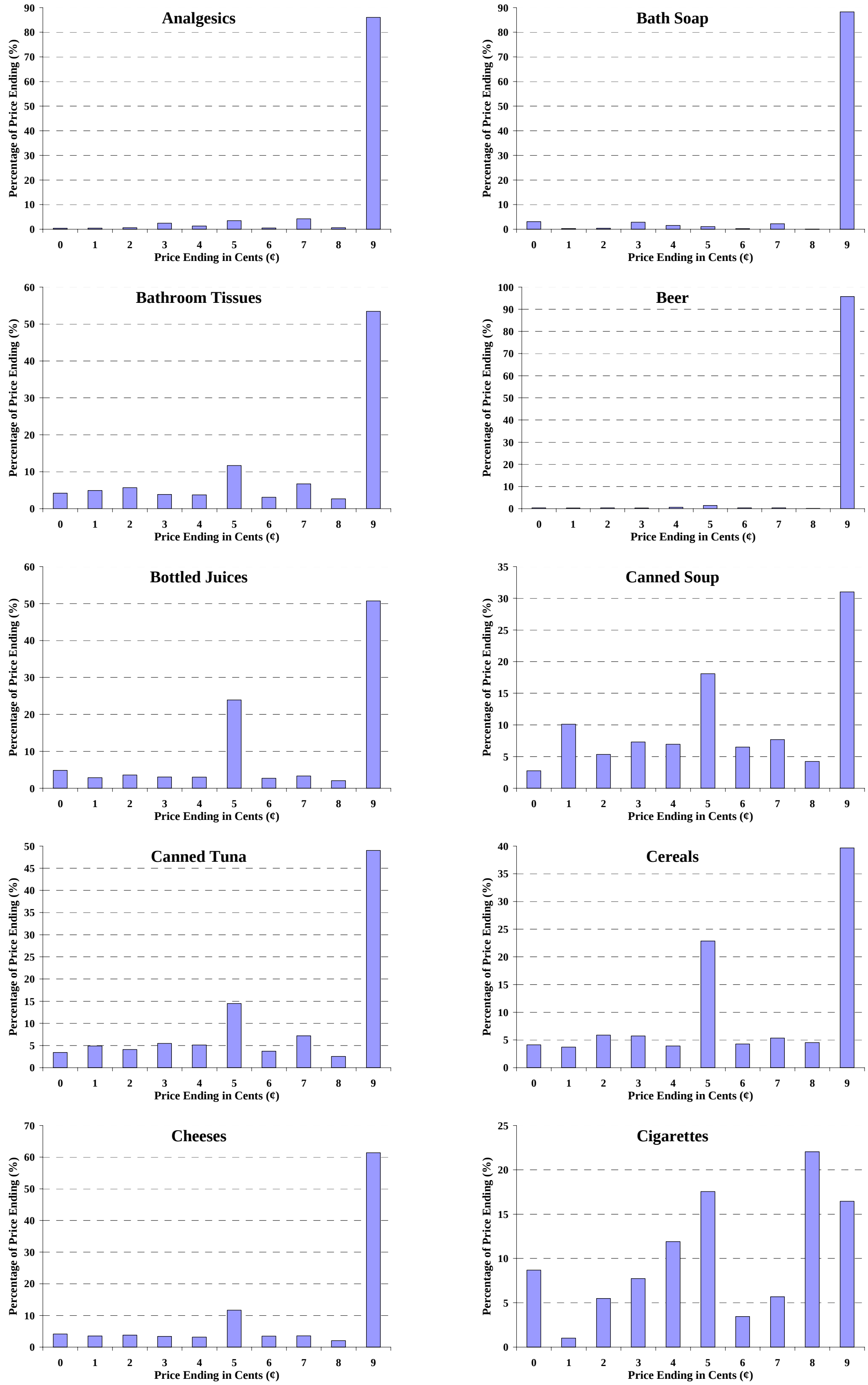


Figure R1b. Frequency Distribution of the Last Digit by Product Category - Dominick's

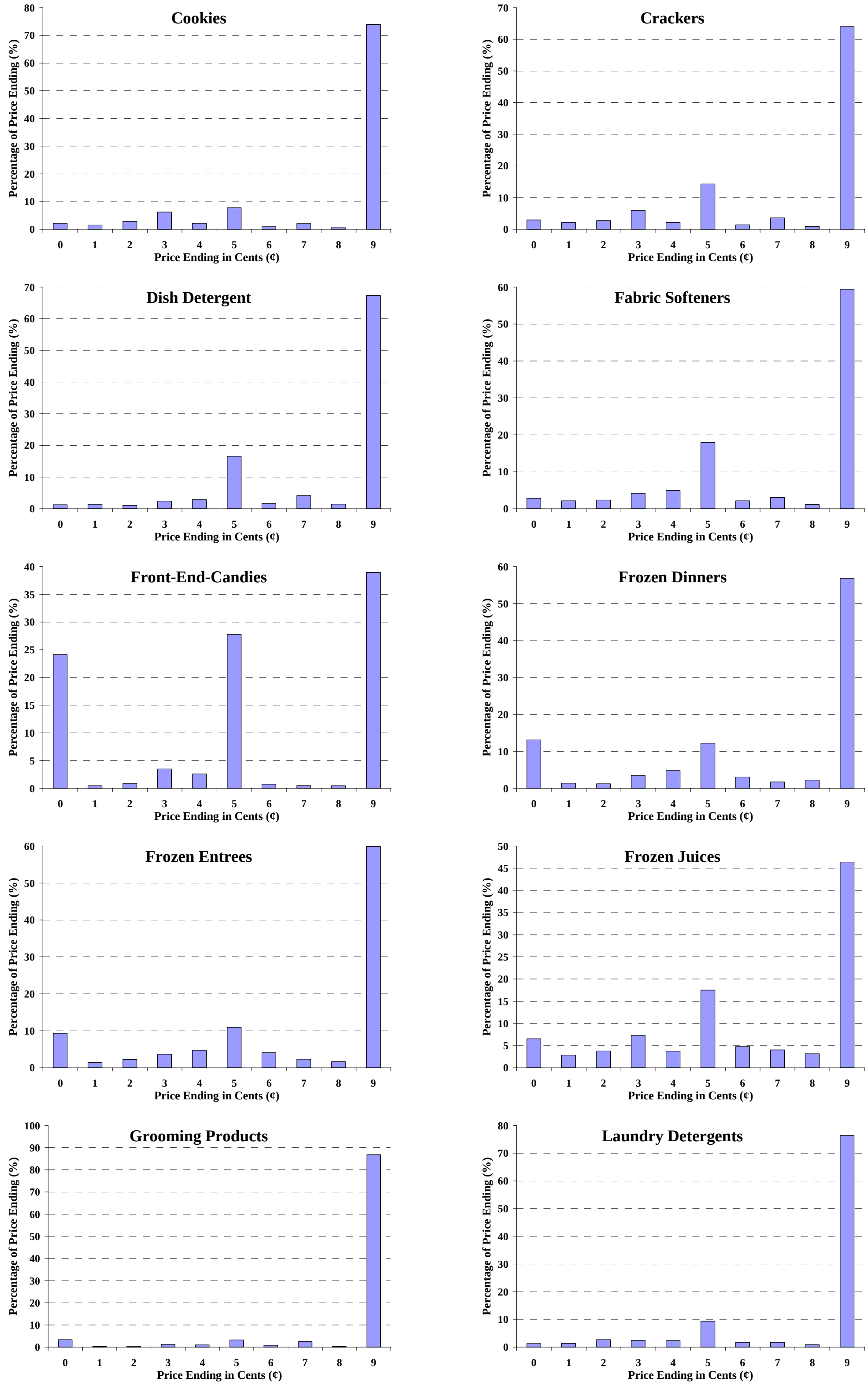


Figure R1c. Frequency Distribution of the Last Digit by Product Category - Dominick's

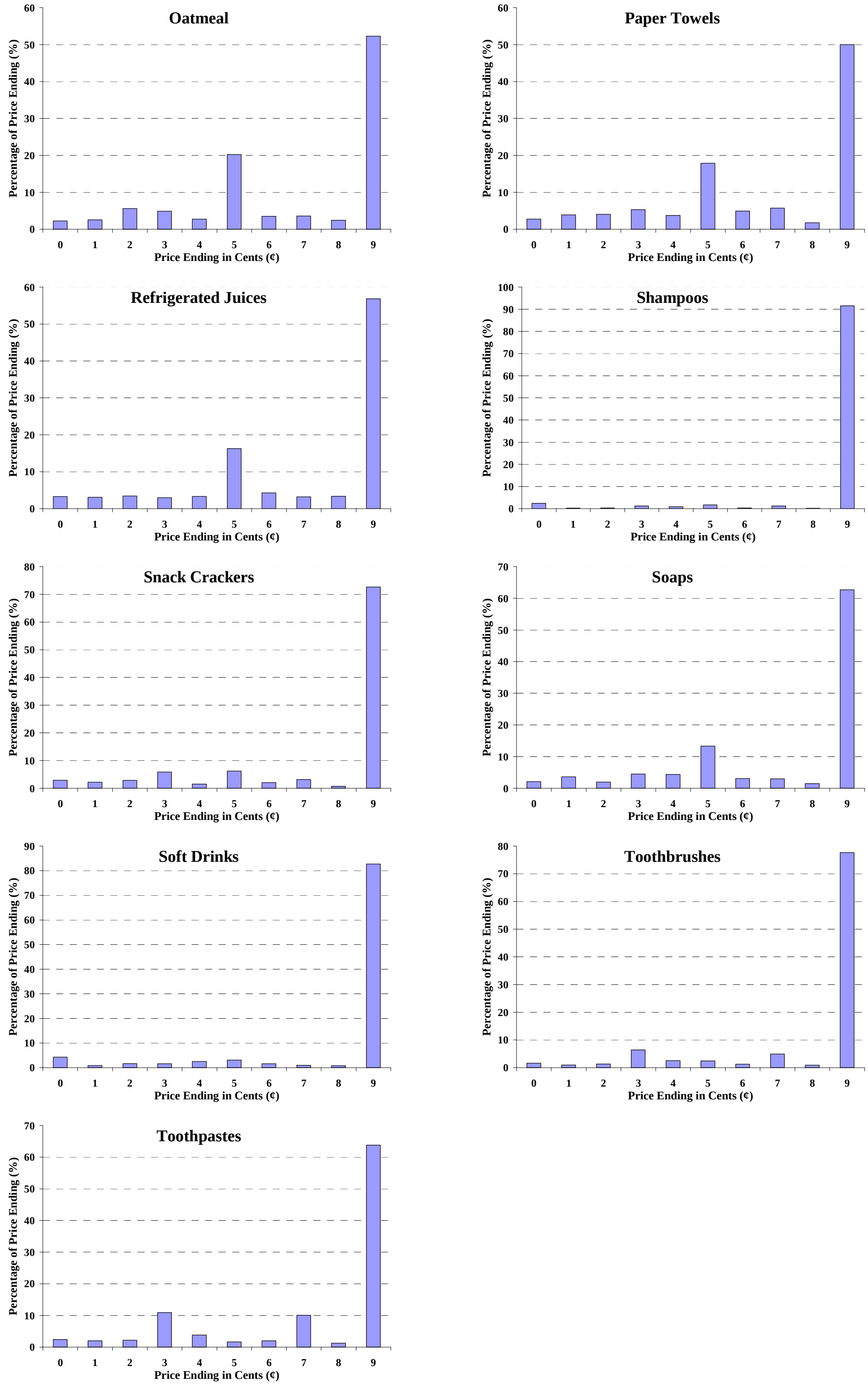


Figure R2a. Frequency Distribution of the Last Two Digits by Product Category - Dominick's

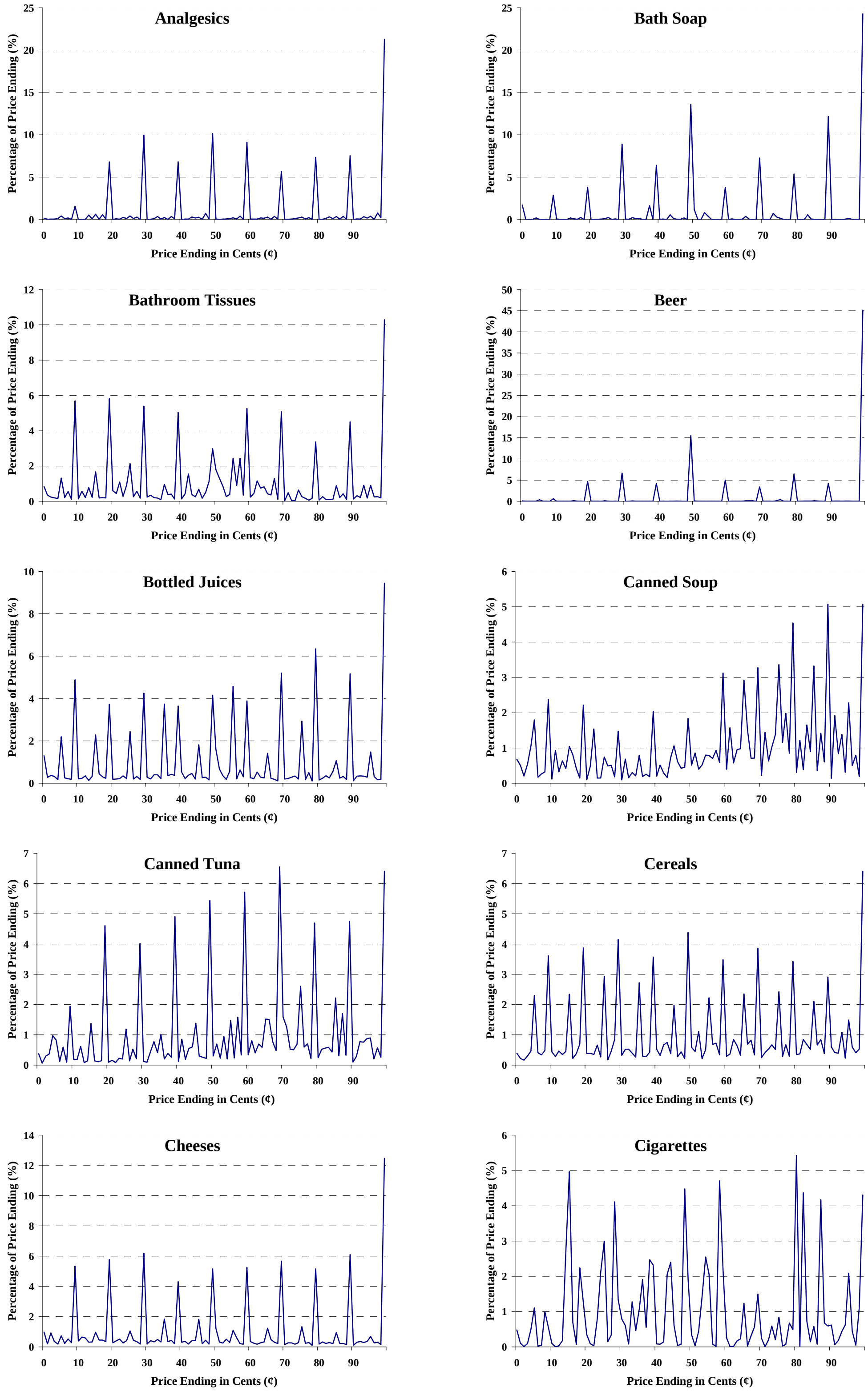


Figure R2b. Frequency Distribution of the Last Two Digits by Product Category - Dominick's

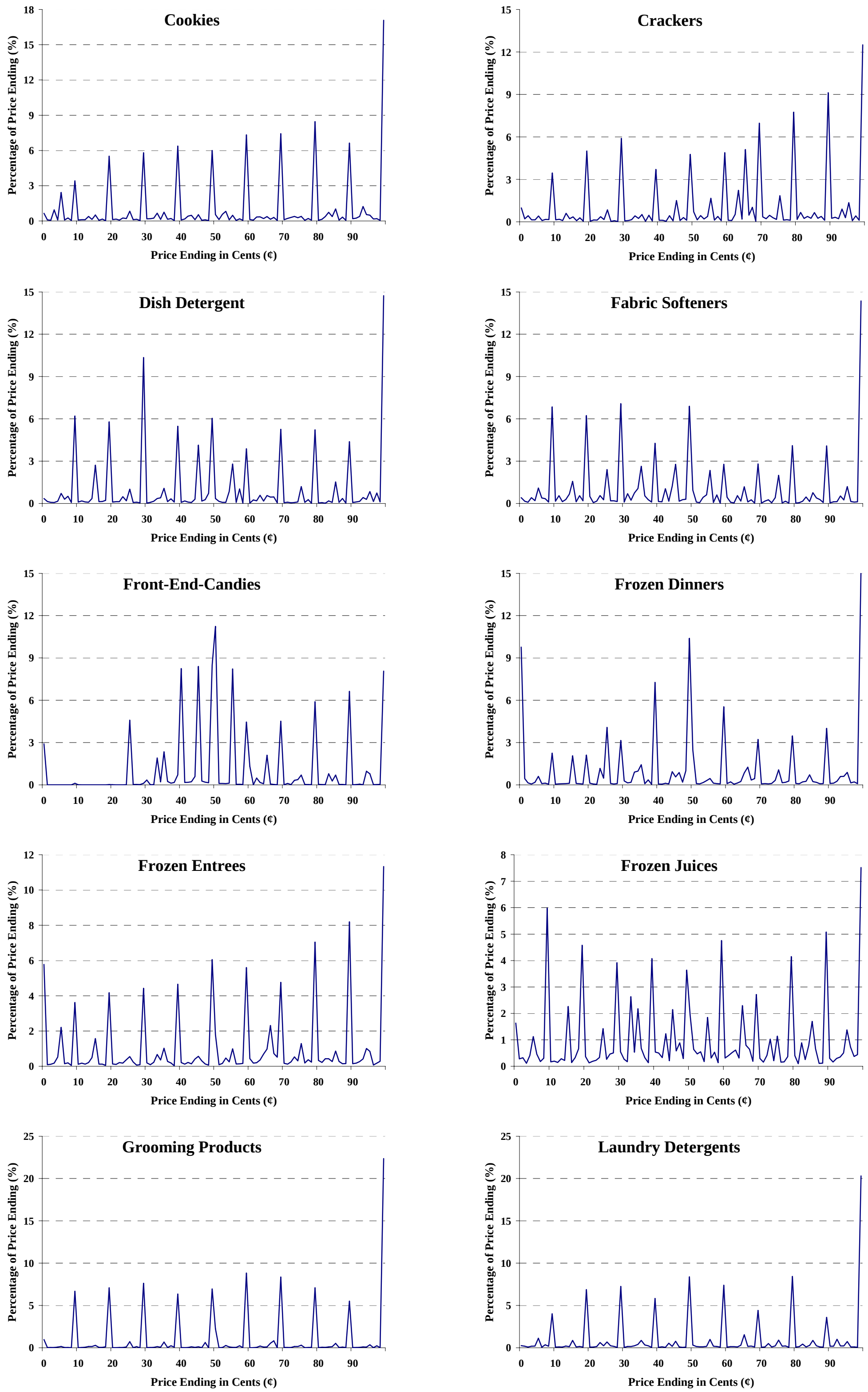


Figure R2c. Frequency Distribution of the Last Two Digits by Product Category - Dominick's

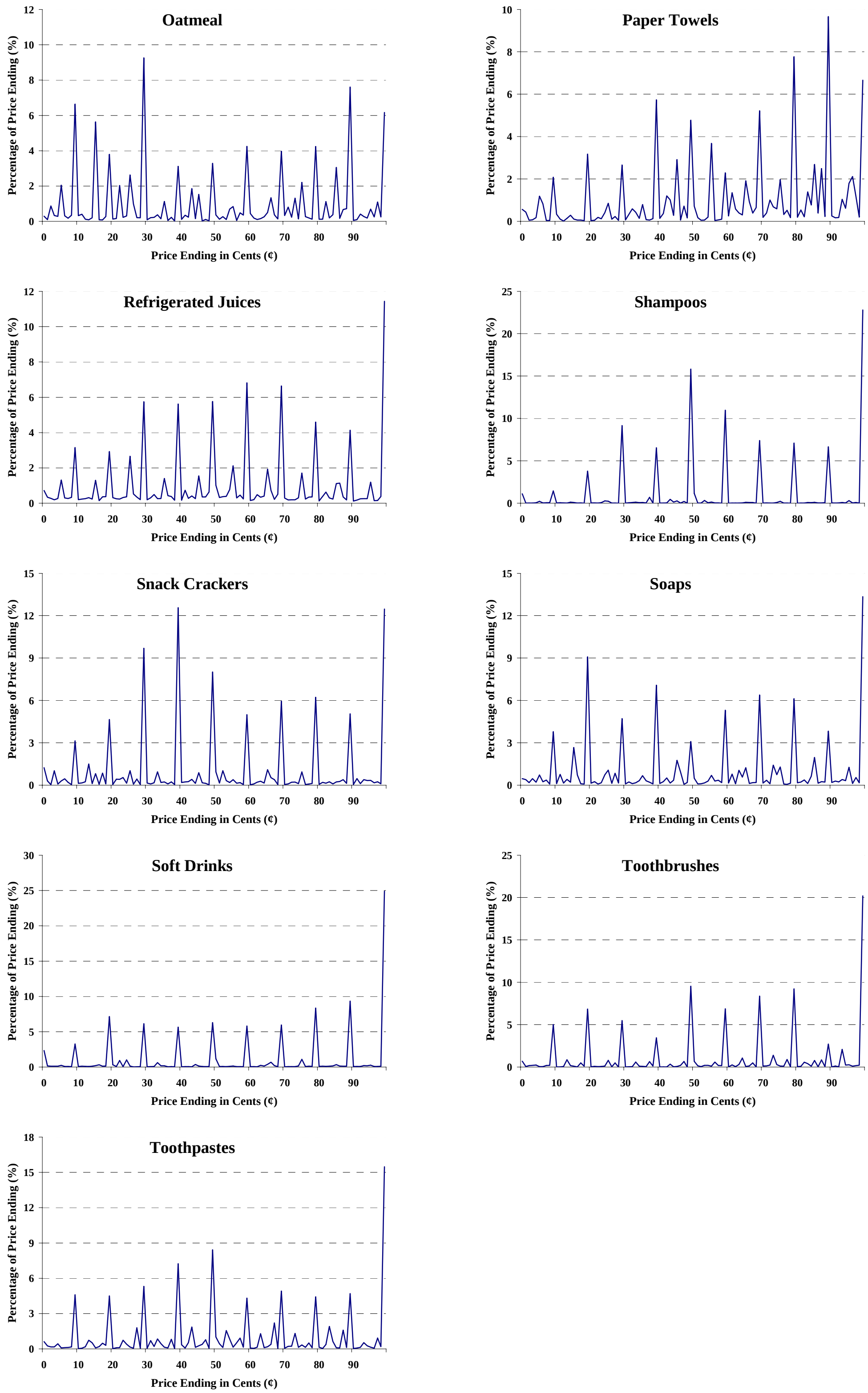


Figure R3. Frequency Distribution of the Last Digit by Product Category - Internet Data

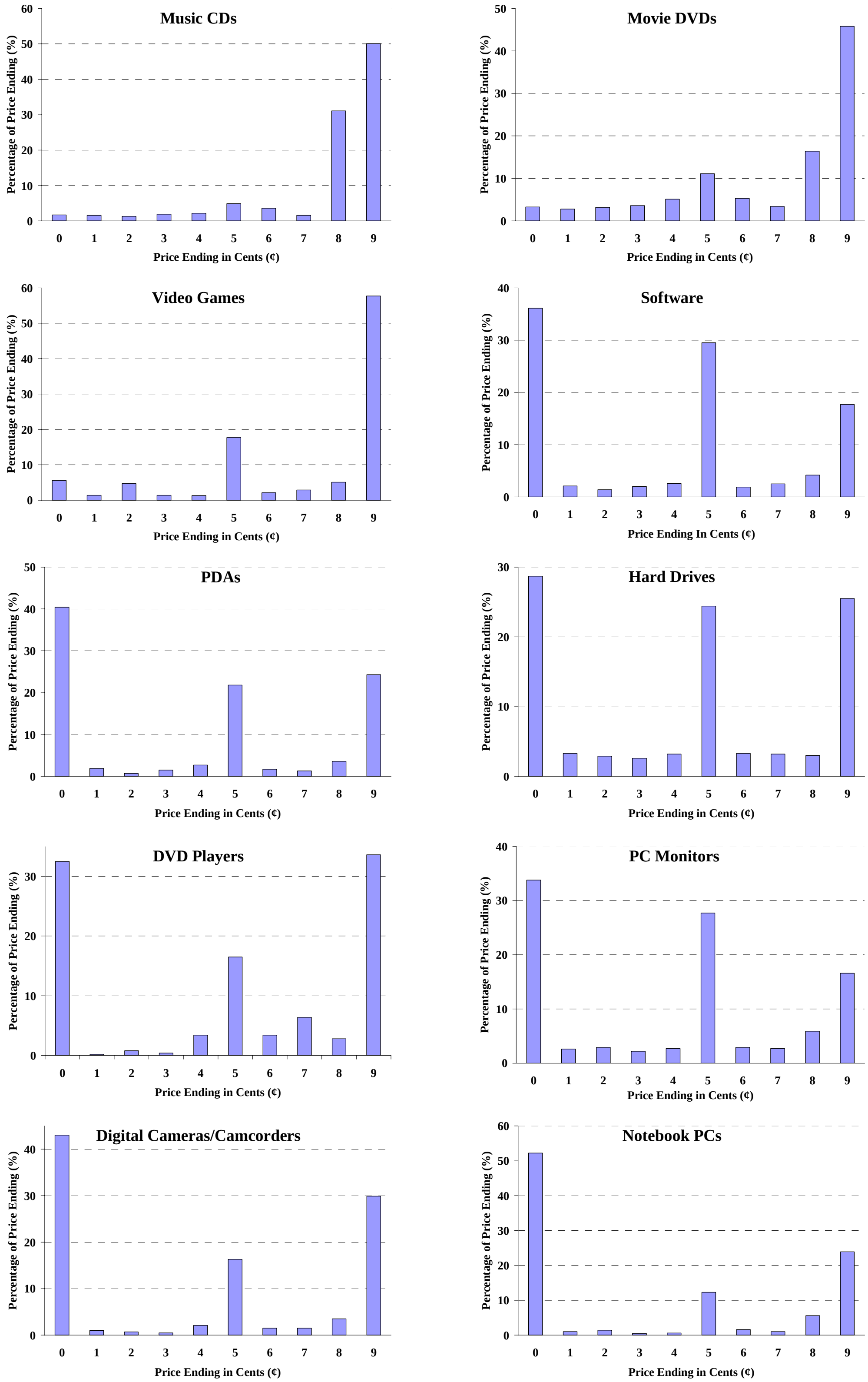


Figure R4. Frequency Distribution of the Last Two Digits by Product Category - Internet Data

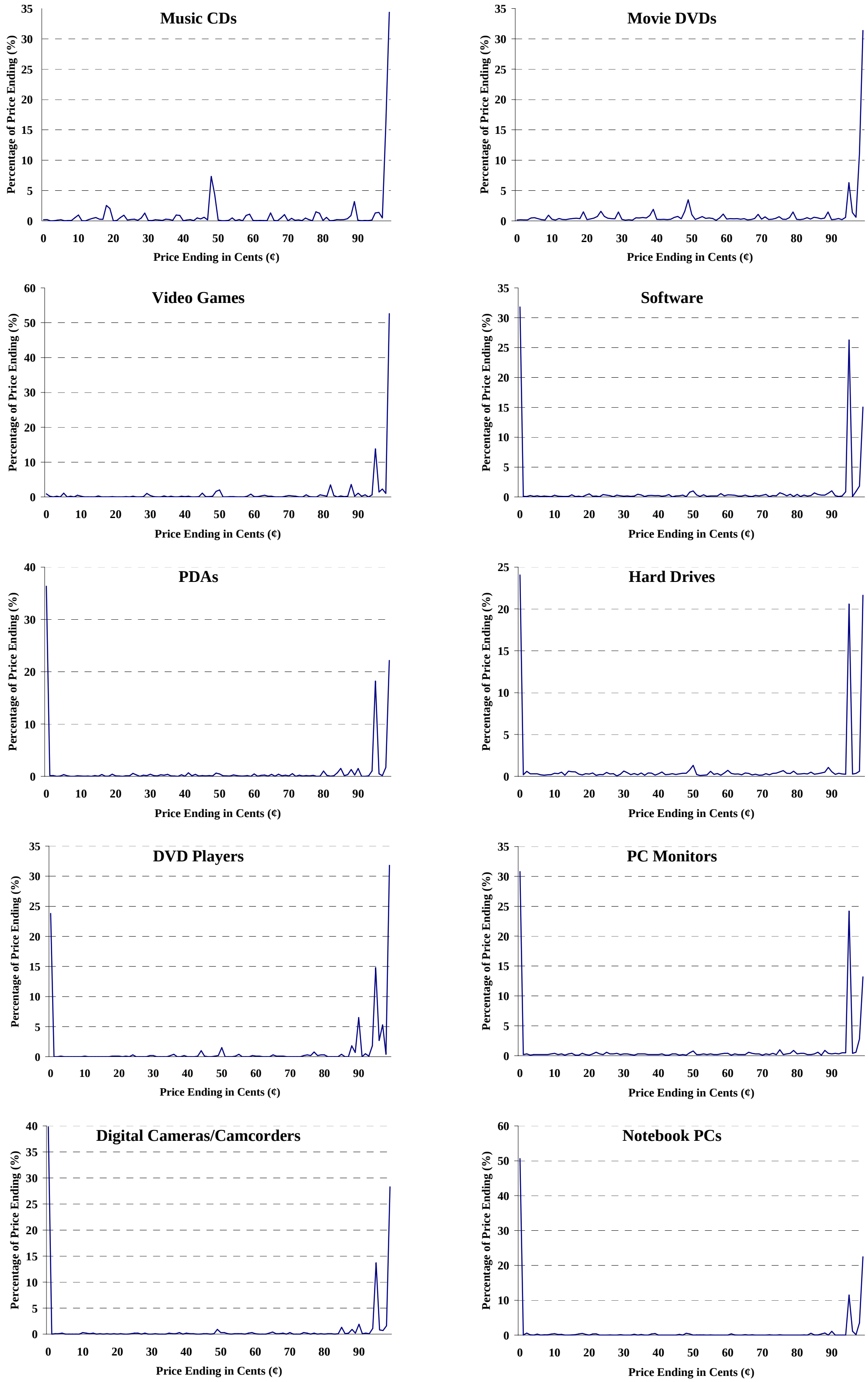


Figure R5. Frequency Distribution of the Last Dollar Digit by Product Category - Internet Data

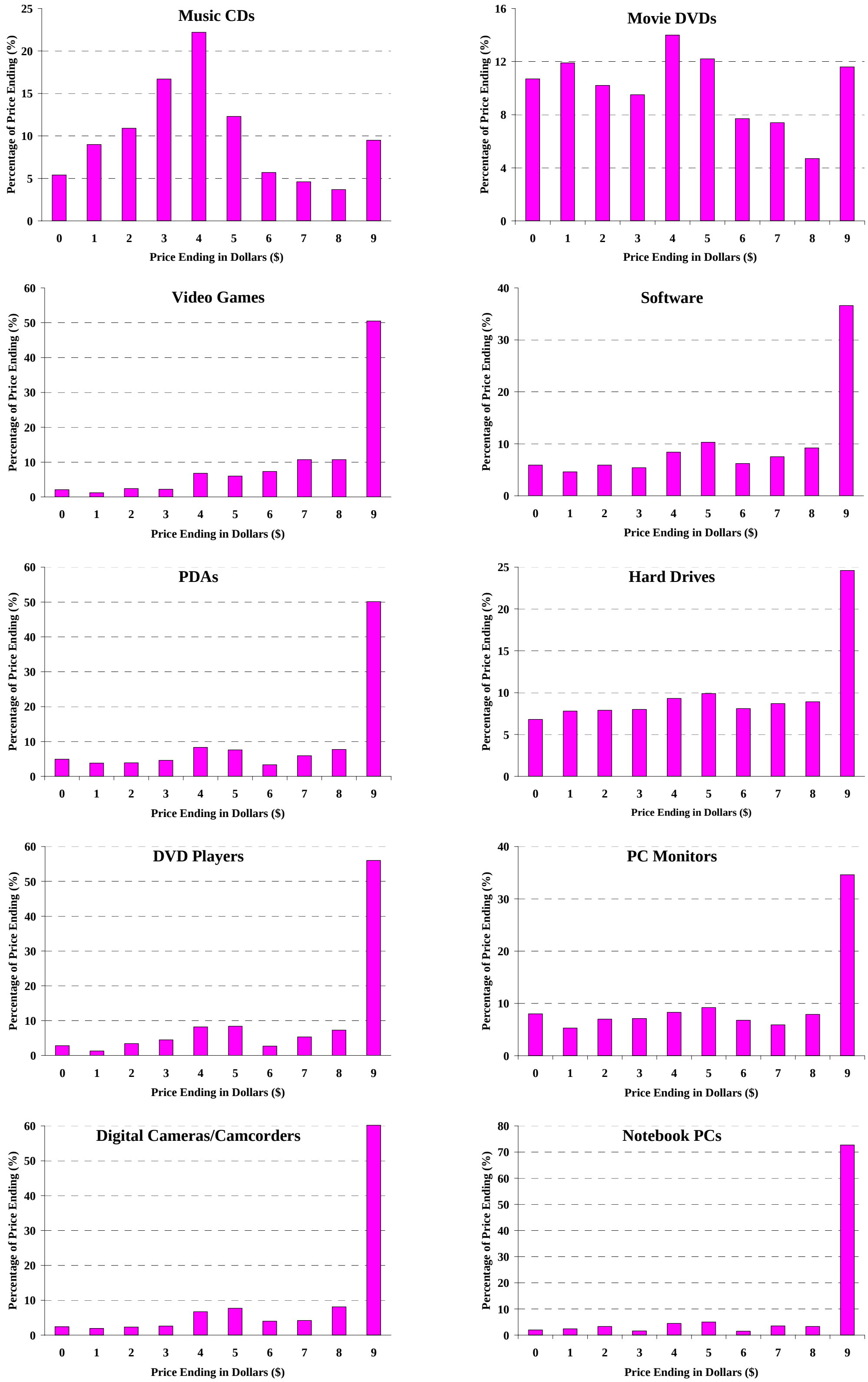


Figure R6. Frequency Distribution of the Last Two Dollar Digits by Product Category - Internet Data

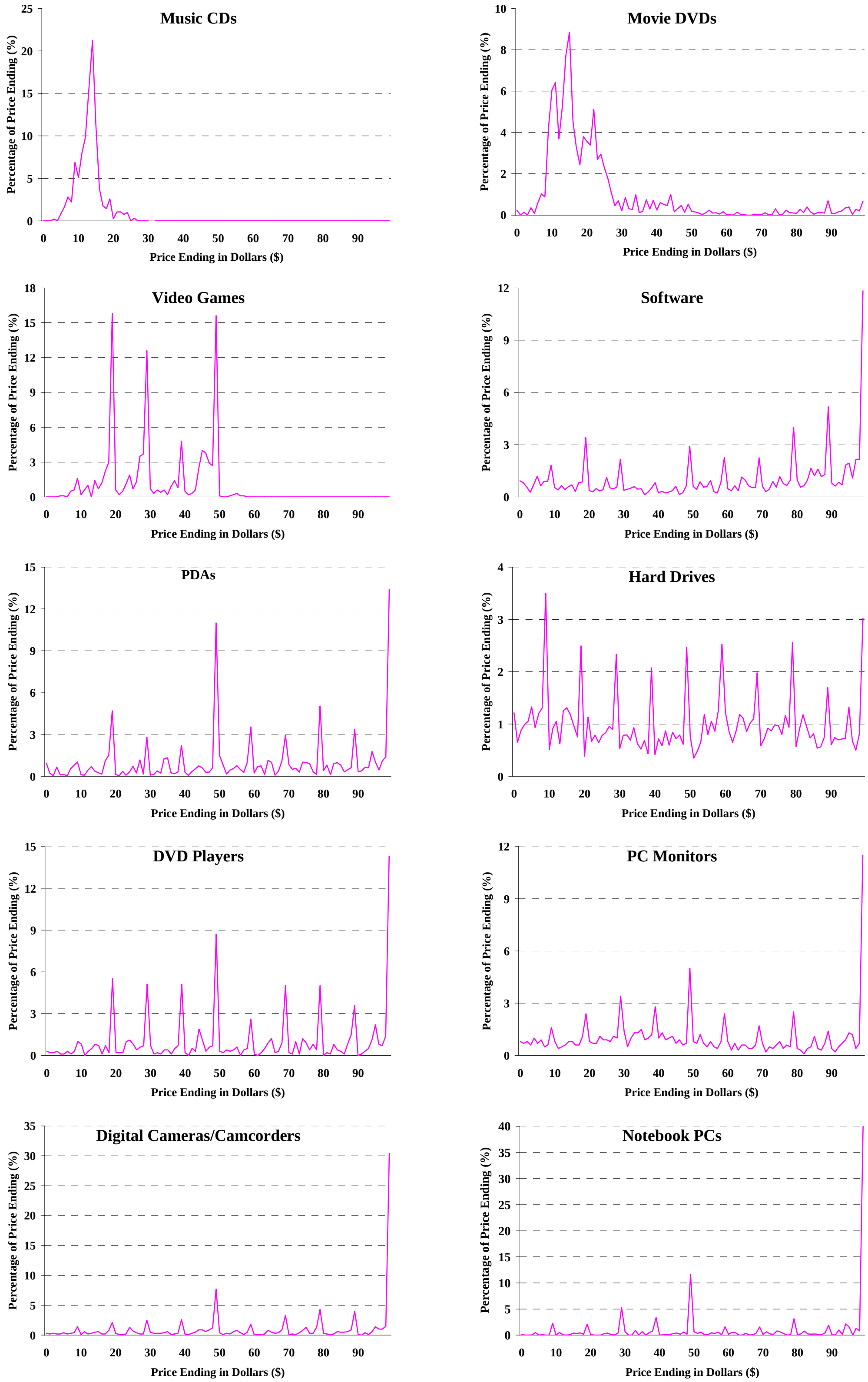


Figure R7a. Frequency Distribution of the Price Changes by Category - Dominick’s

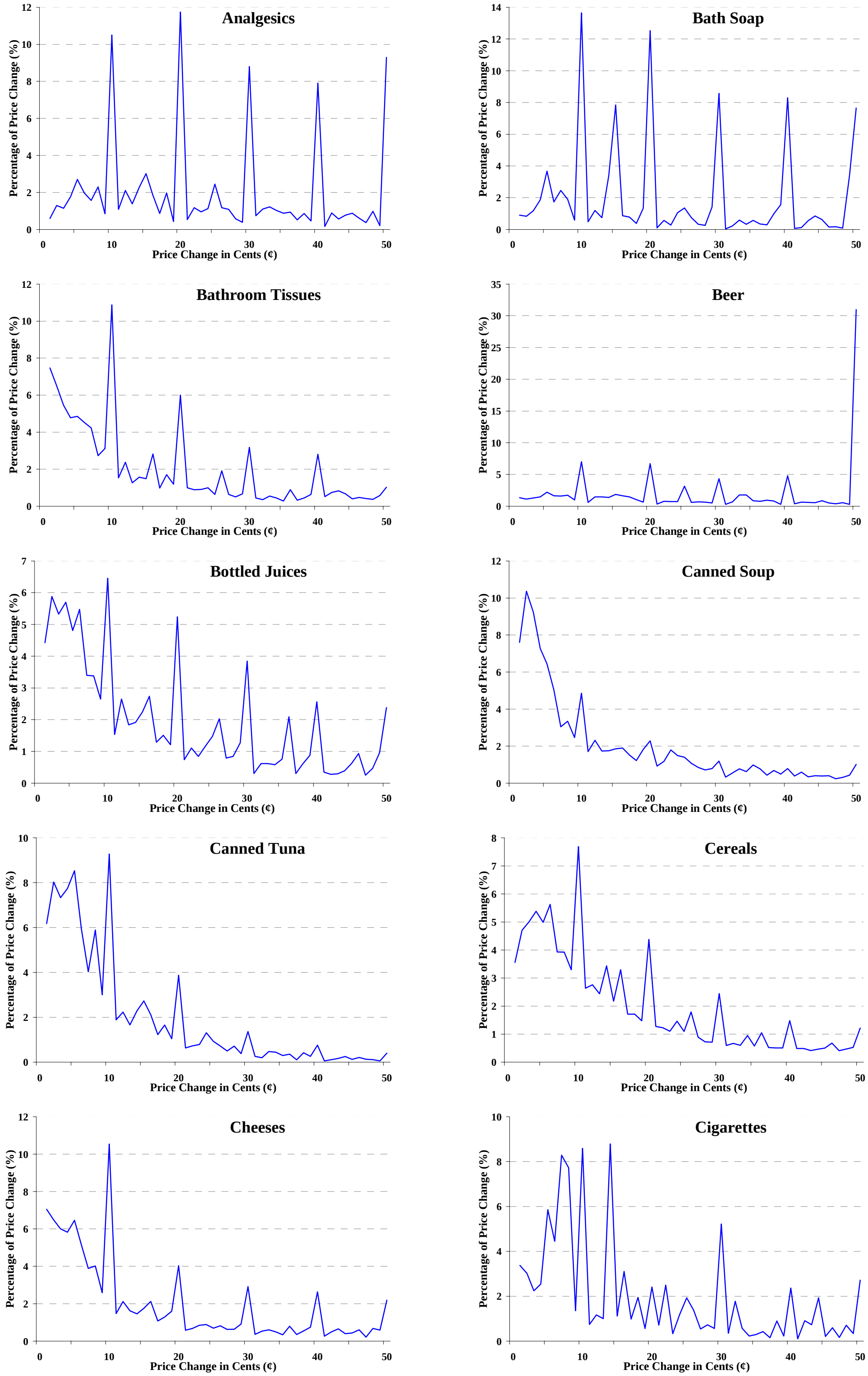


Figure R7b. Frequency Distribution of the Price Changes by Category - Dominick's

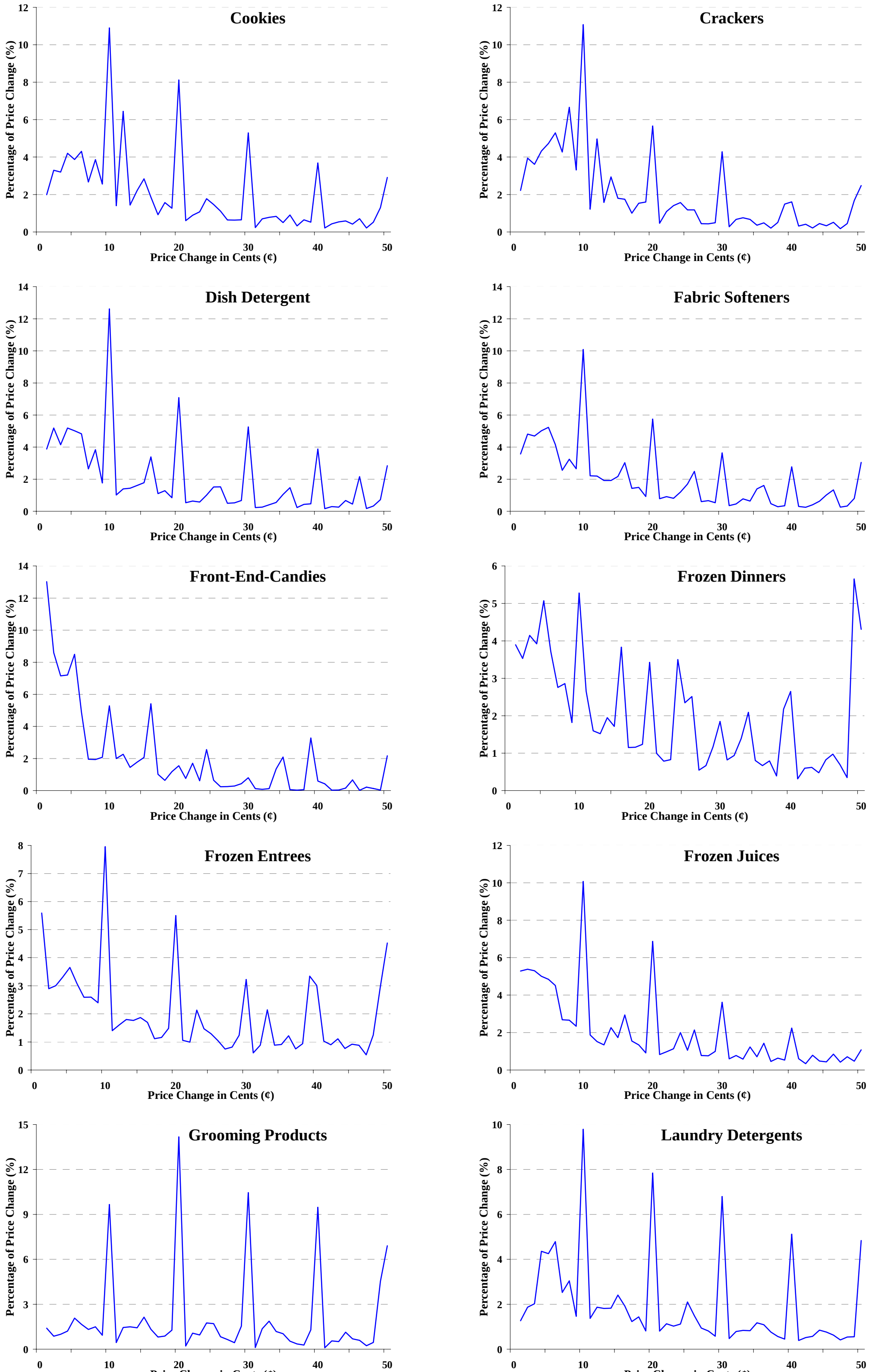


Figure R7c. Frequency Distribution of the Price Changes by Category - Dominick's

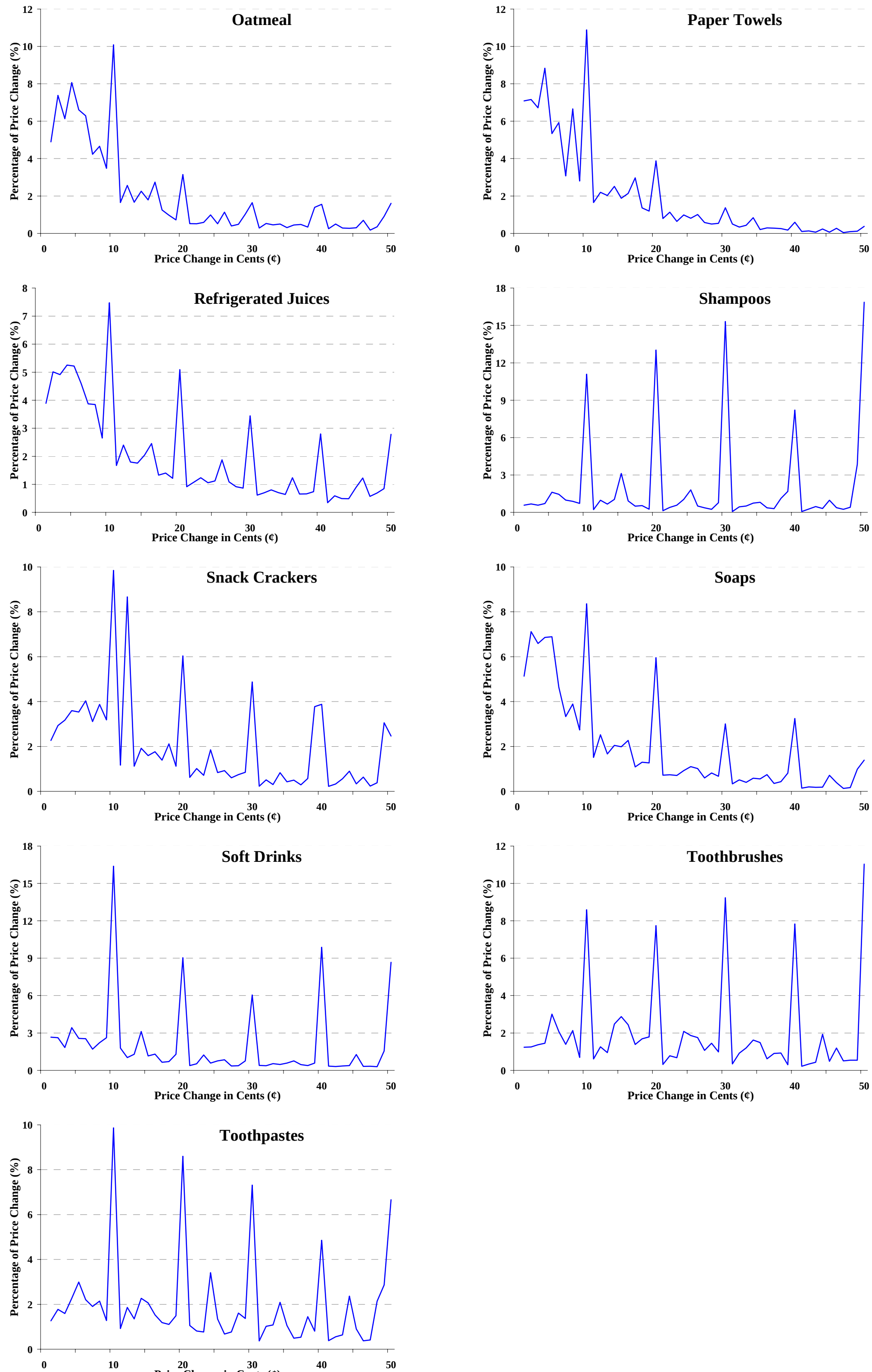


Figure R8a. Price of a CD (Product #3, Store #194)
743 Days (March 26, 2003 –April 15, 2005)

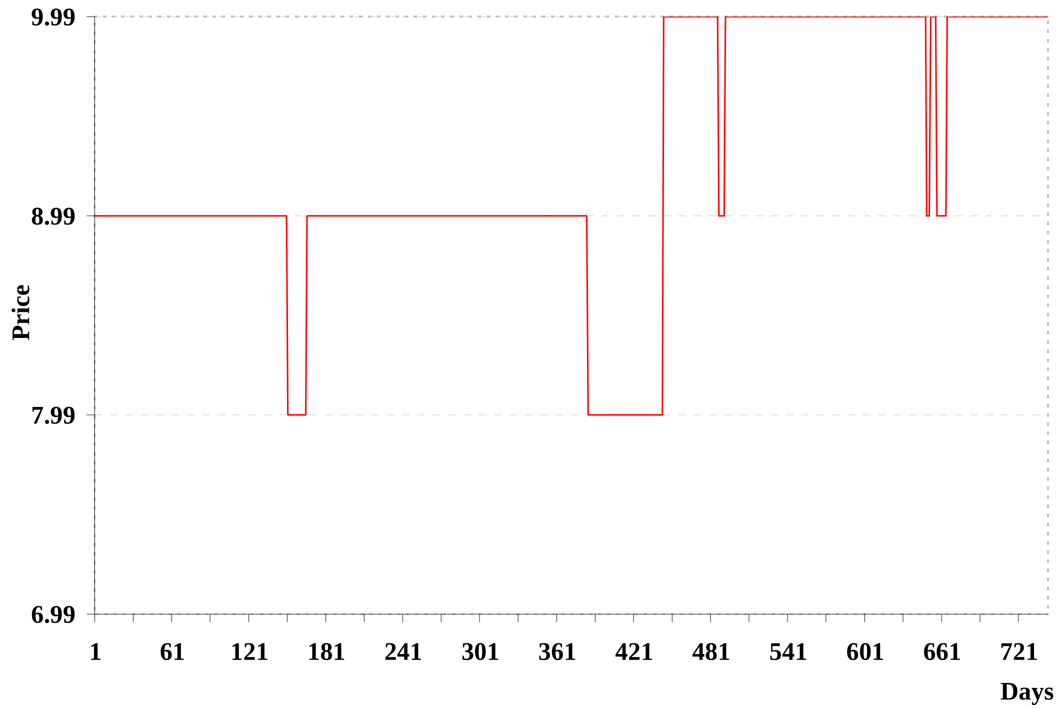


Figure R8b. Price of a DVD (Product #23, Store #194)
743 Days (March 26, 2003 – April 15, 2005)

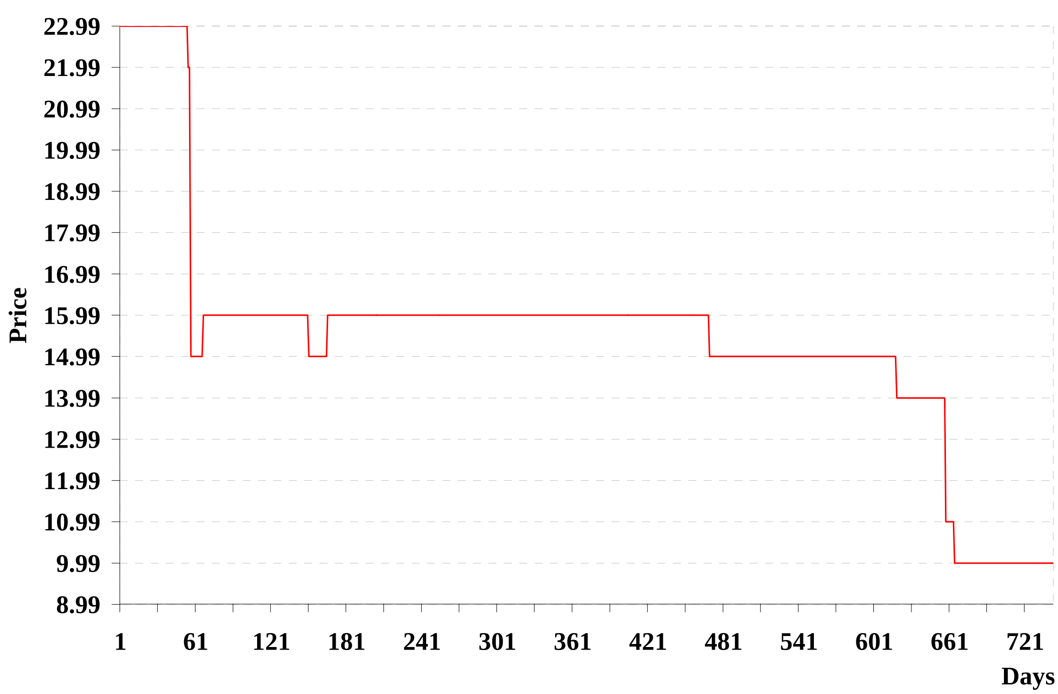


Figure R8c. Price of a Notebook PC (Product #422, Store #258)
743 Days (March 26, 2003 – April 15, 2005)

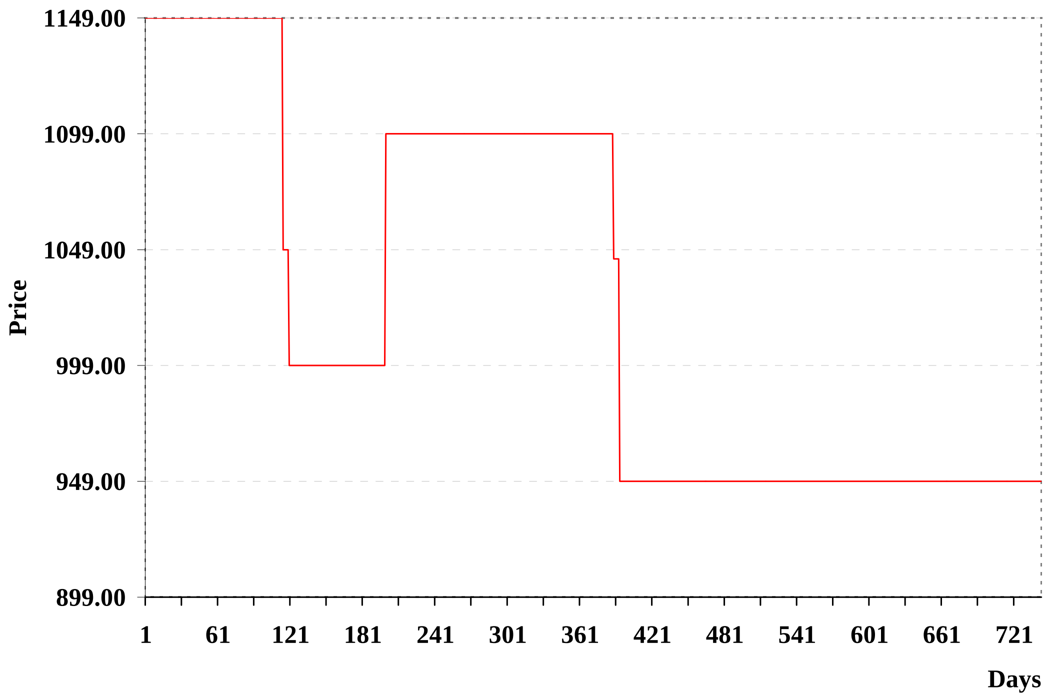


Figure R8d. Price of a Hard Drive (Product #71, Store #324)
743 Days (March 26, 2003 – April 15, 2005)

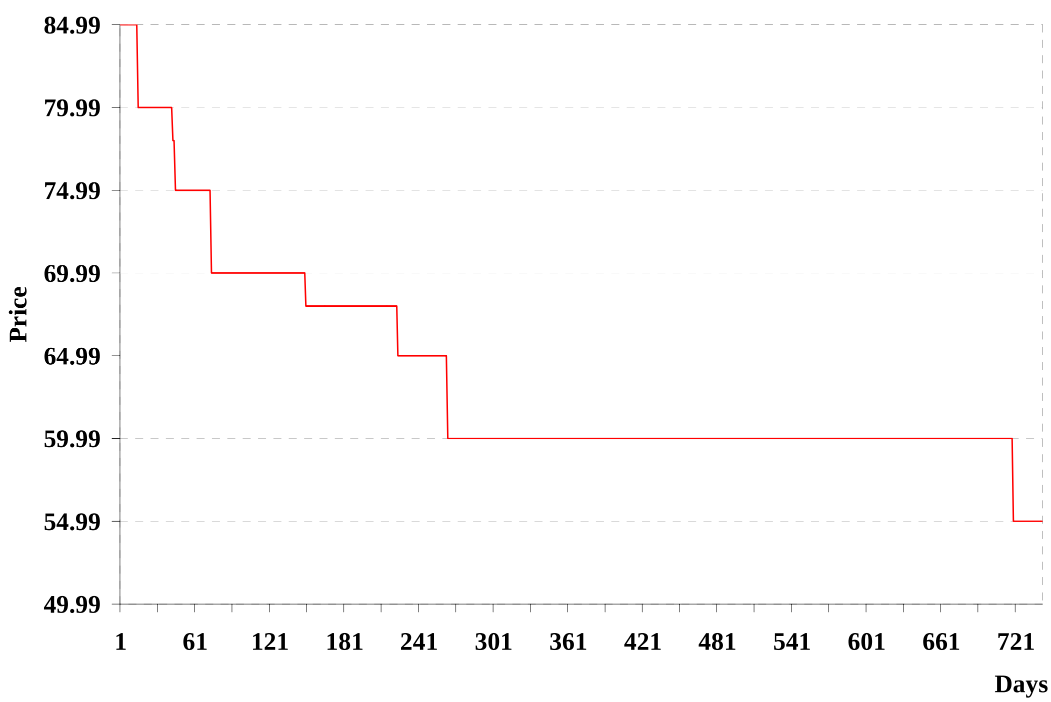


Figure R8e. Price of a DVD Player (Product #262, Store #230)
743 Days (March 26, 2003 – April 15, 2005)

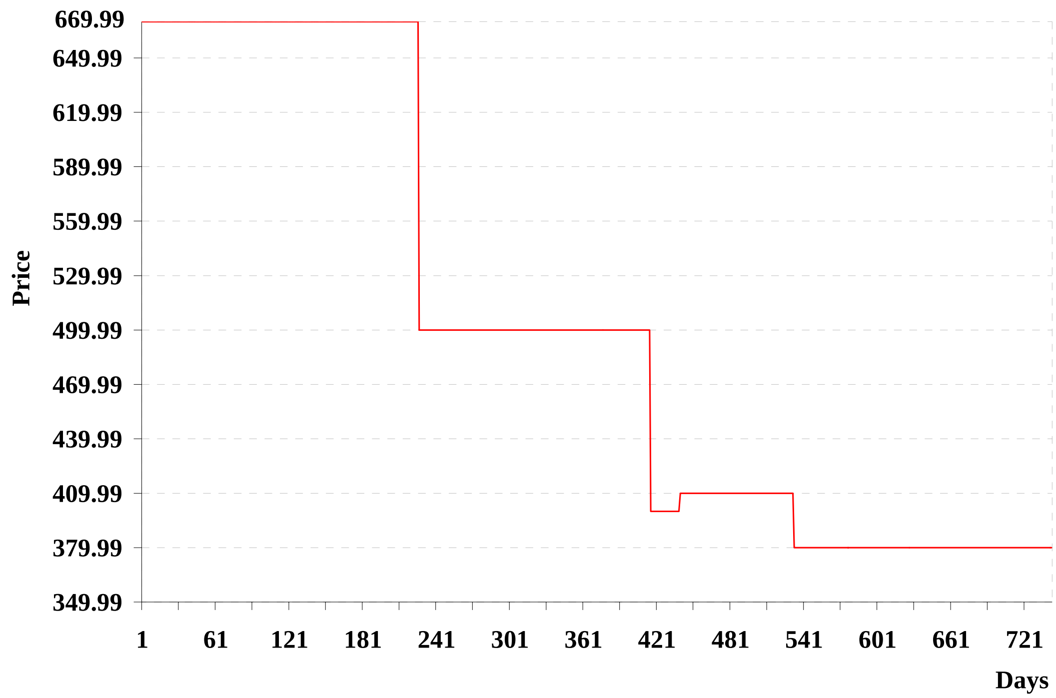


Figure R8f. Price of a Digital Camera (Product #273, Store #108)
743 Days (March 26, 2003 – April 15, 2005)

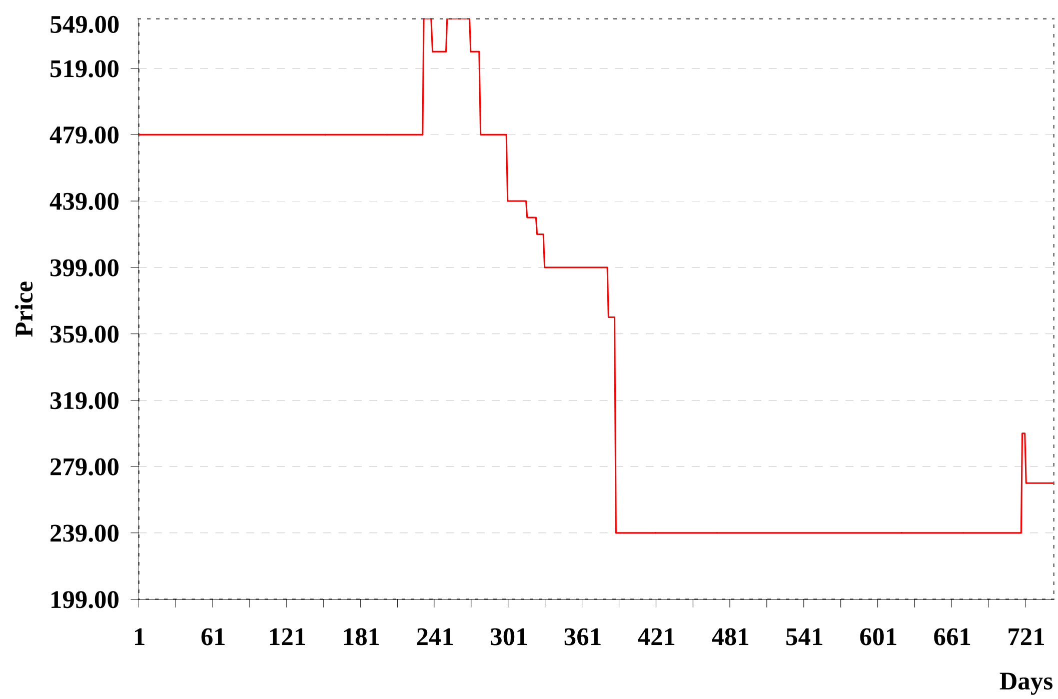


Figure R8g. Price of a PC Monitor (Product #189, Store #17)
743 Days (March 26, 2003 – April 15, 2005)

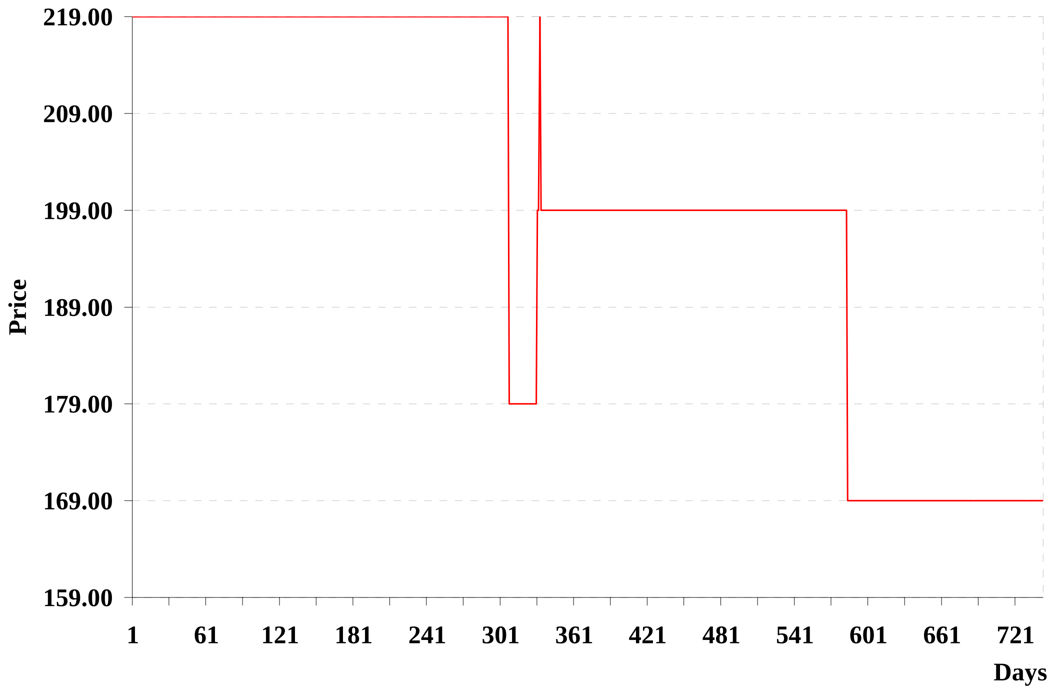


Figure R8h. Price of a PDA (Product #490, Store #207)
743 Days (March 26, 2003 – April 15, 2005)

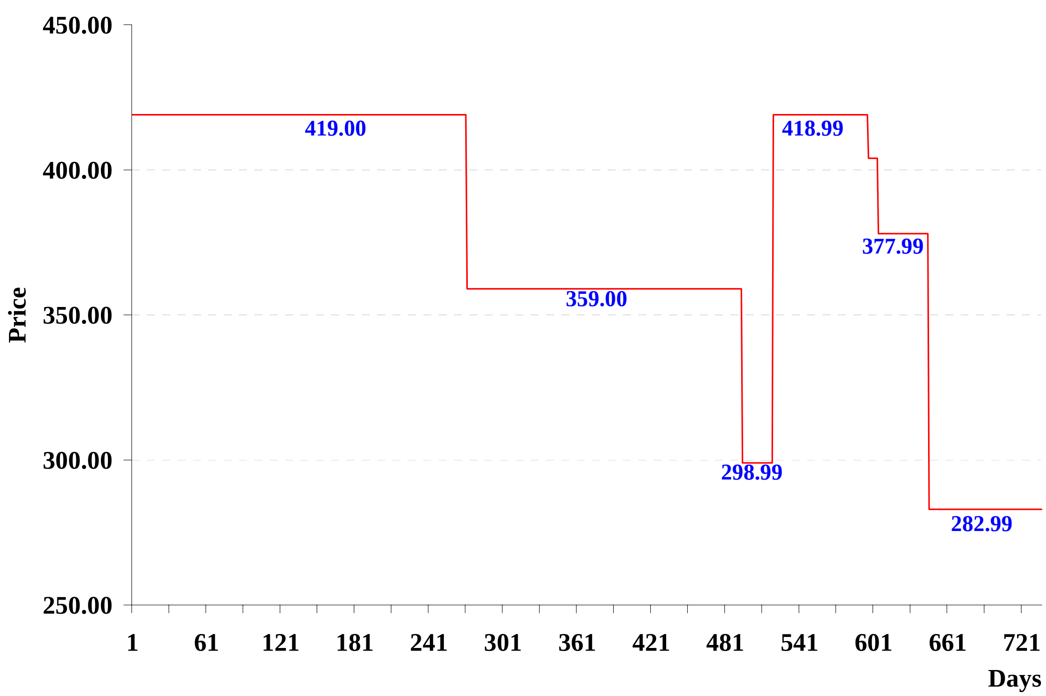
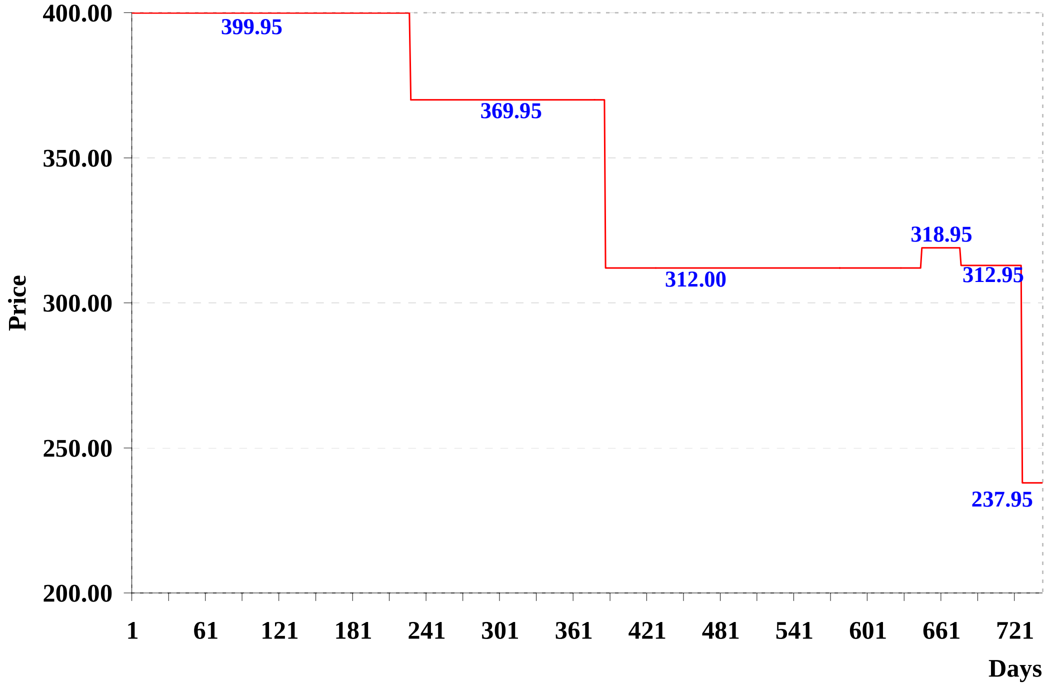


Figure R8i. Price of a Software Product (Product #96, Store #292)
743 Days (March 26, 2003 – April 15, 2005)



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743 Days (March 26, 2003 – April 15, 2005)