Asymmetric Price Adjustment "in the Small:" An Implication of Rational Inattention*

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Abstract

Analyzing scanner price data that cover 27 product categories over an eight-year period from a large Mid-western supermarket chain, we uncover a surprising regularity in the data—small price increases occur more frequently than small price decreases. We find that this asymmetry holds for price changes of up to about 10 cents, on average. The asymmetry disappears for larger price changes. We document this finding for the entire data set, as well as for individual product categories. Further, we find that the asymmetry holds even after excluding from the data the observations pertaining to inflationary periods, and after allowing for various lengths of lagged price adjustment. The findings are insensitive also to the measure of price level used to measure inflation (the PPI or the CPI). To explain these findings, we extend the implications of the literature on rational inattention to individual price dynamics. Specifically, we argue that processing and reacting to price change information is a costly activity. An important implication of rational inattention is that consumers may rationally choose to ignore—and thus not to respond to—small price changes, creating a "range of inattention" along the demand curve. This range of consumer inattention, we argue, gives the retailers incentive for asymmetric price adjustment "in the small." These incentives, however, disappear for large price changes, because large price changes are processed by consumers and therefore trigger their response. Thus, no asymmetry is observed "in the large." An additional implication of rational inattention is that the extent of the asymmetry found **"**in the small**"** might vary over the business cycle: it might diminish during recessions and strengthen during expansions. We find that the data are indeed consistent with these predictions. An added contribution of the paper is that our theory may offer a possible explanation for the presence of small price changes, which has been a long-standing puzzle in the literature.

"In the absence of computation costs, more frequent assessments … might be optimal. However, if reflection about the attitudes of producers is costly, consumers will seek to economise on this type of analysis and will only carry out the required computations when conditions change *noticeably*." (Our emphasis) Julio Rotemberg (2002, p. 5)

"MINNEAPOLIS (AP) – The cost of General Mills cereals such as Wheaties Cheerios, and Total is increasing an average of 2 percent. The price jump averages out to roughly 6 or 7 cents a box for cereals such as Chex, Total Raisin Bran and Total Corn Flakes, … which typically cost around $3 in the Minneapolis area, ... John French, 30, *doubted he would even notice* the higher prices for cereal on his next grocery trip. 'A few cents? Naw, that's no big deal,' said French, of Plymouth, Minn." (Our emphasis)
Associated Press, June 2, 2001, 7:20am ET ("General Mills Hikes Prices")

1. Introduction

Do prices adjust asymmetrically? We often hear about gas prices that seem to be "rising like rockets … [but]… falling like feathers,"[1] or food prices, where "retail pork prices do not come down even if hog prices do,"[2] and "government subsidies to dairy farmers do not lower dairy product prices."[3] There are many studies of asymmetric price adjustment, but as Peltzman (2000) points out, economic theory suggests no pervasive tendency for prices to respond asymmetrically. Indeed, we find that the existing literature offers only a handful of theoretical explanations for asymmetric price adjustment. Empirically, asymmetric price adjustment has been studied mostly with individual or industry level data.[4] Studies that use more macro data are scarcer. See Ball and Mankiw (1994) for a recent example of the latter.

This paper contributes to the literature on asymmetric price adjustment in five ways. First, using a large weekly scanner price data from a major US supermarket chain, we uncover a surprising regularity in the data—there are more small price increases than decreases. This asymmetry "in the small" is found for price changes of up to about 10 cents, on average. The asymmetry disappears for larger price changes.

Second, we explore the literature on asymmetric price adjustment and find that the only theory that can explain our findings is a menu cost model under inflation (Tsiddon, 1993; Ball and Mankiw, 1994). If firms must incur a cost to change their prices then during inflationary periods they will make more price increases than decreases because of the expected inflation. Moreover, these asymmetric incentives may be stronger for small changes. We, however, rule out this theory as a main explanation because our findings hold even after excluding the observations pertaining to inflationary periods. Moreover, the findings we report appear insensitive to the inflation measure used (PPI or two alternative measures of CPI). Analyses of the individual products whose prices have declined during the sample period and thus are free from any inflationary trend, further confirm these findings.

Third, we extend the theory of rational inattention to individual price dynamics to explain the findings. We demonstrate that asymmetric price adjustment "in the small" follows naturally from consumers' "rational inattention." We argue that processing price change information and responding to it is a costly activity. If these costs exceed the benefits, then consumers may rationally choose to be

[1] *Octane*, Vol. 13, No. 3, June 1999, pp. 6–7.
[2] *The New York Times*, January 7, 1999, "The Great Pork Gap: Hog Prices Have Plummeted, Why Haven't Store Prices?"
[3] *Canadian Press Newswire*, December 18, 2000.
[4] See Meyer and Cramon-Taubadel (2004) for a recent survey.

inattentive to such price change information and therefore, not react to it. Thus, in a “small region” around the current price, customers might rationally choose to ignore price changes, making demand less elastic for those small price changes.

For the retailer, consumers’ rational inattention to small price changes makes small price *decreases* less valuable because the consumers do not "notice" them and thus do not respond by increasing the quantity they purchase. However, consumers’ rational inattention to small price changes makes small price *increases* more valuable to the retailer, also because the consumers do not "notice" them, and thus do not respond by purchasing less. Thus, the retailer has incentive to make more frequent small price increases than decreases. The idea of consumer inattention, however, is limited to small price changes. A large price change will have more significant consequences for consumers, and therefore, they will be attentive to large price changes, prompting them to adjust their behavior accordingly. The price setters, therefore, will have no incentive to make asymmetric price adjustments “in the large.”

Fourth, we consider another implication of rational inattention and examine its empirical validity. The theory of rational inattention suggests that there might be a variation in the extent of the asymmetry over the business cycle. In situations where consumers have more time and thus a greater opportunity to be attentive, we would expect to see reduced asymmetry. Similarly, in situations where consumers are pressed for time and thus have limited opportunity to be attentive, we would expect to see greater asymmetry. The business cycle might offer an opportunity—a natural experiment—to observe such a variation in the extent of attention/inattention and the resulting variation in the extent of the asymmetry because of the variation in unemployment over the cycle. During high (low) unemployment people have more (less) time available to be attentive, while the value of being attentive to small price changes is higher (lower). Higher unemployment, therefore, should coincide with greater attention and thus with lower asymmetry while lower unemployment would coincide with less attention and thus with greater asymmetry. Our 8-year sample period contains an 8-month recession period, as defined by the NBER, which we exploit for comparing the extent of asymmetry during the highest and the lowest unemployment periods. We find that our data are consistent with these predictions.

The fifth contribution of the paper is that our theory may offer an intriguing explanation for the presence of small price changes, which has been a long-standing puzzle in the literature (Carlton, 1986; Lach and Tsiddon, 1996 and 2005; Kashyap, 1995).

Similar to the rational inattention argument, several recent studies assume departures from full rationality. Akerlof, et al. (2000), relying on psychologists' studies that show that agents often ignore potentially relevant considerations in order to simplify their decisions, assume that when inflation is low, people ignore it when setting wages/prices. Rotemberg (2002) assumes that consumers assess price change decisions according to their fairness. Woodford (2001) and Sims (2003) posit agents with limited information-processing capacity. In Mankiw and Reis (2002) and Ball, et al. (2004), price setters are slow to incorporate macroeconomic information into their decisions. In Reis (2003, 2004), agents face costs of acquiring and processing information and thus update their information and re-compute their optimal plans only sporadically, remaining inattentive in-between the updates. In Gabaix, et al.'s (2003) model, agents allocate their thinking time according to option-value calculations. Caplin, et al. (2003) model absent-minded consumers who do not keep track of their spending.

Models of near rationality offer two advantages. First, departures from full rationality are plausible and consistent with our experience. For example, we all have limited resources to spend on obtaining and processing information and thus treating it as an ordinary, costly good appears plausible. Consistent with this idea, Zbaracki et al. (2004) show that the costs of processing information and setting optimal price plans might be large in real settings. They document the presence of information gathering and processing cost for a price setter. We argue that consumers likely face similar types of costs.

Second, near rationality may account for a wide range of observations. For example, Akerlof, et al.'s (2000) model successfully traces out a range of equilibrium unemployment rates associated with different inflation rates. Rotemberg's (2002) model helps in reconciling two observations: (1) price increases antagonize consumers, but (2) we don't see sharp decreases in purchases in response to price increases. Woodford (2001) and Ball, et al. (2004) study monetary policy and find that their model fits the data well. Sims (2003) finds that his model's predictions fit macro data quite well. Reis (2003, 2004) studies consumption and inflation and reports improvements in the model fit. Caplin, et al. (2003) study consumption and offer novel explanations for the link between spending and credit card use.

The studies listed above all focus on *macroeconomic* implications of rational inattention. We, in contrast, study the implications of rational inattention for *individual price dynamics*. We argue that the amount of information people choose to process depend on both, the cost and the benefit. Thus, the cost of processing and reacting to some information may exceed its benefit. Here that information takes the form of small price changes: agents may rationally choose to ignore them and based on this idea we derive the implications of rational inattention for a price setter, and thus for individual price dynamics.

We proceed as follows. In section 2, we describe the data, followed by the empirical findings in section 3. In section 4, we assess the existing theories. In section 5, we develop the theory of rational inattention. In section 6, we study the variation in rational inattention over the business cycle. Section 7 concludes and offers some caveats. In the appendix we formalize our arguments by offering two examples of a simple optimization model with rational inattention, which generate asymmetry "in the small."

2. Data

We use scanner price data from Dominick's—one of the largest supermarket chains in the Chicago area, operating 94 stores with a market share of about 25 percent. Large multi-store US supermarket chains of this type made up about $310 billion in total annual sales in 1992, which was 86.3% of total retail grocery sales (*Supermarket Business*, 1993). In 1999 the retail grocery sales have reached $435 billion. Thus the chain we study is representative of a major class of the retail grocery trade. Moreover, Dominick's type large supermarket chains' sales constitute about 14 percent of the total retail sales of about $2.25 trillion in the U.S. Because the retail sales account for about 9.3 percent of the GDP, our data set is a representative of as much as 1.28 percent of the GDP, which is substantial. Thus the market we are studying has quantitative economic significance as well.

We have 400 weekly observations of retail prices in 27 product categories that represent 30 percent of the revenues, from September 14, 1989 to May 8, 1997.[5] The length of individual series varies depending on when the data collection for the specific category began and ended. In Table 1, we list the product categories along with the number of observations in each category. As the table indicates, the data set contains more than 98 million weekly price observations.

The data come from the chain's scanner database, and contains the actual prices paid at the cash register each week. If the item was on sale, or if the retailer's coupon was used, then the data reflect that. The retail prices are set on a chain-wide basis but there is some price variation across the stores depending on the local competition (Barsky, et al., 2003a). We use all the data available from all stores.

3. Empirical Findings

Before presenting the findings, it is worth looking at a sample series from the data. Figure 1 displays the actual weekly prices of Heritage House frozen concentrate orange juice, 12oz (from Dominick's Store No. 78). According to our count, which we limited to price changes of up to 5¢ in absolute value, the series contain the following "small" price changes:

(1) **1**cent: <u>9 positive</u> (at weeks 13, 237, 243, 245, 292, 300, 307, 311, and 359) and <u>6 negative</u> (at weeks 86, 228, 242, 275, 386, and 387);

(2) **2** cent: <u>7 positive</u> (at weeks 248, 276, 281, 285, 315, 319, and 365) and <u>1 negative</u> (at week 287);

(3) **3** cent: <u>3 positive</u> (at weeks 254, 379, and 380) and <u>2 negative</u> (at weeks 203 and 353);

(4) **4** cent: <u>4 positive</u> (at weeks 23, 197, 318, and 354) and <u>1 negative</u> (at week 229); and

(5) **5** cent: <u>1 positive</u> (at week 280) and <u>1 negative</u> (at week 302).

[5] We have data for two additional categories, Beers and Cigarettes. However, because of the regulations and tax rules imposed on them, we do not discuss the results for these categories, although we do present their plots for the sake of completeness. See Barsky, et al. (2003a) for more details about the data.

Thus, the price series contains many "small" changes—a fact that would be hard to tell based on visual observation of the plot.

Below we analyze the patterns of price changes using the entire data set as well as individual product categories. We begin by studying the patterns of price changes for each possible size of price change, by calculating the frequency of positive and negative price changes in cents, 1¢, 2¢, 3¢,…, 50¢.[6]

3.1. Findings for the Entire Sample Period

In Figure 2 we plot the cross-category average frequency of positive and negative price changes, during the 8-year sample period. We immediately note an interesting and robust empirical regularity in the data: there are more small price increases than decreases. We call this *asymmetry "in the small*." This asymmetry lasts for price changes of up to about 10–15 cents. Beyond that, the two lines start crisscrossing each other and therefore, the phenomenon of systematic asymmetry disappears.

In Figures 3a–3c, we plot the frequency of positive and negative price changes by product categories. Table 2 reports corresponding *Z*-tests' results from comparing the frequency of positive and negative price changes for each size of price change for identifying the asymmetry thresholds, i.e., the first point where the asymmetry does not hold. In four categories the asymmetry threshold is less than 5 cents, and in two categories it exceeds 25 cent. In most categories, however, the asymmetry holds for price changes of up to about 5–25 cents. Overall, the asymmetry threshold is about 11.3 cents, on average. Thus, we conclude that the retail prices exhibit asymmetric price adjustment "in the small."[7]

We should note that these findings cannot be explained by promotions or sales as promotions likely generate more price decreases than increases, which is opposite to what we observe. In addition, a temporary price reduction during a sale is usually followed by a price increase at the end of the sale period.[8] Price promotions, therefore, cannot produce the observed asymmetry.

3.2. Could It Be the Inflation? Findings for Low-Inflation and Deflation Periods

A possible explanation for the above findings might be the fact that during the sample period we cover, the U.S was experiencing a moderate inflation, as indicated by the PPI-inflation figures reported in Table 3.[9] During inflationary period, we would expect to see more frequent price increases than decreases, *ceteris paribus*. One counter-argument to this idea is that if the reason for the asymmetry is

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[6] The average price at a retail supermarket is about $2.50 (Levy, et al., 1997; Bergen, et al., 2004) and therefore, considering price changes of up to 50¢ appears sufficient given our focus on the asymmetry in the *small*. We have actually calculated the price changes of *all sizes*, and found that most price changes are indeed smaller than 50¢.

[7] We have also calculated the *total* number of positive and negative price changes in the entire data set and found that it contains a total of 10,298,995 price increases and 9,438,350 price decreases. Thus, in total, there are more price increases than decreases. Further, 1¢, 2¢, 3¢, 4¢, and 5¢ increases account for 3.60%, 3.50%, 3.39%, 3.30%, and 3.20% of all price increases, respectively. In other words, 17.09% of the price increases are of 5¢ or less. In contrast, 1¢, 2¢, 3¢, 4¢, and 5¢ decreases account for 2.49%, 2.88%, 2.75%, 2.99%, and 2.88% of all price increases, respectively. Thus 14.00% of price decreases are of 5¢ or less. Thus, our findings hold proportionally as well.

[8] This has been documented for Dominick's data by Rotemberg (2002).

[9] As discussed below, we have also analyzed the data using the CPI as well as the CPI-Chicago, and the results remain similar.

inflation, then we would see more positive than negative price changes not only “in the small” but also “in the large.” The data, however, do not exhibit such an asymmetry “in the large.”

A more direct answer to this question can be given by asking whether the asymmetry we find for the entire sample, also exists in the data when the observations pertaining to the inflationary periods are excluded from the analysis. Given the large sample we have, such an analysis is indeed feasible.

We have conducted two such analyses. The first included only those observations during which the *monthly* PPI inflation did not exceed 0.1 percent. We define this sample as the *low-inflation* period. In the second analysis, we took even a more conservative stand by including only those observations in which the *monthly* PPI inflation rate was non-positive. We define this sample as the *deflation*-period.[10]

According to the middle column of Table 2, for the low-inflation sub-sample, the extent of the asymmetry is statistically significant for price changes of up to 8.2 cents on average, with the majority of the thresholds falling in the range of 2–20 cents. The findings remain similar for individual categories: in all but one category (bath soap), the asymmetry still holds, with some decrease in the asymmetry thresholds. Thus, we conclude that the retail prices exhibit asymmetry “in the small” and the exclusion of the observations pertaining to moderate inflationary periods appear to make little difference. Moving next to the deflation period sample, the last column of Table 2, the threshold is 6.2 cents, on average. At the category level, we still find asymmetry “in the small” for all but one category, Frozen Entrees.

In sum, the results for the low inflation and deflationary periods are similar to the results obtained from the entire sample. There is a decrease in the asymmetry thresholds as we move from the entire period to the low inflation period and further to the deflation period, suggesting that inflation might be playing a role in the asymmetry. However, a large proportion of the asymmetry still remains unexplained.

3.3. Robustness Check

While the above analyses suggest that inflation is not the main explanation for our findings, we further explore the validity of this conclusion by checking its robustness using five different tests.

3.3.1. Lagged Price Adjustment

In the analysis above we did not take into account the fact that the retail price adjustment is not instantaneous. To check the robustness of our findings, therefore, we allow for lagged adjustment. The speed of adjustment of retail prices vary between 2–4 weeks (Dutta, et al. 2002; Müller and Ray, 2005) and 12–16 weeks (Bils and Klenow, 2004). Therefore, we have repeated the analysis under four possible lags: 4 weeks, 8 weeks, 12 weeks, and 16 weeks. The results, reported in Table 4**,** suggest that the asymmetric price adjustment in the small still remains. This holds true for 26 of the 27 categories, the exception being bath soups. In 99 of the 108 cases presented in the table, that is, in 92 percent of the cases, the asymmetry thresholds are positive with the (four-column) average of 5.95 cents.

3.3.2. Alternative Measures of Inflation

The analysis reported so far was based on PPI-inflation. To examine the robustness of our findings, we use two other measures of inflation: CPI, and CPI-Chicago. The latter is useful as it covers the area where many of Dominick's stores operate, and thus it might be the most relevant measure of inflation for the retailer. In Table 3, along with the PPI inflation series, we report the CPI and CPI-Chicago series. It is apparent that these series indicate fewer deflationary periods, which reduces the sample size. Nevertheless, the results remain essentially unchanged as Table 5 suggests. We observe asymmetry in the small in all but one category (bath soaps), with the average threshold of 7 cents.

3.3.3. Alternative Measures of Inflation with Lagged Price Adjustment

The analysis in subsection 3.3.2 assumes completely flexible prices. To allow for lagged price adjustment, we have repeated the analysis with 4-week, 8-week, 12-week, and 16-week adjustment periods while using the CPI and the CPI-Chicago measures of inflation. The findings reported in Table 6, suggest that for the overwhelming majority of the categories, the asymmetry in the small still holds. Of the 216 asymmetry threshold figures reported in the table, only in 32 cases, that is in only 14.8% of the cases, the asymmetry threshold is zero indicating no asymmetry. Thus, in over 85% of the cases the asymmetry still remains, with the average threshold of 4.6 cents.

3.3.4. First Year of the Sample Period versus the Last Year of the Sample Period

The period from September 1989 to May 1997, is characterized by a downward inflationary trend. For example, during 1989–1990 (the start of our sample) the average inflation rate was 5.1 percent per year, while during 1996–1997 (the end of our sample), it was 2.6 percent. Therefore, if inflation is the main explanation for the asymmetry, then the asymmetry during the first 12 months should be stronger than the asymmetry during the last 12 months. The results of the comparison are reported in Table 7. Of the 27 product categories, six categories had no observations during the first 12 months. In the remaining 21 categories, we have only one category (canned tuna), where the asymmetry threshold is higher in the first 12 months in comparison to the last 12 months, and one category, soft drinks with equal asymmetry threshold. In the remaining 19 categories, that is, in over 90 percent of the categories, we see greater asymmetry in the last 12 months of the sample, averaging 9.1 cent in comparison to 1.1 cent in the first 12 months. Thus, for the overwhelming majority of the cases, the asymmetry *increases* from the beginning of the sample to the end, which is inconsistent with the inflation-based explanation.

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[10] The frequency plots for the low inflation and the deflation periods are included in the referee appendix which is available upon request.

3.3.5. Products Whose Prices Have Not Increased During the Sample Period

As a final check, we have identified all products whose prices have not increased during the sample period by comparing the average price during the first four weeks and the last four weeks of the sample period.[11] To identify these products, we used the list price, if it differed from the actual price, in order to avoid the sales' effect on the results. In conducting the asymmetry analysis, however, we use the actual price to make the current results comparable to the previous results. The findings reported in Table 8, indicate that in 23 of the 27 categories, i.e., in over 85 percent of the cases, we have asymmetric price adjustment. Thus, even when we limit the analysis only to those products whose prices have decreased or remained unchanged over the 8-year sample period, we find that the asymmetry in the small still holds.[12]

Based on the analyses discussed in this section, therefore, we conclude that inflation is unlikely to be the main driver of the observed asymmetry in the small.

4. Existing Theories of Asymmetric Price Adjustment

Despite economists' considerable interest in this area, the existing literature offers only handful of theories—which Peltzman (2002, p. 467) argues is a "…serious gap in a fundamental area of economic theory." The main theories of asymmetric price adjustment include capacity constraints, vertical market links, imperfect competition, and menu costs under inflation. Below we briefly look at each theory.

The theory of capacity adjustment costs (Peltzman, 2002) argues that it is costly to increase inventory capacity. When procurement costs drop by a large amount, retailers tend to increase the inventory. Lower prices then move the larger volumes off the shelves. However, it is difficult to increase capacity. Therefore, when price cuts are substantial enough to run into the capacity constraint, the incentive to lower prices is reduced. When costs go up substantially, on the other hand, retailers do not face such capacity constraints because they now just buy less, making up the lower volumes by higher prices. Thus, there is no capacity constraint and therefore no disincentive to raise prices. Thus, capacity constraints might lead to asymmetric price adjustment. This theory, however, predicts that asymmetric adjustment should be observed especially for large price changes because small price changes are less likely to make capacity constraints binding. This is exactly the opposite of what we observe in our data.

Similarly, theories based on vertical channel linkages (Peltzman 2002) and imperfect competition (Neumark and Sharpe, 1992) cannot explain simultaneous asymmetry "in the small" and symmetry "in the large" because we do not see noticeable changes in the market or the channel structure during our study. More importantly, these cannot really vary between small and large price changes. Clearly, large-

[11] The analysis with an 8-week window yielded similar results.

scale changes in the market or the channel structures are too slow and infrequent to explain variation in adjustment across small and large price changes. Thus, although these factors could lead to asymmetry in general, they cannot explain the specific form of asymmetric price adjustment we document.[13]

Another possible explanation could be menu cost under inflation (Tsiddon, 1993; Ball and Mankiw, 1994). While the idea that menu cost may lead to price rigidity is widely accepted, menu cost by itself should not lead to asymmetric price adjustment. If, however, firms face inflation then they will undertake more price increases than decreases because of the expected inflation. Recent studies have documented a presence of non-trivial menu costs at retail supermarket settings (Levy et al., 1997 and 1998; Dutta et al., 1999). However, if the reason for the asymmetry we find were inflation and menu cost, then we should not have seen asymmetry in periods of low inflation, and even more so in periods of deflation. The empirical findings discussed in section 3.2, however, suggest that the asymmetry in the small is present in our data during low inflation, and even during deflation periods.

If we consider a broader notion of price adjustment costs, which might include managerial and customer costs (Zbaracki, et al. 2004), then price adjustment costs could lead to asymmetric price adjustment: the cost of price increase could be higher than the cost of price decrease. The reason for such asymmetry might be potential consumer anger (Rotemberg, 2002) or search triggered by a price increase. Also, pricing mistakes can cause consumer goodwill loss, especially if the consumers link them to price increase (Bergen, et al. 2004; Levy and Young, 2004). The explanation, however, predicts that we should see more price decreases than increases. That is opposite to what we find in our data.

Finally, Rotemberg (2002) proposes a model which could imply asymmetric price adjustment. In his model, consumers assess the price change fairness and act accordingly (Kahneman, et al (1986). Assuming that it would be price increases, not price decreases, that would trigger such an assessment, firms would be more hesitant to increase prices than decrease them. This could generate asymmetric price adjustment. However, the asymmetry would go in the opposite direction to what we find.

5. Rational Inattention and Asymmetric Price Adjustment "in the Small"

Given the inability of existing theories to explain our findings, we offer an extension of theories of rational inattention as an explanation for the asymmetric price adjustment "in the small." We argue that it may be rational for consumers to be "inattentive" to information on small price changes if processing and responding to such information is costly. Therefore, asymmetric price adjustment in the small may be the outcome of the retailers' optimal reaction to their customers' "rational inattention" to small price changes, and rational attention to large price changes. In this section we discuss the idea of

[12] We obtained similar results after repeating the entire analyses for price changes in relative terms, i.e., by considering the frequency distribution of positive and negative price changes in percents (1%, 2%, …, 50%) rather than in cents. We do not report them here for the sake of brevity. They, however, are available from the authors upon request.

rational inattention from consumers' and producers' perspective and derive its implications.

5.1. Rational Inattention

We draw from a body of a work which studies the idea of rational inattention under the label of information processing or re-optimization costs. The idea of rational inattention follows naturally from these information-processing requirements and the scarcity of the resources needed to process them, as the opening quotes suggest.[14] Urbany, et al. (1996) echo Samuelson and Zeckhauser's (1988, p. 35) claim that in the context of retail shopping, "… it may be optimal for individuals to perform an analysis once, as their initial point of decision, and defer to the status quo choice in their subsequent decisions, *barring significant changes in the relevant circumstances*" (emphasis ours).

We argue that it may be rational for consumers to be "inattentive" to small price changes if they face: (i) large amounts of information which are costly to process and react to, and (ii) time, resource, and information-processing-capacity constraints. It seems reasonable to argue that these resource and information costs are non-trivial. Calculating the optimal purchase behavior for every possible price, for example, is a costly process requiring time and mental resources, especially when customers are engaged in purchasing a basket of many—often tens and occasionally hundreds—of different goods.

If the cost of processing information on a price change exceeds the benefit, then the customer might ignore and not react to the price change. This scenario is most likely for small price changes, because the costs of processing and reacting to small price changes might outweigh the benefits. This introduces a price insensitive region in the demand curve, as shown in Figure 4.[15] If P_A was the price when the customer last evaluated/acted with rational attention, then the demand curve in future periods will be less elastic within the range where the costs of processing the price change information outweigh its benefits. Thus, between P_A^l and P_A^u, the buyer will be rationally inattentive. If the price moves outside of this "region of inaction," however, then she will process the new price information, triggering her response to the price change by adjusting her purchase along the original demand curve.[16]

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[13] This conclusion likely holds for any explanation that relies on institutional features and arrangements.
[14] Tobin (Nobel Lecture, 1982, p. 189) makes a similar statement: "Some decisions by economic agents are reconsidered daily or hourly, while others are reviewed at intervals of a year or longer *except when extraordinary events compel revisions*. It would be desirable in principle to allow for differences among variables in frequencies of change and even to make these frequencies endogenous" (our emphasis). Frank and Jagannathan (1998, p. 188) suggest a similar mechanism to explain stock price behavior: "The idea is that for many investors it is not worth paying attention to small dividends, while at sufficiently high dividend levels almost all investors pay attention."
[15] The region of inattention does not have to be vertical; it only needs to be less elastic. See the Appendix for two alternative formulations.
[16] The demand curve we obtain under rational inattention differs from the standard "kinked" demand curve (Andersen, 1994). There the idea is that price decreases are instantaneously matched by competitors, but price increases are not. This makes customers *less* sensitive to price cuts and *more* sensitive to price increases. The *reduced* sensitivity to price cuts and *increased* sensitivity to price increases make both less valuable for the firm. As a result, firms have less incentive to change prices in either direction. In contrast to this, the inelastic region on the demand curve that is caused by customers' rational inattention is symmetric around the current price, and thus leads to a *reduction* in the sensitivity to price changes symmetrically in *both* directions. Our model differs also from the model where customers are less price-sensitive in the SR than in the LR (Okun, 1981). In Okun's model, buyers are unaware of the prices of all retailers in the SR because it takes time for customers to update their price information. In the LR, however, customers can shop around and update their price information. The two theories are similar in that they make a distinction between different types of price changes, and customer reactions to

5.2. Retailer's Reaction to Consumers' Rational Inattention

Now, consider a price-setter who recognizes that his customers are "rationally inattentive," and thus sees a region on the demand curve around the current price, where his customers' price sensitivity is low for both small price increases *and* small price decreases. The consumers' reduced price sensitivity to small price decreases makes small price decreases less valuable to the seller because the lower price does not trigger the consumer's response: she does not buy more. However, a small price increase will be very valuable to the price setter for the same reason: his consumer will not reduce her quantity purchased.

The reduced price sensitivity in both directions gives the retailer incentive to price at the upper bound of the inelastic range, e.g., P_A^u in Figure 4. Pricing lower than P_A^u will reduce margins without gaining enough sales volume to make up for the lower margin, whereas pricing above P_A^u will trigger adjustment by customers. The latter imposes a natural limit on the ability of retailers to take advantage of rational inattention. A large price change, therefore, will trigger an adjustment of consumer purchase behavior along the original demand curve. Thus, the asymmetry will not hold for large price changes.

Given the firm's reaction to its customers' inattention to small price changes, rational consumers know that retailers have incentive to make more small price increases than decreases. Therefore, both firms and consumers will expect asymmetric price adjustment in the small. Thus, asymmetric price adjustment in the small can be a rational expectations equilibrium. Both consumers and the retailers know that if prices move outside the range of inattention, the consumer will react to the change. Therefore, *symmetric* price adjustment can emerge as an equilibrium for *large* price changes.[17]

5.3. Impossibility of Indefinite Continuous Small Price Increases

The idea of rational inattention imposes a natural limit on how much surplus a retailer can extract from the consumer by strategically taking advantage of the customer's information-processing costs. According to our assumption, when information-processing is costly, the customer keeps buying the same old quantity of A (or the same old ratio of A and B, as discussed in the Appendix) when the price change for A is small. Thus, the customer relies on the price for which she has last optimized her purchase behavior (i.e., P_A^*) to determine her quantity demanded. With the demand curve as depicted in Figure 4, that means the retailer can only raise its price to P_A^u. Any additional price increase beyond that will push the price far enough from the last optimization price to trigger a re-optimization and consequently a

them. The difference is that we focus on the size of price changes, while Okun focuses on the duration of the delay in the buyers' reaction to the price change. Thus, whereas Okun suggests that customers will not react to SR price changes as fully as to LR price changes, we posit that customers will not react to small price changes but will react to large ones.

reduction in her purchase. Thus, under the assumption that the consumer bases her purchase behavior on the price for which she has last optimized, indefinite continuous small price increases are not feasible.

5.4. Small Price Decreases Are Still Possible

Our theory does not require that all pricing decisions a retailer faces involve rationally inattentive customers. Considering the large number of pricing decisions faced by retailers—across product categories, individual products, across stores, and across seasons, holidays and non-holiday periods, etc.—this assumption would be too strong. From a customer perspective the costs of information processing may depend on, among other things, consumer's opportunity cost of time, the ease with which she can carry out such calculations, her experience with doing this type of calculations which may be a function of the competitive environment the retailer faces, and the amount of the calculations required.

Pricing decisions, therefore, could vary over the seasons (e.g., holiday vs. non-holiday), over competitive actions and reactions, etc. with different levels of customer attentiveness. Now, let the probability that the retailer faces a pricing decision best characterized by rationally inattentive and attentive customers be α and $(1 - \alpha)$, respectively, $0 \leq \alpha \leq 1$. Then, as long as α is large enough, we will observe prices adjusting asymmetrically in the small. In other words, the retailer will still be making small price decreases, but he will be making *more* frequent small price increases than decreases.[18]

Our theory thus offers a possible explanation for the presence of small price changes, which has been a long standing puzzle in this literature. For example, Carlton (p. 121, 1986) finds "…a significant number of price changes that one would consider small (less than 1%)." Lach and Tsiddon (2005) also find small price changes in the Israeli grocery store data.[19] In Kashyap's (1995) data, 2.7 percent of the price changes are less than 1% in size, 7.2 percent—are of 1–2 percent in size, and 21 percent—are less than 3 percent in size. Our theory offers a possible explanation of these puzzling facts: when the costs of making small changes (menu costs) are offset by the possible gains accrued from an inelastic demand curve, firms may find it optimal to engage in small price changes, especially in small price increases.

6. Variation in Rational Inattention over the Business Cycle

Rational inattention implies that there might be a variation in the price adjustment asymmetry

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[17] The idea of rational inattention builds on a customer-based argument, and therefore, assuming that competitors are selling to similar types of customers, they will also have the ability as well as the incentive to adjust their prices in an asymmetric manner. It is unlikely, therefore, that competitive reactions would necessarily undermine asymmetric pricing "in the small" by retailers.

[18] In the appendix we offer two examples of a simple optimization model with rational inattention, which generate asymmetric price adjustment "in the small."

[19] They argue that the menu cost model extended to a multi-product setting (Sheshinski and Weiss, 1997) will be consistent with small price changes, as long as the *average* price change of different products is not small. Gordon (1990) suggests that small price changes may be observed under menu costs if the price changes are necessitated by a permanent change in market conditions. Consistent with this prediction, Levy, et al. (2002) show that price response to cost shocks will be faster and more complete, the more persistent the cost shocks are.

over the business cycle.[20] In situations where consumers have more time and greater opportunity to be attentive, we would expect to see reduced asymmetry. Similarly, in situations where consumers are pressed for time and have limited opportunity to be attentive, we would expect to see greater asymmetry.

The business cycle might offer an opportunity—a kind of natural experiment—to observe such a variation in asymmetry because of the variation in unemployment over the cycle. During periods of high unemployment people have more time available to be attentive. At the same time, the value of being attentive to small price changes increases during periods of high unemployment. Thus, higher unemployment would coincide with greater attention and therefore, with lower asymmetry. During periods of low unemployment people have less time available to be attentive, while at the same time, the value of being attentive to small price changes diminishes. Lower unemployment would, therefore, coincide with less attention and greater asymmetry. For example, during periods of high unemployment people may react to single digit price changes, but during low unemployment periods, they might react only to double digit price changes or greater. This implies that we will expect to see smaller asymmetry thresholds during periods of high unemployment in comparison to low unemployment periods.

Our 8-year sample period, from September 1989 to May 1997, contains an 8-month recession period from August 1990 to March 1991 as defined by the NBER, and we try to exploit it for comparing the extent of asymmetry during the recession and expansion periods. However, because unemployment lags output over the business cycle by about two quarters, the highest and the lowest unemployment periods do not coincide exactly with recession and expansion, respectively. We therefore conduct two analyses. In the first, we compare the asymmetry thresholds obtained using the data pertaining to the *NBER recession months* with the asymmetry thresholds obtained using the data pertaining to the lowest unemployment months. In the second, we compare the asymmetry thresholds obtained using the data pertaining to the *highest unemployment months* with the asymmetry thresholds obtained using the data pertaining to the lowest unemployment months. In each case we repeat the analysis twice: in one we use the US unemployment rate, and in the second the Chicago-unemployment rate. These two series are included in Table 3. Because the recession observed in our sample lasted 8-month period, all asymmetry thresholds reported in this section are based on the analysis of the data over 8-month windows.

The findings are reported in Table 9. On the LHS of the table we report the asymmetry thresholds while on the RHS we report the corresponding sample size. As Table 3 indicates, the period of lowest unemployment rates for the US coincides with that of Chicago, and occurs during September 1996–April 1997, with the average unemployment rates of 4.8 percent and 5.2 percent, respectively. The highest unemployment rate period according to the u-US series is from February 1992 to September 1992

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[20] Another interesting implication of rational inattention is the optimality of price points, such as 9¢, 99¢, $1.29, etc. See Chen, et al. (2004).

averaging 7.6%, while according to the u-Chicago series it is from December 1991 to July 1992, averaging 8.1 percent. In Table 9, the Low column indicates the asymmetry thresholds obtained using the data pertaining to the lowest unemployment 8-month period. There is only one such column because, as mentioned above, the periods in which the US and the Chicago unemployment rates attain their lowest average value over an 8-month period, coincide with each other. The column NBER indicates the asymmetry thresholds obtained using the data pertaining to the 8-month period of the NBER recession, during which the average unemployment rate was 6.3 percent. Finally, the High-Chicago and the High-US columns indicate the asymmetry thresholds obtained using the data pertaining to the highest unemployment 8-month periods based on Chicago- and US-unemployment rates, respectively.

According to the results in Table 9, the asymmetry threshold is larger for the lowest unemployment periods than for the other periods. Across the 27 product categories, in 60 cases out of 75 possible comparisons, i.e., in 80 percent of the cases, we find a stronger asymmetry for the lowest unemployment period, in 5 cases, i.e., in 6.7 percent of the cases, we find equal asymmetry, and in 10 cases, i.e., in 13.3 percent of the cases, we find weaker asymmetry for the lowest unemployment period than for the other periods.[21] Further, these figures imply that for the low unemployment period sample, the average asymmetry threshold is 9.6 cent, for the NBER recession sample it is 0.6 cent, for the high-Chicago sample the threshold is 4 cent, and for the high-US sample, the threshold occurs at 3.4 cent.

Thus, we find that the asymmetry is stronger when unemployment is low, as predicted by the theory of rational inattention. This holds true regardless of the criterion used for identifying the high unemployment period (the NBER months or the highest unemployment months).[22] The finding that the asymmetry threshold obtained for the NBER recession period is lower than those obtained for either of the two high unemployment periods, suggests that unemployment rate, being a single-variable indicator of the economic activity, perhaps is not a good measure of the overall economic conditions, in

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[21] The theoretical prediction of rational inattention is statistically supported: 77.6% > 50%, $z = 6.81$, with $p < .0001$. Paired t-test confirms this conclusion: for the 27 product categories, the asymmetry is larger for the lowest unemployment period than for the other three periods ($p < .01$ or better). This difference is unlikely to be driven by differences in sample size; even though the lowest unemployment period has a large sample size than the other three periods, the differences are not statistically significant ($p > .05$ or worse). Also, if we focus on product categories where the sample size is smaller for the lowest unemployment period, the difference in asymmetry threshold is still in the right direction, and most of the time statistically significant ($p < .05$ in 13 out of 18 comparisons). In the remaining five cases, the difference is in the predicted direction but not statistically significant, largely because of the small sample size (5 to 10 for t-tests).

[22] Could the results we report in this section be an artifact of the negative relationship between inflation and unemployment? In that case, the finding that the asymmetry threshold is smaller during the 8 months that had the highest unemployment rate could simply mean that there was a deflation during that specific period. To check if that is the case, we calculated the inflation rates for each of the three 8-month periods, using the PPI, CPI- and CPI-Chicago price indexes. When we compare the 8 months that had the highest unemployment rate with the 8 months that had the lowest unemployment rate, the inflation rate is higher for the former, regardless of which price index is used. We see the same pattern when we compare the 8 months that had the lowest unemployment rate with the NBER's 8 month long recession period. The unemployment rate is higher during recession, but the inflation rate is also higher (again, regardless of which index we use). Thus, we conclude that the findings are not related to the inflation-unemployment relationship. Another explanation might be that during high unemployment periods there are more price decreases, perhaps because retailers use price promotions more frequently to boost sales during economic downturns. As pointed out earlier, however, price promotions are generally temporary and therefore reversed in the subsequent period, in which case they should not lead to any change in the asymmetry. To the extent that some of the price promotions are not reversed, however, that could reduce the extent of asymmetry we see in the data. This rival explanation is not inconsistent with our rational inattention argument. On the contrary, rational inattention provides a possible explanation as to why offering small price discounts

comparison to the NBER composite index on which the identification of the NBER recession is based.

7. Conclusion and Caveats

In this paper we find overwhelming evidence of asymmetry "in the small," for price changes of up to about 10 cents, on average. The asymmetry disappears for larger price changes. The findings, which hold in low inflation and in deflation periods, are robust to variety of tests. As far as we know, this type of asymmetry has not been reported in the literature before, and is small enough to fly under the radar screen, which suggests that asymmetric price adjustment may be more prevalent than we think.

To explain our findings, we offer a model in which price-setters act strategically by taking advantage of the fact that their consumers face information processing costs, and making asymmetric price adjustments "in the small."[23] Our paper also offers a possible resolution of a long-standing puzzle: the presence of small price changes in many transaction price data. Further, our model predicts that the extent of the asymmetry observed "in the small" should vary over the business cycle: it should diminish during recessions and strengthen during expansions. Our data appear consistent with these predictions.

We are aware of at least two studies, which reports findings of asymmetric price adjustment "in the small" in another data. Baudry, et al. (2004) study the distribution of price changes using French micro data for the 1994–2003 period. Their Figure 9 (p. 55) clearly indicates an asymmetric price adjustment "in the small" (although the authors fail to "notice" it…). A similar form of asymmetry is found also in Spanish data for the 1993–2001 period (Álvarez and Hernando, 2004). Indeed, according to Cecchetti (2004), the phenomenon of asymmetric price adjustment in the small is quite widespread in Europe and is not limited to just food store prices. This suggests that the phenomenon we document might be more widespread and not limited to grocery chains or to the U.S.

However, it is still unclear how generalizable our findings are to other types of goods or markets. In the specific setting we study, the retailer faces buyers with little at stake in the price of an individual item. It is likely, therefore, that asymmetric price adjustment in the small will be present in other settings where low-priced, commonly consumed retail goods are sold. For example, customers of retail establishments like Target, Sears, Wal-Mart, as well as the customers of large chain drugstores, who purchase perishables and small consumer packaged goods, are likely to behave in a similar way. We speculate, therefore, that such settings, we will likely see asymmetric price adjustment in the small.

There are markets, however, where attention is critical. For example, in financial and business-to-business markets and in where a typical transaction involves a large quantity of the same asset, buyers will certainly be more attentive. In fact, in these markets, there are people whose only job is to pay

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works better during high unemployment periods than during low unemployment periods.

attention to individual pennies or even less. In such settings, it is unlikely to see asymmetry in the small.

It is less clear whether rational inattention will be optimal in other settings. For example, in markets for big-ticket items people are likely to be more attentive because these transactions involve large expenditures (Bell, et al., 1998; Nagle and Holden, 2002). However, when considering big-ticket items, shoppers might ignore some rightmost digits. For example, car shoppers may choose to be inattentive to the rightmost digits, and thus focus on fourteen thousand eight hundred dollars when the actual price is $14,889.00. This would create some room for asymmetric price adjustment in the small.

It will be valuable, therefore, to study other data sets, products, and markets. In this regard, exploring internet prices might be particularly useful because on the internet, information gathering costs appear lower. Search engines enable instantaneous price comparisons at many sites simultaneously, reducing the cost of information gathering and processing (Lee, et al., 2003). We suspect, therefore, that internet prices will exhibit less asymmetry.

[23] In support of the idea of rational inattention and its relevance for retail settings, we shall note the fact that many retailers such as large US supermarket chains find it necessary to alert the public about their promotions by posting sales' signs on shelves or at end-of-the-isles. Such signs may help ensure that shoppers *notice and react to* the price discounts.

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Appendix: Two Models of Rational Inattention

In this appendix, we formalize the idea of rational inattention by offering two examples of a simple optimization model with rational inattention, which generate asymmetry in small price adjustments. We begin by considering two possible pricing situations a retailer could face. First we explore a standard economic setting where the retailer faces customers that are rationally attentive, i.e. they have a negligible information-processing cost. Then we explore a setting with rational inattention, where the retailer faces customers that have a sizeable information-processing cost.

For each situation we first solve the problem of consumer's optimal purchase behavior. We then obtain solutions for the retailer's optimal pricing strategy. When the information-processing cost is zero, the solution we obtain is a standard one. However, when the information processing cost is greater than zero, then consumers find it beneficial to be rationally inattentive to small price changes, while knowing that the firm will find it optimal to adjust prices asymmetrically. The firm's ability to adjust prices asymmetrically in those situations, however, is limited to the customer's region of rational inattentiveness.

Consider a market with two products, A and B. Assume a utility function $U(A, B) = v \ln A + \ln B$, where v denotes the degree of substitutability between the two products. The customer calculates her optimal purchase behavior for products A and B, taking as given prices P_A and P_B. Further assume that the customer spends all her income, has no savings, and consumes all the products bought that period. Also, let the probability that the retailer faces a pricing decision best characterized by rationally inattentive and attentive customers be α and $(1 - \alpha)$, respectively, with $0 \le \alpha \le 1$. We focus on the seller of product A, who maximizes profits facing costs $C = a / A^2 + b$, $(a > 0, b > 0)$, and with full information about the customer's demand function. We first derive the optimality conditions under rational *attention*, i.e., when consumer information-processing cost is zero.

i. *Optimal Purchase and Pricing Policy under Rational Attention*

The optimal purchase behavior and pricing behavior for any period is given as follows.

Customer's Purchase Policy:

The customer solves the following optimization problem:

Maximize: $U(A, B) = v \ln A + \ln B$ (A1)

s.t. $P_A A + P_B B = M$ (A2)

where M is the customer's single period income. The optimal quantities of A and B, and the utility obtained by this consumer are given by

$$A^* = \frac{v}{(v+1)P_A} M \tag{A3}$$

$$B^* = \frac{1}{(v+1)P_B} M \tag{A4}$$

$$U^* = (v+1)\ \ln M - v\ \ln\ \frac{v+1}{v} P_A - \ln\ (v+1)\ P_B \tag{A5}$$

This is a standard solution to consumer's utility maximization problem, where consumer's optimal consumption level of product A is completely flexible with respect to changes in the price of product A. That is, any change in P_A will bring about a corresponding change in A^*.

Retailer's Pricing Policy:

A retailer who produces good A and faces the demand function given in equation (A3), solves the following optimization problem:

Maximize: $\pi = (P_A - C)A$

where $C = \frac{a}{A^2} + b$,

$a > 0$, $b > 0$, and A is given by equation (A3). Solving the maximization problem, we obtain:

$$P_A^* = \frac{vM}{v+1}\sqrt{\frac{b}{a}} \tag{A6}$$

$$\pi^* = \frac{v}{v+1} M - 2\sqrt{ab} \tag{A7}$$

Substituting equation (A6) into equation (A3), we obtain:

$$A^* = \sqrt{\frac{a}{b}} \tag{A8}$$

This is a standard solution to retailer's profit maximization problem, where retailer's optimal price for product A is completely flexible with respect to changes in its cost for product A. That is, any change in b, for example, will bring about a corresponding change in P_A^*. Recall that the retailer faces this type of pricing situation α percent of the time.

ii. *Optimal Purchase and Pricing Policy under Rational Inattention*

However, on other occasions, the retailer believes that it faces a different type of consumers. Specifically, $(1 - \alpha)$ percent of the time, the retailer believes that it faces consumers that have a sizeable information processing cost. To understand the consumer and retailer behaviors in such pricing situations, we need to consider a two-period game.

In such a game, suppose that the price of A changes from P_A in period 1 to P_A' in period 2, and that the price of B remains unchanged. We assume that the consumer has memory of the prices in period

1. However, she will incur information-processing cost, which we measure in terms of lost utility, x, if she decides to re-optimize by recalculating her optimal consumption level for the new price. Such a cost might be nontrivial given the wide range of prices that a retailer may offer in period 2.

Nevertheless, for a given consumer, the cost of doing such calculations remains largely fixed.[24] In the meantime, the benefit of doing such calculations increases with the magnitude of the price change. Therefore, for a rather small price change, it may be optimal to keep the same purchase behavior and avoid paying the information-processing cost, x. We assume that the consumer decides before period 2 unravels on whether to re-optimize by incurring the information-processing cost and adjust her consumption accordingly, or keep the earlier purchase behavior.

Example 1: A Model with Customer Decision Rule Based on a Constant Quantity of A

If the consumer decides to keep the earlier purchase behavior, she needs to use some rule to decide what and how much to purchase. We assume the consumer stays within her budget constraint and applies a heuristic rule to the purchase of good A. According to this rule, we assume, the customer buys the same amount of the good, and then gets the other good with whatever money is left under her budget constraint.[25] We demonstrate below that for a positive information-processing cost, there is a price range in which it is optimal for the consumer to be rigid in her purchase behavior.

From equation (A5), we can easily infer that if the customer processes the price information and adjusts her consumption, the new utility, *before* incurring x, is:

$$U^* = (v+1)\ln M - v \ln \frac{v+1}{v} P_A' - \ln (v+1)\, P_B \tag{A9}$$

Alternatively, if she keeps her consumption of A constant, the new demand functions can be calculated from:

$$A^* = \frac{v}{(v+1)P_A} M \tag{A3}$$

$$P_A' A + P_B B = M \tag{A10}$$

$$B = \frac{P_A(v+1) - P_A' v}{P_A P_B (v+1)} M \tag{A11}$$

which yield

$$U = v \ln \frac{v}{(v+1)P_A} M + \ln \frac{P_A(v+1) - P_A' v}{P_A P_B (v+1)} M \tag{A12}$$

We know that $U^* \geq U$, since U^* is the maximum utility; $U = U^*$ when $P_A' = P_A$.

Since the customer will recalculate only if $U - U^* > x$, there exists a range of small price changes

[24] The information-processing cost of a consumer may be changed by, for example, (un)employment, birth of a child, education, etc. At the occurrence of such events, the consumer may have to re-calculate her region of rational inattention.

within which the consumer will find it optimal not to recalculate. To see this, let $P_A' = \theta P_A$. Then:

$$U - U^* = -\ln\,(\theta^v (v+1-\theta v) > 0 \qquad \text{(A13)}$$

Let $E = \theta^v (v+1-\theta v)$. Then $\frac{\partial E}{\partial \theta} = v\theta^{v-1}(v+1)(1-\theta)$, which is negative when $\theta > 1$, equals 0 when $\theta = 1$, and is positive when $\theta < 1$. Since natural log is a monotonically increasing function, ($U^* - U$) is convex in θ and takes on its minimum value when $\theta = 1$ (i.e., $P_A' = P_A$). We know from above that $U^* - U = 0$ when $\theta = 1$ (i.e., $P_A' = P_A$). Therefore, there exists a region around $\theta = 1$, in which $U^* - U < x$. Let $P_A^u = \theta_A^u P_A$ be the upper limit of this range, and let $P_A^l = \theta_A^l P_A$ be the lower limit of this range ($\theta_A^u > 1$, $\theta_A^l < 1$).[26] In this region, the customer does not find it optimal to process the price change information; she just keeps buying A in the quantity given by equation (A3). This is the region of rational *inattention*.

Customer's Purchase Policy:

A forward-looking customer who is aware of the existence of her information processing cost, knows that the retailer will act strategically to take advantage of the situation by increasing the price in the second period by a factor of $\theta_A^u > 1$. The consumer faces the following optimization problem:

Maximize: $U(A, B) = v \ln A + \ln B + \beta (v \ln A + \ln B)$ (A14)

s.t. $P_A A + \theta_A^u P_A A + 2P_B B = 2M,$ (A15)

where β is the customer's discount rate. Thus the customer maximizes her total utility over two periods, knowing that in the second period the price will be increased by a factor of θ_A^u and that she will not change her purchase behavior. The solution of the problem is given by

$$A^* = \frac{2v}{(v+1)(1+\theta_A^u)P_A} M \qquad \text{(A16)}$$

$$B^* = \frac{1}{(v+1)P_B} M \qquad \text{(A17)}$$

A demand curve of this type is displayed graphically in Figure 4.

Retailer's Pricing Policy:

Now, since the retailer is able to raise the price a little bit in the second period without triggering a change in the customer's purchase behavior, and given the forward-looking customer's demand function

[25] Our results on asymmetric price adjustment in the small are robust to some alternative heuristic purchase rules (see Example 2 below) as long as the consumer stays within her budget constraint, or if she violates the budget constraint in one period but adjusts in later periods.

[26] When $v = 1$, a closed-form solution exists for this region. Specifically, $\theta \in \left[1 - \sqrt{1-c},\ 1 + \sqrt{1-c}\right]$, where $c = e^{-x}$. For example, when $x = 0.01$, θ is between 0.9 and 1.1, meaning that if P_A = \$1.00, then a price change in the range of [−10¢, 10¢] will be ignored and not reacted to.

in equation (A16), the firm's optimization problem is:

Maximize: $\pi = (P_A - C)A + \tau(\theta_A^u P_A - C)A$ (A18)

where $C = \frac{\boldsymbol{a}}{\boldsymbol{A}^2} + \boldsymbol{b}$,

$a > 0$, $b > 0$, A is given by equation (A16), and τ is the retailer's discount rate. Thus, the retailer maximizes its total profit over two periods, knowing that it can increase the price in the second period by a factor of θ_A^u without triggering a change in customer's behavior. Solving the problem in (A18) yields:

$$P_A^* = \frac{v}{(v+1)} \frac{2}{(1+\theta_A^u)} M \sqrt{\frac{b}{a}} \tag{A19}$$

$$P_A^u = \theta_A^u P_A^* = \frac{v}{(v+1)} \frac{2\theta_A^u}{(1+\theta_A^u)} M \sqrt{\frac{b}{a}} \tag{A20}$$

Compared with the price in equation (A6), the price in equation (A19) is lower, and the price in equation (A20) is higher, for $\theta_A^u > 1$. Substituting equation (A19) into equation (A16), we get $\boldsymbol{A}^* = \sqrt{\frac{\boldsymbol{a}}{\boldsymbol{b}}}$, which is exactly the same as the demand function in equation (A8).

Therefore, when faced with a forward-looking customer who must incur an information-processing cost x to re-calculate optimal consumption level, which occurs $(1-\alpha)$ percent of the time, the retailer will act strategically by setting a low initial price and raising it in the second period by a little bit. Because of the optimality of inattentiveness in the small, the customer will keep her consumption constant, in the price range of $P_A^l = \theta_A^l P_A^*$ and $P_A^u = \theta_A^u P_A^*$, as given in equation (A20).

Thus, the main implication of the model is asymmetric price adjustment "in the small," and symmetric price adjustment in the large. This example also demonstrates how the idea of rational inattention in the small imposes a natural limit on how much surplus a retailer can extract from the consumer by strategically taking advantage of the customer information-processing costs. Recall that according to our assumption, when there is a positive information-processing cost, the customer keeps buying the same old quantity of A (or the same old ratio, as modeled further below) when the price change for A is small. Thus, the customer relies on the price for which she last optimized her purchase behavior (i.e., P_A^*) to determine her quantity demanded. With the demand curve as depicted in Figure 4, that means the retailer can only raise its price to P_A^u. Any additional price increase will trigger the customer's re-optimization and consequently a reduction in her purchase. Therefore, under the assumption that the consumer bases her purchase behavior on the price for which she has last optimized, indefinite continuous small price increases are not feasible.[27]

We shall emphasize that this result does not require that all pricing decisions the retailer faces involve rationally inattentive customers. As long as α is large enough, prices will adjust asymmetrically in the small. In other words, the retailer will still be making small price decreases but it will make *more* small price increases than decreases.

Example 2: A Model with Customer Decision Rule Based on a Constant Ratio of A and B

We now present another version of the model presented above by constructing an example in which the region of rational inattention along the demand curve is not necessarily vertical. In this version we assume the same structure as in the example above except that for the α percent of the situations where consumers face a sizeable information processing cost, the consumer's decision rule, if she doesn't re-optimize, is to buy the same ratio of the quantities of products A and B, until her budget constraint is violated. Thus, the only difference between this model and the model studied above is in the type of heuristic rule the consumer adopts.

Before period 2 unravels, the consumer has to make a choice between two options. She can decide to re-optimize to maximize her utility under the new price, and incur the information processing cost of x. Or she can decide to keep buying the same ratio of the quantities of A and B as in period 1: $A^*/B^* = vP_B/P_A$. Which option she will choose depends on the magnitude of her information processing cost.

As before, suppose the price of A changes from P_A to P_A', and the price of B does not change. Recall that if she re-optimizes, the new utility, *before* incurring the information processing cost x, is:

$$U^* = (v+1)\ln M - v\ln\frac{v+1}{v}P_A' - \ln(v+1)P_B \quad \text{(A9)}$$

If she keeps the old ratio, the new demands can be determined by solving from

$$P_A'A + P_B B = M, \text{ and} \quad \text{(A10)}$$

$$A = Bv(P_B/P_A) \quad \text{(A21)}$$

where (A21) is derived from equations (A3) and (A4). These yield:

$$A = \frac{v}{(vP_A'+P_A)}M \quad \text{(A22)}$$

$$B = \frac{P_A}{(vP_A'+P_A)P_B}M \quad \text{(A23)}$$

$$U = v\ln\frac{vM}{P_A'+P_A} + \ln\frac{P_A M}{P_B(vP_A'+P_A)} \quad \text{(A24)}$$

She will re-optimize only if $U^* - U > x$. We know that $U^* \geq U$, since U^* is the maximum utility; $U = U^*$

[27] The model implies that *ceteris paribus,* retailers will adjust asymmetrically once and keep the price there. However, note that retailers may re-price in response to changing market conditions, e.g. costs, leading to large price changes. In our model, the cycle will start again

when P_A' = P_A.

Since the customer will re-optimize only if $U - U^* > x$, there will exist a range of a small price change within which the consumer will not recalculate her demands. To see this, let P_A' = θP_A. Then:

$$U - U^* = \ln \frac{(vt+1)^{v+1}}{(v+1)^{v+1}\theta^r} \tag{A25}$$

Since $(v+1)^{v+1}$ is not a function of θ, and letting $E = \frac{(v\theta+1)^{v+1}}{(v+1)^{v+1}\theta^r}$, $\frac{\partial E}{\partial \theta} = v(v\theta+1)^v \theta^{-v-1}(\theta-1)$, which is negative when $\theta > 1$, equals 0 when $\theta = 1$, and is positive when $\theta < 1$. Since natural log is a monotonically increasing function, ($U^* - U$) is convex in θ, and takes on its minimum value when $\theta = 1$ (i.e., P_A' = P_A). And we know from above that $U^* - U = 0$ when $\theta = 1$ (i.e., P_A' = P_A). Therefore, there exists a region around $\theta = 1$, in which $U^* - U < x$. Let $P_A^u = \theta_A^u P_A$ be the upper limit of this range, and $P_A^l = \theta_A^l P_A$ be the lower limit of this range ($\theta_A^u > 1$, $\theta_A^l < 1$). In this region, it will be optimal for the customer not to incur the information processing cost; she should keep buying A and B at the ratio as given in equation (A21). When $v = 1$, a closed-form solution exists for this region. Specifically, we'll have $\theta \in [2c - 1 - 2\sqrt{c^2 - c}, 2c - 1 + 2\sqrt{c^2 - c}]$, where $c = \exp(x)$. For example, if P_A = \$1.00, and $x = 0.01$, then $c = 1.01$, and θ is between 0.82 and 1.22. That is, a price change in the range of [−18¢, 22¢] will go unnoticed. Compared with the demand curve in Figure 4, when the consumer uses the last period's ratio as her decision rule, we obtain a demand curve with a kink that is not completely vertical, but simply less elastic, as shown in Figure A1. The rest of the model derivation is the same as above.

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with consumers re-processing the information beginning with this new price. Thus, periods of unchanged prices are not predicted when the market experiences both large as well as small changes.

Figure A1. Demand Curve under Rational Inattention (Using the Same Ratio Heuristic Rule)

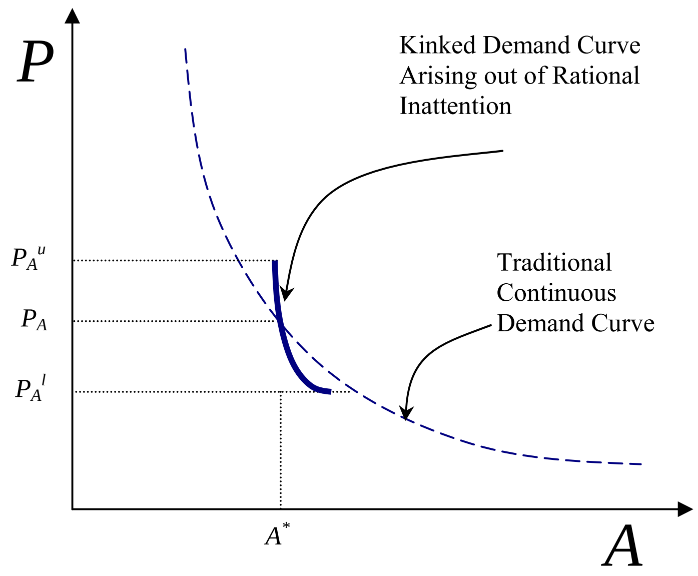


Table 1. Product Categories and the Number of Weekly Price Observations

Product Category	Number of Weekly Observations	Proportion of the Total
Analgesics	3,059,922	0.0310
Bath Soap	418,097	0.0042
Bathroom Tissue	1,156,481	0.0117
Beer	1,970,266	0.0200
Bottled Juice	4,324,595	0.0438
Canned Soup	5,549,149	0.0562
Canned Tuna	2,403,151	0.0244
Cereals	4,747,889	0.0481
Cheeses	7,571,355	0.0767
Cigarettes	1,810,614	0.0183
Cookies	7,634,434	0.0774
Crackers	2,245,305	0.0228
Dish Detergent	2,183,013	0.0221
Fabric Softeners	2,295,534	0.0233
Front-End-Candies	3,952,470	0.0400
Frozen Dinners	1,654,051	0.0168
Frozen Entrees	7,231,871	0.0733
Frozen Juices	2,373,168	0.0240
Grooming Products	4,065,691	0.0412
Laundry Detergents	3,302,753	0.0335
Oatmeal	981,106	0.0099
Paper Towels	948,550	0.0096
Refrigerated Juices	2,176,518	0.0221
Shampoos	4,676,731	0.0474
Snack Crackers	3,509,158	0.0356
Soaps	1,834,040	0.0186
Soft Drinks	10,547,266	0.1069
Toothbrushes	1,852,487	0.0188
Toothpastes	2,997,748	0.0304
Total	98,691,750	1.0000

Table 2. Asymmetry Thresholds in Cents Based on the PPI-Measure of Price Level

	Entire Sample Period	Low Inflation Period	Deflation Period
Analgesics	30	10	10
Bath Soap	6	0	0
Bathroom Tissues	6	4	4
Bottled Juices	12	15	12
Canned Soup	12	12	10
Canned Tuna	1	2	1
Cereals	29	24	1
Cheeses	9	9	9
Cookies	11	11	9
Crackers	10	2	4
Dish Detergent	5	4	6
Fabric Softeners	5	11	7
Front-end-candies	5	5	5
Frozen Dinners	2	10	6
Frozen Entrees	20	22	0
Frozen Juices	9	9	10
Grooming Products	20	12	12
Laundry Detergents	16	13	17
Oatmeal	25	2	5
Paper Towels	2	2	2
Refrigerated Juices	15	9	6
Shampoos	0	10	10
Snack Crackers	11	2	2
Soaps	1	1	1
Soft Drinks	5	3	5
Tooth Brushes	20	3	3
Tooth Pastes	18	14	6
Average	11.3	8.2	6.2
Median	10	9	6

Notes:
PPI = Producer Price Index.
The figures reported in the table are the cutoff points of what might constitute a "small" price change for each category. The cutoff point is the first point at which the asymmetry is not supported statistically. Thus, for example, in the Analgesics category, when the entire sample is used, we see that for price changes of up to 30 cents, there is asymmetry.

Table 3. Three Measures of Inflation (PPI, CPI, and CPI-Chicago) and Two Measures of Unemployment (u) (u-US and u-Chicago), September 1989–May 1997

Year	Month	PPI	%ΔPPI	CPI	%ΔCPI	CPI-Chicago	%ΔCPI-Chicago	u-US	u-Chicago
1989	September	113.6	-	125.0	-	127.1	-	5.3	-
1989	October	114.9	1.14	125.6	0.5	126.8	–0.2	5.3	-
1989	November	114.9	0.00	125.9	0.2	126.7	–0.1	5.4	-
1989	December	115.4	0.44	126.1	0.2	126.5	–0.2	5.4	-
1990	January	117.6	1.91	127.4	1.0	128.1	1.3	5.4	6.1
1990	February	117.4	–0.17	128.0	0.5	129.2	0.9	5.3	6.0
1990	March	117.2	–0.17	128.7	0.5	129.5	0.2	5.2	6.0
1990	April	117.2	0.00	128.9	0.2	130.4	0.7	5.4	5.9
1990	May	117.7	0.43	129.2	0.2	130.4	0.0	5.4	5.8
1990	June	117.8	0.08	129.9	0.5	131.7	1.0	5.2	6.3
1990	July	118.2	0.34	130.4	0.4	132.0	0.2	5.5	6.1
1990	August	119.3	0.93	131.6	0.9	133.2	0.9	5.7	6.2
1990	September	120.4	0.92	132.7	0.8	133.8	0.5	5.9	6.1
1990	October	122.3	1.58	133.5	0.6	133.3	–0.4	5.9	5.9
1990	November	122.9	0.49	133.8	0.2	134.2	0.7	6.2	6.0
1990	December	122.0	–0.73	133.8	0.0	134.6	0.3	6.3	6.1
1991	January	122.3	0.25	134.6	0.6	135.1	0.4	6.4	6.7
1991	February	121.4	–0.74	134.8	0.1	135.5	0.3	6.6	6.7
1991	March	120.9	–0.41	135.0	0.1	136.2	0.5	6.8	6.9
1991	April	121.1	0.17	135.2	0.1	136.1	–0.1	6.7	6.8
1991	May	121.8	0.58	135.6	0.3	136.8	0.5	6.9	6.6
1991	June	121.9	0.08	136.0	0.3	137.3	0.4	6.9	7.2
1991	July	121.6	–0.25	136.2	0.1	137.3	0.0	6.8	6.9
1991	August	121.7	0.08	136.6	0.3	137.6	0.2	6.9	7.0
1991	September	121.4	–0.25	137.2	0.4	138.3	0.5	6.9	7.0
1991	October	122.2	0.66	137.4	0.1	138.0	–0.2	7.0	7.2
1991	November	122.3	0.08	137.8	0.3	138.0	0.0	7.0	7.5
1991	December	121.9	–0.33	137.9	0.1	138.3	0.2	7.3	7.9
1992	January	121.8	–0.08	138.1	0.1	138.9	0.4	7.3	8.4
1992	February	122.1	0.25	138.6	0.4	139.2	0.2	7.4	8.4
1992	March	122.2	0.08	139.3	0.5	139.7	0.4	7.4	8.3
1992	April	122.4	0.16	139.5	0.1	139.8	0.1	7.4	8.0
1992	May	123.2	0.65	139.7	0.1	140.5	0.5	7.6	7.9
1992	June	123.9	0.57	140.2	0.4	141.2	0.5	7.8	8.3
1992	July	123.7	–0.16	140.5	0.2	141.4	0.1	7.7	7.8
1992	August	123.6	–0.08	140.9	0.3	141.9	0.4	7.6	6.4
1992	September	123.3	–0.24	141.3	0.3	142.7	0.6	7.6	6.2
1992	October	124.4	0.89	141.8	0.4	142.1	–0.4	7.3	6.1
1992	November	124.0	–0.32	142.0	0.1	142.4	0.2	7.4	6.4
1992	December	123.8	–0.16	141.9	–0.1	142.9	0.4	7.4	6.8
1993	January	124.2	0.32	142.6	0.5	143.2	0.2	7.3	7.6
1993	February	124.5	0.24	143.1	0.4	143.6	0.3	7.1	7.8
1993	March	124.7	0.16	143.6	0.3	144.1	0.3	7.0	7.9
1993	April	125.5	0.64	144.0	0.3	144.7	0.4	7.1	7.7
1993	May	125.8	0.24	144.2	0.1	145.7	0.7	7.1	7.5
1993	June	125.5	–0.24	144.4	0.1	145.6	–0.1	7.0	7.9
1993	July	125.3	–0.16	144.4	0.0	145.5	–0.1	6.9	7.5
1993	August	124.2	–0.88	144.8	0.3	146.1	0.4	6.8	7.5
1993	September	123.8	–0.32	145.1	0.2	146.7	0.4	6.7	7.7

1993	October	124.6	0.65	145.7	0.4	147.2	0.3	6.8	7.3
1993	November	124.5	–0.08	145.8	0.1	146.4	–0.5	6.6	5.8
1993	December	124.1	–0.32	145.8	0.0	146.1	–0.2	6.5	5.9
1994	January	124.5	0.32	146.2	0.3	146.5	0.3	6.6	6.7
1994	February	124.8	0.24	146.7	0.3	146.8	0.2	6.6	6.6
1994	March	124.9	0.08	147.2	0.3	147.6	0.5	6.5	6.3
1994	April	125.0	0.08	147.4	0.1	147.9	0.2	6.4	5.7
1994	May	125.3	0.24	147.5	0.1	147.6	–0.2	6.1	5.5
1994	June	125.6	0.24	148.0	0.3	148.1	0.3	6.1	5.8
1994	July	126.0	0.32	148.4	0.3	148.3	0.1	6.1	5.5
1994	August	126.5	0.40	149.0	0.4	149.8	1.0	6.0	5.4
1994	September	125.6	–0.71	149.4	0.3	150.2	0.3	5.9	5.2
1994	October	125.8	0.16	149.5	0.1	149.4	–0.5	5.8	5.1
1994	November	126.1	0.24	149.7	0.1	150.4	0.7	5.6	4.8
1994	December	126.2	0.08	149.7	0.0	150.5	0.1	5.5	4.9
1995	January	126.6	0.32	150.3	0.4	151.8	0.9	5.6	5.5
1995	February	126.9	0.24	150.9	0.4	152.3	0.3	5.4	5.5
1995	March	127.1	0.16	151.4	0.3	152.6	0.2	5.4	5.2
1995	April	127.6	0.39	151.9	0.3	153.1	0.3	5.8	5.2
1995	May	128.1	0.39	152.2	0.2	153.0	–0.1	5.6	5.0
1995	June	128.2	0.08	152.5	0.2	153.5	0.3	5.6	5.1
1995	July	128.2	0.00	152.5	0.0	153.6	0.1	5.7	5.0
1995	August	128.1	–0.08	152.9	0.3	153.8	0.1	5.7	5.1
1995	September	127.9	–0.16	153.2	0.2	154.0	0.1	5.6	4.8
1995	October	128.7	0.63	153.7	0.3	154.3	0.2	5.5	4.7
1995	November	128.7	0.00	153.6	–0.1	154.0	–0.2	5.6	4.7
1995	December	129.1	0.31	153.5	–0.1	153.8	–0.1	5.6	5.0
1996	January	129.4	0.23	154.4	0.6	154.6	0.5	5.6	5.6
1996	February	129.4	0.00	154.9	0.3	155.2	0.4	5.5	5.5
1996	March	130.1	0.54	155.7	0.5	156.3	0.7	5.5	5.4
1996	April	130.6	0.38	156.3	0.4	156.4	0.1	5.6	5.1
1996	May	131.1	0.38	156.6	0.2	156.9	0.3	5.6	4.9
1996	June	131.7	0.46	156.7	0.1	157.6	0.4	5.3	5.3
1996	July	131.5	–0.15	157.0	0.2	157.7	0.1	5.5	5.1
1996	August	131.9	0.30	157.3	0.2	158.1	0.3	5.1	5.0
1996	September	131.8	–0.08	157.8	0.3	158.3	0.1	5.2	4.8
1996	October	132.7	0.68	158.3	0.3	158.8	0.3	5.2	4.5
1996	November	132.6	–0.08	158.6	0.2	159.4	0.4	5.4	4.5
1996	December	132.7	0.08	158.6	0.0	159.7	0.2	5.4	4.7
1997	January	132.6	–0.08	159.1	0.3	160.4	0.4	5.3	5.2
1997	February	132.2	–0.30	159.6	0.3	161.1	0.4	5.2	5.1
1997	March	132.1	–0.08	160.0	0.3	161.0	–0.1	5.2	4.9
1997	April	131.6	–0.38	160.2	0.1	160.9	–0.1	5.1	4.5
1997	May	131.6	0.00	160.1	–0.1	161.1	0.1	4.9	4.2

Table 4. Asymmetry Thresholds in Cents for the PPI-Deflationary Period with Lagged Price Adjustment

	4-Week Lag	8-Week Lag	12-Week Lag	16-Week Lag
Analgesics	12	5	10	1
Bath Soap	0	0	0	0
Bathroom Tissues	4	4	4	3
Bottled Juices	10	2	6	7
Canned Soup	11	10	12	11
Canned Tuna	2	2	1	6
Cereals	25	0	25	11
Cheeses	9	2	9	8
Cookies	11	10	11	4
Crackers	4	2	4	3
Dish Detergent	10	2	6	6
Fabric Softeners	13	2	1	1
Front-end-candies	4	6	2	0
Frozen Dinners	9	9	2	8
Frozen Entrees	4	20	10	5
Frozen Juices	9	1	6	1
Grooming Products	18	18	10	4
Laundry Detergents	13	11	5	2
Oatmeal	4	4	12	1
Paper Towels	2	2	2	2
Refrigerated Juices	6	18	11	5
Shampoos	5	5	0	0
Snack Crackers	2	2	2	1
Soaps	2	1	1	1
Soft Drinks	2	9	2	0
Tooth Brushes	1	10	8	3
Tooth Pastes	6	7	20	7
Average	7.3	6.1	6.7	3.7
Median	6	4	6	3

Table 5. Asymmetry Thresholds in Cents, Deflation Periods,
Based on CPI-Chicago and CPI

	CPI-Chicago	CPI
Analgesics	7	10
Bath Soap	0	0
Bathroom Tissues	4	9
Bottled Juices	8	9
Canned Soup	14	10
Canned Tuna	1	1
Cereals	33	28
Cheeses	5	8
Cookies	4	11
Crackers	1	1
Dish Detergent	9	7
Fabric Softeners	8	3
Front-end-candies	7	9
Frozen Dinners	1	1
Frozen Entrees	11	10
Frozen Juices	5	7
Grooming Products	23	13
Laundry Detergents	20	9
Oatmeal	4	2
Paper Towels	2	2
Refrigerated Juices	9	6
Shampoos	5	0
Snack Crackers	6	3
Soaps	6	2
Soft Drinks	2	1
Tooth Brushes	1	8
Tooth Pastes	6	6
Average	7.5	6.5
Median	6	7

Table 6. Asymmetry Thresholds in Cents Based on CPI-Chicago and CPI with Lagged Price Adjustment

	4-Week Lag		8-Week Lag		12-Week Lag		16-Week Lag	
	CPI-Chicago	CPI	CPI-Chicago	CPI	CPI-Chicago	CPI	CPI-Chicago	CPI
Analgesics	0	1	0	0	5	0	14	0
Bath Soap	0	0	0	0	0	0	0	0
Bathroom Tissues	4	5	4	4	4	4	3	6
Bottled Juices	10	2	16	2	0	0	2	3
Canned Soup	12	11	13	0	11	2	12	8
Canned Tuna	1	1	2	2	1	1	1	1
Cereals	29	0	29	21	0	25	29	28
Cheeses	9	12	10	2	6	1	2	10
Cookies	11	3	11	5	12	5	10	10
Crackers	1	7	3	4	6	10	2	6
Dish Detergent	5	1	2	4	1	1	2	3
Fabric Softeners	2	5	1	0	1	1	1	2
Front-end-candies	6	9	5	6	2	6	1	1
Frozen Dinners	2	2	3	1	1	2	1	1
Frozen Entrees	3	10	0	12	0	0	4	9
Frozen Juices	1	1	9	1	14	5	2	4
Grooming Products	5	13	12	8	18	14	6	1
Laundry Detergents	3	0	1	3	1	12	3	13
Oatmeal	5	2	1	4	3	4	4	17
Paper Towels	1	2	2	2	2	2	1	2
Refrigerated Juices	3	6	3	2	6	9	9	5
Shampoos	5	0	2	0	0	8	0	0
Snack Crackers	2	2	2	5	2	1	2	2
Soaps	1	1	1	2	1	1	1	1
Soft Drinks	5	1	1	4	3	3	3	2
Tooth Brushes	1	0	8	0	2	0	2	2
Tooth Pastes	6	10	18	8	10	0	12	3
Average	4.9	4	5.9	3.8	4.2	4.3	4.8	5.2
Median	3	2	3	2	2	2	2	3

Table 7. Asymmetry Thresholds in Cents, First 12-Month Period of the Sample vs Last 12-Month Period of the Sample

	Sample Size		Threshold	
	First 12 Months	Last 12 Months	First 12 Months	Last 12 Months
Analgesics	312,534	430,029	0	16
Bath Soap	0	98,529	-	-
Bathroom Tissues	111,584	165,986	2	4
Bottled Juices	391,379	611,627	11	12
Canned Soup	657,039	406,997	0	24
Canned Tuna	290,860	203,939	3	2
Cereals	550,364	672,046	0	13
Cheeses	748,883	949,382	0	22
Cookies	970,126	922,640	0	10
Crackers	242,707	402,834	1	11
Dish Detergent	266,158	308,769	0	15
Fabric Softeners	243,900	299,302	0	1
Front-end-candies	525,912	517,081	0	1
Frozen Dinners	0	327,646	-	-
Frozen Entrees	782,633	976,451	1	20
Frozen Juices	236,961	306,801	1	13
Grooming Products	0	1,010,036	-	-
Laundry Detergents	347,556	376,475	1	6
Oatmeal	0	168,849	-	-
Paper Towels	100,437	119,194	1	4
Refrigerated Juices	192,878	319,187	0	10
Shampoos	0	1,209,605	-	-
Snack Crackers	377,000	460,508	0	3
Soaps	0	354,449	-	-
Soft Drinks	918,306	1,890,469	0	0
Tooth Brushes	226,573	238,089	0	1
Tooth Pastes	317,591	424,639	1	2
Average			1.1	9.1
Median			0	10

Note:

In six product categories, the sample size was 0 for the first 12 months, and thus no comparison could be performed.

Table 8. Asymmetry Thresholds in Cents for Products Whose Average Price during the First 4 Weeks Was Higher than (or the Same as) the Average Price during the Last 4 Weeks

	Threshold
Analgesics	3
Bath Soap	0
Bathroom Tissues	5
Bottled Juices	5
Canned Soup	0
Canned Tuna	1
Cereals	14
Cheeses	1
Cookies	2
Crackers	2
Dish Detergent	5
Fabric Softeners	1
Front-end-candies	0
Frozen Dinners	2
Frozen Entrees	14
Frozen Juices	9
Grooming Products	2
Laundry Detergents	12
Oatmeal	2
Paper Towels	2
Refrigerated Juices	7
Shampoos	0
Snack Crackers	2
Soaps	1
Soft Drinks	1
Tooth Brushes	3
Tooth Pastes	10
Average	3.9
Median	2

Table 9. Variation in the Asymmetry Thresholds in Cents over the Business Cycle

	Threshold				Sample Size			
	Low	NBER	High-Chicago	High-US	Low	NBER	High-Chicago	High-US
Analgesics	16	0	8	8	290,098	243,554	275,751	271,589
Bath Soap	0	--	0	0	66,850	--	29,693	40,445
Bathroom Tissues	4	3	1	1	119,928	81,772	95,866	97,704
Bottled Juices	12	2	6	6	396,630	296,436	398,069	400,885
Canned Soup	12	0	1	1	270,074	480,363	510,137	513,003
Canned Tuna	21	1	2	2	169,238	204,450	225,749	229,596
Cereals	0	0	20	0	444,826	435,170	465,991	469,343
Cheeses	29	0	1	1	640,023	545,066	590,552	594,712
Cookies	19	1	8	6	629,269	658,658	720,327	724,924
Crackers	11	1	1	1	267,978	184,937	198,575	194,353
Dish Detergent	15	0	2	2	208,650	192,674	191,233	191,155
Fabric Softeners	1	2	4	4	195,268	180,544	190,898	193,299
Front-end-candies	16	1	1	1	339,746	391,849	409,466	414,510
Frozen Dinners	5	--	7	3	219,267	--	52,357	104,752
Frozen Entrees	19	0	10	8	666,595	595,097	626,024	627,971
Frozen Juices	10	0	2	1	200,042	190,792	209,811	211,856
Grooming Products	0	--	8	8	686,463	--	292,428	408,529
Laundry Detergents	13	0	2	2	239,687	256,294	301,483	304,595
Oatmeal	2	--	0	18	116,311	--	112,143	107,397
Paper Towels	2	0	1	1	81,136	73,354	84,240	83,448
Refrigerated Juices	15	0	10	1	207,171	149,588	177,756	176,872
Shampoos	17	--	3	6	816,157	--	493,778	683,457
Snack Crackers	3	0	2	2	309,361	297,408	301,817	304,149
Soaps	12	--	1	1	226,417	--	183,734	214,697
Soft Drinks	3	1	0	0	1,262,488	658,506	774,846	791,416
Tooth Brushes	1	1	8	8	168,467	162,515	187,868	192,626
Tooth Pastes	1	0	0	0	294,654	238,442	251,899	252,323
Average	9.6	0.6	4.0	3.4				
Median	14	1	7	6				

Note: Low = Lowest Unemployment Rate Period for both Chicago and the U.S.
NBER = NBER Recession Period
High-Chicago = Highest Chicago Unemployment Rate Period
High-US = Highest U.S. Unemployment Rate Period.

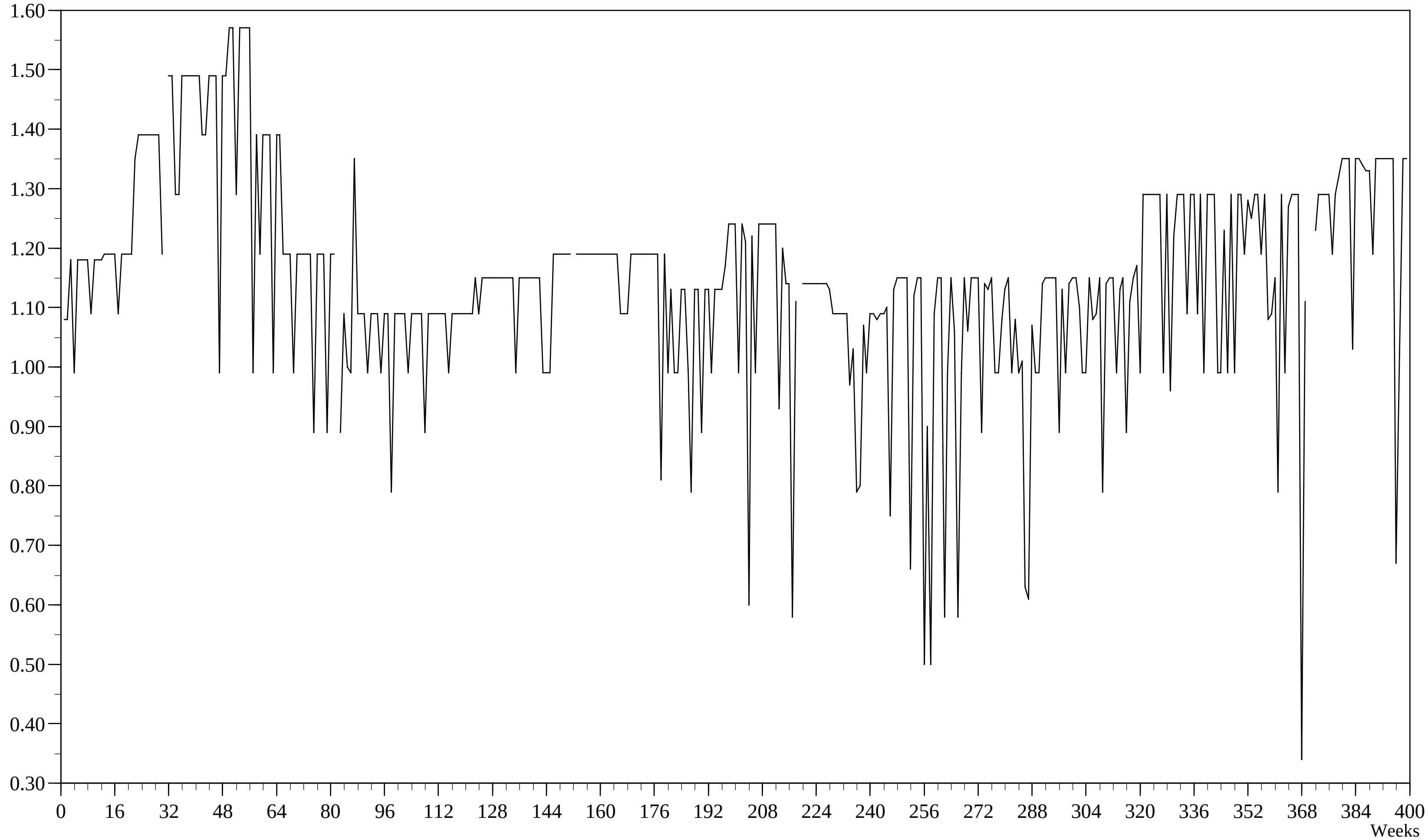


Figure 1. Price of Frozen Concentrate Orange Juice, Heritage House, 12oz (UPC = 3828190029, Store 78), September 14, 1989–May 8, 1997 (Source: Dutta, et al., 2002, and Levy, et al., 2002).

Notes: (1) Week 1 = Week of September 14, 1989, and Week 399=Week of May 8, 1997.
(2) There are 6 missing observations in the series.
(3) A careful visual examination of the plot will reveal that the series contain many small price changes. See the text for details.

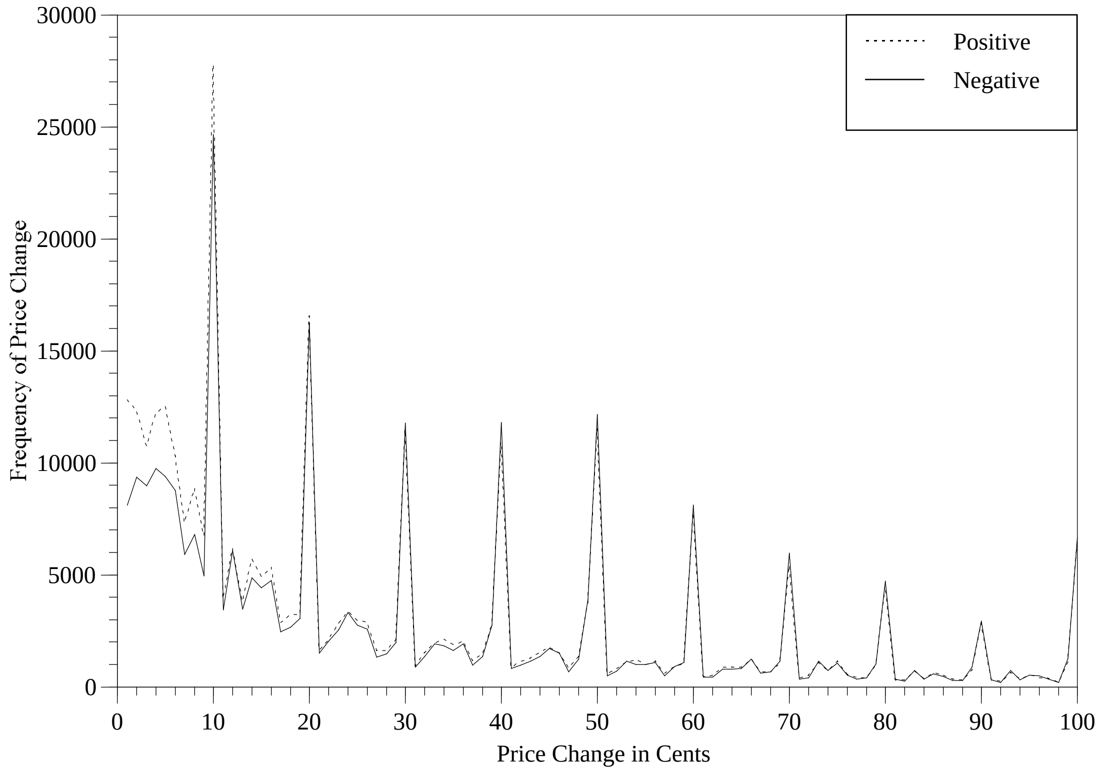


Figure 2. Average Frequency of Positive and Negative Price Changes, All 29 Categories

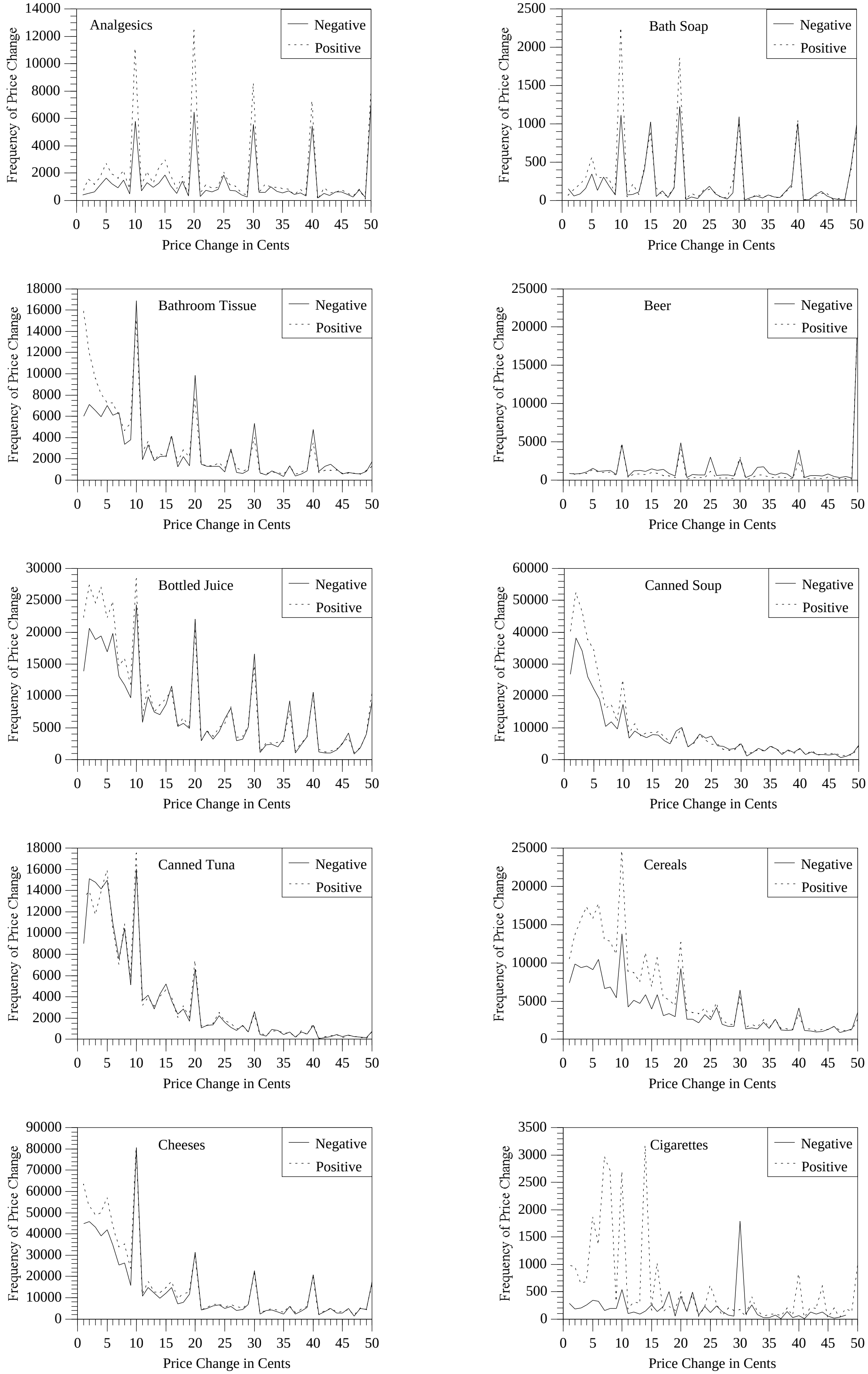


Figure 3a. Frequency of Positive and Negative Price Changes in Cents by Category

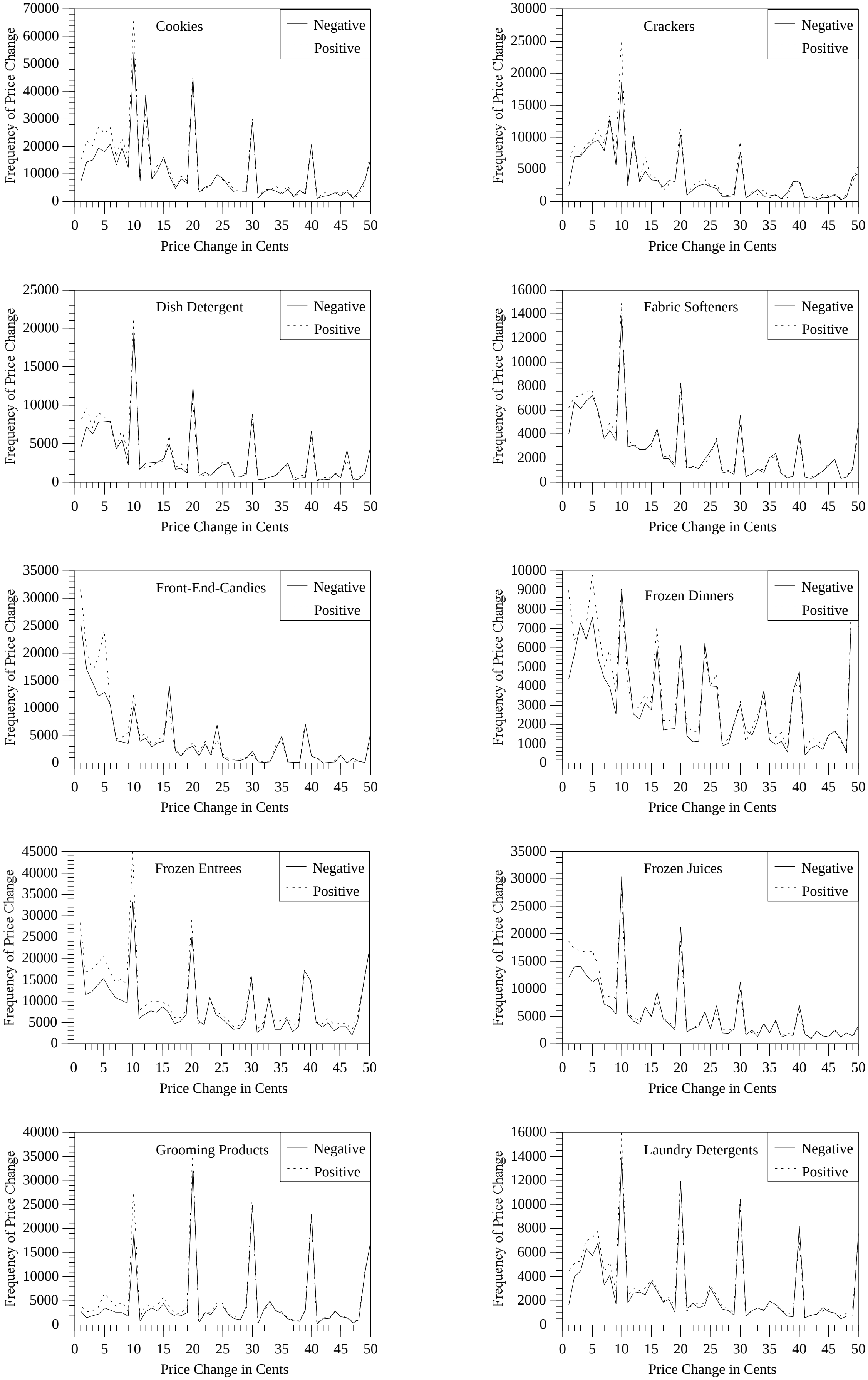


Figure 3b. Frequency of Positive and Negative Price Changes in Cents by Category

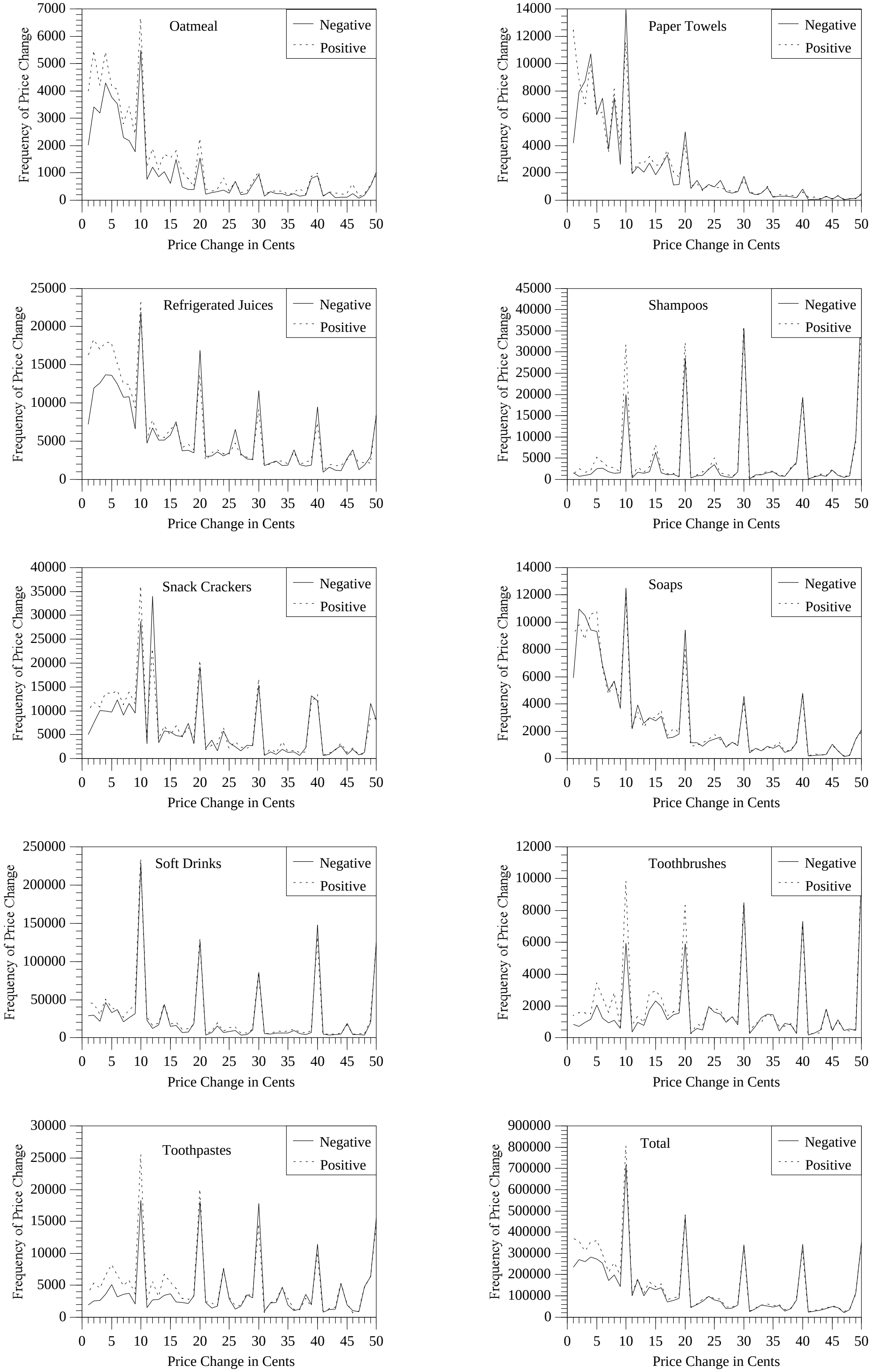
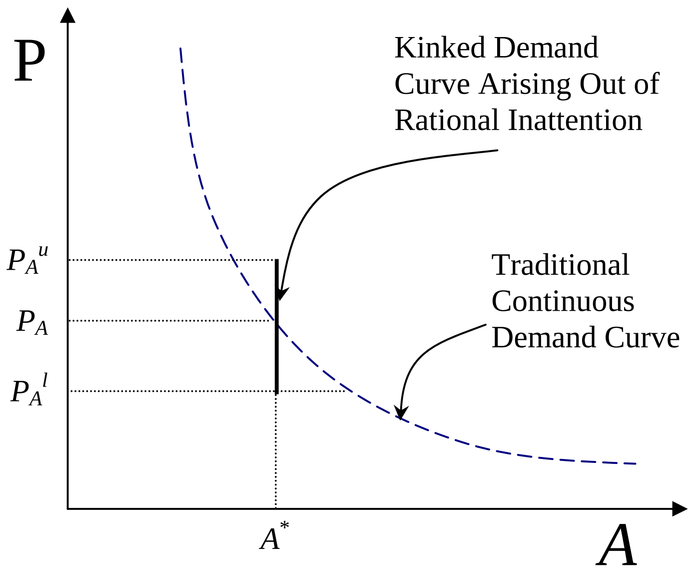


Figure 3c. Frequency of Positive and Negative Price Changes in Cents by Category

Figure 4. Demand Curve Due to Rational Inattention (Using the Same Quantity Heuristic)



Referee Appendix

In Figure R1 we present the cross-category average frequency of positive and negative price changes in cents for the low/zero-inflation period sample.

In Figures R1.1a–R1.1c we present the frequency of positive and negative price changes in cents by categories for the low/zero-inflation period sample.

In Figure R2 we present the cross-category average frequency of positive and negative price changes in cents for the deflation period sample.

In Figures R2.1a–R2.1c we present the frequency of positive and negative price changes in cents by categories for the deflation period sample.

For the discussion of these findings see section 3.2 of the manuscript.

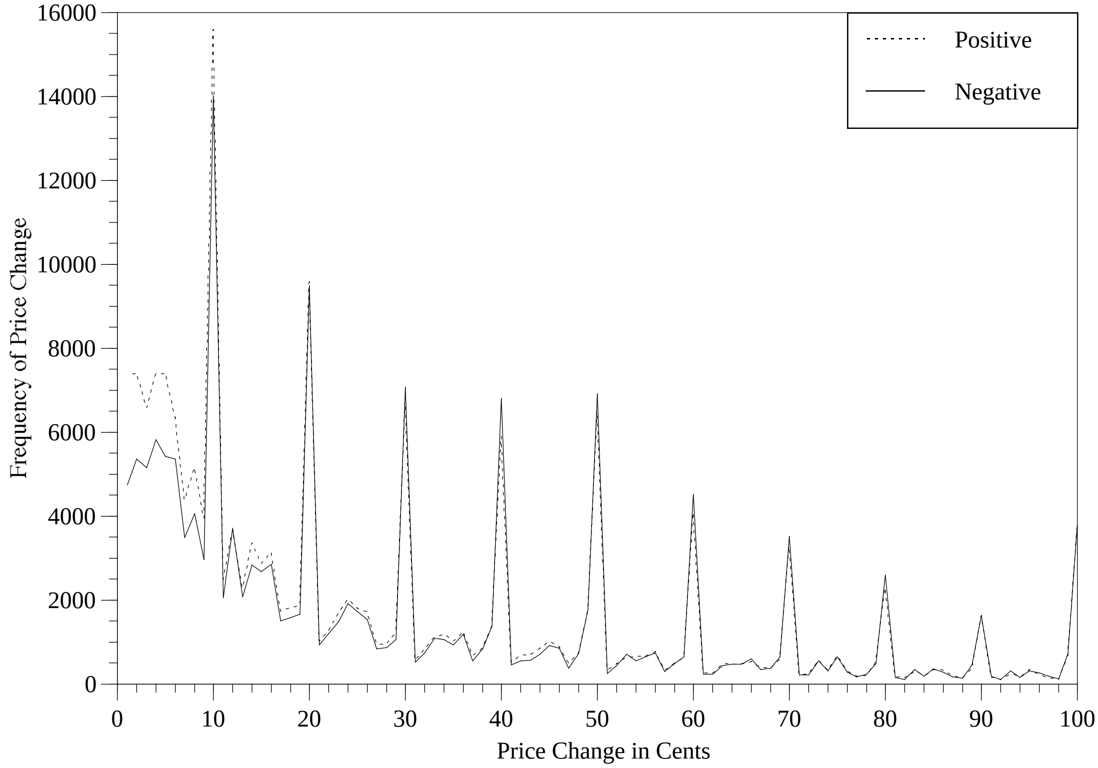


Figure R1. Average Frequency of Positive and Negative Price Changes
All 29 Categories, Low/Zero Inflation Period

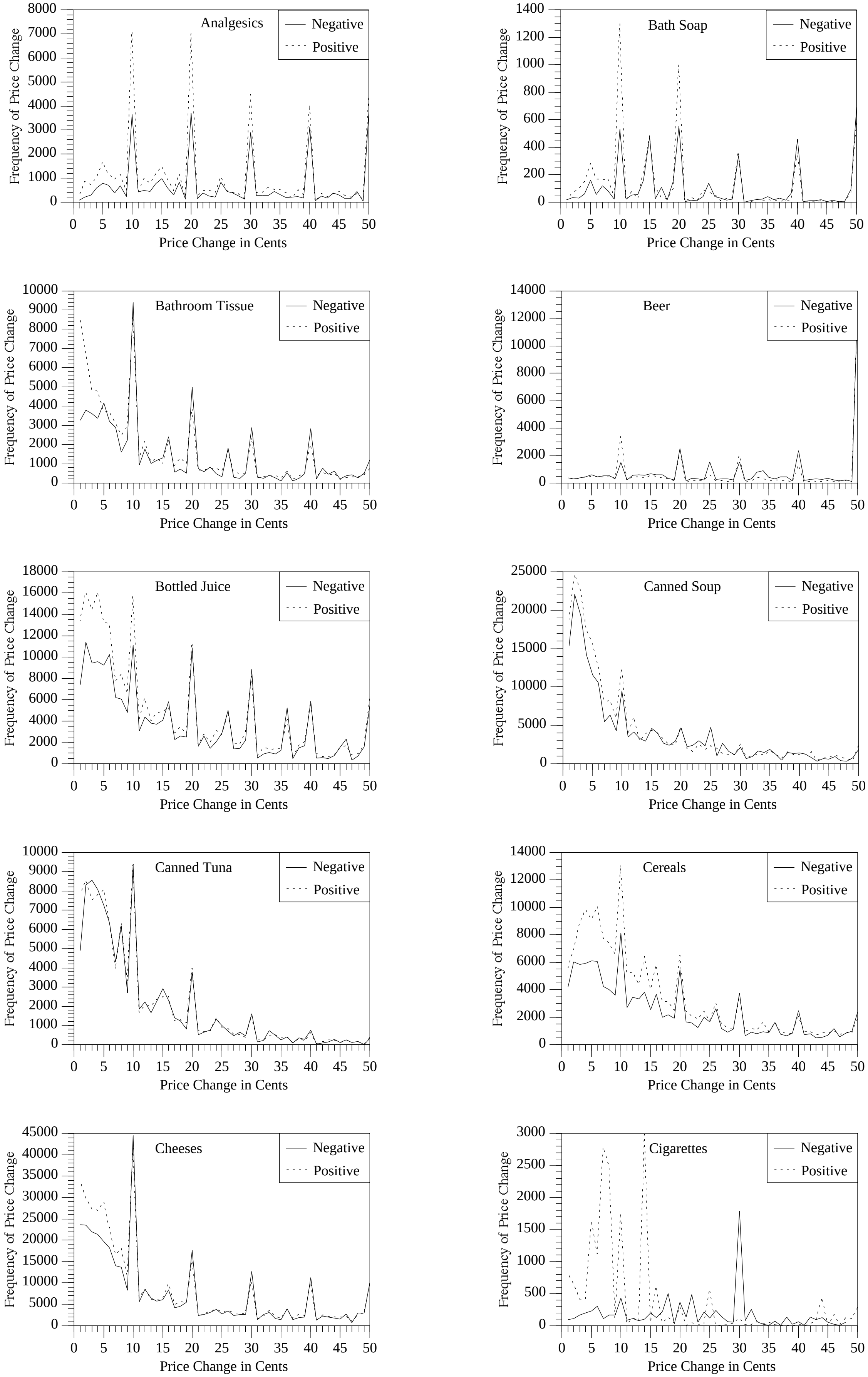


Figure R1.1a. Frequency of Positive and Negative Retail Price Changes in Cents by Category, Low/Zero Inflation Period

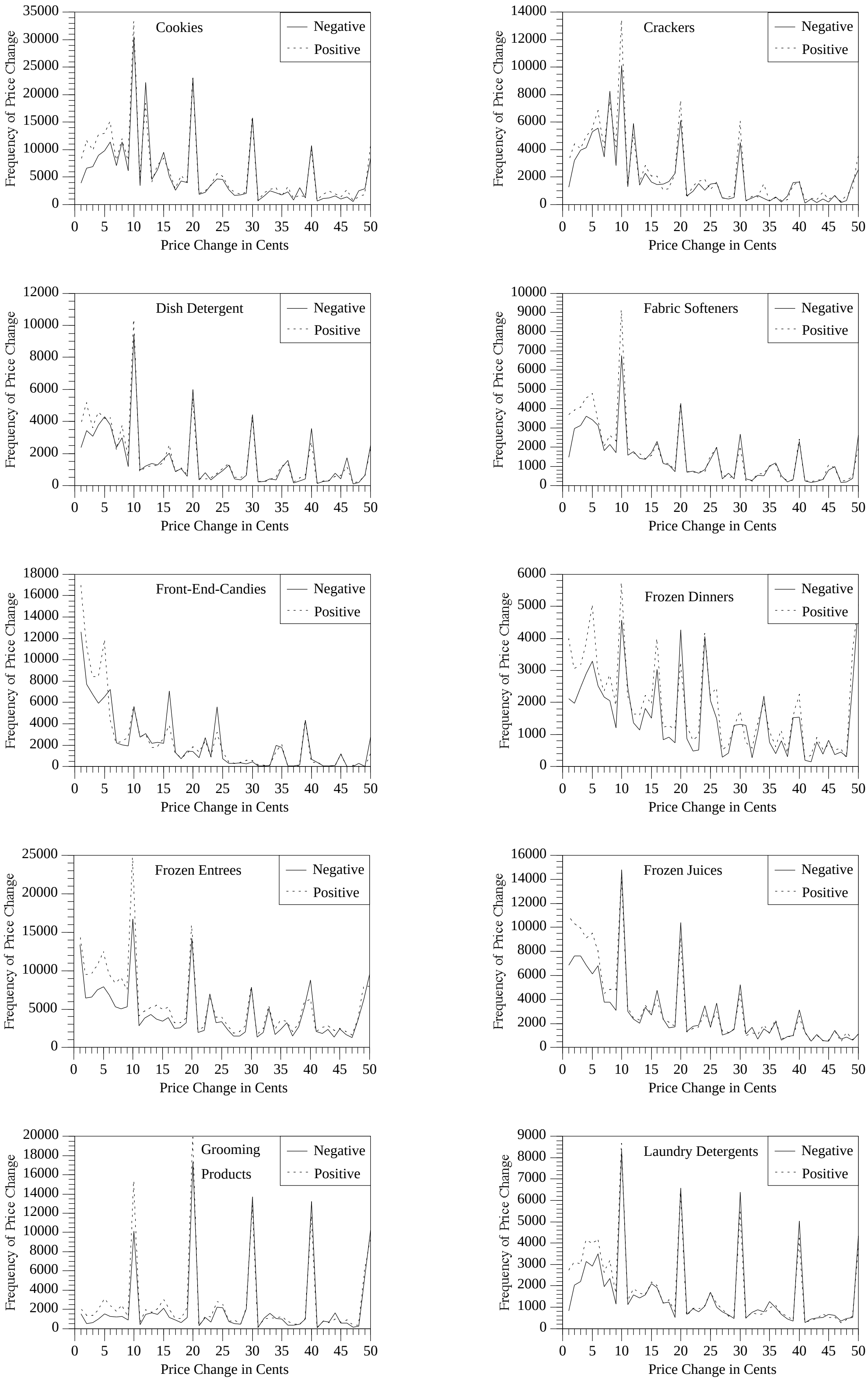


Figure R1.1b. Frequency of Positive and Negative Retail Price Changes in Cents by Category, Low/Zero Inflation Period

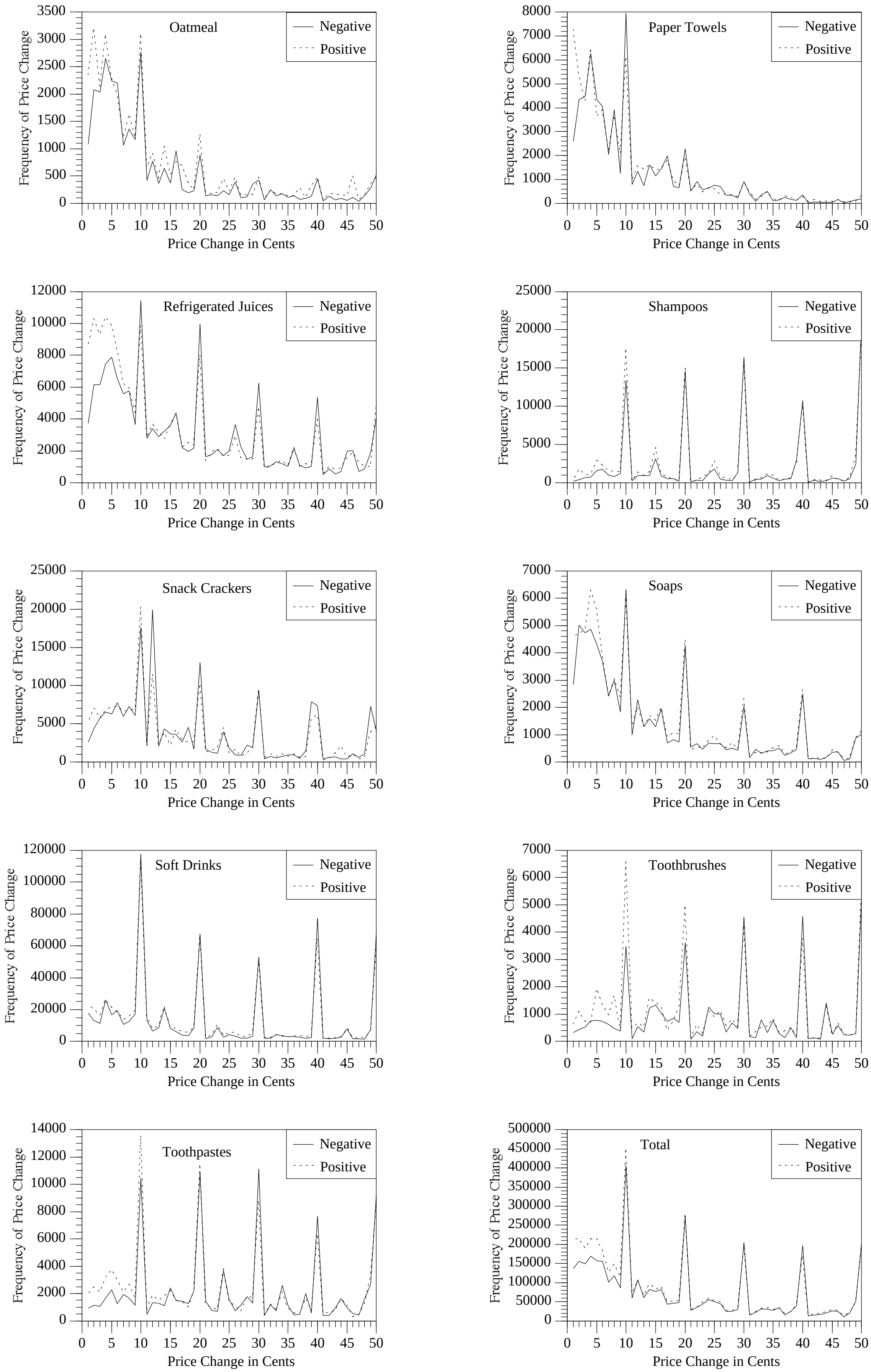


Figure R1.1c. Frequency of Positive and Negative Retail Price Changes in Cents by Category, Low/Zero Inflation Period

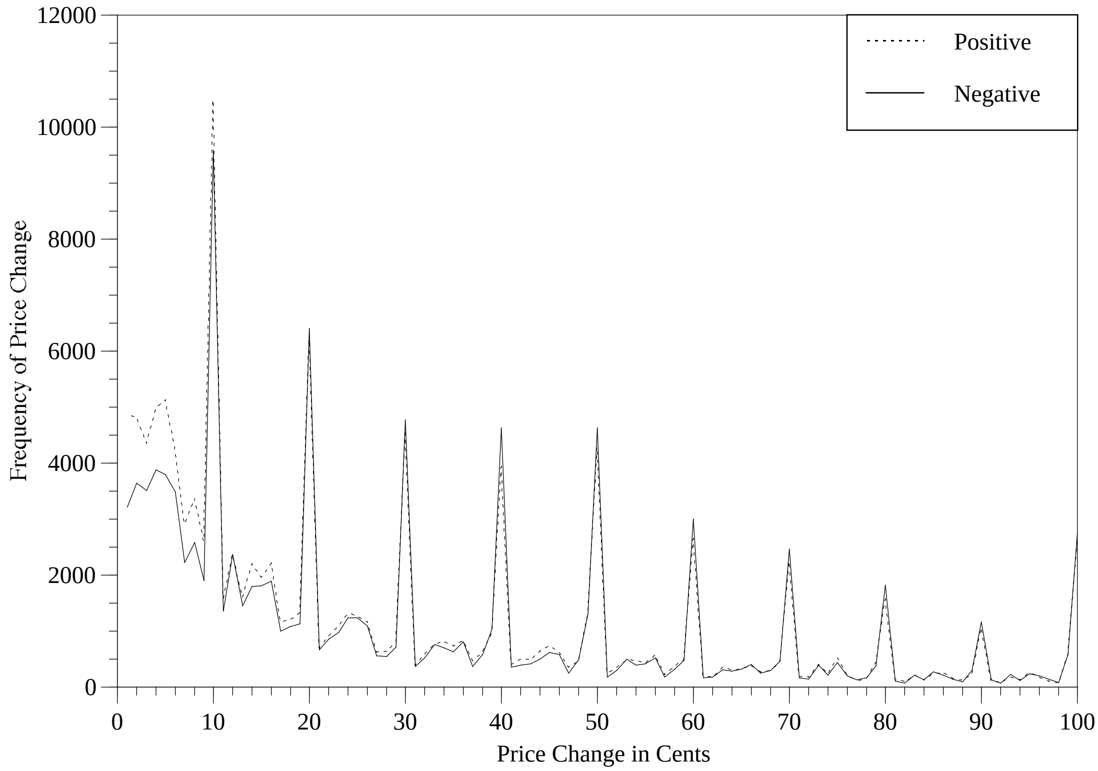


Figure R2. Average Frequency of Positive and Negative Price Changes
All 29 Categories, Deflation Period

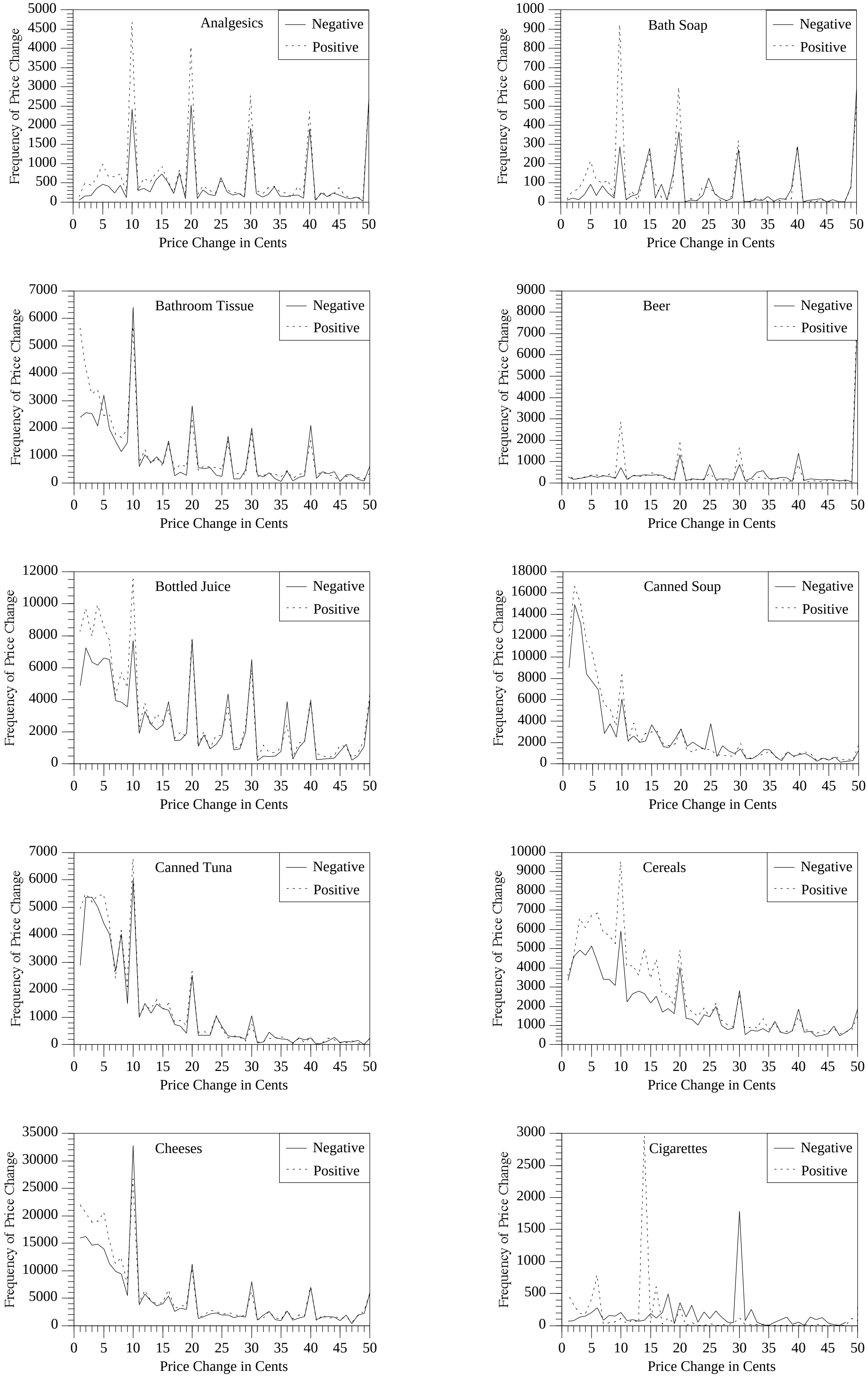


Figure R2.1a. Frequency of Positive and Negative Retail Price Changes in Cents by Category, Deflation Period

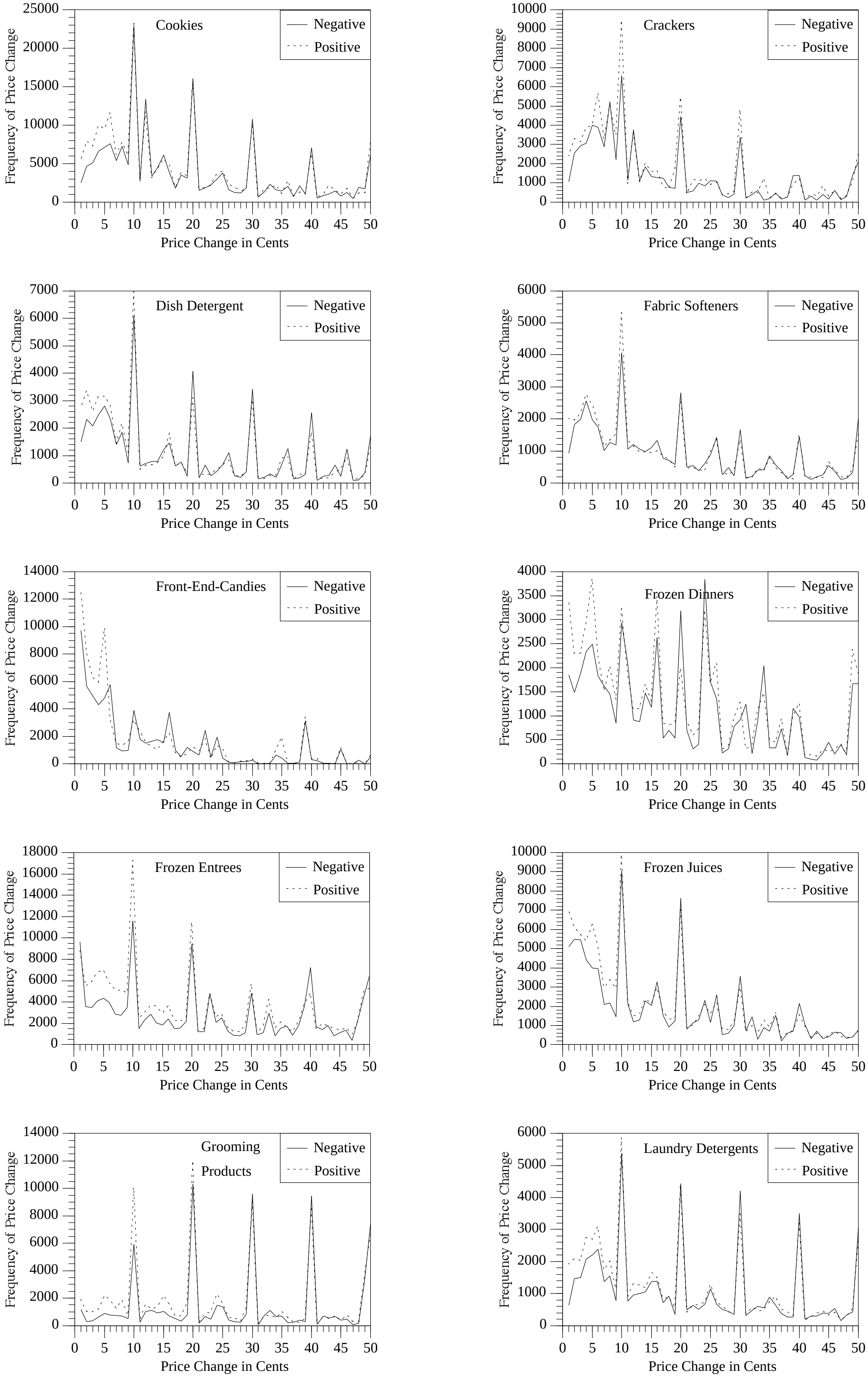


Figure R2.1b. Frequency of Positive and Negative Retail Price Changes in Cents by Category, Deflation Period

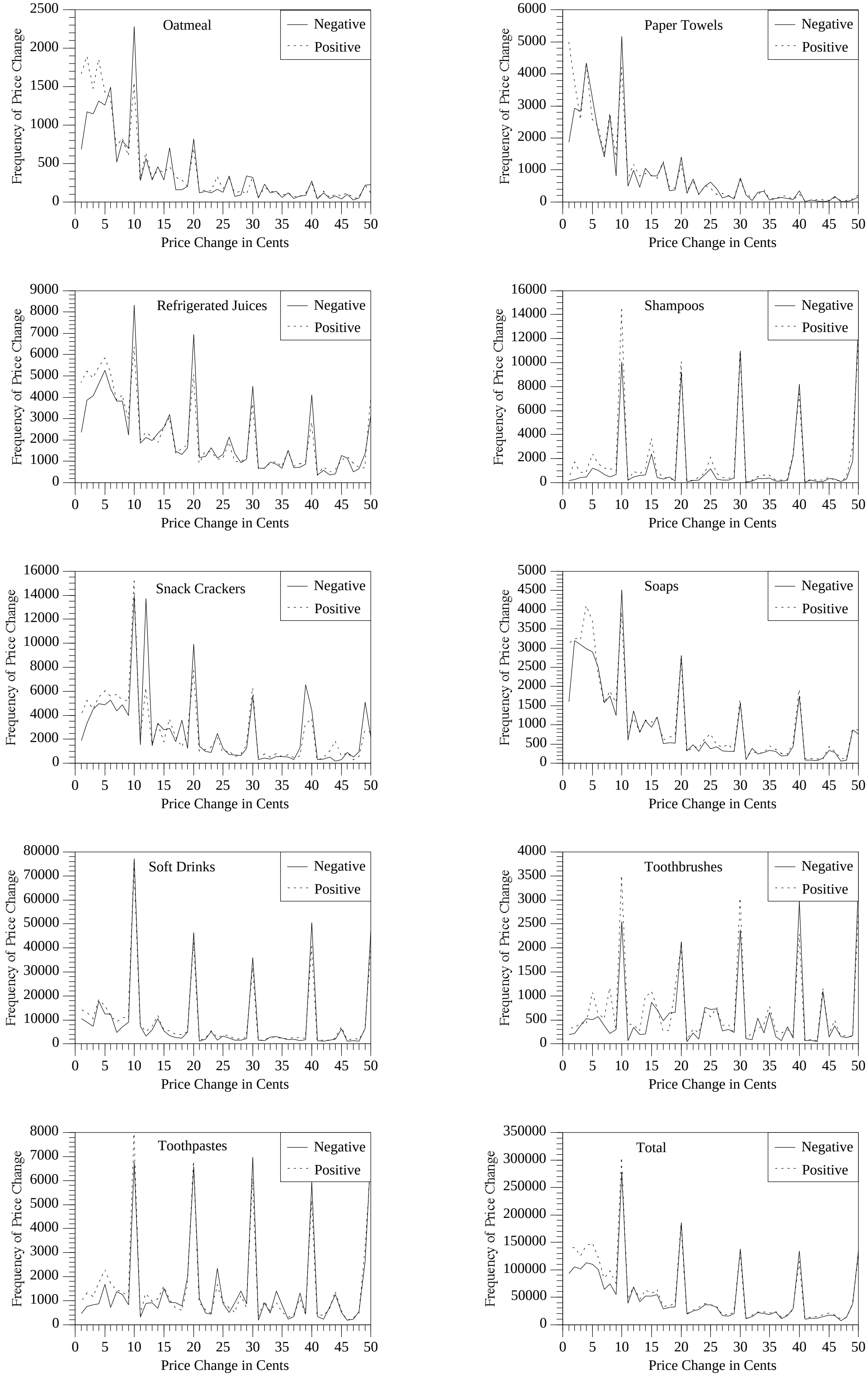


Figure R2.1c. Frequency of Positive and Negative Retail Price Changes in Cents by Category, Deflation Period