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

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Abstract

Analyzing scanner data that cover 29 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 15–30 cents (in absolute terms) and 3–10 percent (in relative terms). The asymmetry disappears for larger price changes. We document this finding for the entire data set, as well as for individual product categories considered. Moreover, we find that the asymmetry holds even when we exclude from the data the observations pertaining to inflationary periods. 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."

"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)**

"Because individuals have many things to think about and limited time, they can devote only limited intellectual resources to the tasks of data-gathering and analysis. We know from personal experience that many data that we could look up daily, and that are in principle relevant to our optimal economic decision-making, do not in fact influence our behavior, *except when they change dramatically*, or perhaps when we occasionally set aside some time to re-assess our portfolio." (Our emphasis.) **Christopher Sims (1998, pp. 320–321)**

"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]

1. Introduction

One of the most interesting aspects of retail pricing is the question of whether patterns of retail price increases are different from patterns of retail price decreases, a phenomenon known as asymmetric price adjustment. This is a particularly important issue for retail prices because they are readily visible to consumers, the media and policy makers. We often hear about gas prices that seem to be "rising like rockets …[but]… falling like feathers."[2] The same is true for food prices, where "retail pork prices do not come down even if hog prices do,"[3] and "government subsidies to dairy farmers do not lower dairy product prices."[4]

Economists have devoted considerable attention to the issue of asymmetric price adjustment. However, as Peltzman (2000) points out, economic theory suggests no pervasive tendency for prices to respond asymmetrically. Indeed, on the theoretical level, we find that the existing literature offers only a handful of explanations for asymmetric price adjustment.[5] Empirically, asymmetric price adjustment has been studied mostly with individual or industry level data such as banking, gasoline, fruit and vegetables, pork, etc.[6] Studies of asymmetric price adjustment that use aggregate data are scarce. See Ball and Mankiw (1994) for a recent example of the latter.

In this paper we contribute to the literature on asymmetric price adjustment in three ways. First, using a large weekly scanner price data that cover 29 different 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. This asymmetry is found for price changes of up to about 15–30 cents (in absolute terms) and 3–10 percents (in relative terms). We find that the

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[1] We thank Andy Young for bringing this news article to our attention.
[2] *Octane*, Vol. 13, No. 3, June 1999, pp. 6–7.
[3] *The New York Times*, January 7, 1999, "The Great Pork Gap: Hog Prices Have Plummeted, Why Haven't Store Prices?"
[4] *Canadian Press Newswire*, December 18, 2000.
[5] See Peltzman (2000) and Meyer and Cramon-Taubadel (2004) for recent critical surveys.
[6] See, for example, Ward (1982), Boyde and Brorsen (1988), Bacon, (1991), Hannan and Berger (1991), Karrenbrock (1991), Pick, et al. (1991), Neumark and Sharpe (1993), Borenstein and Shepard (1994), and Peltzman (2000).

asymmetry disappears for larger price changes. These results hold for the entire data set combined, as well as for almost every individual product category included in the data set.

Second, we explore the literature on asymmetric price adjustment to see if existing theories can explain this asymmetric price adjustment "in the small" and simultaneous symmetric price adjustment "in the large." We conclude that the only theory that is capable of explaining the pricing pattern documented in our data is the presence of menu cost under inflation as suggested by Tsiddon (1993) and Ball and Mankiw (1994). For example, according to Ball and Mankiw, firms must incur a cost to change their prices, and therefore, during inflationary periods they may find it optimal to undertake price increases but less optimal to undertake price decreases because of the expected inflation. Moreover, these asymmetric incentives may be stronger for small changes. We, however, rule out this theory also as a possible explanation because we find that the asymmetry in the small holds in our data even after excluding the observations pertaining to inflationary periods. Moreover, these findings hold even after allowing for various lengths of lagged price adjustment. The findings are insensitive also to the measure of price level used to measure inflation: producer price index (PPI) or consumer price index (CPI).

Third, we suggest that these findings can be explained by extending the literature on "rational inattention," a class of models that conjecture deviations from the assumption of computationally unconstrained and fully rational agents. More specifically, our model extends the implications of the recently emerging literature on rational inattention to individual price dynamics. We demonstrate that asymmetric price adjustment "in the small" that we find at the level of individual product prices, follows naturally from the idea of individual "rational inattention" of consumers (Sims, 1998; Mankiw and Reis, 2002; Rotemberg, 2002; Ball, et al, 2004; Reis, 2003 and 2004; Shugan, 1980).

The essence of the idea of rational inattention is that processing price change information is not a costless activity. For example, customers incur costs in processing price change information and changing purchase behavior in response to this information. If the costs of processing price change information exceed the benefits, consumers may rationally choose to be inattentive to such price change information and therefore, not react to the price changes. In other words, these costs may lead to inflexibility in customers' purchase behavior. This suggests that 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.

From the retailer's perspective, consumers' rational inattention to small price changes creates asymmetry in the net benefit of a small price increase in comparison to a small price decrease. On the one hand, consumers' rational inattention to small price changes makes small price *decreases* less valuable to the retailer because the consumers do not respond to small price changes. On the other hand, however, consumers' rational inattention to small price changes makes small price *increases* more valuable to the retailer, also because the consumers do not respond to small price changes. Thus, the retailer will have incentive to make more frequent small price increases in comparison to small price decreases. In other words, consumers' rational inattention and its concomitant rigidity in consumer behavior create incentives for asymmetric price adjustment by the seller.

The idea of consumer inattention as formulated above, however, is limited to small price changes, as alluded to in the open quotations by Rotemberg (2002) and Sims (1998). Consistent with this idea, we argue that a large price change will likely lead to more significant consequences for consumers, and therefore, consumers 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." In other words, the asymmetry should disappear for large price changes. Indeed, this is what we find in our data.

An additional 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. Numerous authors have noted the presence of small price changes in various types of data (e.g., Carlton, 1986; Lach and Tsiddon, 1992, 1996, and 2004; Kashyap, 1995). Our theory can explain the occurrences of such small price changes.

Before proceeding with the data description, it is worthwhile to note how this paper fits in the recent behavioral macroeconomic literature. Several authors, such as Sargent (1993), Sims (1998, 2003), Akerlof, Dickens, and Perry (2000), Akerlof (2002), Gabaix and Laibson (2002), Rotemberg (2002), Gabaix, Laibson, and Moloche (2003), Ball, Mankiw, and Reis (2004), Reis (2003, 2004), and Ameriks, Caplin, and Leahy (2004) have suggested recently on behavioral grounds the usefulness of near-rational models which postulate departures from the standard, full rationality, for many macroeconomic issues.

These departures take various forms. For example, Woodford (2001), Adam (2003), and Sims (2003) posit agents with limited information-processing capacity constraint. Sargent (1993) explores the idea of learning. Akerlof, Dickens, and Perry (2000) cite studies done by psychologists, which show that decision makers often ignore potentially relevant considerations and discard potentially relevant information in order to simplify the decision problems they face. [7] Relying on these findings, Akerlof, et al. assume that when inflation is low, a significant number of people may ignore it when setting wages and prices. Mankiw and Reis (2002) and Ball, et al. (2004) assume that price setters are slow to incorporate macroeconomic information into their price-setting decisions. Gabaix and Laibson (2002) develop a directed cognition model, in which time-pressured agents allocate their thinking time according to simple option-value calculations. The model is empirically tested by Gabaix, Laibson, and Moloche (2003). Rotemberg (2002) hypothesizes that consumers interpret sellers' price change decision according to its fairness and react accordingly. Reis (2003, 2004) assumes that agents face costs of acquiring, absorbing and processing information and therefore, they rationally choose to update their information and re-compute their optimal plans only sporadically, while remaining inattentive in-between the updates. Ameriks, Caplin, and Leahy (2003) model absent-minded consumers who do not keep track of their spending, and find that the wealthier the agents, the more absent-minded they are.

These types of models of near rationality offer two important advantages. First, the departures from the standard form of individual rationality, which typically rely on the assumption of full, complete, and costless information, are plausible and accord well with our daily experience (Sims, 2003). For example, we all have limited resources to spend on obtaining and processing information, and therefore treating information as an ordinary, costly good appears plausible. Consistent with this idea, Zbaracki et al. (2004) provide evidence indicating that the costs of processing information and coming up with optimal price plans might be substantial in real settings. The study by Zbaracki, et al. documents the presence of such information gathering and processing cost for a manufacturer, that is, a price setter. In this paper, we argue that consumers face similar types of costs.

Second, it turns out that various forms of 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 ongoing inflation rates. Woodford (2001), Adam (2003), and Ball, et al. (2004) study the conduct of monetary policy and demonstrate that their models generate predictions that accord well with observed data. Rotemberg's (2002) model of fairness of price changes helps in reconciling two conflicting observations: that price increases antagonize consumers (Blinder, et al., 1998) but still, we seldom see a drastic decrease in purchases in response to many price increases. Sims (2003) studies a class of dynamic optimization macroeconomic models and finds that the models' predictions fit various macroeconomic data quite well. Reis (2003, 2004) explores the implications of rational inattention for the behavior of aggregate consumption and inflation and documents significant improvements in the model fit in comparison to the existing models. Ameriks, et al. (2003) study the behavior of precautionary consumption and are able to offer novel explanations for a relationship between spending and credit card use and for the decline in consumption at retirement.

The studies listed above all focus on various forms of aggregate or macroeconomic implications of rational inattention. Our paper differs from the above in that we study the implications of rational inattention for *individual price dynamics*. The second difference is that in our paper, information is

[7] Kahneman and Tversky (1979) describe this phenomenon as "editing," which is followed by "evaluation." See also Gleitman (1996),

explicitly treated as a common, normal good, with cost and benefit. In this sense, our paper is closest to the studies of Gabaix and Laibson (2002), Ameriks, et al. (2003), and Reis (2003, 2004). The optimal amount of information people will choose to process will, therefore, depend on both, the cost as well as the benefit. This implies that the cost of processing and reacting to some information may not justify the benefit. In the specific setting we study, that information takes the form of small price changes. We argue that agents may rationally choose to ignore information on small price changes, and based on this idea we derive the implications of rational inattention for individual price setter, and consequently for individual product price dynamics.

The rest of the paper is organized as follows. In section 2, we describe the data, followed by a discussion of the empirical findings in section 3. In section 4, we examine the ability of the existing asymmetric price adjustment theories to explain our results, and find that none of them are satisfactory. In section 5, therefore, we extend the theory of rational inattention, to offer an explanation for our findings of asymmetric price adjustment in the small. We develop a simple model to show that in a world with rational inattention, such an asymmetric price adjustment can indeed be an equilibrium outcome. In section 6, we discuss how our findings fit into the existing studies in the economics and marketing literature, and point out some limitations. We conclude in section 7 by offering some speculative remarks on possible generalizability of our findings. In the Appendix, we solve a slightly different version of the model studied in section 5, which leads to a more general form of demand curve.

2. Data

We use scanner price data from Dominick's—one of the largest retail 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 $2,250 billion in the US. Since 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 seems substantial. Thus the market we are studying has a quantitative economic significance as well.

The data consist of up to 400 weekly observations of retail prices in 29 different product categories, covering the period from September 14, 1989 to May 8, 1997.[8] The length of individual product's price

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Nisbett and Ross (1980), and Ariely and Zakay (2001).

[8] Note that Dominick's UPC-level database does not include all products the chain sells. The database we use represents approximately 30 percent of Dominick's revenues.

time series, however, varies depending on when the data collection for the specific category began and ended. In Table 1 we list the product categories contained in our data set along with the number of observations included 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, which contains actual retail transaction prices of its products, i.e., the price customers paid at the cash register each week. If the item was on sale, then the price data we have reflect the sale price. Also, the retail prices reflect any retailer's coupons or discounts, but not manufacturers' coupons. The retail prices are set on a chain-wide basis at the corporate headquarters of Dominick's, but there may still be some price variation across the stores depending on the competitive market structure in and around the location of the individual stores (Levy, et al., 2002; Barsky, et al., 2003a). According to Chevalier, et al. (2003), Dominick's maintains three price zones. Thus, for example, if a particular store of the chain is located in the vicinity of a Cub Food store, then the store may be designated a "Cub-fighter" and as such, it may pursue a more aggressive pricing policy in comparison to the stores located in other zones. In the analysis described below we use all the data available from all stores.

As an example, consider Figure 1, which displays the time series of the price of Heritage House frozen concentrate orange juice, 12oz (from Dominick's Store No. 78), which is the series used by Dutta, et al. (2002) and Levy, et al. (2002). There are many "small" price changes in the series—a fact that would be hard to tell based on just visual observation of the plot.[9] 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) One-cent price changes: nine positive (at weeks 13, 237, 243, 245, 292, 300, 307, 311, and 359) and six negative (at weeks 86, 228, 242, 275, 386, and 387);
(2) Two-cent price changes: seven positive (at weeks 248, 276, 281, 285, 315, 319, and 365) and one negative (at week 287);
(3) Three-cent price changes: three positive (at weeks 254, 379, and 380) and two negative (at weeks 203 and 353);
(4) Four-cent price changes: four positive (at weeks 23, 197, 318, and 354) and one negative (at week 229); and
(5) Five-cent price changes: one positive (at week 280) and one negative (at week 302).

[9] Note that the price data in Figure 1 are not average prices. Rather, they are actual weekly transaction prices at a particular store.

3. Empirical Findings

Below we analyze the patterns of price changes using the entire data set of all 29 product-categories combined as well as for each one of the individual categories. In each case, we consider the entire sample period, as well as two sub-samples. In one sub-sample, we only include observations pertaining to low-inflation periods, and in the other—deflationary periods.

We begin by studying the pattern of price changes for each possible size of price adjustment, by calculating the frequency of positive and negative price changes in cents, 1¢, 2¢, 3¢, … up to 50¢, and in percents, 1%, 2%, 3%, … up to 50%.[10]

3.1. Analysis of the Data for the Entire Sample Period

In Figure 2 we report the frequency of positive and negative price changes found in the entire Dominick's data-set, when we use all available price series for all products and all 29 categories, during the entire 8-year sample period. Figure 2a displays the frequency of negative and positive price changes in *cents* (i.e., in absolute terms), and Figure 2b in *percents* (i.e., in relative terms).

We immediately note an interesting and robust empirical regularity in the data: for small price changes the frequency of price increases far outweigh the frequency of price decreases. Yet for larger price changes these differences disappear. This finding holds for price changes in both cents and percents. According to Figure 2a, indeed, for small price changes we find a systematic pattern of more price increases than decreases. That is, the line depicting the frequency of positive price changes systematically lies above the line depicting the frequency of negative price changes. The difference appears substantial for price changes of up to about 30¢. Beyond that, the difference essentially disappears. According to Table 2, the differences are indeed statistically significant for absolute price changes of up to 30¢. Beyond that, the two lines start crisscrossing each other and therefore, the phenomenon of asymmetry, that is the frequency of positive price changes systematically exceeding the frequency of negative price changes, disappears.

A similar pattern is obtained if we consider the frequency of price changes in percents. Specifically, for price changes of up to 5–6 percent, we indeed observe more frequent price increases than decreases. Beyond that the two series do not exhibit a clear systematic pattern, as they tend to crisscross each other. Further, the differences between positive and negative price changes slowly diminish and disappear. According to the figures in Table 3, the higher frequency of positive price changes "in the small" is statistically significant for relative price changes of up to 6%. Thus, we find that for small percentage

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[10] 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 size, and indeed most price changes are less than 50¢ in size.

price changes there are more increases than decreases. This asymmetry does not hold for larger changes.

Next we consider the behavior of the price data for individual product categories. In Figures 2.1a–2.1c, we plot the frequency of negative and positive price changes as a function of the size of price change in cents, and in Figures 2.2a–2.2c, in percents.[11]

Beginning with Figure 2.1a, we find that of the ten categories displayed, the frequency of positive price changes exceeds the frequency of negative price changes "in the small" in all but one category (Beer).[12] The difference is particularly significant for price changes of up to about 5¢–15¢. Beyond that the two series exhibit very similar behavior. Analgesics and cereals seem to be an exception in that the frequency of positive price changes in these categories exceeds the frequency of negative price changes for price changes of up to about 30¢. Statistical test results for identifying the asymmetry threshold for each product category are reported in first two columns of Table 4.

According to Figure 2.1b, for all 10 categories displayed in this figure, the frequency of positive price changes exceeds the frequency of negative price changes "in the small" for price changes of up to 20¢. A similar behavior is found in the remaining 9 categories, which are displayed in Figure 2.1c. Again, the frequency of positive price changes exceeds the frequency of negative price changes "in the small" in all but one category, Shampoo. In the categories of Oatmeal and Toothbrushes, the asymmetry lasts for up to about 20¢–25¢ price change. Thus, overall we find more frequent small price increases than small price decreases in 27 of the 29 individual product categories considered.

Turning now to the retail price change behavior in percents, we see from Figures 2.2a–2.2c that for 27 of the 29 categories considered, the frequency of positive price changes exceeds the frequency of negative price changes "in the small." Here "small" seems to mean about 3%–6% in most cases. In the categories of Analgesics, Canned Soup, Cereals (Figure 2.2a), Frozen Entrees (Figure 2.2b) and Oatmeal (Figure 2.2c), the asymmetry lasts for up to about 10% price change. The only category (besides Beer) in which no asymmetry is found is Soaps.

Thus, we conclude that the retail prices for the entire dataset and at the level of individual categories, exhibit asymmetric price adjustment "in the small" in both absolute and relative terms.[13] The

[11] We limit the category level analysis to price changes of up to 50¢ (in absolute terms) and up to 50% (in relative terms). That is because of the finding that for the entire dataset the price-change asymmetry "in the small" holds for price changes of up to 30¢ (in absolute terms) and 6% (in relative terms).

[12] It should be noted that the scanner price data for the products included in the Beer and Cigarettes categories are unlikely to be informative because of the way these products are handled by the retailer and also because of various government regulations and tax rules that are imposed on them. In the analysis that follows, therefore, we do not discuss further the results for these two categories, although we do present their plots for the sake of completeness.

[13] A reader may be puzzled from the apparent inconsistency between the absolute and relative asymmetry thresholds. For example, consider the category of analgesics. According to Table 4, here we have asymmetry "in the small" for price changes of up to 30 cents in absolute terms and 13% in relative terms. Given the average price of $5.18 in this category, the two cutoff points appear inconsistent with each other, as 13% of $5.18 is 67 cents. We believe there are two reasons for this. First, some randomness might result from the use of statistical tests on which these cutoff points are based. Second, and perhaps more importantly, a great majority of the price changes in our data are related to sales, where a price decrease is almost always followed by an equal amount of price increase. See, for example, Figure 1. However, when

asymmetry is particularly pronounced for price changes of up to about 10¢–15¢ and 3%–6%, although for some categories the asymmetry may last for up to about 20¢–30¢ and up to about 10% price change. For larger price changes the pattern of price adjustment is symmetric.[14]

We should note that these findings cannot be explained by the existence of price promotions, or sales. First of all, price promotions will generate more price decreases than increases, which is opposite to what we observe. In addition, a temporary price reduction during a sale is necessarily reversed and thus accompanied by a price increase at the end of the sale period.[15] Price promotions, therefore, cannot produce the observed asymmetry.

Another possible explanation is the fact that during the sample period covered in this study, the U.S was experiencing a moderate inflation, as indicated by the inflation rate figures reported in Table 5, which is based on the PPI.[16] It is possible that the finding we are documenting is merely a reflection of that fact. That is, during inflationary period, we would expect to see more frequent price increases than price decrease, *ceteris paribus*. A possible counter-argument to this idea is that if the reason for the asymmetry we are documenting is inflation, then we should see more positive than negative price changes not only "in the small" but also "in the large." As discussed above, however, the data do not indicate such an asymmetry "in the large."

A more direct answer to this question can be given by conducting the following experiment. Let us try and see whether the asymmetric price adjustment we document "in the small" for the entire sample period, also exists in the data when the observations pertaining to the inflationary periods are excluded from the analysis. Given the large sample of observations we have, such an analysis is indeed practically feasible.

We have conducted two analyses. In the first, we have included only those observations during which the *monthly* PPI inflation rate did not exceed 0.1 percent, a very low rate by any historical standard. We define this sub-sample as the *low-inflation* period. In the second analysis, we took even a more conservative stand by including in the analysis only those observations in which the *monthly* PPI

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converted into percents, a given amount of price decrease, say a price cut of 50 cents, and its following reversal by increasing the price by 50 cents, will show up as asymmetric adjustment: 50 cent decrease will equal 9.65 percent, while the following 50 cent increase will equal 10.68 percent. Thus, many price changes which are symmetric in absolute terms will show up as asymmetric in relative terms. Consequently, the cutoff point in percents will indicate a higher cutoff value than in cents.

[14] 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, consistent with our findings. 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. Thus 17.09% of 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. In other words, our findings hold proportionally as well: the proportion of small price increases (in the total number of price increases) exceeds the proportion of small price decreases (in the total number of price decreases) for each size of price change.

[15] This has been documented for Dominick's data by Dutta, et al. (2002), Levy, et al. (2002), Barsky, et al. (2003a), Chevalier, et al. (2003), and Rotemberg (2002).

inflation rate was either zero or negative. We define this sub-sample as the *deflation*-period. It turns out that the results remain qualitatively unchanged whether we consider the low inflation-period or the deflationary period. That is, we still observe asymmetry in the small *and* the lack of asymmetry in the large even after the inflation period is excluded from the data analysis. Below we describe the results of these analyses.[17]

3.2. Analysis of the Data for the Low Inflation Period

As before, for price changes in cents, we still find more frequent price increases than decreases "in the small." Indeed, the higher frequency of positive price changes is statistically significant for absolute price changes of up to 11¢. Beyond that, there is no systematic difference between the frequency of positive and negative price changes as the two series crisscross each other. Similarly, for price changes in relative terms, we see more price increases than decreases for price changes of up to about 6%. Thus, the exclusion of inflationary periods from the data seems to make little difference for the general pattern of asymmetric price adjustment. The retail prices still exhibit asymmetry “in the small.” The only difference is that the frequencies of both positive and negative price changes are now smaller, which is due to the reduction in the sample size that resulted from the elimination of the inflationary period observations.

The findings remain essentially unchanged for individual categories as well. The asymmetry thresholds for each product category are shown in the middle two columns of Table 4. For example, as before, in the category of Frozen Entrees the asymmetry in the frequency of positive and negative price changes lasts for price changes of up to about 20¢. In all other categories except bath soap, the asymmetry still holds, with some decrease in the asymmetry threshold, perhaps due to the smaller sample size. Only in the category of bath soap, the asymmetry seems to have disappeared, but now the Shampoos category shows asymmetry for price changes of up to 10¢.

Focusing now on the frequency of price changes in percents, we find that for all 29 categories considered, the frequency of positive price changes again exceeds the frequency of negative price changes “in the small,” where “small” appears to mean about 5–6%, except in the categories of Analgesics and Shampoos, where the asymmetry lasts for up to about 10% change. Thus, we conclude that the retail prices for the entire dataset as well as at the level of individual categories, exhibit asymmetric price adjustment “in the small” in both absolute (¢) and relative (%) terms even when we exclude the observations pertaining to moderate inflationary periods.

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[16] We first used the PPI rather than the CPI because the PPI is likely to be a better indicator of the retailer’s costs and thus it may be more relevant to the question at hand. However, as discussed below, we have also analyzed the data using the CPI as well as the CPI-Chicago, and the results remain qualitatively similar.

[17] Because of their sheer volume, the price-change frequency plots for the low inflation and the deflation sub-samples are included in the Referee Appendix, which is available from the corresponding author upon request.

3.3. Analysis of the Data for the Deflation Period

Now consider the results for the deflation period, that is, when the data contain only observations pertaining to the months of zero or negative inflation. The results here are no different from the previous sets of results. Overall, there are more positive than negative price changes for price changes of up to 11¢ and 6%. The asymmetry threshold for each product category is summarized in the last two columns of Table 4. Comparing the results for the deflation periods with those for the low inflation periods, we find that the asymmetry in absolute terms no longer holds for the category of Frozen Entrees, and the asymmetry in relative terms no longer holds for the categories of Fabric Softeners and Frozen Juices. For all the remaining categories, we still find asymmetry "in the small" in terms of both absolute and relative changes. In sum, the results for the low inflation and deflationary periods are qualitatively similar to the results obtained when data pertaining to inflationary periods were included in the analysis. We, therefore, conclude that inflation cannot explain the asymmetric price adjustment in the small.

3.4. Robustness Check to Lagged Retail Price Adjustment

The empirical analysis in sections 3.2–3.3 does not take into account the fact that the retail price adjustment is not instantaneous. Retail prices exhibit some rigidity and therefore, to check the robustness of our findings, we introduce a possibility of lagged adjustment in the retail prices. According to the findings reported in the recent empirical price rigidity literature that use the US data, the speed of adjustment of retail food prices varies between 2–4 weeks (Dutta, et al. 2002) and 12–16 weeks (Bils and Klenow, 2004). Therefore, we have repeated the analysis of section 3.3 under four possible scenarios of lagged price adjustment: 4 weeks, 8 weeks, 12 weeks, and 16 weeks. In each case we report the findings in both absolute and relative terms.

The results, reported in Table 6, suggest that the phenomenon of asymmetric price adjustment in the small remains even after allowing for lags in the adjustment. This holds true in terms of both, cents and percents for 24 of the 27 categories, the exceptions being the categories of bath soup, front-end candies, and toothbrushes. The main difference in the results is that the asymmetry threshold cutoff points have changed a little bit. Qualitatively, however, the results remain essentially unchanged.

3.5. Robustness Check to Other Measures of Inflation

The analysis reported so far is based on PPI-inflation. We chose to use the PPI measure of inflation because PPI is perhaps a better proxy for the retailers' costs. However, in order to further examine the robustness of our findings, we have also analyzed the data using two additional measures of inflation.

These are the CPI inflation, and CPI-Chicago inflation.[18] The latter is useful because the area it covers is precisely the area where Dominick's stores are located, and thus it may be the most relevant measure of inflation for the specific retailer we are studying.

Given that we have already covered the entire period analysis, here we only need to focus on the deflation period. In Table 5, along with the PPI inflation series, we also report the monthly inflation rates calculated using the CPI-Chicago and CPI series. It is apparent that CPI-Chicago and CPI series indicate fewer deflationary periods. This effectively reduces the sample size we are analyzing. Nevertheless, the results remain qualitatively almost unchanged. According to Table 7, the only category in which no asymmetry is observed in a consistent fashion (i.e., regardless of the inflation measure used) is the category of bath soaps. Depending on the inflation measure used, the data reject the hypothesis of asymmetry for 1–3 additional categories, as the figures in Table 7 indicate. Thus, for the overwhelming majority of the categories, the phenomenon of asymmetry in the small is still observed. The only difference is in the cutoff points of that asymmetry, which now occur at lower points, presumably due to smaller sample size.

4. Existing Theories of Asymmetric Price Adjustment

In this section we briefly consider other possible explanations from the existing literature on asymmetric price adjustment. Unfortunately, despite economists' considerable interest in this area, the existing literature offers only handful of theories—a situation that Peltzman (2002, p. 467) suggests is a "…serious gap in a fundamental area of economic theory." The main theories of asymmetric price adjustment we were able to find include capacity constraints, vertical market links, imperfect competition, and menu costs under inflation. We briefly look at each theory.

The theory of capacity adjustment costs (Peltzman, 2002) explains asymmetric price adjustment by arguing that it is difficult and costly to increase inventory capacity. When procurement costs drop by a large amount, retailers tend to substantially increase their inventory of that product. Lower prices then move the larger volumes off the shelves. However, retailers may find it 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

[18] The CPI-inflation is based on the BLS' standard series, CPI-U (CPI-All Urban Consumers, Series ID: CUUR0000SA0, Not Seasonally Adjusted). The CPI-Chicago inflation is based on the BLS' series CPI-Chicago-IL, Gary-IN, Kenosha-WI (All Items, Series ID: CUURA207SA0, Not Seasonally Adjusted).

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 of asymmetric price adjustment 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 observe noticeable changes in the market structure or in the channel structure during our study. In addition, these cannot really vary between small and large price changes. Clearly, large-scale changes in the market or the channel structure of the retail food industry are too slow and infrequent to explain differences in asymmetric price adjustment between 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.[19]

Another possible explanation could be a combination of menu costs and inflation, as suggested by the works of Tsiddon (1993) and Ball and Mankiw (1994). Menu costs are costs of changing prices, such as the cost of physically changing shelf price tags. 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.[20] If, however, firms face inflation then they will find it optimal to undertake price increases because prices will only be rising in the future. On the other hand, they will find it less optimal to cut prices because they will soon be dissipated by subsequent price increases. Therefore, firms will have less incentive to lower prices. Although studies have documented a presence of non-trivial menu costs at retail supermarket settings (Levy et al., 1997 and 1998; Dutta et al., 1999), 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 sections 3.2–3.3, however, suggest that the asymmetry in the small is present in our data during low inflation, and even during deflation periods, which is counter to the predictions of the theory of menu costs under inflation.

Finally, Rotemberg (2002) proposes a theory to explain the observation that price increases are not always matched with equally large sales decreases. This despite the perception that much of price rigidity may be related to sellers' concerns about potential consumer reaction to price increases. To explain this apparent inconsistency, Rotemberg proposes a theory in which consumers assess the fairness of the sellers' price change decision and act accordingly. Assuming that it would be price increases, not price

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[19] This conclusion likely holds for any explanation that relies on institutional features and arrangements, including implicit and explicit contracts, nature of relationships, etc.

[20] If we consider a broader notion of price adjustment costs, which might include, for example, managerial and customer costs of price adjustment, as noted by Ball and Mankiw (1994), Blinder, et al. (1998), and Zbaracki, et al. (2004), then the costs of price adjustment could lead to asymmetric price adjustment, because the cost of price increase could be higher than the cost of price decrease. The reason for such asymmetry might be potential consumer anger at unfair price increases (Rotemberg, 2002), or consumer search triggered by a price increase (Stiglitz, 1984). Also, mistakes that occur during the price change process can cause consumer goodwill loss, which can be particularly damaging if the consumers link it to price increase (Levy, et al., 1997, 1998; Dutta, et al., 1999). The problem with these, and other similar

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 empirical findings, in this section 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, we argue, 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. After discussing the idea of rational inattention from consumers' and producers' perspective and deriving its implications, we present as an example a simple model of rational inattention, where these ideas are developed more formally.

5.1. Rational Inattention

We draw from a body of work in economics and marketing, which study the idea of rational inattention under the label of information processing or reoptimization costs.[21] The idea of rational inattention follows naturally from these information-processing requirements and the scarcity of the resources needed to process them. In Sims (1998) words, "… many data that we could look up daily, and that are in principle relevant to our optimal economic decision-making, do not in fact influence our behavior, *except when they change dramatically*, or perhaps when we occasionally set aside some time to re-assess our portfolio" (pp. 320–321; emphasis ours). Rotemberg (2002) makes a similar statement in different context.[22] 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.)

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explanations, however, is that if any of them were reasons for asymmetric price adjustment, then we would expect to see a reverse asymmetry. That is, we should have seen more frequent price decreases than increases. That is opposite to what we find in our data.

[21] Other labels include "thinking costs" (Shugan, 1980, Kashyap, 1995), "reoptimization costs" (Roufagalas, 1994), or "decision-making costs" that result from either "costs of acquiring information or costs of reoptimization" (Mankiw and Reis, 2002; Reis, 2003 and 2004; Ball, et al., 2004; and Zbaracki, et al., 2004) or "limited channel capacity for absorbing information" (Woodford, 2001; Sims, 1998 and 2003; Adam, 2003).

[22] Tobin (1982, p. 189) makes a similar statement in his Nobel Lecture: "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.)

We argue that it may be rational for consumers to be "inattentive" to small changes in prices when (1) the consumers face large amounts of information, which are costly to process and react to; and (2) the consumers have 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 "rational attention" to information on a price change exceeds the benefits a customer may obtain from processing and reacting to the information, then the customer will have incentive to ignore and not to react to the price change. We argue that this scenario is most likely to occur 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 the one shown in Figure 3.[23] Assuming that 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. That is, between P_A^l and P_A^u in Figure 3, the buyer will be rationally inattentive. If the price moves to the outside of this "region of inaction," however, a rationally attentive consumer will start processing the price change, which will trigger her response to the price change by adjusting her purchase behavior along the original demand curve.[24]

5.2. *Retailer's Reaction to Rational Inattention: Asymmetric Price Adjustment "in the Small"*

Now, consider a price-setter, for example a supermarket price manager, who recognizes that his customers are rationally inattentive, and thus notices an inelastic 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. How should such a price-setter price? We suggest they will choose asymmetric pricing for small price changes.

Specifically, dampening the effect of price sensitivity for small price decreases makes them less

[23] The region of inattention does not have to be strictly vertical; it only needs to be less elastic. See the Appendix for a different formulation.
[24] We shall note that our argument is consistent with the literature on "just noticeable differences" (JND) in marketing (Monroe, 1970), which suggests that people may be unable to perceive small differences in the stimulus (in lieu of Weber's Law). In the same spirit, Emery (1970) observes that, "There is a region of indifference about a standard price such that changes in price within this region produce no change in perception." Kalyanaram and Little (1994) explore the implications of JNDs for price elasticity of grocery products and find ranges around reference prices that are less elastic. More recently, industry practitioners have leveraged this to explore the existence of "pricing indifference bands" (Baker, et al., 2001). There is a difference between the notion of JND and our notion of "rational inattention." In the JND literature, it is typically assumed that agents are *unable* to distinguish two stimuli that are close to each other. For example, most of us would be unable to notice one degree increase in the temperature from say 74°F to 75°F. In our model, individuals *rationally choose* not to pay attention to small differences, not because of our inability to notice them, but rather, *because it does not pay to notice them*.

valuable for firms. To see this, consider what a firm hopes to gain by decreasing a price—increased sales volume. If price elasticity is dampened then the incremental sales from a small price decrease are smaller, making a price decrease less valuable. Yet dampening the effect of price sensitivity for small price increases makes them more valuable. Again, consider what a firm hopes to gain by increasing a price—higher margins, albeit with loses in sales volume. Reduced price sensitivity decreases the volume lost with price increases, making price increases more valuable for firms.

The reduced price sensitivity in both directions will give the retailer incentive to price at the upper bound of the inelastic range, e.g., P_A^u in Figure 3. Pricing lower than P_A^u will reduce margins without gaining enough sales volume to make up for the reduced 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 to the price change, 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 will anticipate that retailers will have an increased incentive to make small price increases, and a disincentive to make small price decreases. Therefore, both firms and consumers will rationally expect asymmetric price adjustment in the small. Thus, asymmetric price adjustment in the small will be a rational expectation equilibrium. In the meantime, both consumers and the retailer know that if prices move outside the range of rational inattention, the customer will notice and therefore react to the change. This suggests, therefore, that symmetric price adjustment will emerge as an equilibrium outcome for large price changes.[25]

In sum, retailers' reaction to rational inattention by customers offers an explanation for our finding of asymmetry in small price changes and symmetry in large price changes.[26] In the next section, we formalize this argument by offering an example of a simple equilibrium model, which generates asymmetry in small price adjustment.

5.3. *Example: A Simple Model of Rational Inattention*

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,

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[25] Additionally, since our theory relies on a customer based argument, and assuming that competitors are selling to similar types of customers, the competitors will also have the ability and 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.

[26] Another interesting implication of rational inattention as developed here is that it implies optimality of price points, such as 9¢ or 99¢, as price endings. See Chen, et al. (2004).

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, which a customer can purchase to satisfy her needs. 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. In this example 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: $U(A, B) = v \ln A + \ln B$ (1)

s.t. $P_A A + P_B B = M$ (2)

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

$$A^* = \frac{v}{(v+1)P_A} M \tag{3}$$

$$B^* = \frac{1}{(v+1)P_B} M \tag{4}$$

$$U^* = (v+1) \ln M - v \ln \frac{v+1}{v} P_A - \ln (v+1) P_B \tag{5}$$

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 (3), solves the following optimization problem:

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

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

$a > 0$, $b > 0$, and A is given by equation (3). Solving the maximization problem, we obtain:

$$\boldsymbol{P}_A^* = \frac{\boldsymbol{vM}}{\boldsymbol{v}+1}\sqrt{\frac{\boldsymbol{b}}{\boldsymbol{a}}} \tag{6}$$

$$\pi^* = \frac{\boldsymbol{v}}{\boldsymbol{v}+1}\boldsymbol{M} - 2\sqrt{\boldsymbol{ab}} \tag{7}$$

Substituting equation (6) into equation (3), we obtain:

$$\boldsymbol{A}^* = \sqrt{\frac{\boldsymbol{a}}{\boldsymbol{b}}} \tag{8}$$

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.[27] 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.

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.[28] 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 (5), we can easily infer that if the customer processes the price information and adjusts her consumption, the new utility, *before* incurring *x*, is:

$$U^* = (v+1)\ \ln M - v \ln \frac{v+1}{v} P_A' - \ln (v+1)\ P_B \qquad (9)$$

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

$$A^* = \frac{v}{(v+1)P_A} M \qquad (3)$$

$$P_A' A + P_B B = M \qquad (10)$$

$$B = \frac{P_A(v+1) - P_A' v}{P_A P_B (v+1)} M \qquad (11)$$

which yield

$$U = v \ln \frac{v}{(v+1)P_A} M + \ln \frac{P_A(v+1) - P_A' v}{P_A P_B (v+1)} M \qquad (12)$$

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 should exist a range of small price changes within which the consumer will find it optimal not to recalculate her demands. To see this, let $P_A' = \theta P_A$. Then:

[27] 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.

[28] We've found that our results on asymmetric price adjustment in the small are robust to some alternative heuristic purchase rules 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. See the

$$U - U^* = -\ln\ (\theta^{v}(v+1-\theta v)) > 0 \qquad (13)$$

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., $P_A' = P_A$). 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 let $P_A^l = \theta_A^l P_A$ be the lower limit of this range ($\theta_A^u > 1$, $\theta_A^l < 1$).[29] 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 (3). 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: $U(A, B) = v \ln A + \ln B + \beta(v \ln A + \ln B)$ (14)

s.t. $P_A A + \theta_A^u P_A A + 2P_B B = 2M$, (15)

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

$$A^* = \frac{2v}{(v+1)(1+\theta_A^u)P_A} M \qquad (16)$$

$$B^* = \frac{1}{(v+1)P_B} M \qquad (17)$$

A demand curve of this type is displayed graphically in Figure 3.

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

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appendix for a slightly different version of the model, which yields a demand curve with a rational inattention region that has a more general shape.

[29] 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 a price change in the range of [–10%, 10%] will not trigger purchase adjustment.

function in equation (16), the firm's optimization problem is:

Maximize: $\pi = (P_A - C)A + \tau(\theta_A^u P_A - C)A$ (18)

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

$a > 0$, $b > 0$, A is given by equation (16), 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 purchase behavior. Solving the problem in (18), we obtain:

$$P_A^* = \frac{v}{(v+1)} \frac{2}{(1+\theta_A^u)} M \sqrt{\frac{b}{a}} \quad (19)$$

$$P_A^u = \theta_A^u P_A^* = \frac{v}{(v+1)} \frac{2\theta_A^u}{(1+\theta_A^u)} M \sqrt{\frac{b}{a}} \quad (20)$$

Compared with the price in equation (6), the price in equation (19) is lower, and the price in equation (20) is higher, for $\theta_A^u > 1$. Substituting equation (19) into equation (16), we get $\boldsymbol{A}^* = \sqrt{\frac{\boldsymbol{a}}{\boldsymbol{b}}}$, which is exactly the same as the demand function in equation (8).

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 between $P_A^l = \theta_A^l P_A^*$ and $P_A^u = \theta_A^u P_A^*$, as given in equation (20).

Based on the above, we can see that the main implication of the model is asymmetric price adjustment "in the small," and symmetric price adjustment in the large. This offers a logic supporting our findings in the paper.

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 in the Appendix) 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 3, 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 be rationally processed by the customer, and therefore, it will trigger a 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.[30]

Notice that this result does not require that all pricing decisions the retailer makes involve rationally inattentive customers. Considering the large number of pricing decisions faced by retailers – across product categories, individual products (UPC's), across stores, and across seasons, holidays and non-holiday periods – this assumption would be too strong. From a customer perspective the costs of processing may depend on, among other things, consumer's opportunity cost of time, the ease with which she can carry out such calculations, their experience with doing this type of calculations which may be a function of the competitive environment the retailer faces, and the amount of calculations required. This suggests that there could be pricing decisions driven by different seasons of the year (holiday vs. non-holiday), different competitive actions and reactions that the retailer faces, etc. with different levels of customer attentiveness. One could let the probability that the retailer faces a pricing decision best characterized by rationally inattentive customers be α, and the probability that the retailer faces a pricing decision best characterized by rationally attentive customers be $(1-\alpha)$. As long as there are enough pricing decisions best characterized by rational inattention, i.e., as long as α is large enough, we should observe prices adjusting asymmetrically in the small. In other words, the retailer will be *making more frequent small price increases than decreases*.

6. Discussion of the Findings and Limitations

We should note that the nature as well as the magnitude of the regions of asymmetry we document in this paper, appears consistent with regions of "just noticeable differences" and "price indifference bands," as reported in some marketing literature, mostly in the context of optimal promotion strategies. Recall that according to our data, the consumers "do not notice price changes" in the magnitude of up to 1% (for the canned tuna category) to 13% (for the analgesics category), with the average of 6% (when all categories are combined). These figures are consistent with the range of "noticeable price changes" reported by several studies. For example, according to the evidence of Kalwani and Yim (1992), for a promotion to be noticed by consumers, the price change needs to be in the range of 20%–30% or more. In other words, price changes of less than 20%, will not be noticed by consumers. Indeed, our cut-off

[30] 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 with

points fall below this threshold. Our findings are also consistent with the common managerial perception that a sales promotion of less than 15% cannot attract a customer to a sale (Della Bitta and Monroe 1980; Gupta and Cooper 1992). A similar figure has been reported by the consulting firm McKinsey & Company (Baker, et al, 2001), who find that the "pricing indifference band" is about 17% for branded customer health-and-beauty products.[31] Finally, our findings are consistent with the prediction of Fibich, et al. (2004), who find that for a price change to be noticed, it has to be of the magnitude of between 15%–30% or more.[32]

The notion of rational inattention, and its implication that there is an inelastic (or rigid) region around the current price, is different from the literature on "kinked" demand curves which rely on competitive reactions to price decreases and price increases (Andersen, 1994). There the idea is that price decreases are instantaneously matched by competitors, and price increases are not, which makes customers relatively *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 will have less incentive to change prices in either direction due to the anticipation of such competitive reactions. In contrast to this scenario, 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 kinked demand curve is also different from the kinds of demand curves that would arise in a world where customers are less price-sensitive in the short-term than in the long-term, as suggested by Okun (1981). His argument is based on the idea that customers are unlikely to be aware of prices at all retailers in the short-term since it takes time for customers to update their price information. In the long-term, however, customers have the opportunity to shop around and therefore update their price information. Our theory is similar in spirit to Okun's in that it makes a distinction between different types of price changes, and customer reactions to them. The key difference is that our theory focuses on the size of the price changes, while Okun focuses on the duration of the delay in the consumers' reaction to the price changes. Thus, whereas Okun suggests that customers will not react to short run price changes as fully as to long run price changes, we posit that customers will not react to small price changes but will react to large ones.

From public perspective, these findings offer both good and bad news. The bad news is that

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consumers re-processing the information beginning with this new price. Thus, periods of unchanged prices are not predicted when there is a distribution of both large and small market level changes.

[31] They report that for engineered industrial components the "pricing indifference band" is about 10%.

[32] A preliminary analysis found that the absolute asymmetry threshold (first column in Table 4) is positively correlated with the average price in each product category ($r = 0.263$, $p = 0.042$), suggesting that the quantity rigidity range, due to rational inattention, may increase with the price of a product. This notion that consumers may be thinking in relative terms (rather than in absolute terms) is consistent with findings

asymmetric price adjustment may be more prevalent than we think: as far as we know, the type of asymmetry "in the small" we document has not been reported in the literature before, and is small enough to fly under the radar screen of the public policy makers. Moreover, the explanation we offer for why firms adjust prices asymmetrically "in the small" is that firms take advantage of customer's information processing costs. The good news, however, is that this type of asymmetric price adjustment is limited in its scope, because the range of rational inattention is set by customers themselves. More importantly, it is in the customers' best interests to allow for asymmetric price adjustment in the small to save the information processing cost.

Our paper also offers a possible explanation for a long-standing puzzle in this literature: the presence of small price changes frequently observed in actual transaction data (Stigler and Kindahl, 1970; Carlton 1986; Lach and Tsiddon, 1992, 1996). For example, Carlton (p. 121, 1986) finds "… a significant number of price changes that one would consider small (i.e., less than 1 percent) for most commodities and transaction types." Lach and Tsiddon (2004) also find "small individual price changes" in the Israeli grocery store data.[33] Kashyap (1995) also reports finding many small price changes. For example, according to his account, 2.7 percent of the price changes in his catalogue price data are less than 1% in size, 7.2 percent of the price changes are between 1%–2% in size, and 21 percent of the price changes are less than 3% in size. Our theory of rational inattention offers a customer-based explanation for this phenomenon.

An interesting aspect of the findings we document here, which is of particular interest to macroeconomists and monetary economists, is that transaction price data at the level of individual price-setter appear to fluctuate much more than we would expect based on standard monetary economy models. For instance, according to Figure 2a, over 85% of the price increases found in our data are of 5% or higher, and that is at the weekly frequency. In contrast, average annual inflation rate during the sample period we study was about 2.8%. Thus, many individual store-level product prices appear to change at a rate far greater than we would expect if price changes were primarily driven by monetary shocks. This suggests that much of the fluctuation in these store level price data may be due to micro-level idiosyncratic shocks that are unrelated to monetary policy.[34]

As an example, consider Figure 1, which plots the time series of Heritage House frozen concentrate

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reported in psychology on how individuals perceive price discounts (see, for example, Kahneman and Tversky, 1984, Darke and Freedman, 1993, and Azar, 2003). It is not clear, however, whether this would necessarily translate to big-ticket items such as durable goods, cars, etc.

[33] They argue that the menu cost model extended to a multi-product setting (e.g., 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.

orange juice, 12oz. Indeed, it is apparent from the figure that the retail price is far more volatile than a more aggregated measure of price level such as the GDP deflator or the CPI. Thus, there is a lot of variation in these retail prices, which cannot be explained by aggregate nominal shocks.

The highly volatile nature of individual product prices has been noted by other scholars as well. For example, Golosov and Lucas (2003) note that in their data the individual product prices are on average changed by 10% while the average US aggregate inflation rate during the period was only about 1%. That is, the size of price adjustment they find does not appear to be related to the ongoing inflation rate.[35] Thus, our finding that individual product prices are far more volatile than one would expect based purely on monetary macroeconomic models is consistent with similar phenomena documented by other studies using other data sets.[36]

7. Conclusion and Future Research

In this paper we find overwhelming evidence of asymmetry "in the small," i.e., more frequent increases than decrease for price changes in the range of 15–30 cents and 3–10 percent. The asymmetry disappears for larger price changes. The finding holds in low inflation and even in deflation periods, for a variety of different indices such as the producer price index (PPI), consumer price index (CPI), or CPI-Chicago. We suggest that these findings can be explained by extending the literature on "rational inattention", showing that price setters will have incentive to make asymmetric price adjustment "in the small." In our model, the price setters act strategically by taking advantage of the fact that their consumers face information processing costs and constraints.[37] Our theory also offers an explanation for the presence of small changes in many transaction prices, which has been a long-standing puzzle in the literature.

At this stage, it is unclear how generalizable our findings of asymmetric price adjustment in the small are. In the specific setting our data offers, we are able to study and interpret the behavior of a retail seller who faces buyers with relatively little at stake in the price of an individual item. It is likely that the

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[34] Rotemberg (2002) also notes the failure of the existing macroeconomic models that incorporate nominal rigidities when confronted with individual product price behavior. In his model, however, the frequency of price adjustment depends on aggregate variables that are observed by consumers.

[35] They also note the heterogeneous nature of the individual product price data: they find that prices of some goods increase while the prices of other good decrease. A similar phenomenon has been noted by Klenow and Kryvtsov (2003) and Bils and Klenow (2004), as well as by other studies cited therein. See, for example, Dotsey, et al. (1999), Willis (2000), Burstein (2002), and Barksy, et al. (2003b).

[36] To resolve this discrepancy between the behavior of the aggregate price level and the individual product prices, Golosov and Lucas (2003) construct a menu cost model that incorporates two types of shocks that affect firms pricing decisions: an aggregate shock, which reflects economy-wide inflation, and an idiosyncratic shock, which reflects individual product specific changes in technology or preferences. When they calibrate the model for the US economy, they find that, indeed, the idiosyncratic shocks account for most of the price adjustment in the US. These findings appear reasonable given the behavior of our data. That is, in the particular setting we study, most of the changes in the retail prices appear to be unrelated to fluctuations in marginal cost. Instead, as Warner and Barsky (1995) suggest, they may be primarily driven by retailers' inter-temporal price discrimination practices.

[37] Rubinstein (1993) presents a model in which consumers' heterogeneity with respect to their ability to process information is exploited by a monopolist to derive additional profits through price discrimination.

phenomenon of asymmetric price adjustment in the small will also be present in other similar settings where low-priced, commonly consumed retail goods are sold. For example, customers of retail establishments like Target, Sears, Wal-Mart, K-Mart, as well as the customers of large chain drugstores, who purchase perishables, and other small ticket item consumer packaged goods, are likely to behave in a way similar to the customers of Dominick's. We speculate, therefore, that in these and other similar retail settings, we will likely observe asymmetric price adjustment in the small.

On the other hand, there are markets where inattention is unlikely to be optimal. For example, in commodities' markets as well as in financial markets where a typical transaction involves a large quantity of the same commodity or the same asset, buyers will certainly be more attentive. In fact, in these types of markets, there are people whose only job is to pay attention to individual pennies or even less. In such settings, therefore, it is unlikely to see any asymmetry in the small. For similar reasons, we suspect that no asymmetry in the small will be observed in business-to-business transactions, where large quantities of the same product change hands.

It is less clear whether asymmetric price adjustment in the small will be optimal in other settings. For example, in markets for big-ticket items such as TVs, refrigerators, camcorders, computers, cars, and other durable goods, people are likely to be more attentive because these transactions involve large expenditures.[38] However, when considering big-ticket item purchases, shoppers might ignore some rightmost digits in the price information. For example, car shoppers may rationally choose to be inattentive to the rightmost digits in the car price, 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, in the future work, to study other data sets in different time periods, products, and industries. Exploring internet price data might be particularly useful because on the internet, information processing costs may be much lower in comparison to more traditional brick and mortar stores. The existence of search engines, which enable instantaneous price comparisons at hundreds of sites simultaneously, further reduces the cost of price information processing (Lee, Bergen, and Kauffman, 2003). We suspect, therefore, that internet prices will be characterized by less asymmetry in the small.

Another area for future research is to explore these issues upstream through the channel of distribution. There is, indeed, work suggesting that there is some asymmetry at the wholesale price level (see Ray et. al. 2004). Building on the idea that firm level menu costs can lead to asymmetry (Ball and Mankiw 1994), they explore the implications of distributor menu costs for manufacturer wholesale prices. Their reasoning for wholesale price asymmetry is that distributors may have to incur menu cost whenever they need to adjust their prices, which may lead to a range of rigidity for the distributors when they face small wholesale price changes. A manufacturer may take advantage of distributors' range of price rigidity by adjusting wholesale prices asymmetrically, passing on more small increases than small decreases. This is the upstream channel equivalent of the rational inattention arguments we develop in this paper.

Future research can also examine dynamic aspects of customer information processing costs and its impact on firm's pricing decision in a dynamic setting. The models studied by Ball, et al (2004), Mankiw and Reis (2002), and Reis (2003), are steps in that direction.

[38] Indeed, there evidence in the marketing literature that suggests that the higher the amount people spend on a product/service, the more sensitive they are to its price. See Bell, Ho, and Tang (1998) and Nagle and Holden (2002).

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Appendix

An Example of a Customer Decision Rule Based on a Constant Ratio of A and B

In this appendix we present another version of the model presented in Section 5.3 of the paper. The purpose is to construct 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 in the text 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 in section 5.3 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 in order 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. If she re-optimizes, the new utility, *before* incurring the information processing cost x, is:

$$U^* = (v+1)\ \ln M - v \ln \frac{v+1}{v} P_A' - \ln (v+1)\ P_B \tag{A1}$$

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

$$A = Bv\,(P_B / P_A),\text{ and} \tag{A2}$$

$$P_A'A + P_B\,B = M$$

where, A2 is derived from equations (3) and (4). These yield:

$$A = \frac{v}{(vP_A' + P_A)} M \tag{A3}$$

$$B = \frac{P_A}{(vP_A' + P_A)P_B} M \tag{A4}$$

$$U = v \ln \frac{vM}{P_A' + P_A} + \ln \frac{P_A M}{P_B (vP_A' + P_A)} \tag{A5}$$

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

$$U - U^* = \ln \frac{(vt+1)^{v+1}}{(v+1)^{v+1}\theta^r} \tag{A6}$$

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 (A2). When $v = 1$, a closed-form solution exists for this region. Specifically, $\theta \in [2c-1-2\sqrt{c^2-c}, 2c-1+2\sqrt{c^2-c}]$, where $c = \exp(x)$. For example, when $x = 0.01$, $c = 1.01$, and θ is between 0.82 and 1.22.

Compared with the demand curve in Figure 3, when the consumer uses the last period's ratio as the decision rule, we obtain a demand curve with a kink that is not completely vertical, but simply less elastic, as show in Figure A1. The rest of the model derivation is the same as in the main text.

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

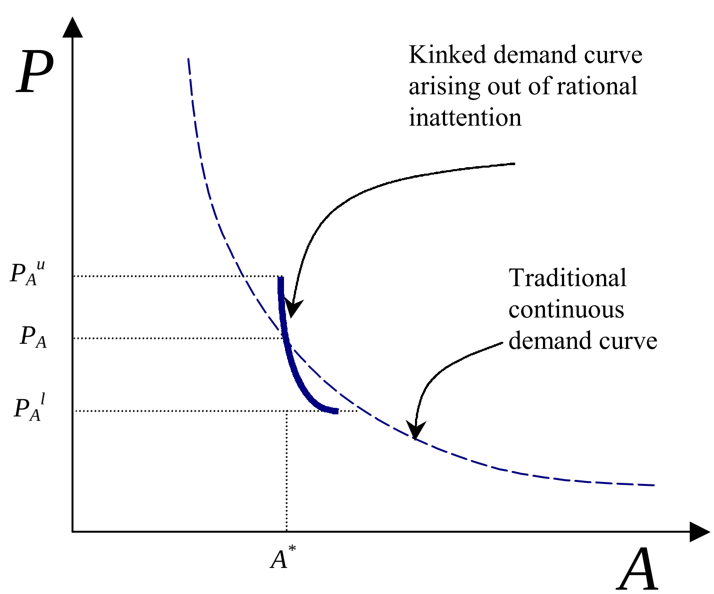


Table 1. Product Categories and the Number of Weekly Price Observations

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. All Categories Combined, Entire Sample: Price Changes in Cents

Price Change in Cents	Positive	Negative	Z-Value
1	371370	235356	174.62
2	358275	271638	109.16
3	312453	260128	69.15
4	355329	282406	91.32
5	363093	272179	114.06
6	299124	254062	60.59
7	212769	171254	66.99
8	256602	197650	87.47
9	195622	143920	88.73
10	805647	715444	73.14
11	114293	99452	32.10
12	179446	176804	4.43
13	110904	100528	22.57
14	165346	140986	44.01
15	142634	128130	27.87
16	154810	137726	31.59
17	83559	71135	31.59
18	93760	77446	39.43
19	94023	88453	13.04
20	480819	471937	9.10
21	47634	44111	11.63
22	62093	59520	7.38
23	82807	74045	22.12
24	98311	96353	4.44
25	85926	79942	14.69
26	83719	74639	22.82
27	47150	38914	28.07
28	47959	42388	18.53
29	61717	57770	11.42
30	334033	341089	–8.59
31	27519	25320	9.57
32	44627	39494	17.70
33	57077	55892	3.53
34	61480	52919	25.31
35	54529	47127	23.22
36	59621	55347	12.61
37	34032	27888	24.69
38	42703	39456	11.33
39	80818	80191	1.56
40	317387	342607	–31.04
41	25555	23823	7.79
42	33537	28467	20.36
43	37876	33615	15.94
44	44340	39392	17.10
45	51836	49981	5.81
46	43634	43716	–0.28
47	24908	19511	25.61
48	39352	36200	11.47
49	108077	113594	–11.72
50	335360	352422	–20.57

Table 3. All Categories Combined, Entire Sample: Price Changes in Percents

Price Change in Percents	Positive	Negative	Z-Value
1	592707	447426	142.45
2	606647	490704	110.68
3	603333	491203	107.18
4	503467	442202	63.00
5	488665	451023	38.83
6	420925	354344	75.62
7	317005	337532	–25.37
8	303521	303465	0.07
9	287011	299729	–16.60
10	296202	347875	–64.39
11	325769	273850	67.05
12	187005	194227	–11.70
13	239614	246659	–10.10
14	188208	195461	–11.71
15	130897	161285	–56.22
16	137878	278869	–218.40
17	164275	267796	–157.49
18	139303	166555	–49.28
19	165303	163408	3.31
20	316386	252657	84.48
21	70534	173069	–207.75
22	126460	94639	67.67
23	119458	166861	–88.59
24	74066	115892	–95.97
25	211663	317868	–145.95
26	102743	120206	–36.98
27	103120	106210	–6.75
28	60830	93703	–83.62
29	64292	101463	–91.30
30	137381	104135	67.65
31	72021	89926	–44.49
32	63642	68904	–14.45
33	124920	249788	–203.99
34	206965	165285	68.31
35	77198	41312	104.24
36	47631	56876	–28.60
37	48186	57128	–27.55
38	77646	71218	16.66
39	43927	36862	24.86
40	81910	64059	46.72
41	26043	60477	–117.07
42	47845	28453	70.20
43	60646	30606	99.44
44	38518	50636	–40.58
45	44771	48857	–13.35
46	34642	30714	15.36
47	38157	67576	–90.47
48	34022	35254	–4.68
49	33697	32498	4.66
50	178001	178212	–0.35

Table 4. What Might Constitute a "Small" Price Change?
Statistical Analysis of the Data by Product Category in Absolute (¢) and Relative (%) Terms

	Entire Sample Period		Low Inflation Period		Deflation Period	
	Absolute (¢)	Relative (%)	Absolute (¢)	Relative (%)	Absolute (¢)	Relative (%)
Analgesics	30	13	10	13	10	6
Bath Soap	6	6	0	6	0	6
Bathroom Tissues	6	3	4	3	4	3
Bottled Juices	12	6	15	6	12	6
Canned Soup	12	12	12	5	10	5
Canned Tuna	1	1	2	1	1	1
Cereals	29	11	24	7	1	7
Cheeses	9	8	9	6	9	6
Cookies	11	4	11	3	9	3
Crackers	10	4	2	4	4	4
Dish Detergent	5	3	4	3	6	3
Fabric Softeners	5	3	11	5	7	0
Front-end-candies	5	7	5	7	5	7
Frozen Dinners	2	3	10	3	6	3
Frozen Entrees	20	9	22	9	0	9
Frozen Juices	9	6	9	6	10	0
Grooming Products	20	6	12	6	12	8
Laundry Detergents	16	4	13	3	17	4
Oatmeal	25	9	2	1	5	1
Paper Towels	2	2	2	3	2	3
Refrigerated Juices	15	6	9	3	6	3
Shampoos	0	7	10	9	10	9
Snack Crackers	11	4	2	1	2	1
Soaps	1	0	1	4	1	4
Soft Drinks	5	6	3	4	5	6
Tooth Brushes	20	8	3	2	3	2
Tooth Pastes	18	7	14	6	6	6
Total (All 29 Categories Combined)	29	6	11	6	11	6

Note:
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 and we consider the price changes in cents, we see that for price changes of up to 30 cents, there is asymmetry. Beyond that point the asymmetry disappears.

Table 5. Three Measures of Monthly Inflation Rate: PPI, CPI, and CPI-Chicago, September 1989–May 1997

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

1993	September	123.8	–0.32	145.1	0.2	146.7	0.4
1993	October	124.6	0.65	145.7	0.4	147.2	0.3
1993	November	124.5	–0.08	145.8	0.1	146.4	–0.5
1993	December	124.1	–0.32	145.8	0.0	146.1	–0.2
1994	January	124.5	0.32	146.2	0.3	146.5	0.3
1994	February	124.8	0.24	146.7	0.3	146.8	0.2
1994	March	124.9	0.08	147.2	0.3	147.6	0.5
1994	April	125.0	0.08	147.4	0.1	147.9	0.2
1994	May	125.3	0.24	147.5	0.1	147.6	–0.2
1994	June	125.6	0.24	148.0	0.3	148.1	0.3
1994	July	126.0	0.32	148.4	0.3	148.3	0.1
1994	August	126.5	0.40	149.0	0.4	149.8	1.0
1994	September	125.6	–0.71	149.4	0.3	150.2	0.3
1994	October	125.8	0.16	149.5	0.1	149.4	–0.5
1994	November	126.1	0.24	149.7	0.1	150.4	0.7
1994	December	126.2	0.08	149.7	0.0	150.5	0.1
1995	January	126.6	0.32	150.3	0.4	151.8	0.9
1995	February	126.9	0.24	150.9	0.4	152.3	0.3
1995	March	127.1	0.16	151.4	0.3	152.6	0.2
1995	April	127.6	0.39	151.9	0.3	153.1	0.3
1995	May	128.1	0.39	152.2	0.2	153.0	–0.1
1995	June	128.2	0.08	152.5	0.2	153.5	0.3
1995	July	128.2	0.00	152.5	0.0	153.6	0.1
1995	August	128.1	–0.08	152.9	0.3	153.8	0.1
1995	September	127.9	–0.16	153.2	0.2	154.0	0.1
1995	October	128.7	0.63	153.7	0.3	154.3	0.2
1995	November	128.7	0.00	153.6	–0.1	154.0	–0.2
1995	December	129.1	0.31	153.5	–0.1	153.8	–0.1
1996	January	129.4	0.23	154.4	0.6	154.6	0.5
1996	February	129.4	0.00	154.9	0.3	155.2	0.4
1996	March	130.1	0.54	155.7	0.5	156.3	0.7
1996	April	130.6	0.38	156.3	0.4	156.4	0.1
1996	May	131.1	0.38	156.6	0.2	156.9	0.3
1996	June	131.7	0.46	156.7	0.1	157.6	0.4
1996	July	131.5	–0.15	157.0	0.2	157.7	0.1
1996	August	131.9	0.30	157.3	0.2	158.1	0.3
1996	September	131.8	–0.08	157.8	0.3	158.3	0.1
1996	October	132.7	0.68	158.3	0.3	158.8	0.3
1996	November	132.6	–0.08	158.6	0.2	159.4	0.4
1996	December	132.7	0.08	158.6	0.0	159.7	0.2
1997	January	132.6	–0.08	159.1	0.3	160.4	0.4
1997	February	132.2	–0.30	159.6	0.3	161.1	0.4
1997	March	132.1	–0.08	160.0	0.3	161.0	–0.1
1997	April	131.6	–0.38	160.2	0.1	160.9	–0.1
1997	May	131.6	0.00	160.1	–0.1	161.1	0.1

Table 6. What Might Constitute a "Small" Price Change?
Statistical Analysis of the Data by Product Category in Absolute (¢) and Relative (%) Terms, Deflationary Period, with Lagged Price Adjustment: 4, 8, 12, and 16 Weeks

	4 week lag		8 week lag		12 week lag		16 week lag	
	Absolute (¢)	Relative (%)	Absolute (¢)	Relative (%)	Absolute (¢)	Relative (%)	Absolute (¢)	Relative (%)
Analgesics	12	9	5	9	10	4	0	1
Bath Soap	0	8	0	6	0	0	0	0
Bathroom Tissues	4	3	4	3	4	3	5	3
Bottled Juices	10	5	2	1	6	3	24	7
Canned Soup	11	10	10	5	12	9	18	11
Canned Tuna	2	8	2	2	1	1	2	6
Cereals	25	11	0	7	25	11	28	11
Cheeses	9	9	2	6	9	5	9	8
Cookies	11	10	10	3	11	8	10	4
Crackers	4	10	2	2	4	3	2	3
Dish Detergent	10	3	2	3	6	4	5	6
Fabric Softeners	13	4	2	1	1	1	5	1
Front-end-candies	4	0	6	0	2	0	9	0
Frozen Dinners	9	3	9	3	2	1	2	8
Frozen Entrees	4	9	20	10	10	8	19	5
Frozen Juices	9	9	1	1	6	4	1	1
Grooming Products	18	8	18	8	10	8	8	4
Laundry Detergents	13	4	11	3	5	2	2	2
Oatmeal	4	1	4	2	12	7	3	1
Paper Towels	2	2	2	2	2	2	1	2
Refrigerated Juices	6	5	18	7	11	5	5	5
Shampoos	5	9	5	6	0	6	0	0
Snack Crackers	2	1	2	1	2	1	2	1
Soaps	2	2	1	1	1	1	1	1
Soft Drinks	2	6	9	4	2	0	0	0
Tooth Brushes	1	0	10	0	8	3	2	3
Tooth Pastes	6	3	7	6	20	6	6	7

Note:
The figures reported in the table are the cutoff points of what might constitute a "small" price change for each category. In each category, the cutoff point is the first point at which the asymmetry is not supported statistically. Thus, for example, in the Analgesics category, with a 4-week lag, we see that for price changes of up to 12 cents, there is asymmetry.

Table 7. What Might Constitute a "Small" Price Change?
Statistical Analysis of the Data by Product Category in Absolute (¢) and Relative (%) Terms

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

Note:
The figures reported in the table are the cutoff points of what might constitute a "small" price change for each category. In each category, the cutoff point is the first point at which the asymmetry is not supported statistically.

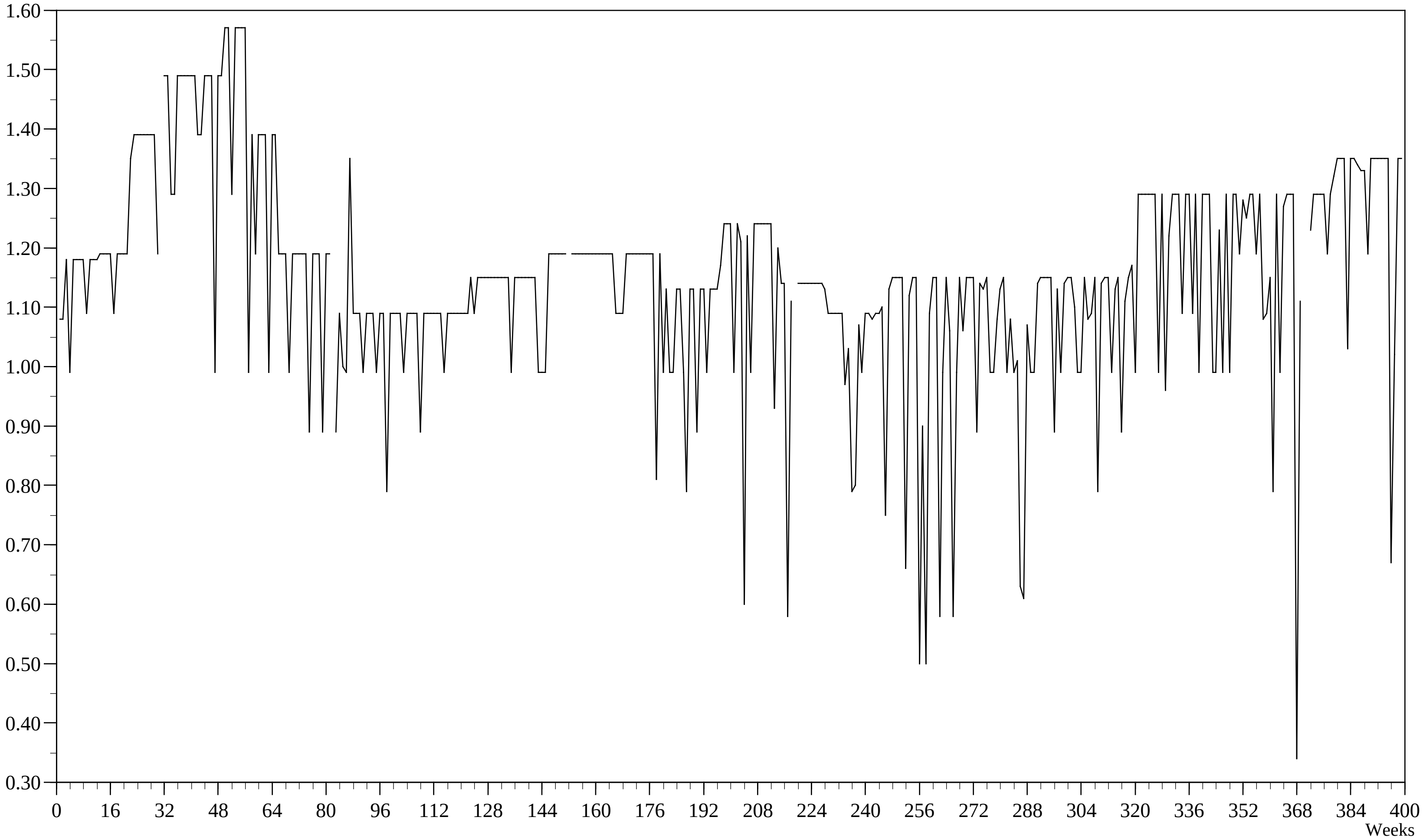


Figure 1. Price of Frozen Concentrate Orange Juice, Heritage House, 12oz (UPC = 3828190029, Store 78), September 14, 1989–May 8, 1997 (Source: Dutta, et al., 2002, and Levy, et al., 2002).

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.

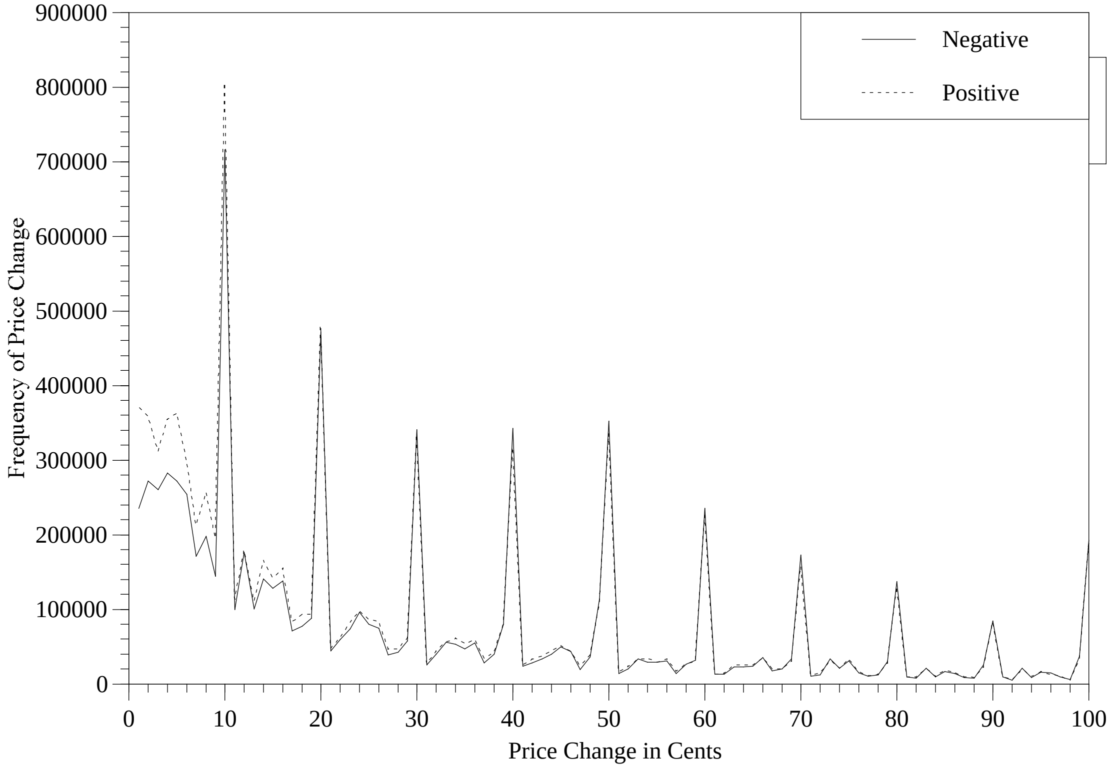


Figure 2a. Frequency of Positive and Negative Retail Price Changes in Cents: All 29 Categories

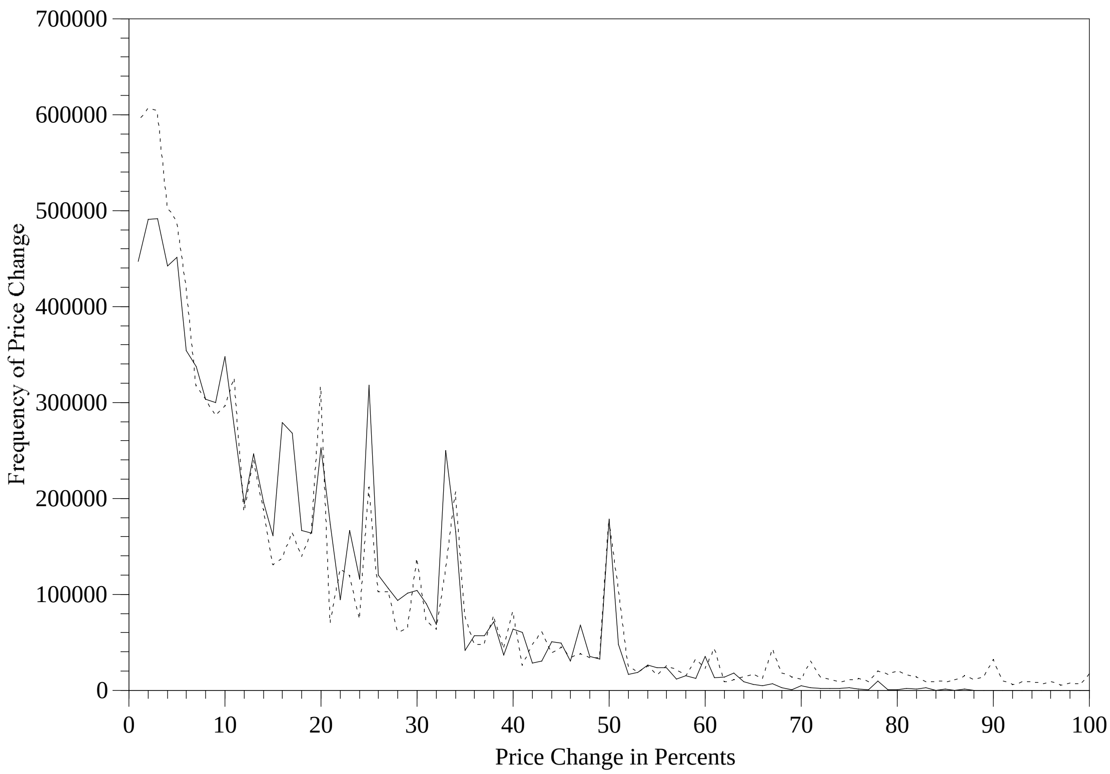


Figure 2b. Frequency of Positive and Negative Retail Price Changes in Percents: All 29 Categories

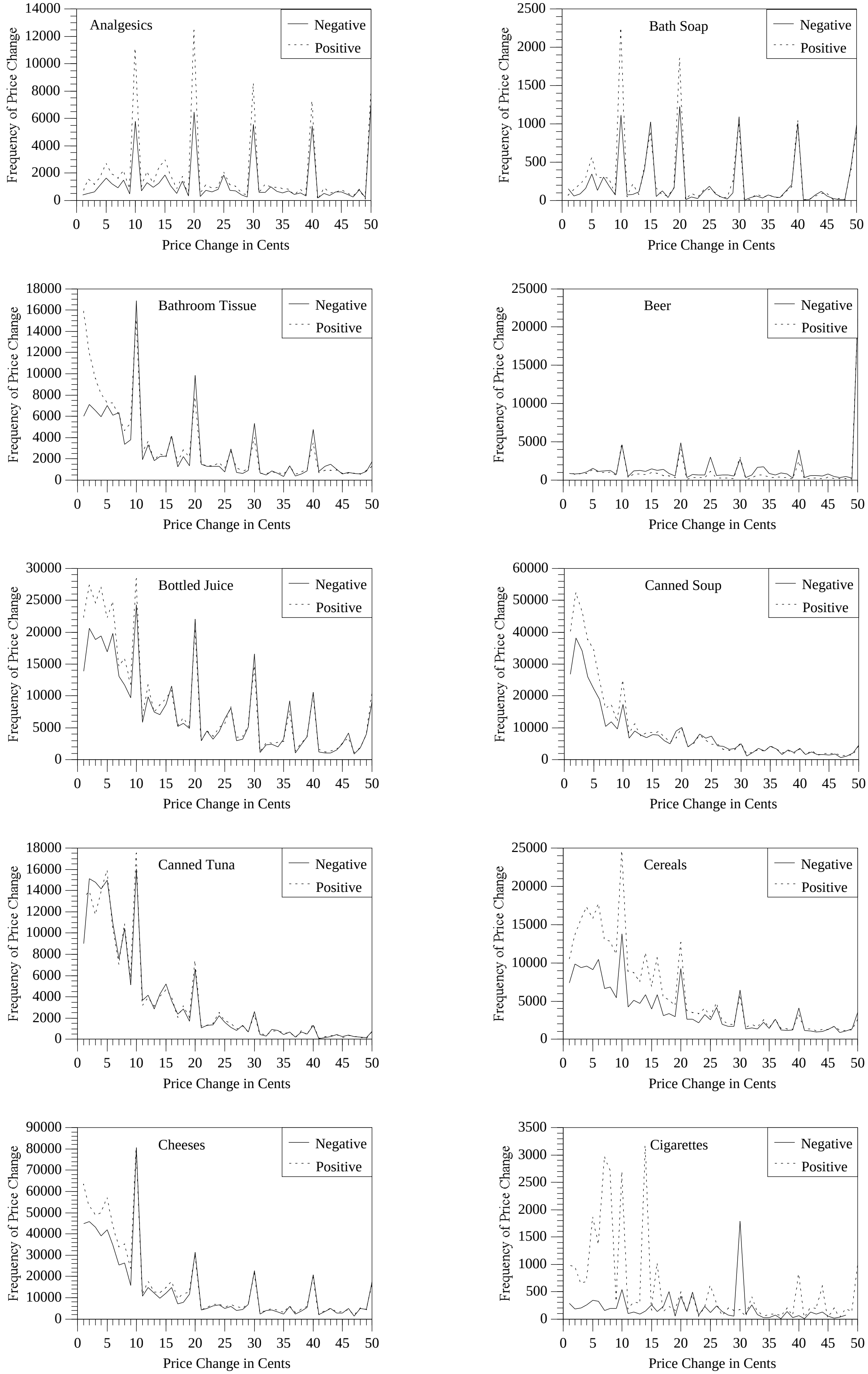


Figure 2.1a. Frequency of Positive and Negative Retail Price Changes in Cents by Category

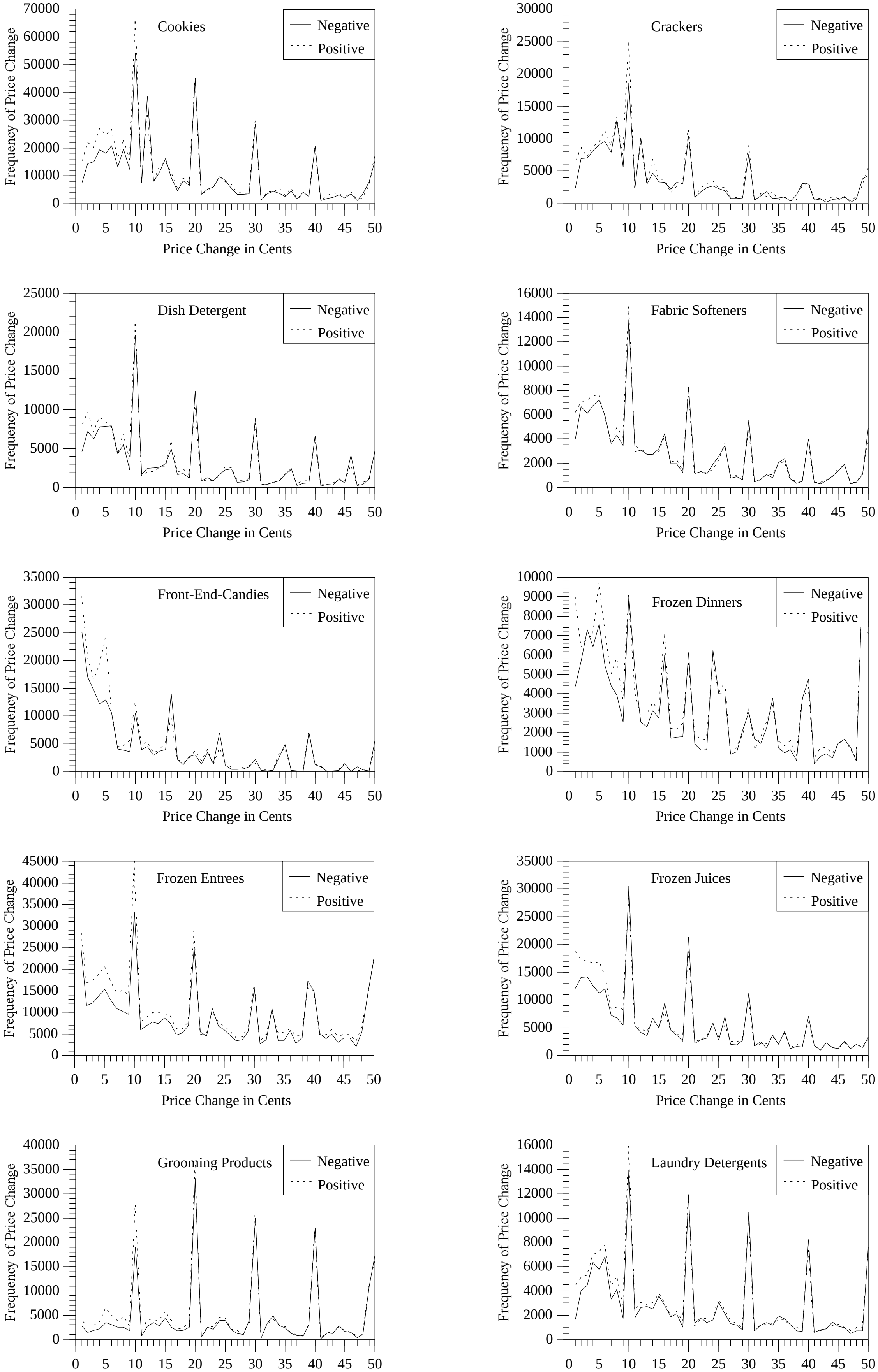


Figure 2.1b. Frequency of Positive and Negative Retail Price Changes in Cents by Category

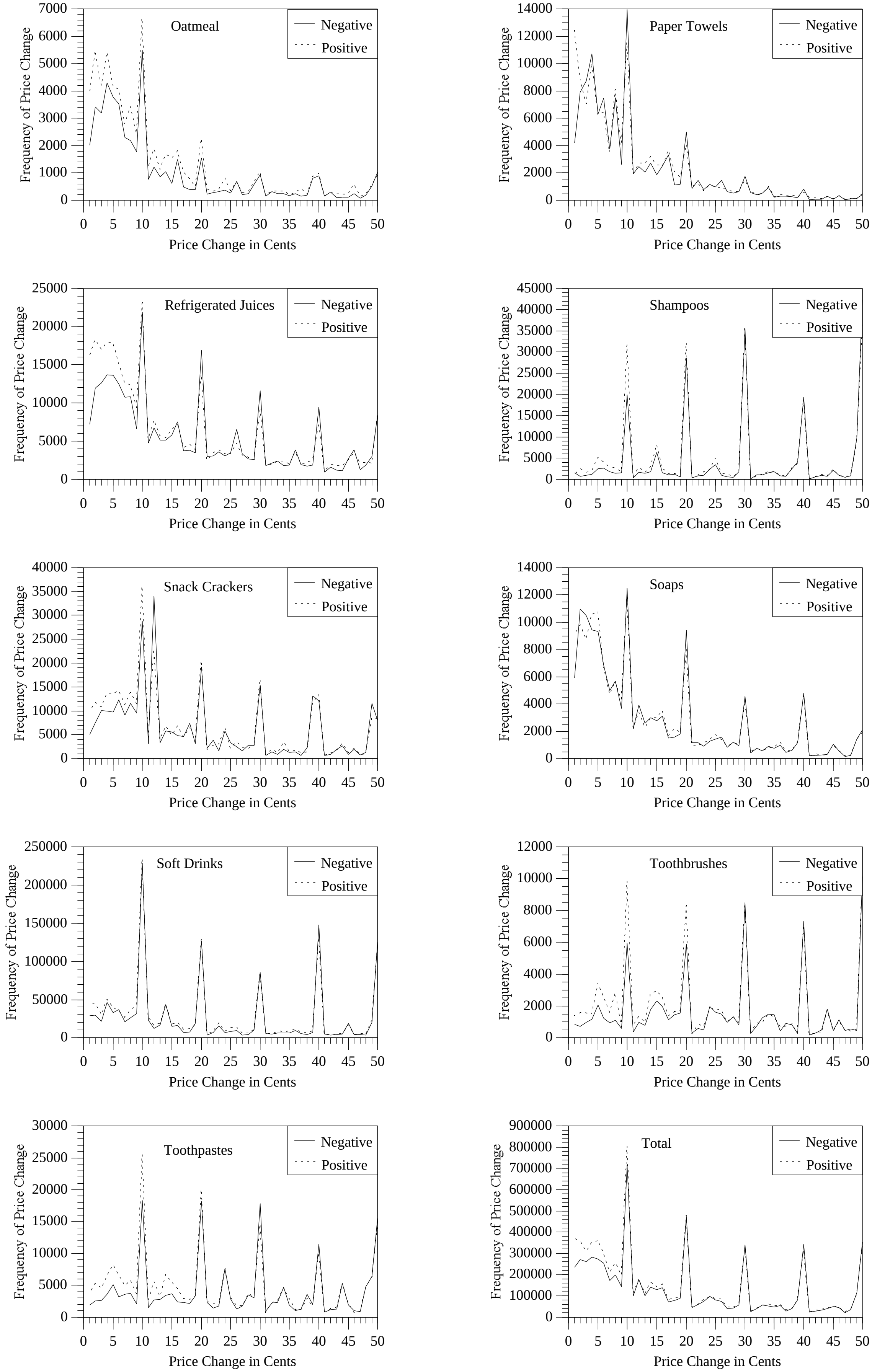


Figure 2.1c. Frequency of Positive and Negative Retail Price Changes in Cents by Category

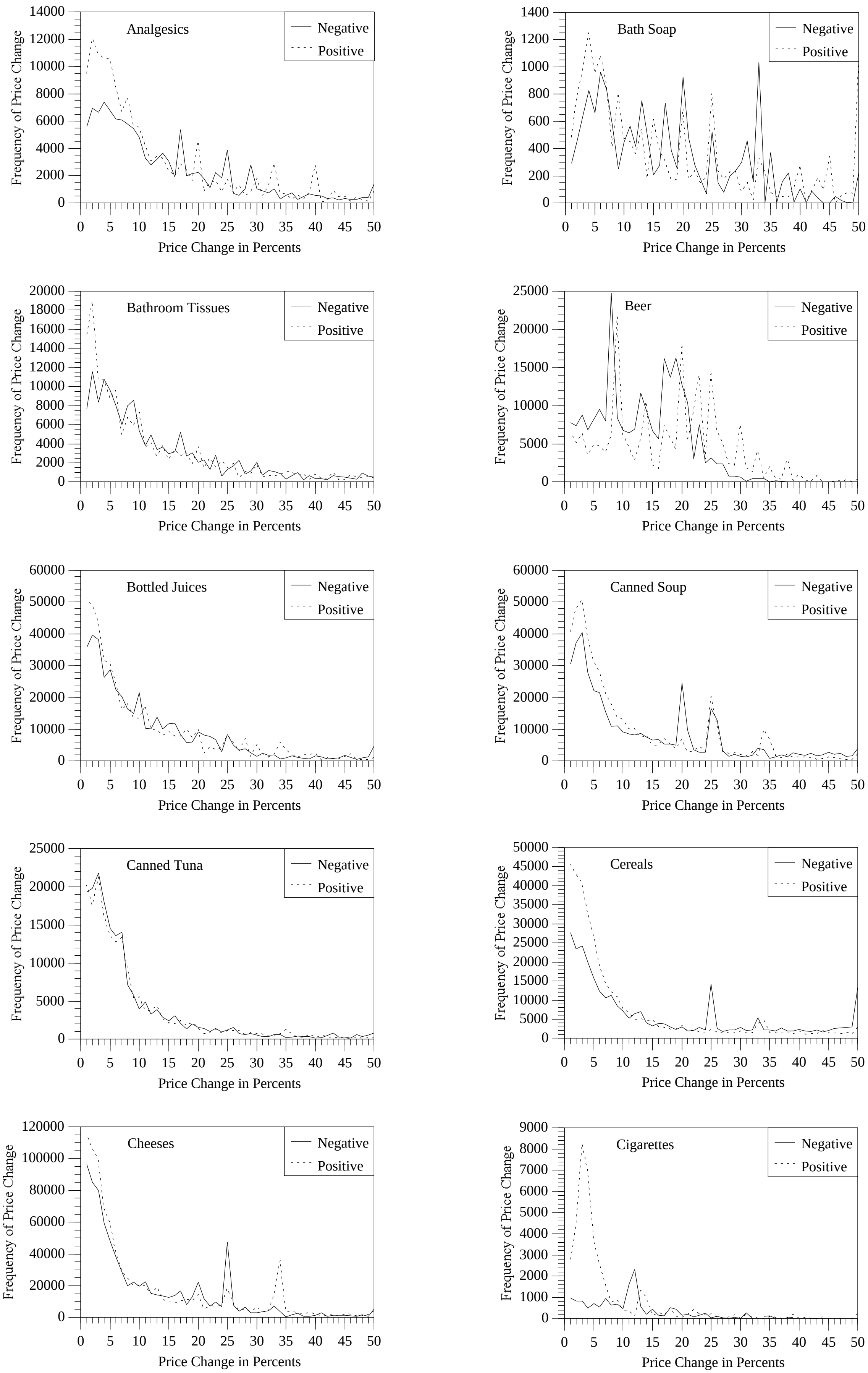


Figure 2.2a. Frequency of Positive and Negative Retail Price Changes in Percents by Category

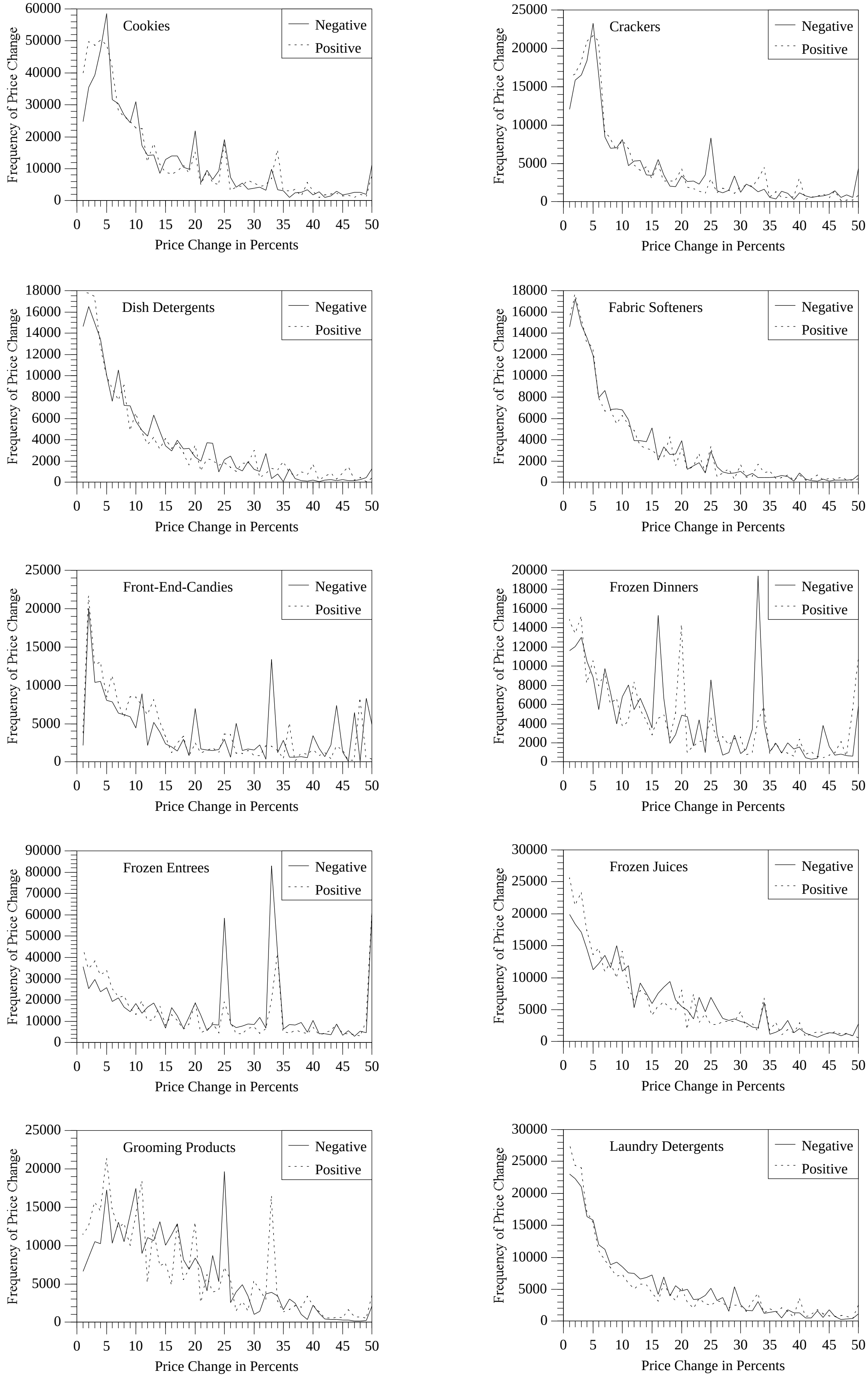


Figure 2.2b. Frequency of Positive and Negative Retail Price Changes in Percents by Category

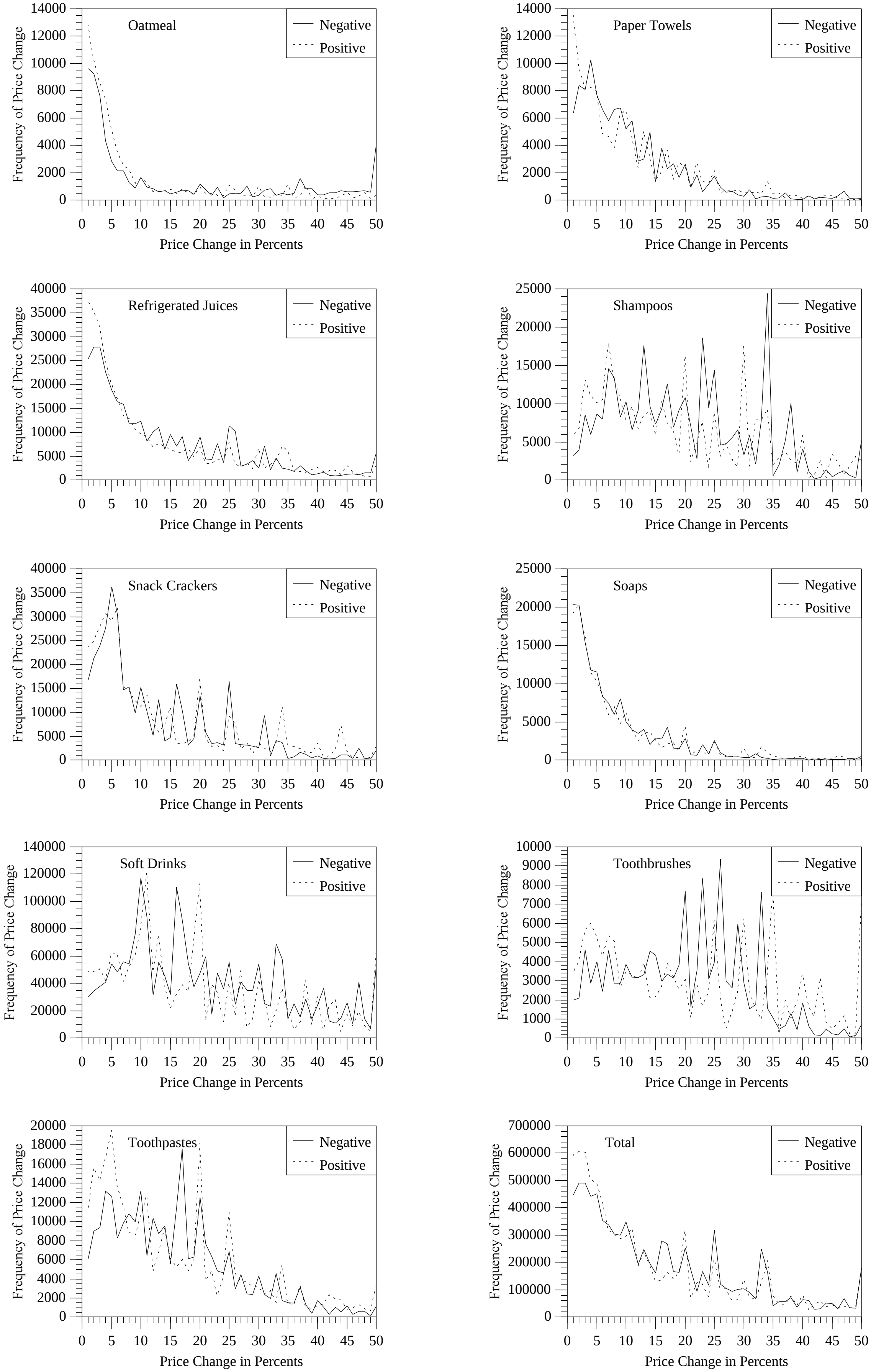
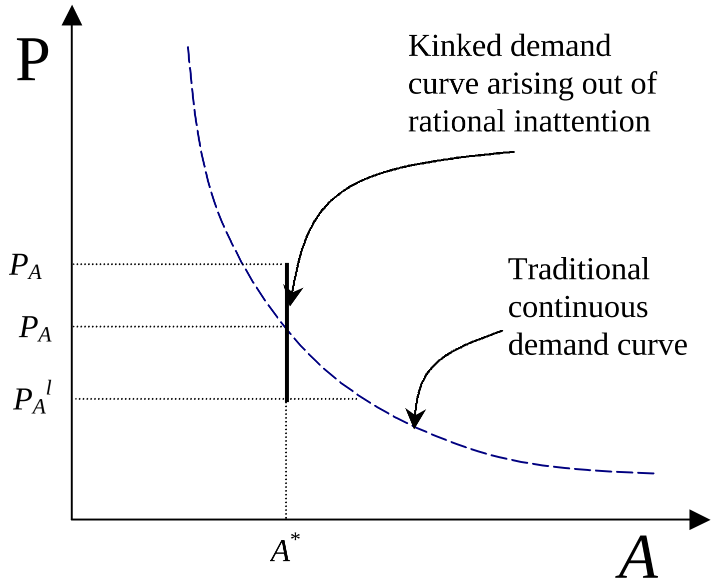


Figure 2.2c. Frequency of Positive and Negative Retail Price Changes in Percents by Category

Figure 3. Demand Curve Due to Rational Inattention (using the same quantity heuristic)



Supplementary Appendix

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

As discussed in the manuscript, a possible explanation of our finding of asymmetric price adjustment in the small may be the fact that during the sample period our study covers, the US was experiencing a moderate inflation. During inflation period we would expect to see more frequent price increases than price decrease, ceteris paribus, and therefore, our finding could merely be a reflection of that fact.

To explore this possibility, we have conducted two analyses. In the first, we have included only those observations during which the *monthly* PPI-inflation rate did not exceed 0.1 percent, a very low inflation rate by any historical standard. We define this sub-sample as the low/zero inflation period. In the second analysis, we took even a more conservative stand by including in the analysis only those observations in which the *monthly* PPI-inflation rate was either zero or negative. We define this sub-sample as the deflation period.

It turns out that the results remain qualitatively unchanged whether we consider the low/zero inflation period or the deflation period. That is, we still observe asymmetry in the small *and* the lack of asymmetry in the large even after the inflation period is excluded from the data analysis. Below we describe the results of these analyses.

R1. Analysis of the Data for the Low/Zero Inflation Period

In Figures R1a and R1b we report the frequency of positive and negative price changes for the entire data set, during low/zero inflation periods, in cents and in percents, respectively. According to Figure R1a, for small price changes we still find more frequent price increases than decreases. According to Table 4 (see the manuscript), the higher frequency of positive price changes “in the small” is statistically significant for absolute price changes of up to 11¢. Beyond that, there is no systematic difference between the frequency of positive and negative price changes as the two series crisscross each other.

Similarly, for price changes in relative terms (Figure R1b), we see more price increases than decreases for price changes of up to about 6%. Thus, the exclusion of inflationary periods from the data seems to make little difference to the general pattern of asymmetric price adjustment. The retail prices still exhibit asymmetry “in the small.” The only difference between the two sets of results is that the frequencies of both positive and negative price changes are now smaller, which is due to the reduction in the sample size that result from the elimination of the observations that pertain to inflationary periods.

The findings remain essentially unchanged for individual categories as well, as can be seen in Figures R1.1a–R1.1c and R1.2a–R1.2c, for price changes in cents and in percents, respectively. The asymmetry thresholds for each product category are shown in Table 4. For example, as before, the category of Beer does not show clear patterns of asymmetry. Also as before, in the category of Frozen Entrees the asymmetry in the frequency of positive and negative price changes lasts for a price change of up to about 20¢. In all other categories except bath soap, the asymmetry still holds, with some decrease in the asymmetry threshold, perhaps due to the smaller sample size. Only in the category of bath soap, the asymmetry seems to have disappeared, but now the category of Shampoos shows asymmetry for price changes of up to 10¢.

Focusing now on the frequency of price changes in percents, Figures R1.2a–R1.2c, we find that for all 29 categories considered, the frequency of positive price changes again exceeds the frequency of negative price changes “in the small.” In most cases “small” here means about 5%–6%, except in the categories of Analgesics and Shampoos, where the asymmetry lasts for up to about 10% change. Thus, we conclude that the retail prices for the entire data set as well as at the level of individual categories, exhibit asymmetric price adjustment “in the small” in both absolute (cents) and relative (percents) terms even when we exclude the observations pertaining to moderate inflationary periods.

R2. Analysis of the Data for the Deflation Period

Now consider the results for the deflation period, that is, when the data contain only observations pertaining to the months of zero or negative inflation. In Figures R2a and R2b we report the frequency of positive and negative price changes for the entire data set, during deflation periods, in cents and in percents, respectively. In Figures R2.1a–R2.1c and R2.2a–R2.2c we present these results for individual product categories.

The results here are no different from the previous sets of results. Overall, there are more positive than negative price changes for price changes of up to 11¢ and 6%. The asymmetry threshold for each product category is summarised in the last two columns of Table 4. Comparing the results for the deflation periods with those for the low/zero inflation periods, we find that the asymmetry in absolute terms no longer holds for the category of Frozen Entrees, and the asymmetry in relative terms no longer holds for the categories of Fabric Softeners and Frozen Juices. For all the remaining categories, we still find asymmetry "in the small" in terms of both absolute and relative changes.

R3. Conclusion

In sum, the results for the low/zero inflation and deflation periods are qualitatively similar to the results obtained when data pertaining to inflationary periods were included in the analysis. We, therefore, conclude that inflation cannot explain the asymmetric price adjustment in the small.

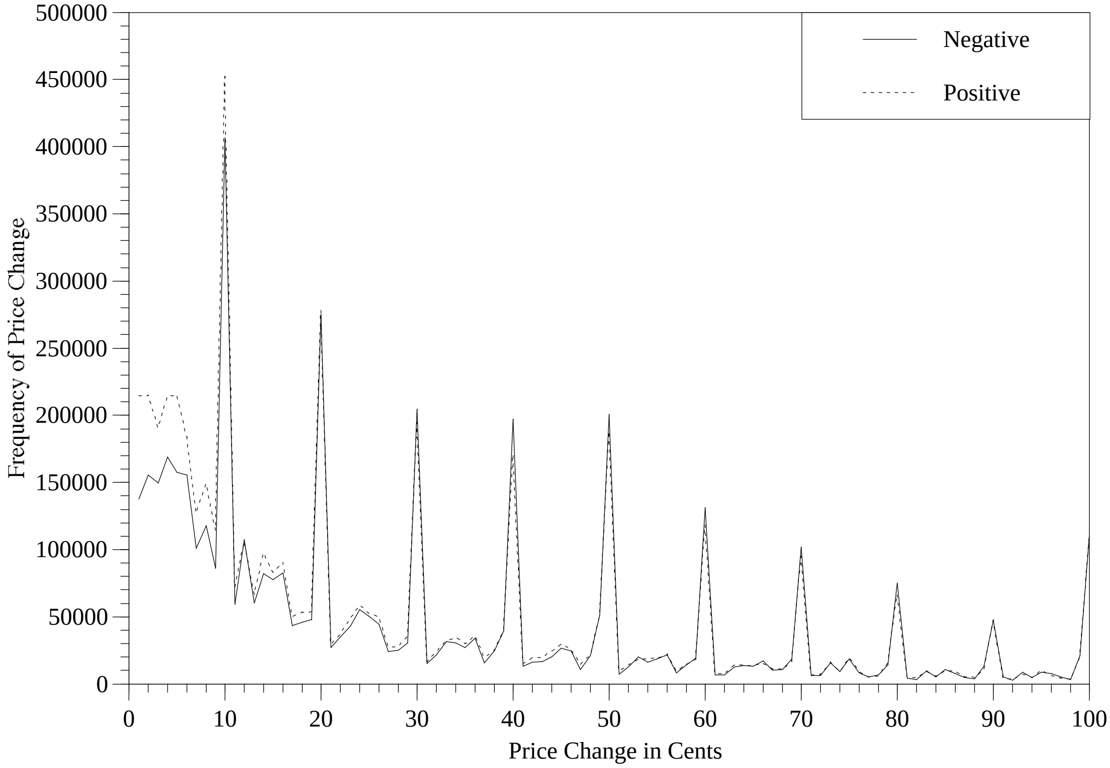


Figure R1a. Frequency of Positive and Negative Retail Price Changes in Cents: All 29 Categories, Low/Zero Inflation Period

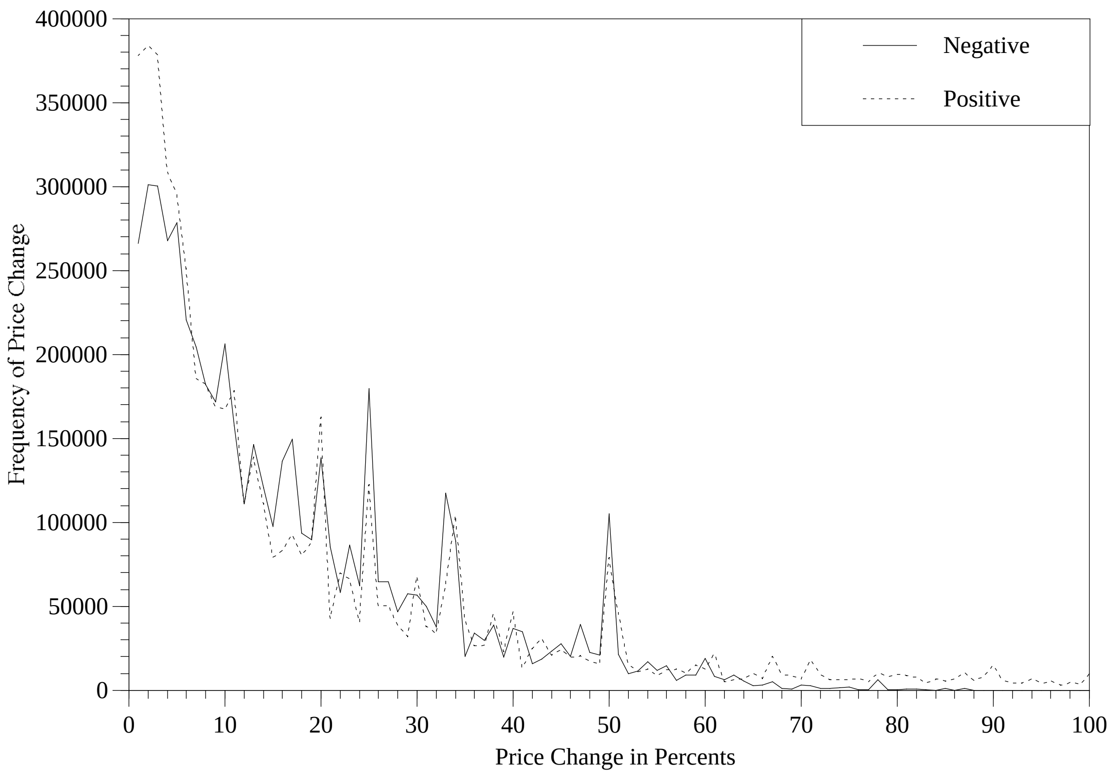


Figure R1b. Frequency of Positive and Negative Retail Price Changes in Percents: All 29 Categories, Low/Zero Inflation Period

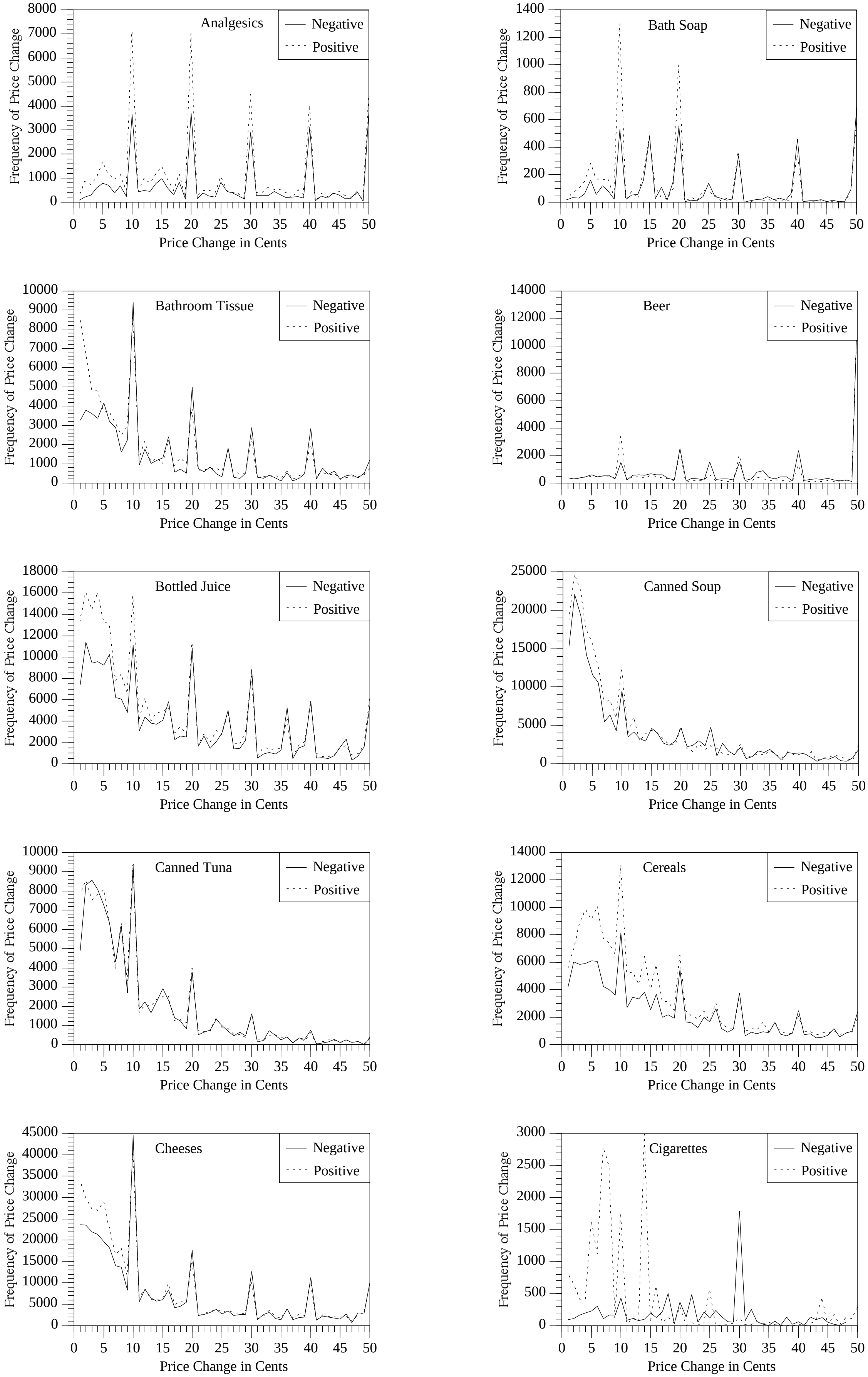


Figure R1.1a. Frequency of Positive and Negative Retail Price Changes in Cents by Category, Low/Zero Inflation Period

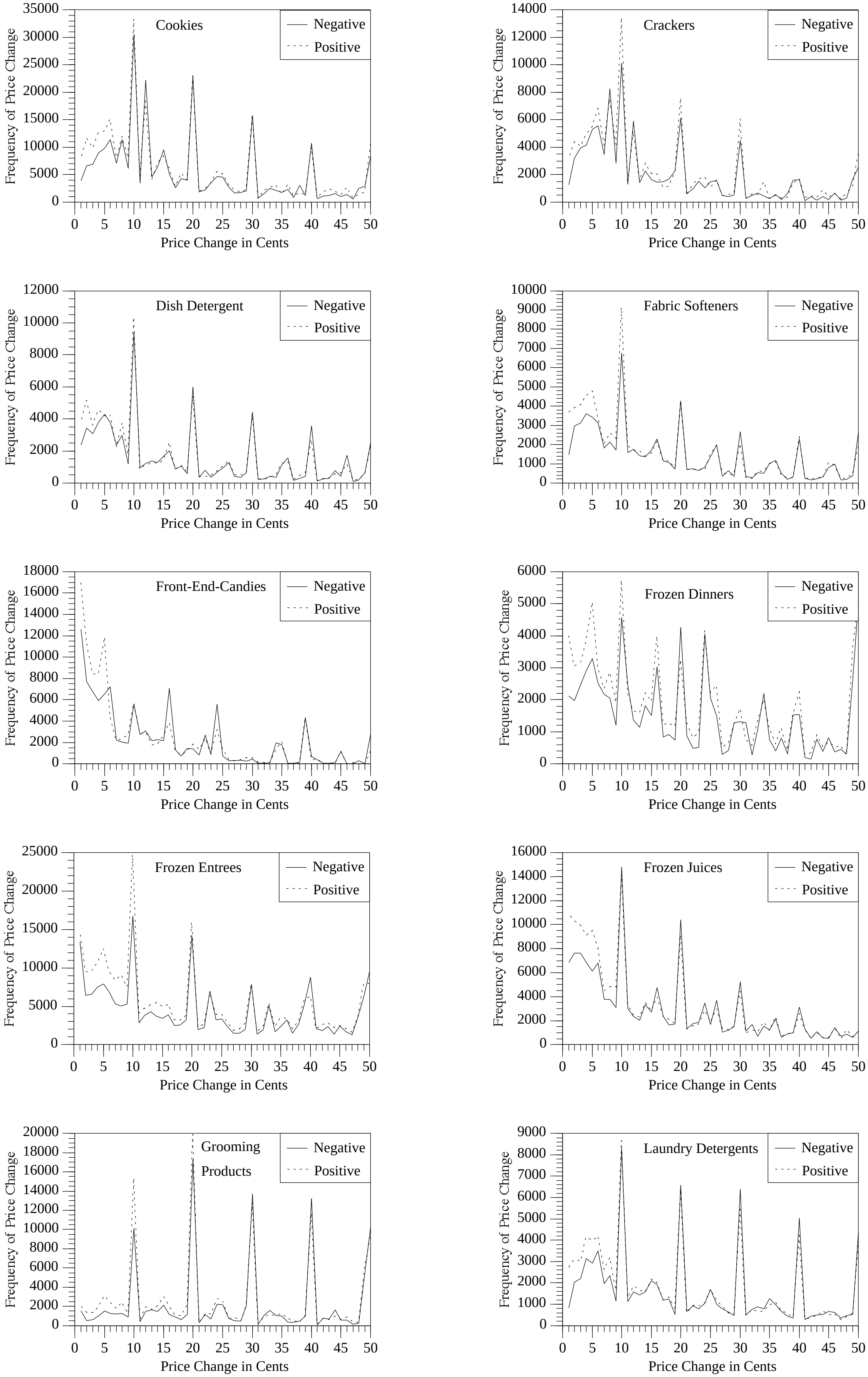


Figure R1.1b. Frequency of Positive and Negative Retail Price Changes in Cents by Category, Low/Zero Inflation Period

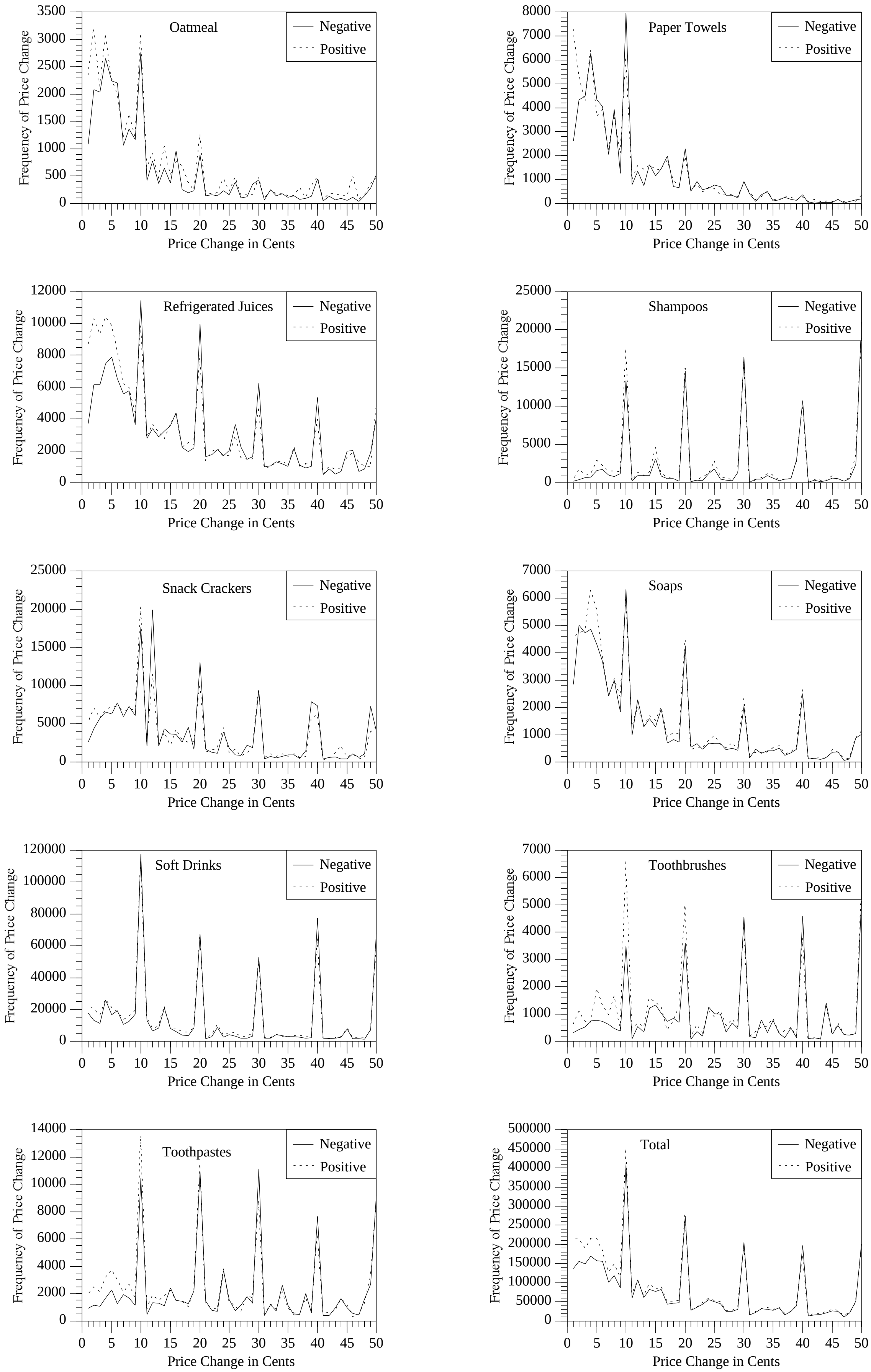


Figure R1.1c. Frequency of Positive and Negative Retail Price Changes in Cents by Category, Low/Zero Inflation Period

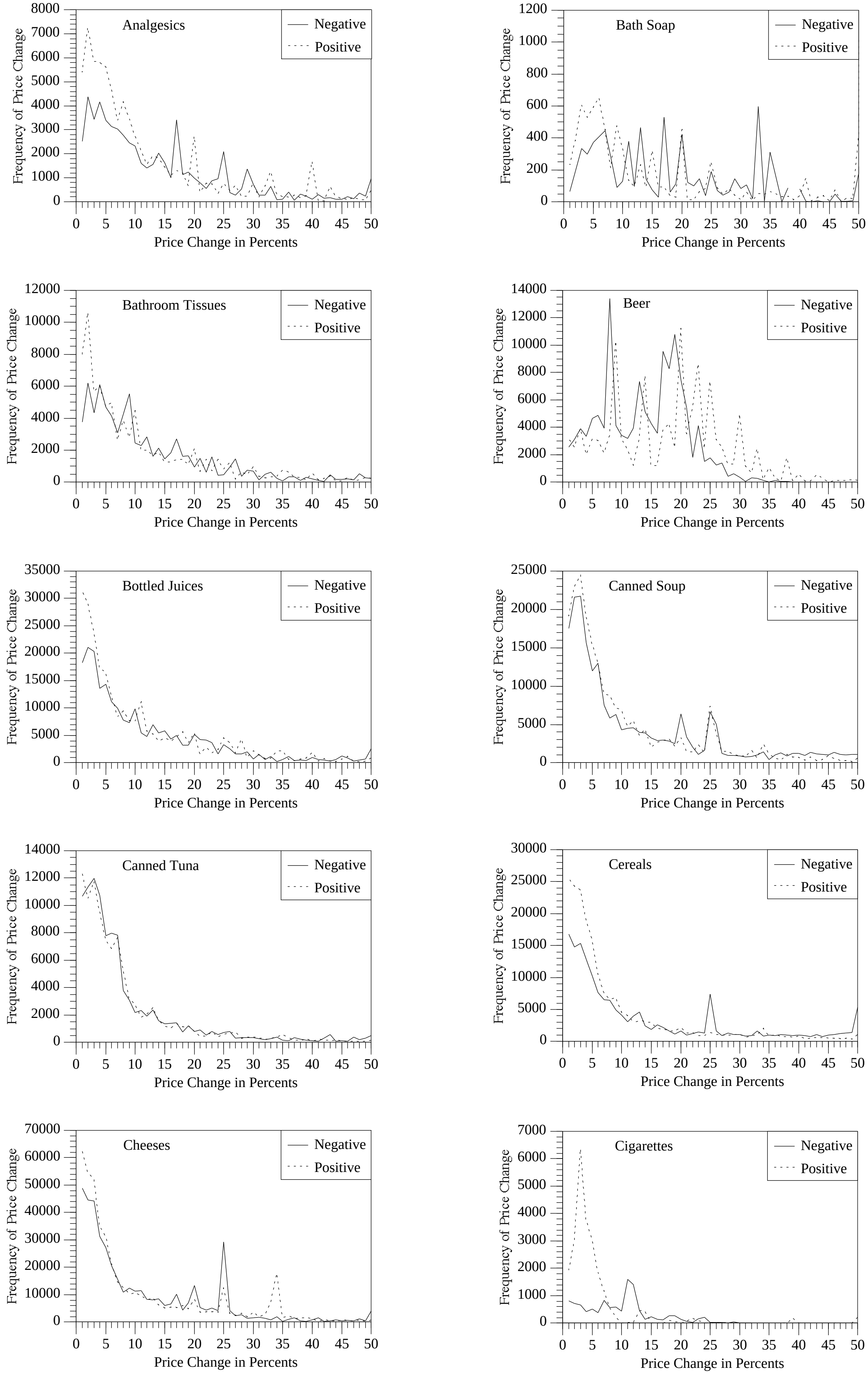


Figure R1.2a. Frequency of Positive and Negative Retail Price Changes in Percents by Category, Low/Zero Inflation Period

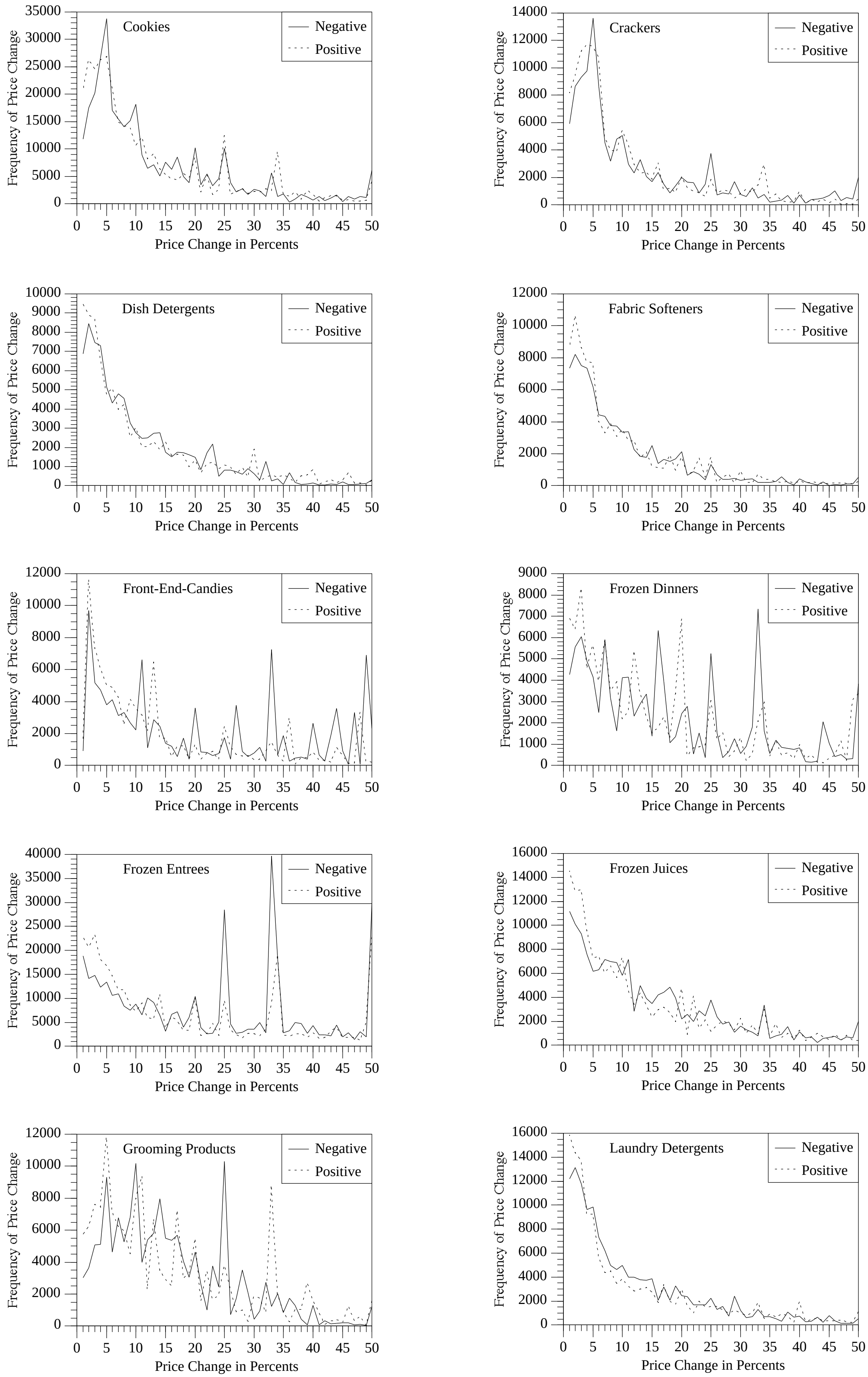


Figure R1.2b. Frequency of Positive and Negative Retail Price Changes in Percents by Category, Low/Zero Inflation Period

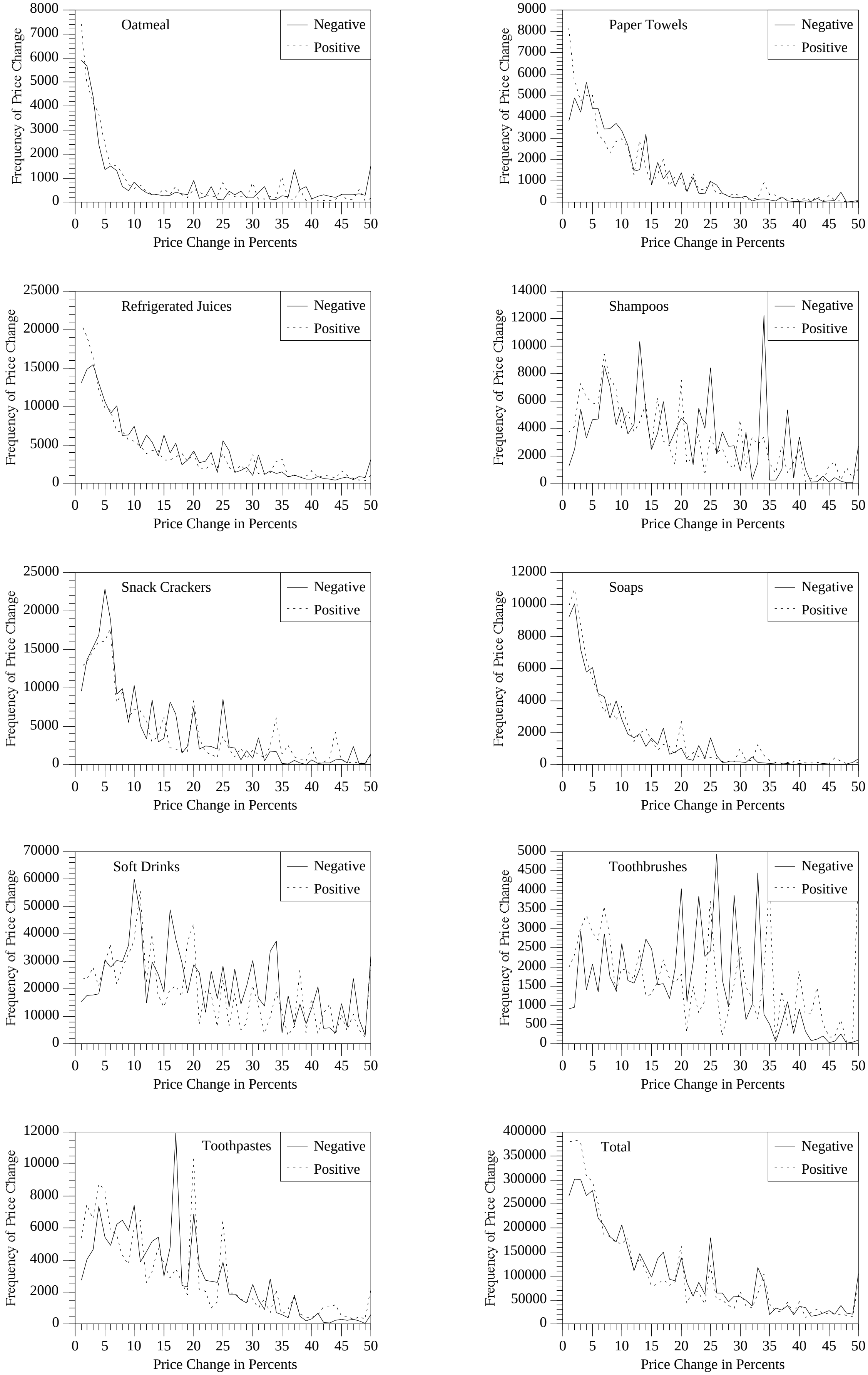


Figure R1.2c. Frequency of Positive and Negative Retail Price Changes in Percents by Category, Low/Zero Inflation Period

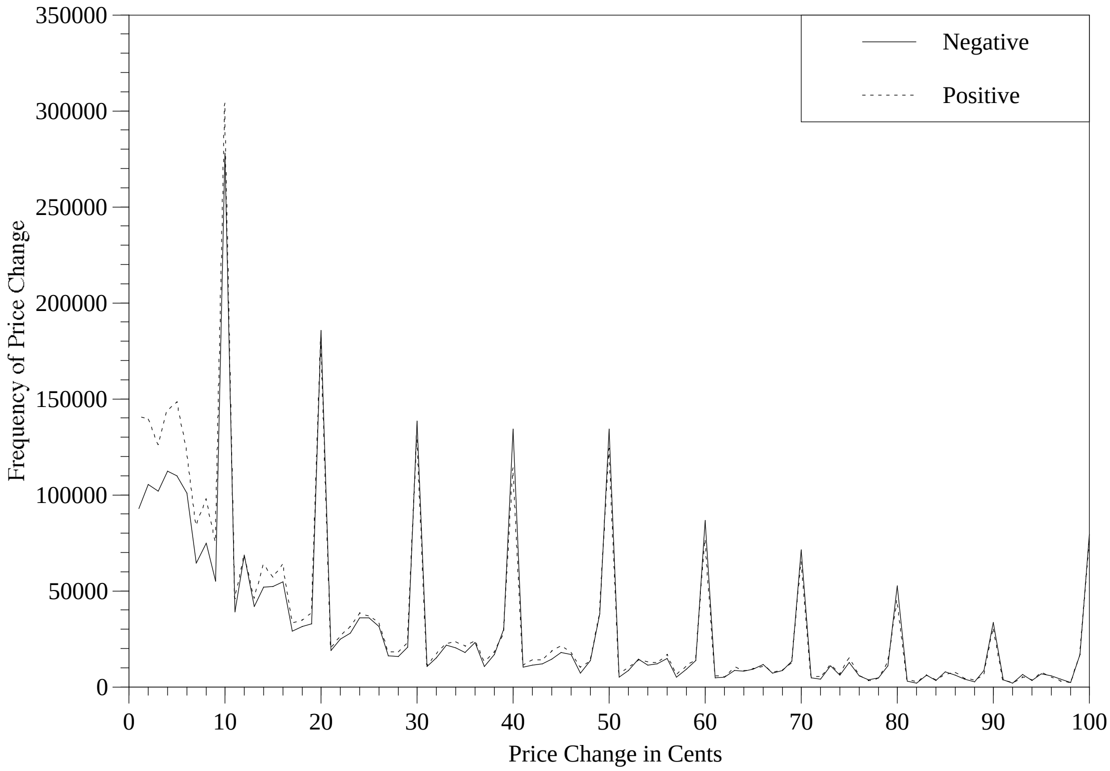


Figure R2a. Frequency of Positive and Negative Retail Price Changes in Cents: All 29 Categories, Deflation Period

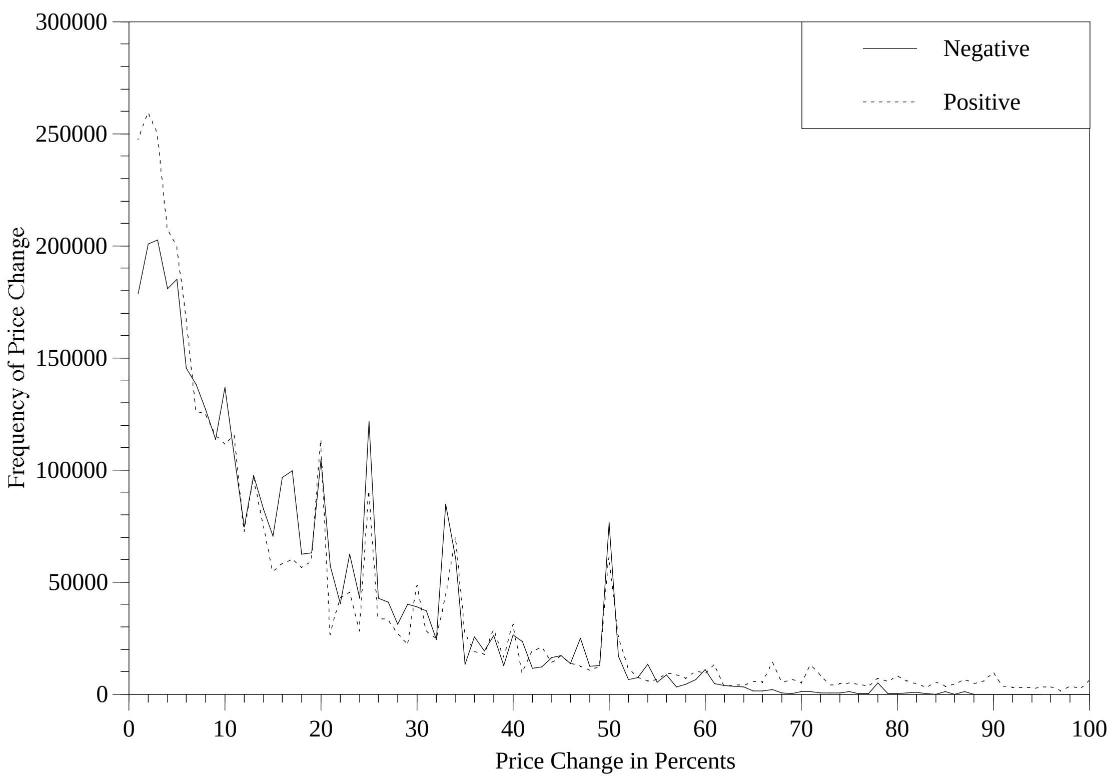


Figure R2b. Frequency of Positive and Negative Retail Price Changes in Percents: All 29 Categories, Deflation Period

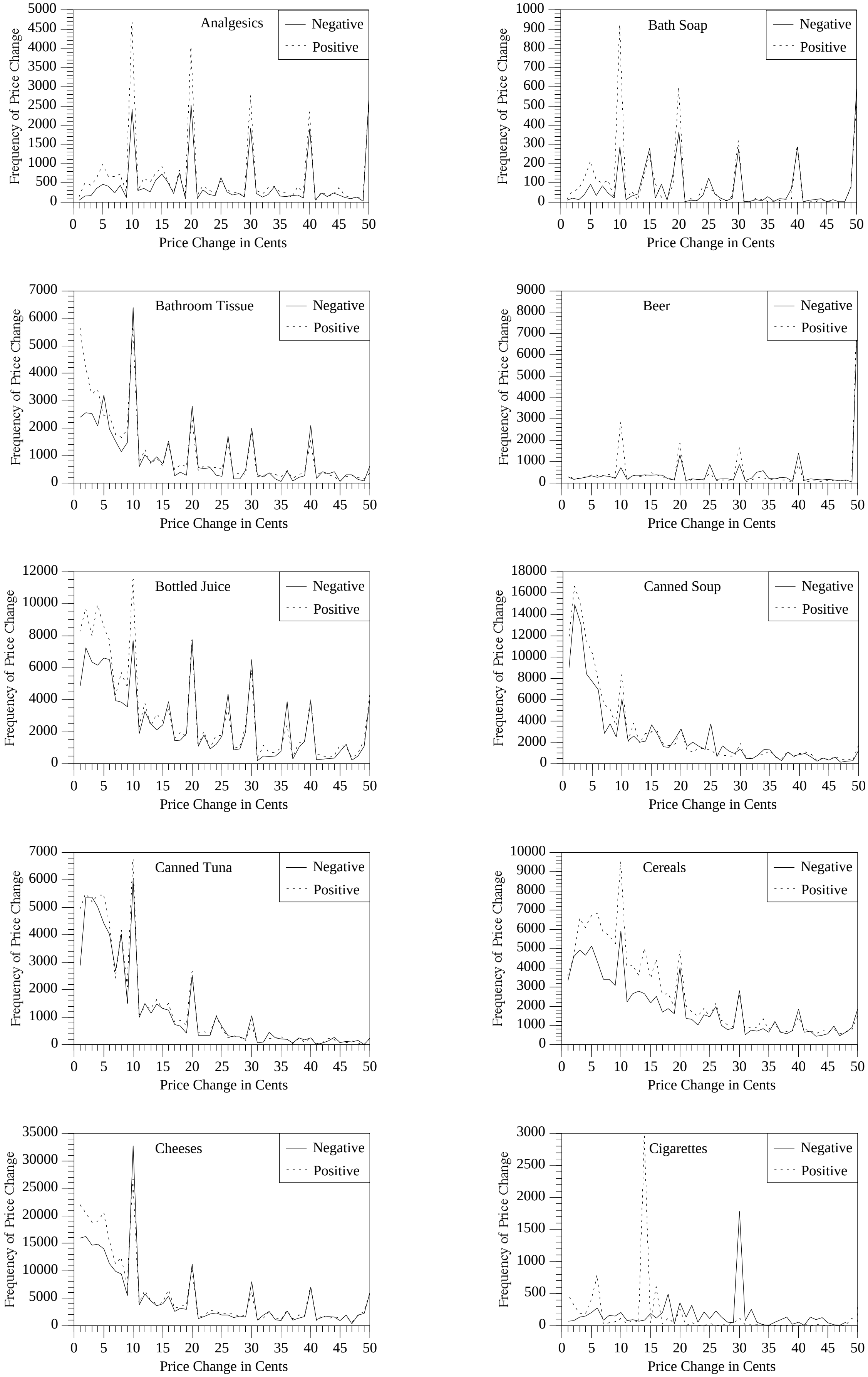


Figure R2.1a. Frequency of Positive and Negative Retail Price Changes in Cents by Category, Deflation Period

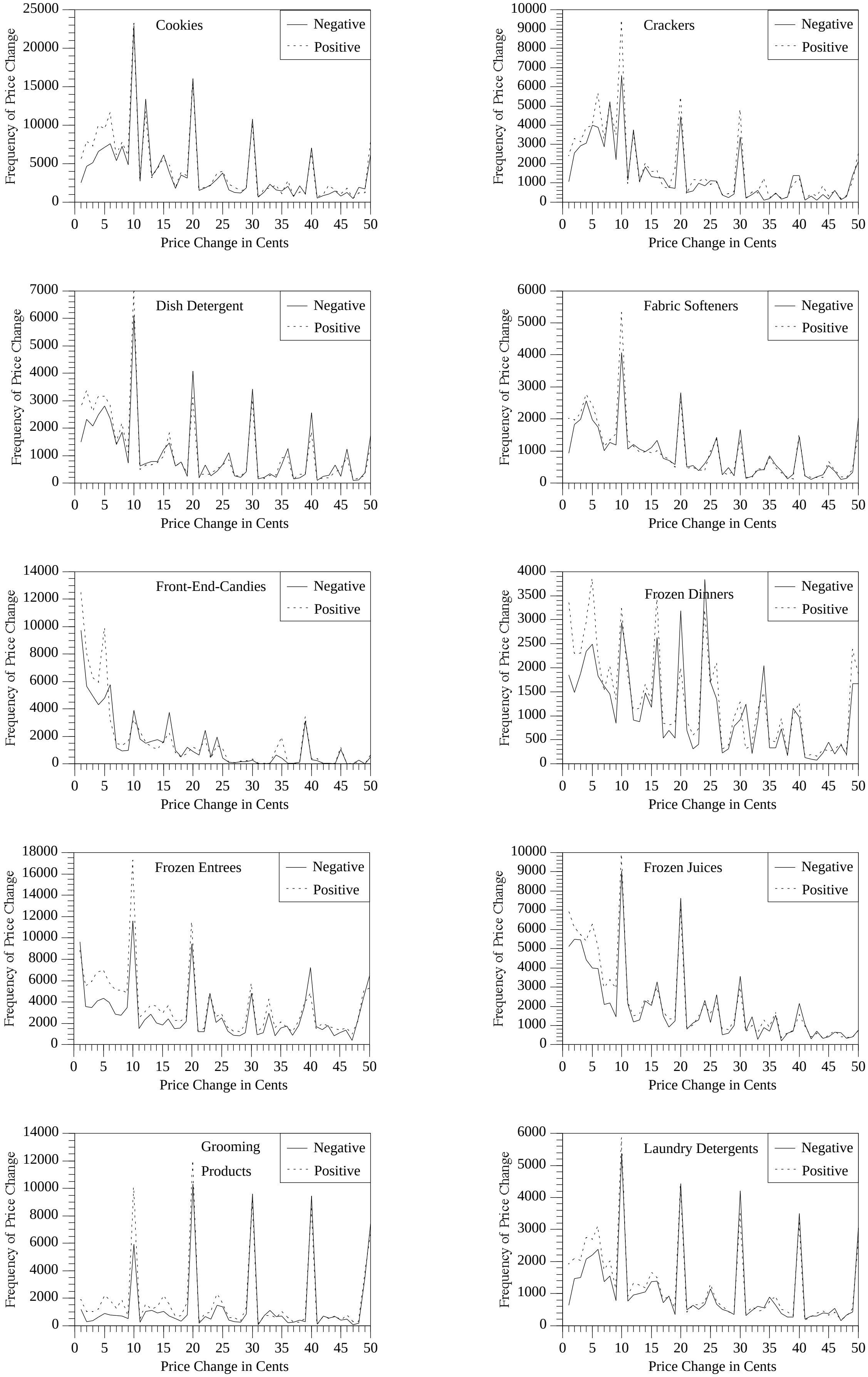


Figure R2.1b. Frequency of Positive and Negative Retail Price Changes in Cents by Category, Deflation Period

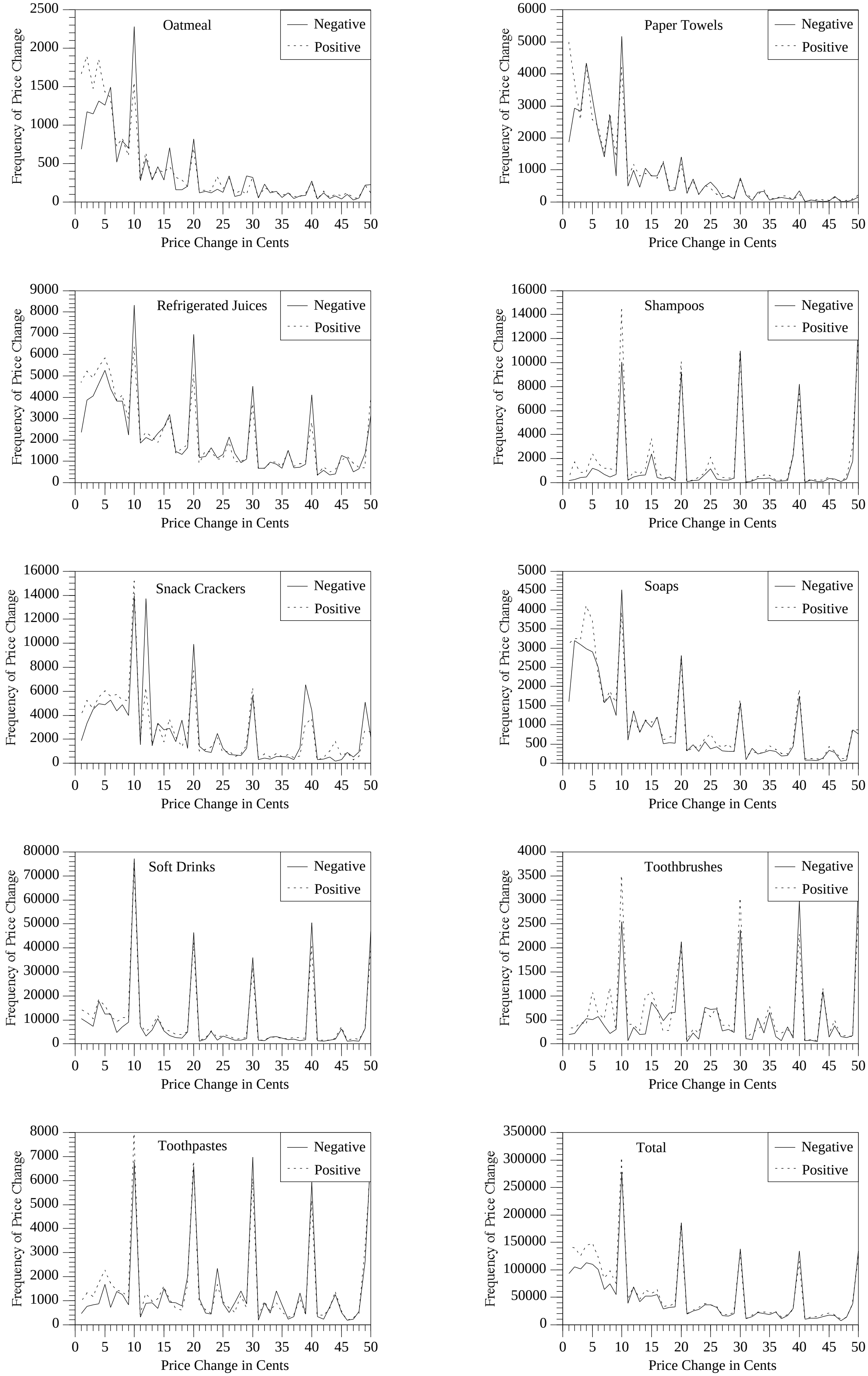


Figure R2.1c. Frequency of Positive and Negative Retail Price Changes in Cents by Category, Deflation Period

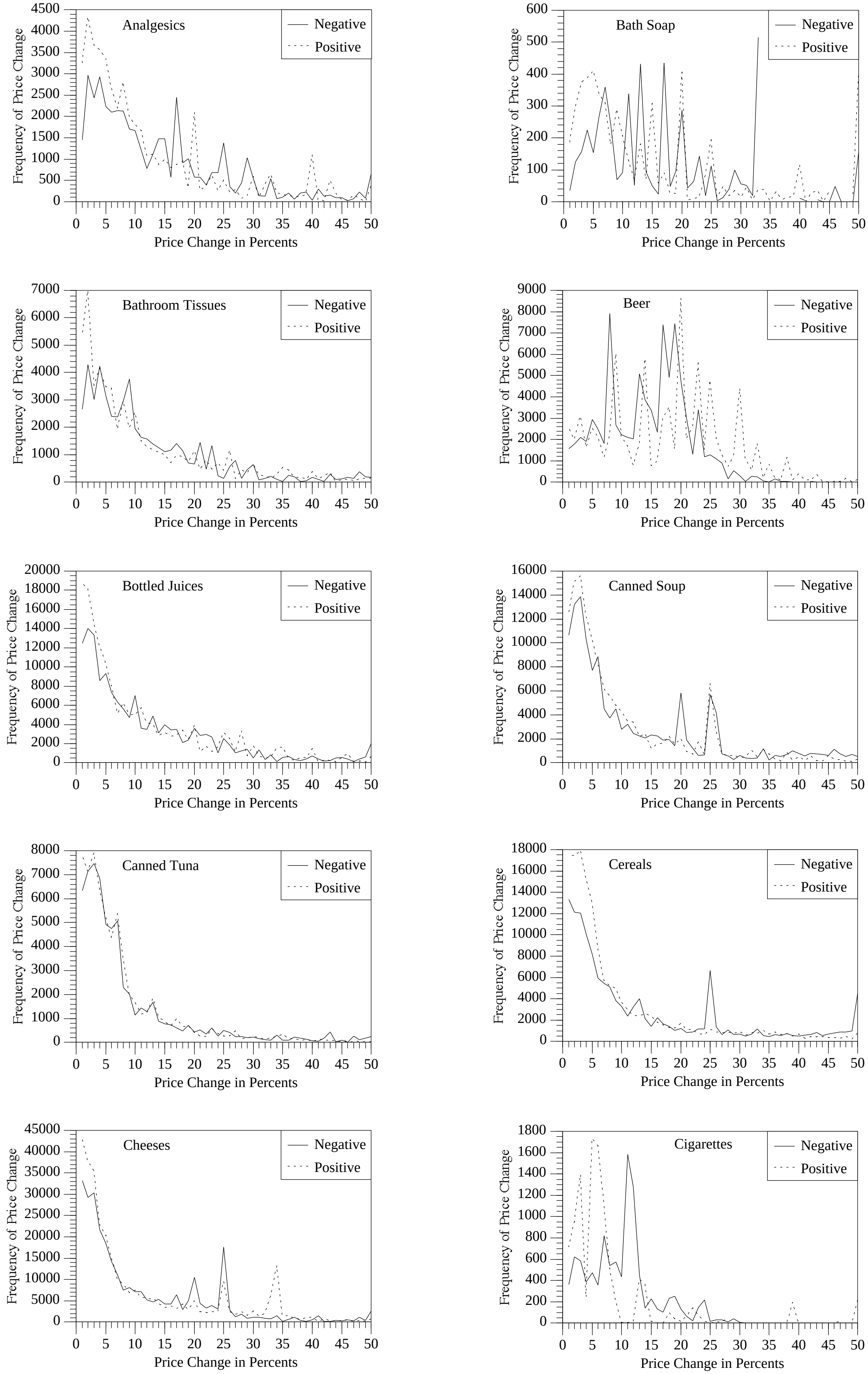


Figure R2.2a. Frequency of Positive and Negative Retail Price Changes in Percents by Category, Deflation Period

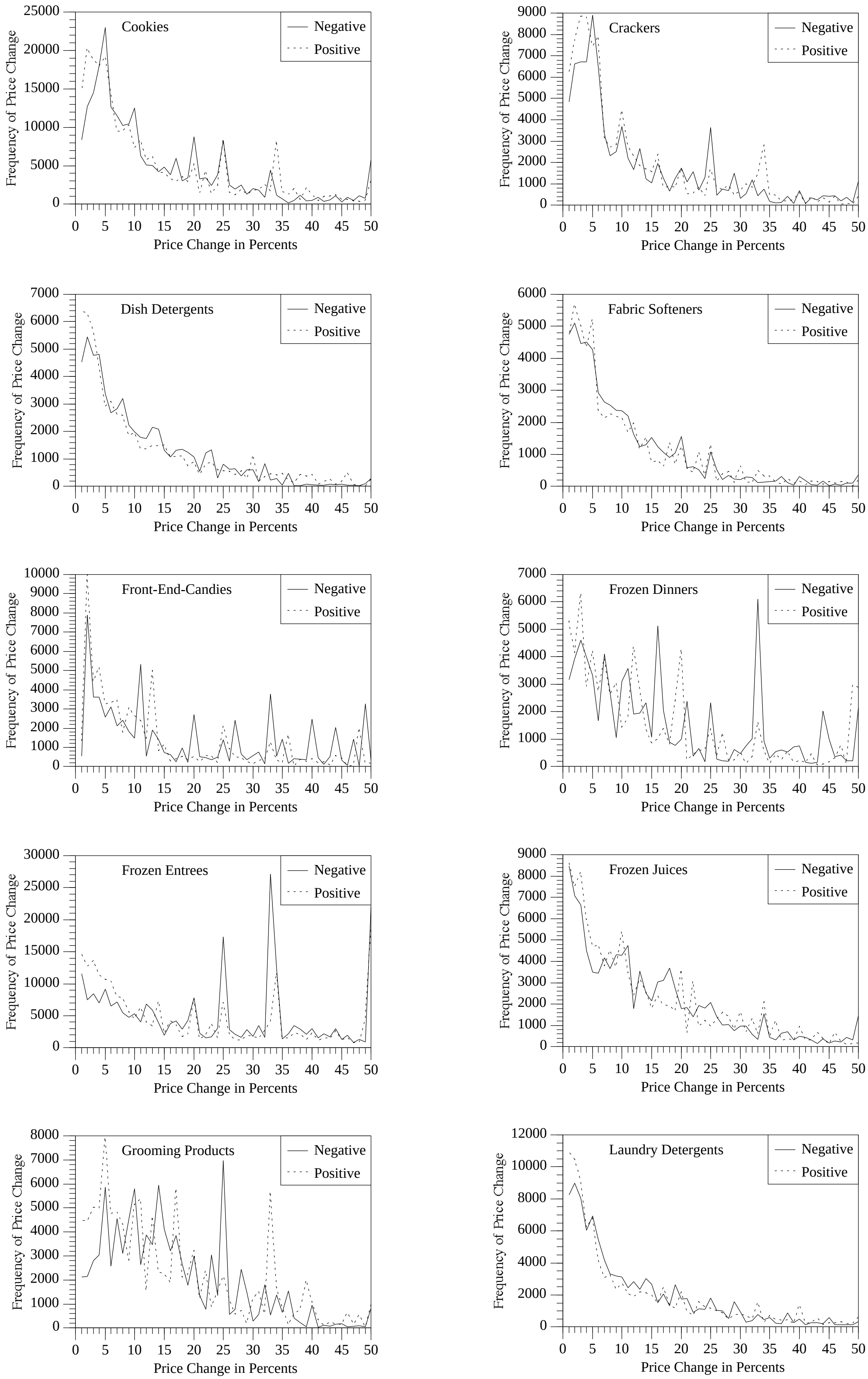


Figure R2.2b. Frequency of Positive and Negative Retail Price Changes in Percents by Category, Deflation Period

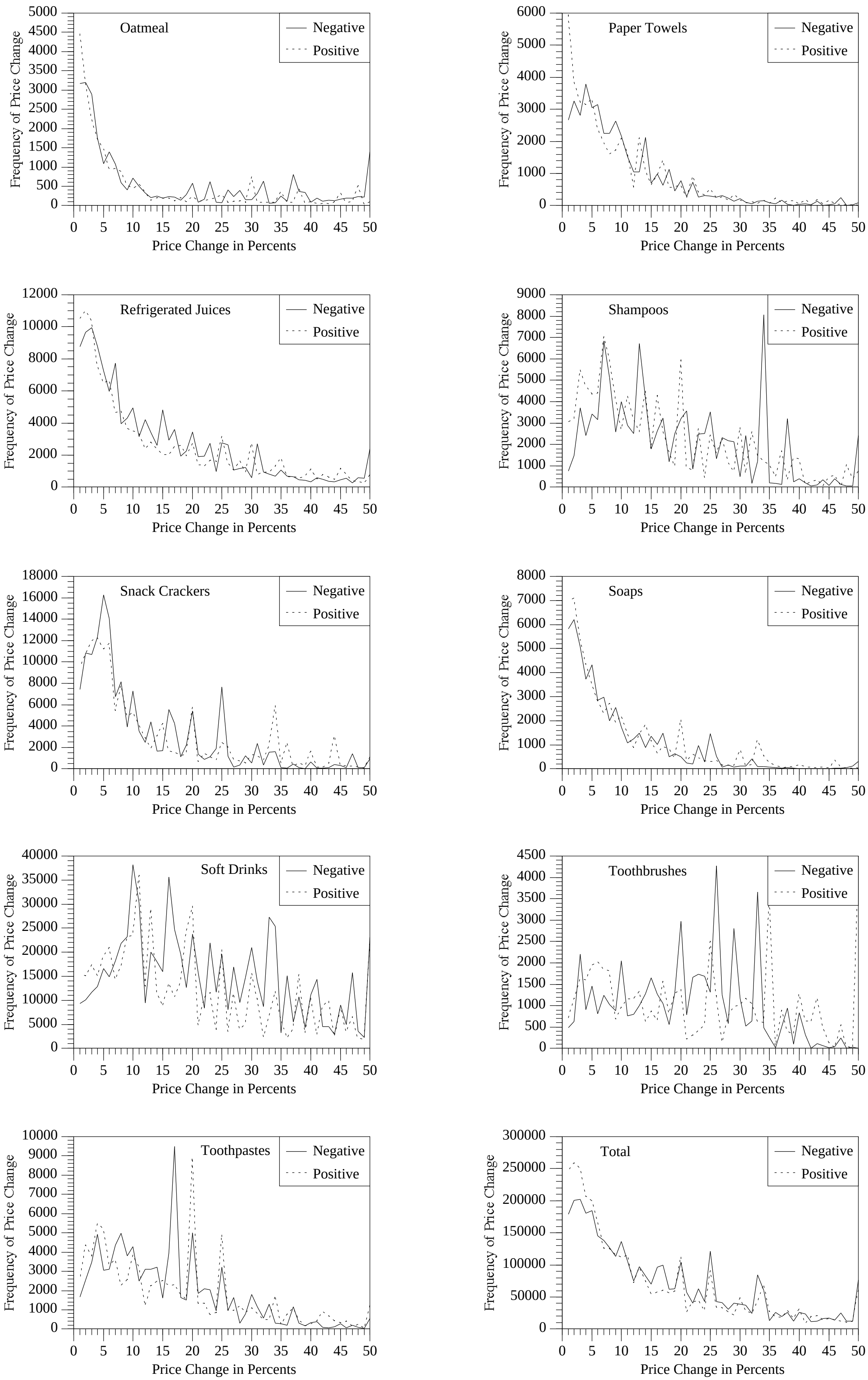


Figure R2.2c. Frequency of Positive and Negative Retail Price Changes in Percents by Category, Deflation Period