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

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

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## Abstract

We study the implications of rational inattention for individual price dynamics. Analyzing scanner data that cover 29 product categories over a 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. Given the inability of the existing theories to explain the particular form of asymmetry we document, we offer a new theory of asymmetric price adjustment, which can explain our findings. The theory, which is an extension of the literature on “rational inattention,” argues that observing, processing, and reacting to price change information is not a costless 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 noticed by consumers and therefore trigger their response. Thus, no asymmetry is observed “in the large.”

**Keywords:** Asymmetric Price Adjustment, Rational Inattention, Cost and Benefit of Information Acquiring and Processing, Price Rigidity

**JEL classification:** E31, D11, D21, D80, L11, M31

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“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)**

“Economic theory suggests no pervasive tendency for prices to respond faster to one kind of cost change than to another.”

**Sam Peltzman (2000, p. 467)**

## 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 more 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.”<sup>1</sup> The same is true for food prices, where “retail pork prices do not come down even if hog prices do,”<sup>2</sup> and “government subsidies to dairy farmers do not lower dairy product prices.”<sup>3</sup>

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.<sup>4</sup> Empirically, asymmetric price adjustment has been studied mostly with individual or industry level data such as banking, gasoline, fruit and vegetables, pork, etc.<sup>5</sup> 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 asymmetry disappears for larger price changes.

<sup>1</sup> *Octane*, Vol. 13, No. 3, June 1999, pp. 6–7.

<sup>2</sup> *The New York Times*, January 7, 1999, “The Great Pork Gap: Hog Prices Have Plummeted, Why Haven’t Store Prices?”

<sup>3</sup> *Canadian Press Newswire*, December 18, 2000.

<sup>4</sup> See Peltzman (2000) and Meyer and Cramon-Taubadel (2004) for recent critical surveys.

<sup>5</sup> 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).

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 the 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.

Third, we offer a new theory of asymmetric price adjustment “in the small” which can explain our empirical finding. The model we formulate belongs to 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).

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 such activities as acquiring, processing, and memorizing price and price change information, comparing prices, 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 offers a partial 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). Our theory can explain the occurrences of small price increases. The presence of small price decreases still remains a puzzle.

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), Akerlof (2002), Sims (1998, 2003), Ball, Mankiw, and Reis (2004), Rotemberg (2002), and Reis (2003 and 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. Mankiw and Reis (2002) and Ball, et al. (2004) assume that price setters are slow to incorporate macroeconomic information into their price-setting decisions. Rotemberg (2002) hypothesizes that consumers interpret sellers' price change decision according to its fairness and react accordingly. Reis (2003 and 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 constant 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 collecting and 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 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, 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 and 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 model, information is explicitly treated as a common, normal good, with cost and benefit. In this sense, our paper is closest to the studies of Ameriks, et al., 2003, and Reis, 2003 and 2004.



The optimal amount of information people will choose to acquire will, therefore, depend on both, the cost as well as the benefit. This implies that the cost of acquiring and processing 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, where we report results for the entire dataset as well as for its two subsets, one covering the low/zero inflation period, and the second—the deflationary periods. In section 4, we examine the ability of the existing asymmetric price adjustment theories to explain our results, and find that none of them is satisfactory. In section 5, therefore, we offer a theory of rational inattention, which can explain the 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 on just noticeable differences. We conclude in section 7. In the Appendix, we formulate and 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.<sup>6</sup> The length of

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<sup>6</sup> 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.

individual product's price 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.<sup>7</sup> 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).

### 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 100¢, and in percents, 1%, 2%, 3%, ... up to 100%.<sup>8</sup>

#### 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), while Figure 2b displays the frequency of negative and positive price changes 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

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<sup>7</sup> Note that the price data in Figure 1 are not average prices. Rather, they are actual weekly transaction prices at a particular store.

<sup>8</sup> Given that the average price at a retail supermarket is about \$2.50 (Levy, et al., 1997; Bergen, et al., 2004), considering price changes of up to \$1.00 appears sufficient. We have actually calculated the price changes of all size, and indeed most price

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 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. In Figures 2.2a–2.2c, we plot the frequency of negative and positive price changes, as a function of the size of price change in percents.<sup>9</sup>

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).<sup>10</sup> 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

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changes are less than a dollar in size. Excel files containing the frequency distribution of price changes of all sizes are available from the corresponding author upon request.

<sup>9</sup> 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).

<sup>10</sup> It should be noted that the scanner price data for the products included in the Beer and Cigarettes’ categories may not be accurate because of the way these products are handled by the retailer and also because of various tax rules and government

most cases. In the categories of Analgesics, Canned Soup, Cereals, Cigarettes (Figure 2.2a), Frozen Entrees (Figure 2.2b) and Oatmeal (Figure 2.2c), the asymmetry lasts for up to about 10% price change. The two categories in which no asymmetry is found are Beer and 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. The 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.<sup>11</sup>

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.<sup>12</sup> Price promotions, therefore, cannot produce the observed asymmetry.

Another possible explanation is the fact that during the sample period covered in this study, the US was experiencing a moderate inflation, as indicated by the inflation rate figures reported in Table 5 (based on producer price index).<sup>13</sup> 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 (and perhaps more methodical) 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

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regulations that are imposed on them. Therefore, in the analysis below we do not discuss further the results of these two categories, although we do present their plots for the sake of completeness.

<sup>11</sup> 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.

<sup>12</sup> 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).

<sup>13</sup> We use 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.

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/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 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.<sup>14</sup>

### ***3.2. Analysis of the Data for the Low/Zero 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 to 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, 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, we find that for all 29

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<sup>14</sup> 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.

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 dataset 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.

### ***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/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. In sum, the results for the low/zero 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.

## **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 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.<sup>15</sup>

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.<sup>16</sup> 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

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<sup>15</sup> This conclusion likely holds for any explanation that relies on institutional features and arrangements, including implicit and explicit contracts, nature of relationships, etc.

<sup>16</sup> 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 explanations, however, is that if any of them were reasons



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 and 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 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 Theory of Asymmetric Price Adjustment “in the Small”

“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.”)*

Given the inability of existing theories to explain our empirical findings, in this section we offer a theory 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 gathering, 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

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for asymmetric price adjustment, then we would expect to see a reverse asymmetry. That is, we should have seen more frequent

inattention under the label of information gathering and/or processing costs.<sup>17</sup> 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 slightly different context.<sup>18</sup> 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*.” (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 gather and process; 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. Monitoring prices, and comparing them to, say, last period prices, 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.<sup>19</sup> 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 “rational attention” outweigh the benefits.

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price decreases than increases. That is opposite to what we find in our data.

<sup>17</sup> 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).

<sup>18</sup> 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.)

<sup>19</sup> 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.

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 notice the change, which will trigger her response to the price change by adjusting her purchase behavior along the original demand curve.<sup>20</sup>

## 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 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 losses 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.

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<sup>20</sup> 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*.

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.<sup>21</sup>

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.<sup>22</sup> 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*

In the following model 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, 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  $U(A, B) = \nu \ln A + \ln B$ , where  $\nu$  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. Optimal Purchase and Pricing Policy under Rational Attention

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

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<sup>21</sup> 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.

<sup>22</sup> 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 Levy, Chen and Bergen (2004).

### Customer's Purchase Policy:

The customer solves the following optimization problem:

$$\text{Maximize: } U(A, B) = v \ln A + \ln B \quad (1)$$

$$\text{s.t. } P_A A + P_B B = M \quad (2)$$

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

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

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

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

### Retailer's Pricing Policy:

A retailer who produces good A and faces the demand function given in equation (3), solves the following optimization problem:

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

$$\text{where } C = \frac{a}{A^2} + b, \quad a > 0, b > 0$$

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

$$P_A^* = \frac{vM}{v+1} \sqrt{\frac{b}{a}} \quad (6)$$

$$\pi^* = \frac{v}{v+1} M - 2\sqrt{ab} \quad (7)$$

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

$$A^* = \sqrt{\frac{a}{b}} \quad (8)$$

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

Now consider a two-period model of the above problem.<sup>23</sup> Suppose that the price of A changes from  $P_A$  in period 1 to  $P_A'$  in period 2. The price of B remains unchanged. The customer has two options here. She can acquire and process the new price information and adjust her consumption accordingly. In that case, she will incur information processing cost, which we measure in terms of lost utility,  $x$ . Alternatively, she can keep the same purchase behavior and

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<sup>23</sup> Extending the model to  $n$  periods, where  $n \geq 2$ , complicates the model derivation without offering additional insights. See footnote 26 for a solution of such a model.

avoid paying the information processing cost,  $x$ . In the latter case, the consumer will be “rationally inattentive,” that is, she will be rigid in her behavior by buying based on the price for which she last optimized her purchase behavior (i.e.,  $P_A$ ). In the case of rational inattention, however, the consumer 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.<sup>24</sup>

If the customer processes the price information and adjusts her consumption, the new utility, *before* incurring  $x$ , is:

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

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

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

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

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

which yield

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

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 not recalculate her demands. To see this, let  $P_A' = \theta P_A$ . Then:

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

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  $\theta$ , 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

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<sup>24</sup> 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 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.

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 ( $\theta_A^u > 1$ ,  $\theta_A^l < 1$ ).<sup>25</sup> In this region, the customer does not adjust her buying behavior; she 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  $x$  knows that the retailer will take advantage of  $x$  by increasing the price in the second period by a factor of  $\theta_A^u > 1$ . The consumer faces the following optimization problem:

$$\text{Maximize: } U(A, B) = v \ln A + \ln B + \beta(v \ln A + \ln B) \quad (14)$$

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

where  $\beta$  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  $\theta_A^u$  and that she will not change her purchase behavior. The solution of the problem is given by

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

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

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

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

$$\text{where } C = \frac{a}{A^2} + b, \quad a > 0, b > 0$$

$A$  is given by equation (16), and  $\tau$  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

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<sup>25</sup> When  $v = 1$ , a closed-form solution exists for this region. Specifically,  $\theta \in [1 - \sqrt{1-c}, 1 + \sqrt{1-c}]$ , where  $c = e^{-x}$ . For example, when  $x = 0.01$ ,  $t$  is between 0.9 and 1.1, meaning that a price change in the range of  $[-10\%, 10\%]$  will not trigger purchase adjustment.

factor of  $\theta_A^u$  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  $A^* = \sqrt{\frac{a}{b}}$ , which is exactly the same as the demand function in equation (8).

Therefore, when faced with a forward-looking customer who must incur information processing cost  $x$  to notice small price changes, the retailer will act strategically by raising the price 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  $P_A^u$  as given in equation (20). The model can be extended to more than two periods without affecting the main conclusion.<sup>26</sup>

This example 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 and adjustment costs. Recall that according to our assumption, 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. That is, a small price change does not lead to an update in the customer's price information. 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

<sup>26</sup>For example, if we generalize the model in this example from two periods to  $n$  periods, where  $n \geq 2$ , then we would obtain:

$$A^* = \frac{nv}{(v+1)(1+(n-1)\theta_A^u)P_A^*} M, \quad P_A^* = \frac{v}{(v+1)} \frac{n}{(1+(n-1)\theta_A^u)} M \sqrt{\frac{b}{a}}, \text{ for period 1, and}$$

$$P_A^u = P_A^* \theta_A^u = \frac{v}{(v+1)} \frac{n\theta_A^u}{(1+(n-1)\theta_A^u)} M \sqrt{\frac{b}{a}}, \text{ for periods 2 to } (n+1), \text{ where } \theta_A^u(x, n) \text{ is determined from the equation}$$

$n(-\ln(\theta^v(v+1-\theta^v))) = x$ . Compared with the price in equation (20), since  $\frac{n\theta_A^u}{1+(n-1)\theta_A^u} < \frac{2\theta_A^u}{1+\theta_A^u}$  for  $n > 2$ , the rational



last optimization price to be rationally noticed by the customer, and therefore, it will trigger 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.

## 6. Discussion of the Findings and Limitations

First, we should point out that the nature as well as the magnitude of the regions of asymmetry we find appear consistent with regions of “just noticeable differences” and “price indifference bands,” which have been reported in the existing 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 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.<sup>27</sup> 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.<sup>28</sup>

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

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inattention region is smaller for a  $n$ -period game ( $n > 2$ ). However, the main implication that there should be more price increases than decrease in the small remains unchanged.

<sup>27</sup> They report that for engineered industrial components the “pricing indifference band” is about 10%.

<sup>28</sup> 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 reported in psychology on how individuals perceive price discounts (see, for example,

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 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 asymmetric price adjustment is limited in its scope, because the range of rational inattention is set by customers themselves. Moreover, 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 partial explanation for a long-standing puzzle in the menu cost literature. Given the existence of firm-level menu costs, it is surprising that small price changes are still observed frequently 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

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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.

commodities and transaction types.” Lach and Tsiddon (2004) also find “small individual price changes” in the Israeli grocery store data.<sup>29</sup> Our theory of rational inattention offers a customer-based explanation for this phenomenon. However, the theory only explains why we see small price *increases*.

A close examination of the plots in Figure 2 reveals that the data contain a substantial number of small price *decreases*, which are not explained by either our theory of rational inattention, nor by other existing theories of asymmetric price adjustment.<sup>30</sup> We can offer several possible reasons for why retail supermarket chains may still choose to reduce prices by small amounts. First, small price changes may be induced by competitive factors, such as price guarantees and price matches (Levy, et. al., 1997 and 1998), as well as by changes in supply conditions (Dutta, et. al., 2002; Levy, et al., 2002) and demand conditions (Warner and Barsky, 1995; Chevalier, et. al., 2003). Second, some food items sold by retail supermarket chains have an expiration date, and some of these products may go on sale as their expiration date approaches. And third, managers may be following simple pricing rules, such as “reduce all prices in a category by 2%,” which could lead to small price reductions.

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.<sup>31</sup>

As an example, consider Figure 1, which plots the time series of Heritage House frozen concentrate orange juice, 12oz. Indeed, it is apparent from the figure that the retail price is far

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<sup>29</sup> 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.

<sup>30</sup> The proportion of “small” price decreases, say price decreases of 5¢ or less, out of the total number of price decreases, are as follows: 2.49% price decreases of 1¢, 2.88% price decreases of 2¢, 2.75% price decreases of 3¢, 2.99% price decreases of 4¢, and 2.88% price decreases of 5¢. Thus, in total, we find that 14% of all price decreases are of 5¢ or less.

<sup>31</sup> 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.

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 as much as 10% while the average US aggregate inflation rate during their sample period was about 1% only. That is, the size of price adjustment they find does not appear to be related to the ongoing inflation rate.<sup>32</sup> 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.<sup>33</sup>

## 7. Conclusion and Future Research

In this paper we find overwhelming evidence of asymmetry, 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. Our theory also offers a partial explanation for the presence of small changes in many transaction price data sets, which has been a long-standing puzzle in the literature.

At this stage, it is unclear how generalizable is our finding of asymmetric price adjustment in the small. It will be valuable, therefore, in the future work, to study other data sets in different time periods, stores, products, industries and countries. 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

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<sup>32</sup> 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 Barsky, et al. (2003b).

<sup>33</sup> 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.

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.

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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 the customer's decision rule, if they don't re-optimize, is to buy the same ratio of the quantities of products A and B, until her budget constraint is violated. Thus, as before, suppose the price of A changes from  $P_A$  to  $P_A'$ , and the price of B does not change. The customer has two options here. She can re-optimize to maximize her utility under the new price, and incur the price change information processing cost of  $x$ . Or she can keep buying the same ratio of the quantities of A and B as in period 1:  $A^*/B^* = vP_B/P_A$ . If she re-optimizes, the new utility, *before* incurring  $x$ , is:

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

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

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

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

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

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

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

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

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 recalculate only if  $U - U^* > x$ , there should 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:

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

Since  $(v+1)^{v+1}$  is not a function of  $\theta$ , 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  $\theta$ , 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, the customer would not adjust her purchase behavior; she will 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  $\theta$  is between 0.82 and 1.22.

Compared with the demand curve in Figure 3, when the consumer used 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 Rule)

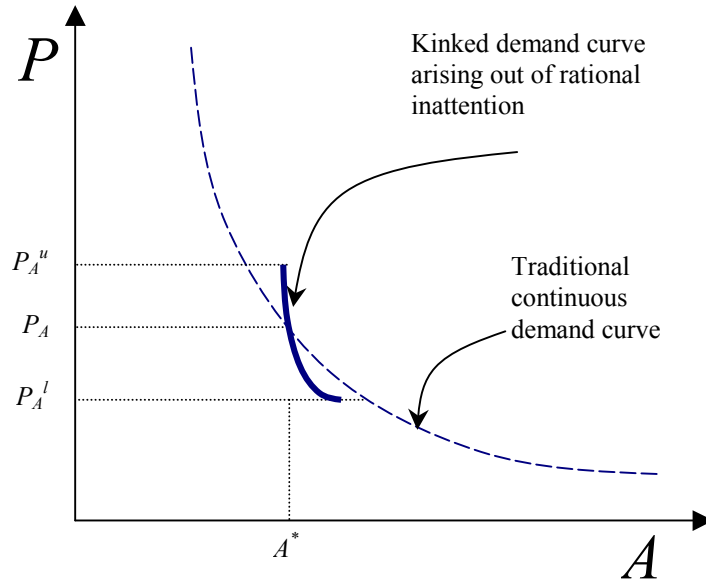


Table 1. Product Categories, and the Total Number of Weekly Price Observations by Category

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/Zero 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
Beer	0	0	0	1	0	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
Cigarettes	14	9	8	7	6	3
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 as our theory predicts. Beyond that point the asymmetry disappears.

Table 5. Monthly Inflation Rate (based on Producer Price Index), September 1989–May 1997

Year	Month	Producer Price Index	Percent Change in PPI (%)
1989	September	113.6	-
1989	October	114.9	1.14
1989	November	114.9	0.00
1989	December	115.4	0.44
1990	January	117.6	1.91
1990	February	117.4	-0.17
1990	March	117.2	-0.17
1990	April	117.2	0.00
1990	May	117.7	0.43
1990	June	117.8	0.08
1990	July	118.2	0.34
1990	August	119.3	0.93
1990	September	120.4	0.92
1990	October	122.3	1.58
1990	November	122.9	0.49
1990	December	122.0	-0.73
1991	January	122.3	0.25
1991	February	121.4	-0.74
1991	March	120.9	-0.41
1991	April	121.1	0.17
1991	May	121.8	0.58
1991	June	121.9	0.08
1991	July	121.6	-0.25
1991	August	121.7	0.08
1991	September	121.4	-0.25
1991	October	122.2	0.66
1991	November	122.3	0.08
1991	December	121.9	-0.33
1992	January	121.8	-0.08
1992	February	122.1	0.25
1992	March	122.2	0.08
1992	April	122.4	0.16
1992	May	123.2	0.65
1992	June	123.9	0.57
1992	July	123.7	-0.16
1992	August	123.6	-0.08
1992	September	123.3	-0.24
1992	October	124.4	0.89
1992	November	124.0	-0.32
1992	December	123.8	-0.16
1993	January	124.2	0.32
1993	February	124.5	0.24
1993	March	124.7	0.16
1993	April	125.5	0.64
1993	May	125.8	0.24
1993	June	125.5	-0.24
1993	July	125.3	-0.16
1993	August	124.2	-0.88
1993	September	123.8	-0.32
1993	October	124.6	0.65
1993	November	124.5	-0.08
1993	December	124.1	-0.32
1994	January	124.5	0.32
1994	February	124.8	0.24
1994	March	124.9	0.08
1994	April	125.0	0.08
1994	May	125.3	0.24

1994	June	125.6	0.24
1994	July	126.0	0.32
1994	August	126.5	0.40
1994	September	125.6	-0.71
1994	October	125.8	0.16
1994	November	126.1	0.24
1994	December	126.2	0.08
1995	January	126.6	0.32
1995	February	126.9	0.24
1995	March	127.1	0.16
1995	April	127.6	0.39
1995	May	128.1	0.39
1995	June	128.2	0.08
1995	July	128.2	0.00
1995	August	128.1	-0.08
1995	September	127.9	-0.16
1995	October	128.7	0.63
1995	November	128.7	0.00
1995	December	129.1	0.31
1996	January	129.4	0.23
1996	February	129.4	0.00
1996	March	130.1	0.54
1996	April	130.6	0.38
1996	May	131.1	0.38
1996	June	131.7	0.46
1996	July	131.5	-0.15
1996	August	131.9	0.30
1996	September	131.8	-0.08
1996	October	132.7	0.68
1996	November	132.6	-0.08
1996	December	132.7	0.08
1997	January	132.6	-0.08
1997	February	132.2	-0.30
1997	March	132.1	-0.08
1997	April	131.6	-0.38
1997	May	131.6	0.00



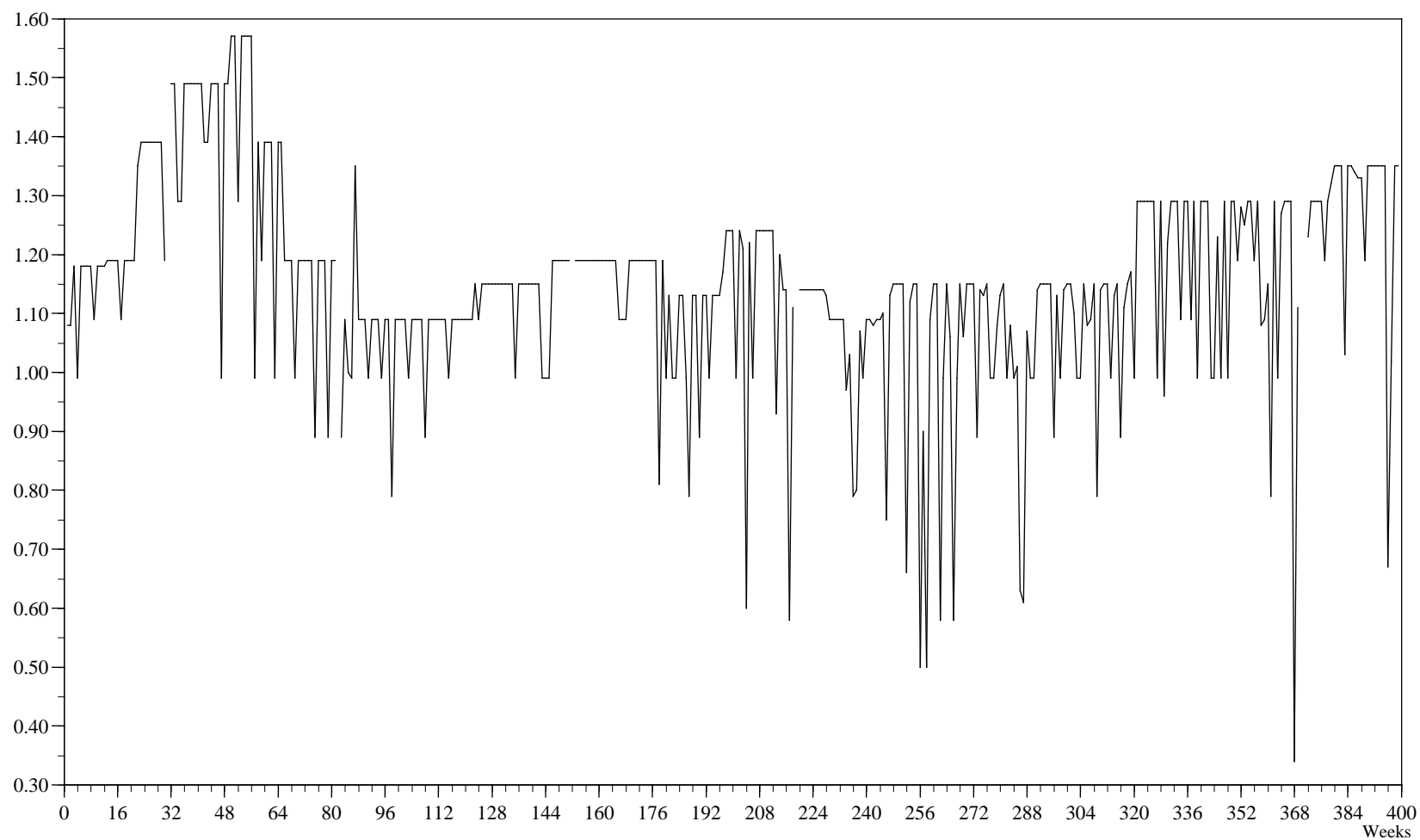


Figure 1. Price of Frozen Concentrate Orange Juice, Heritage House, 12oz (UPC = 3828190029, Store 78), September 14, 1989–May 8, 1997  
(Source: Dutta, et al., 2002, and Levy, et al., 2002).

- 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.

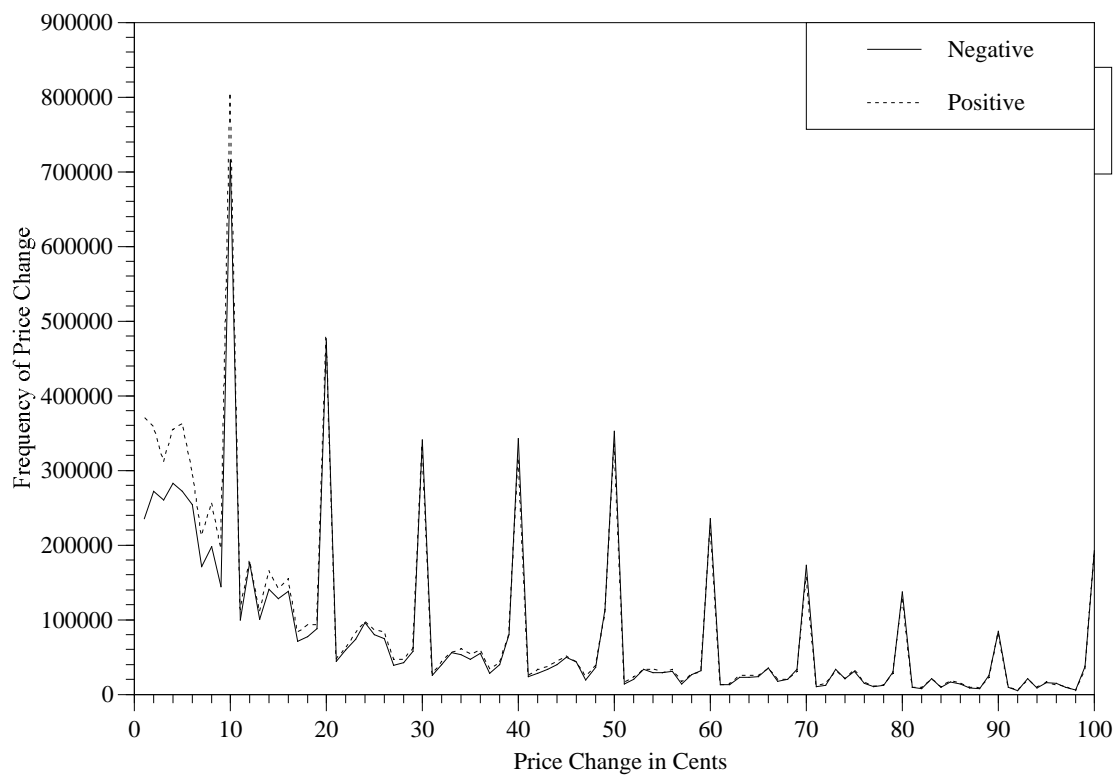


Figure 2a. Frequency of Positive and Negative Retail Price Changes in Cents: All 29 Categories

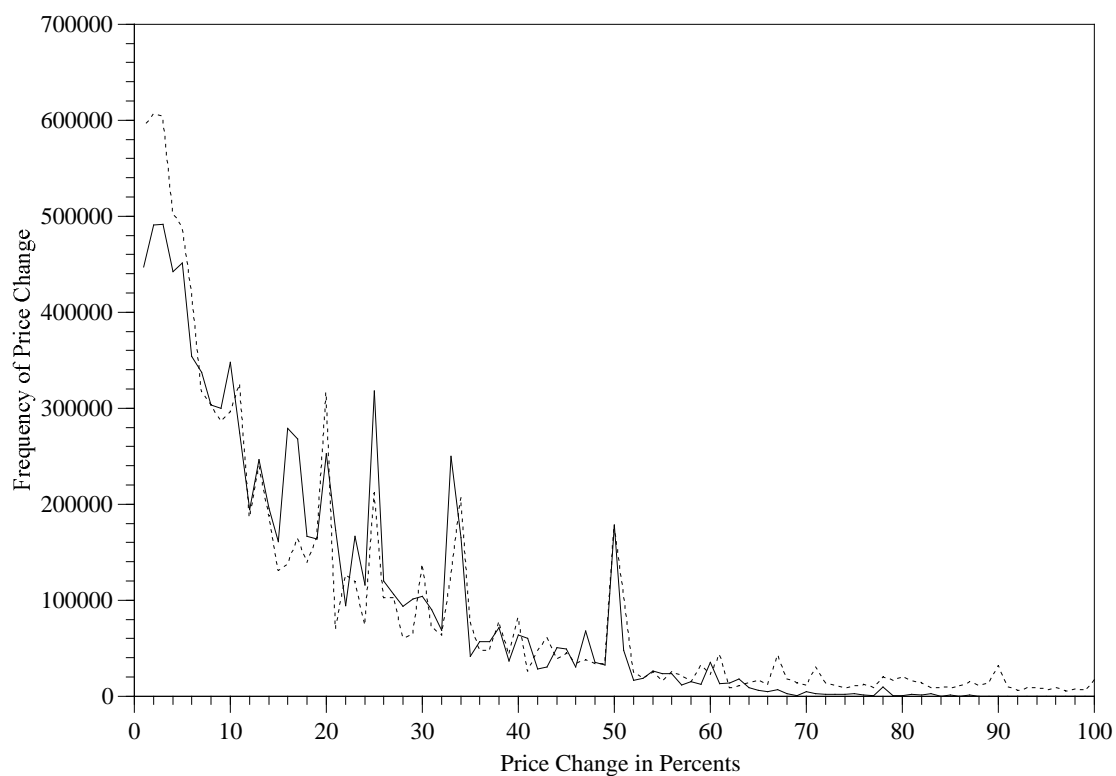


Figure 2b. Frequency of Positive and Negative Retail Price Changes in Percents: All 29 Categories

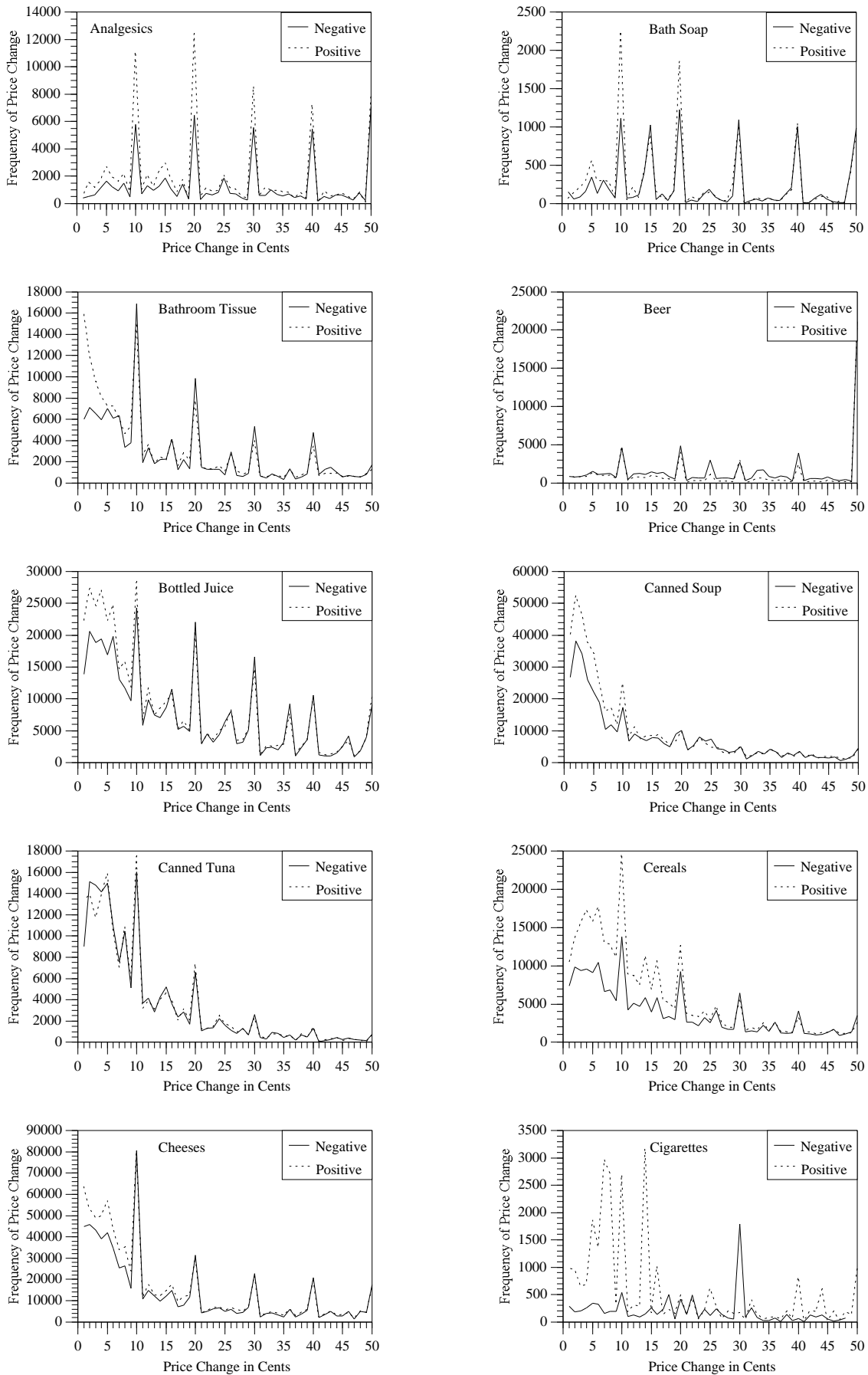


Figure 2.1a. Frequency of Positive and Negative Retail Price Changes in Cents by Category

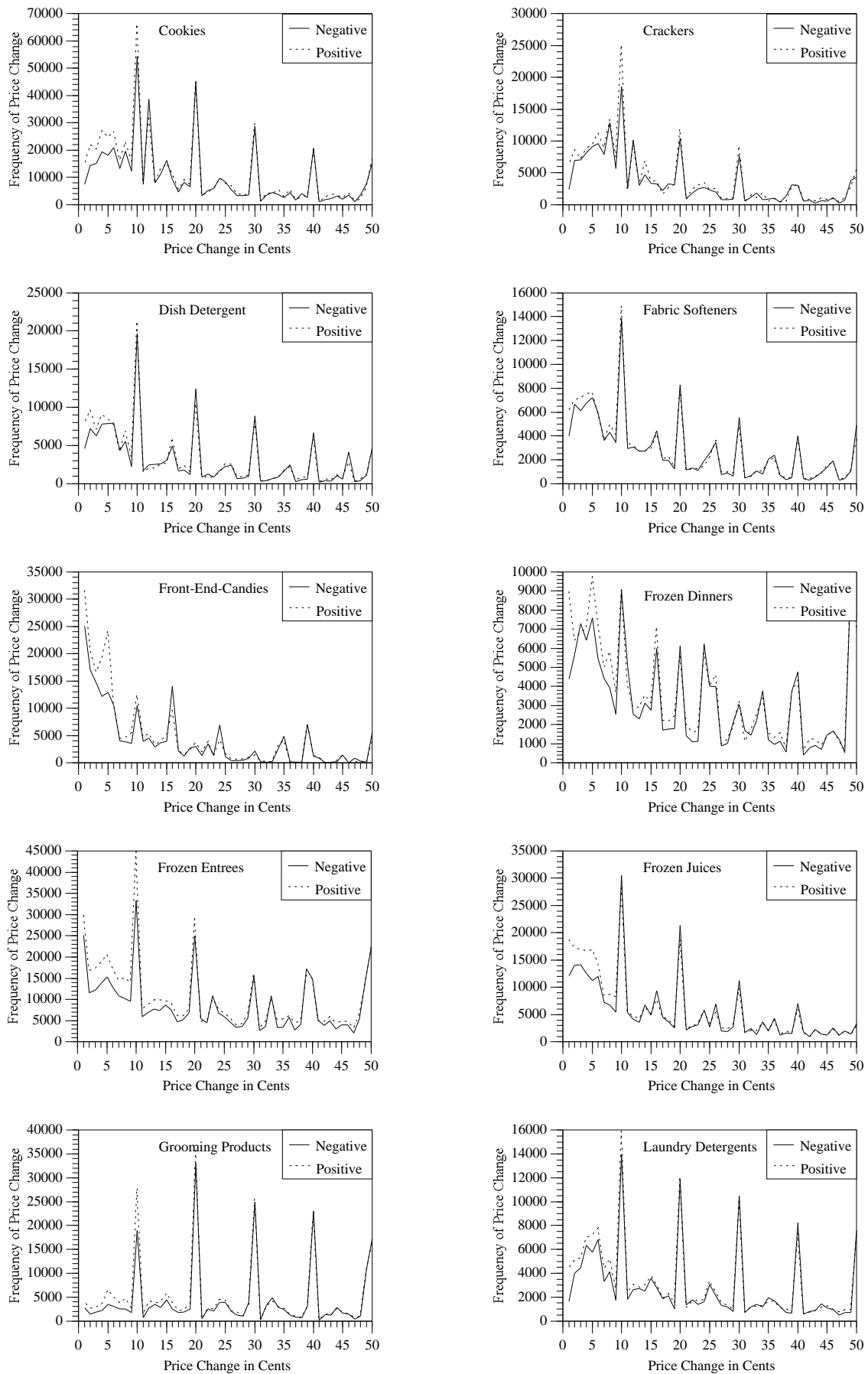


Figure 2.1b. Frequency of Positive and Negative Retail Price Changes in Cents by Category

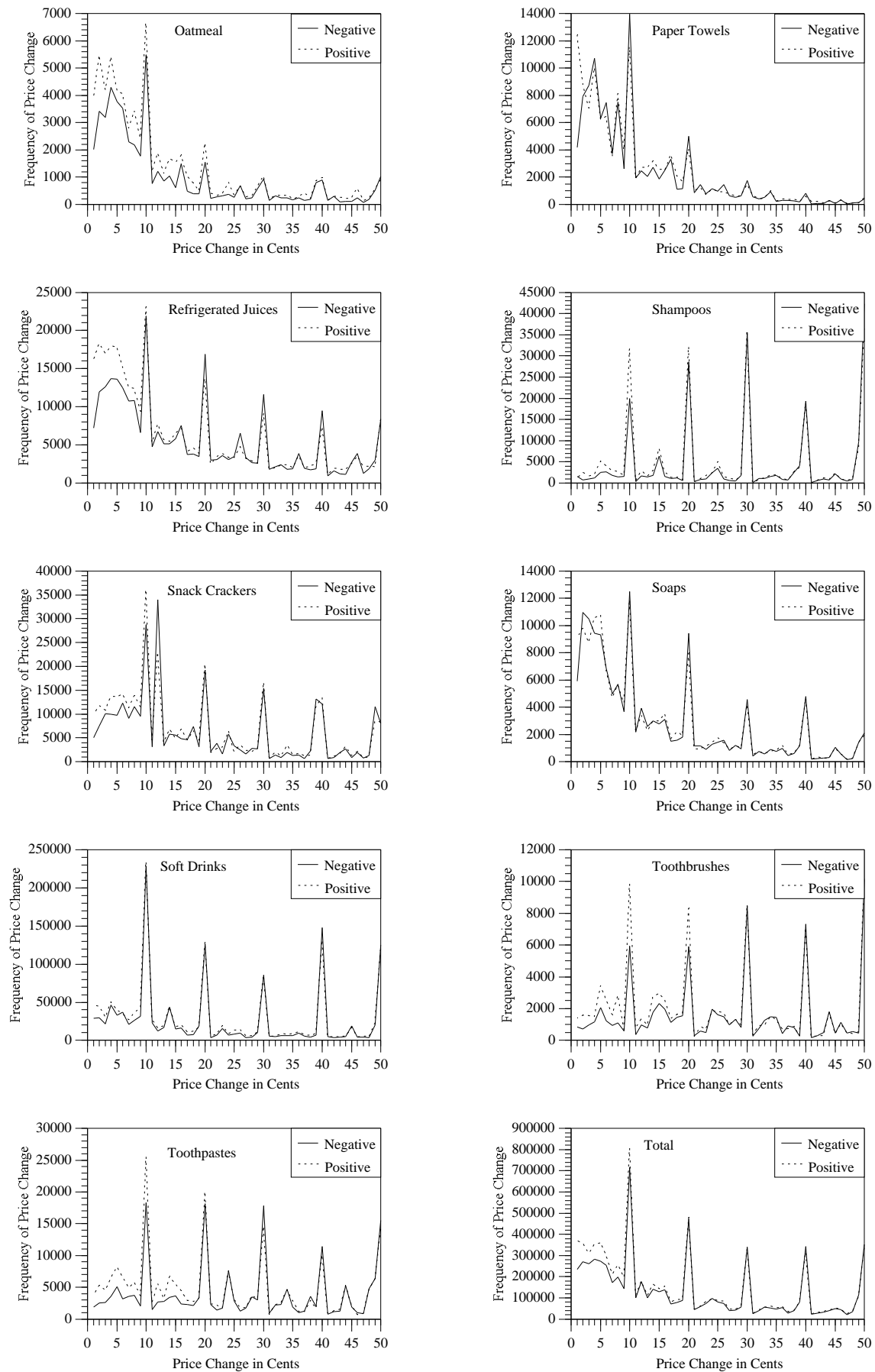


Figure 2.1c. Frequency of Positive and Negative Retail Price Changes in Cents by Category

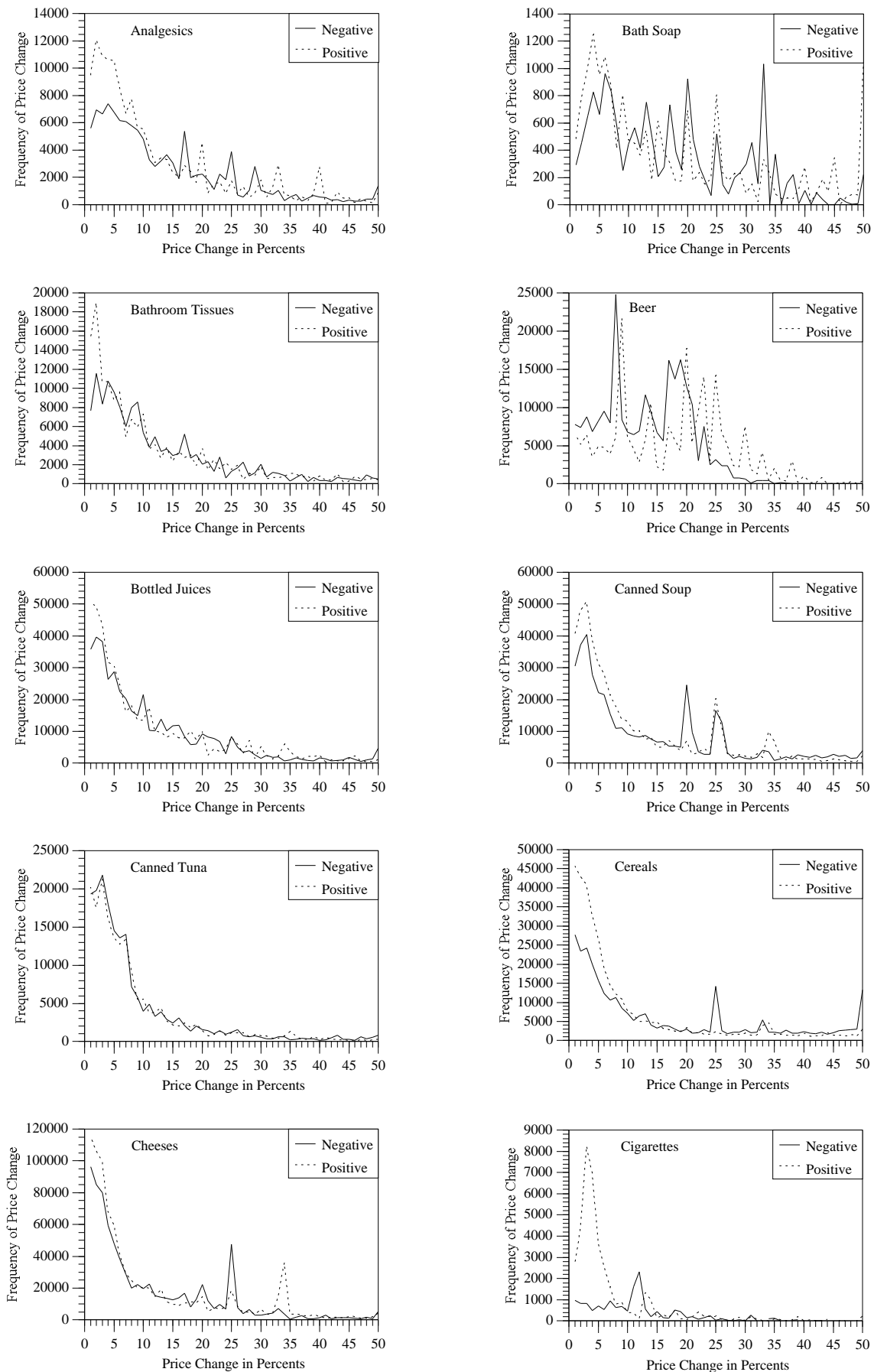


Figure 2.2a. Frequency of Positive and Negative Retail Price Changes in Percents by Category

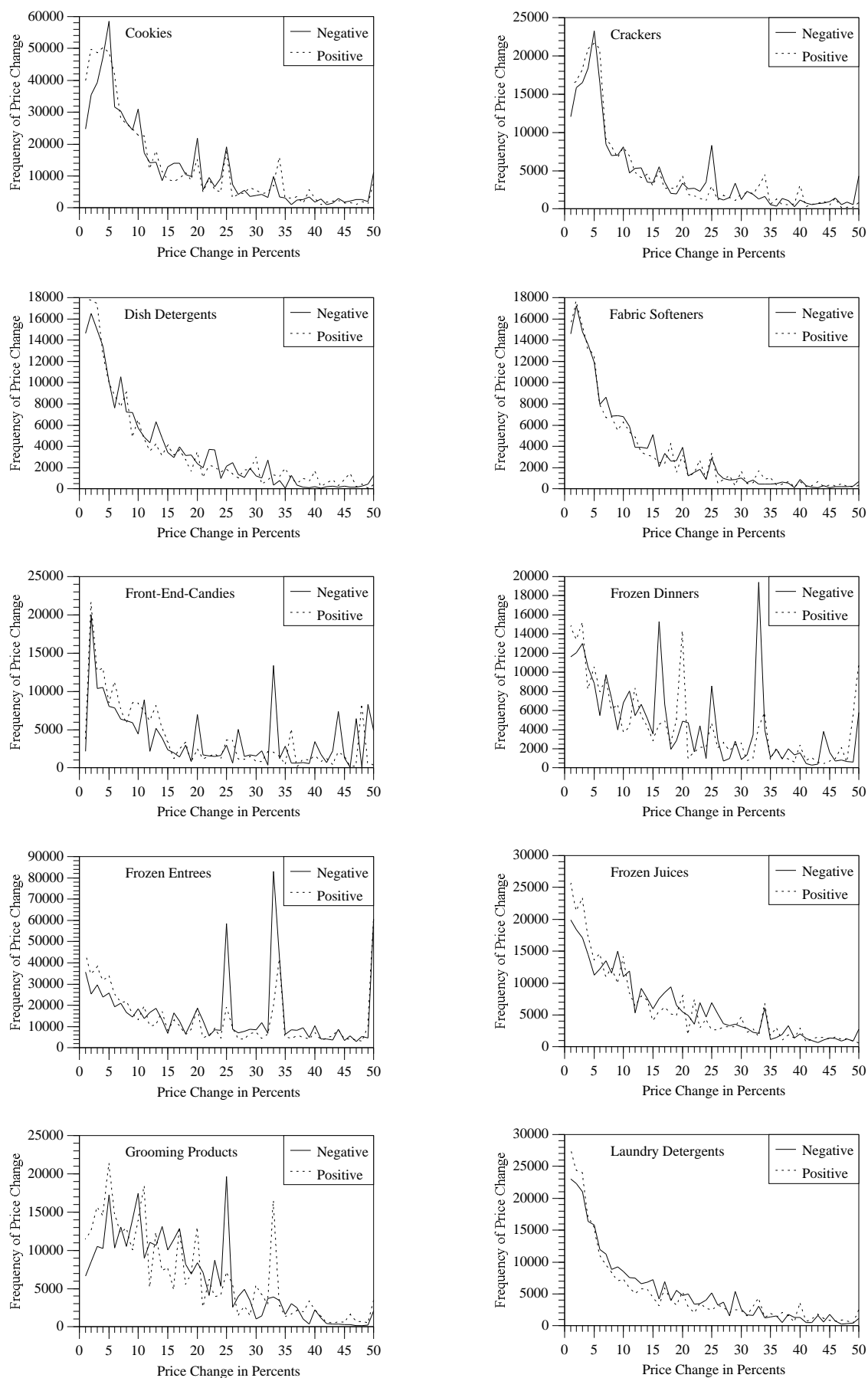


Figure 2.2b. Frequency of Positive and Negative Retail Price Changes in Percents by Category

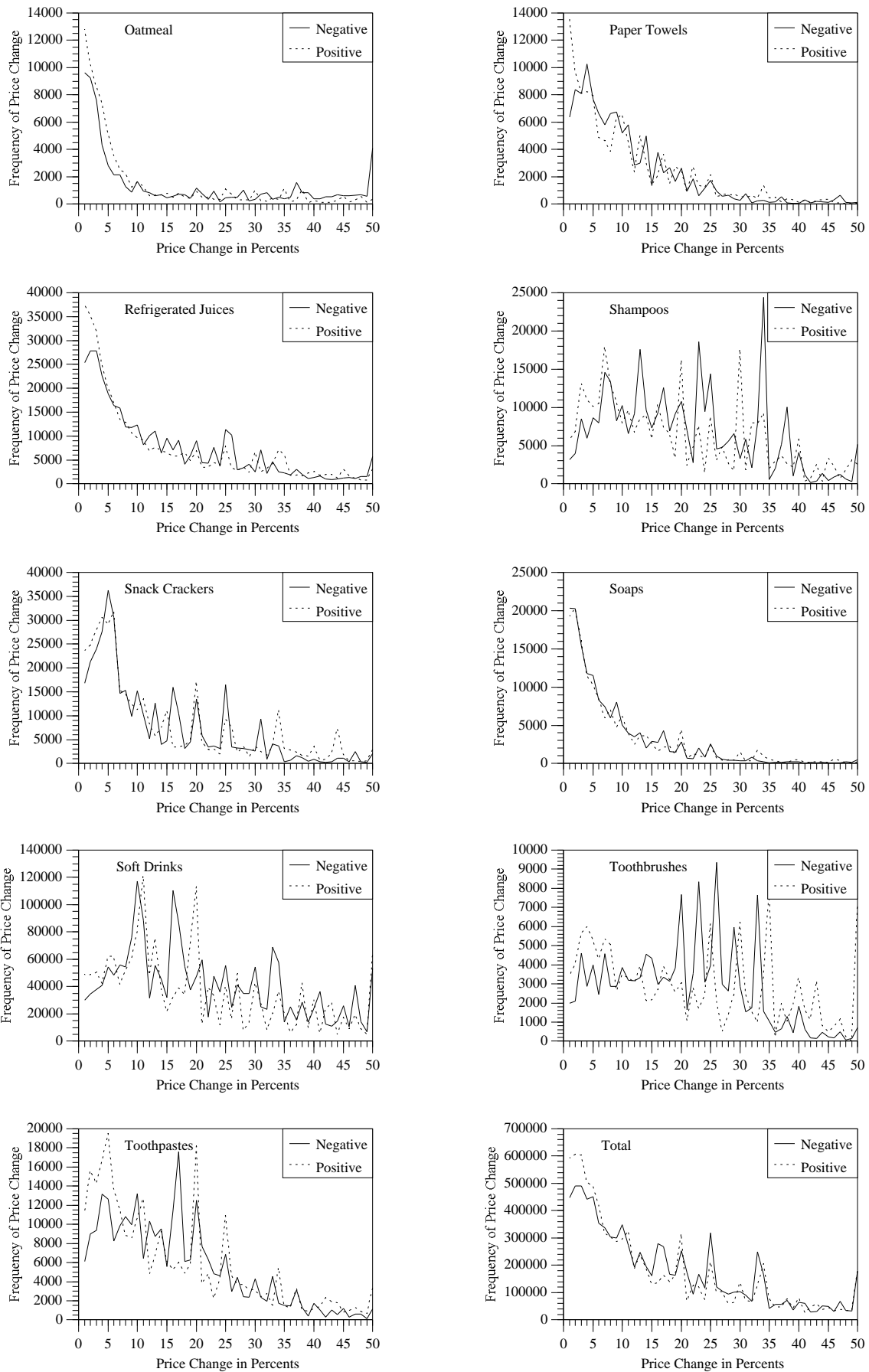
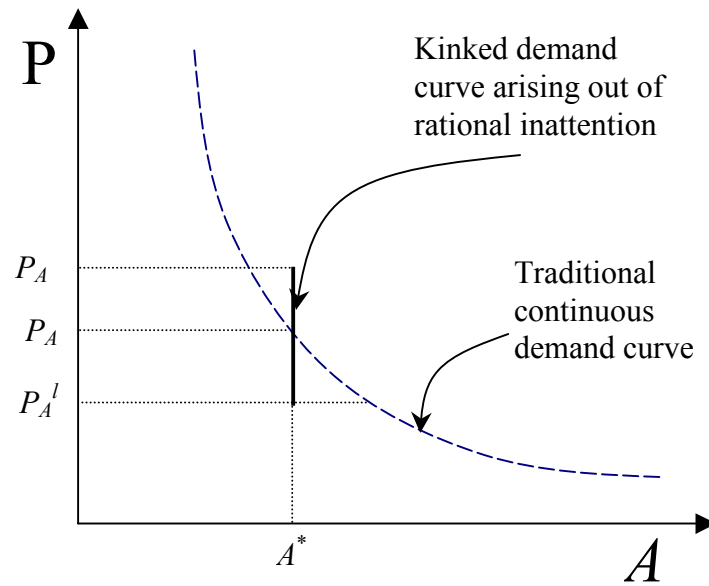


Figure 2.2c. Frequency of Positive and Negative Retail Price Changes in Percents by Category



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



## **Referee 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.

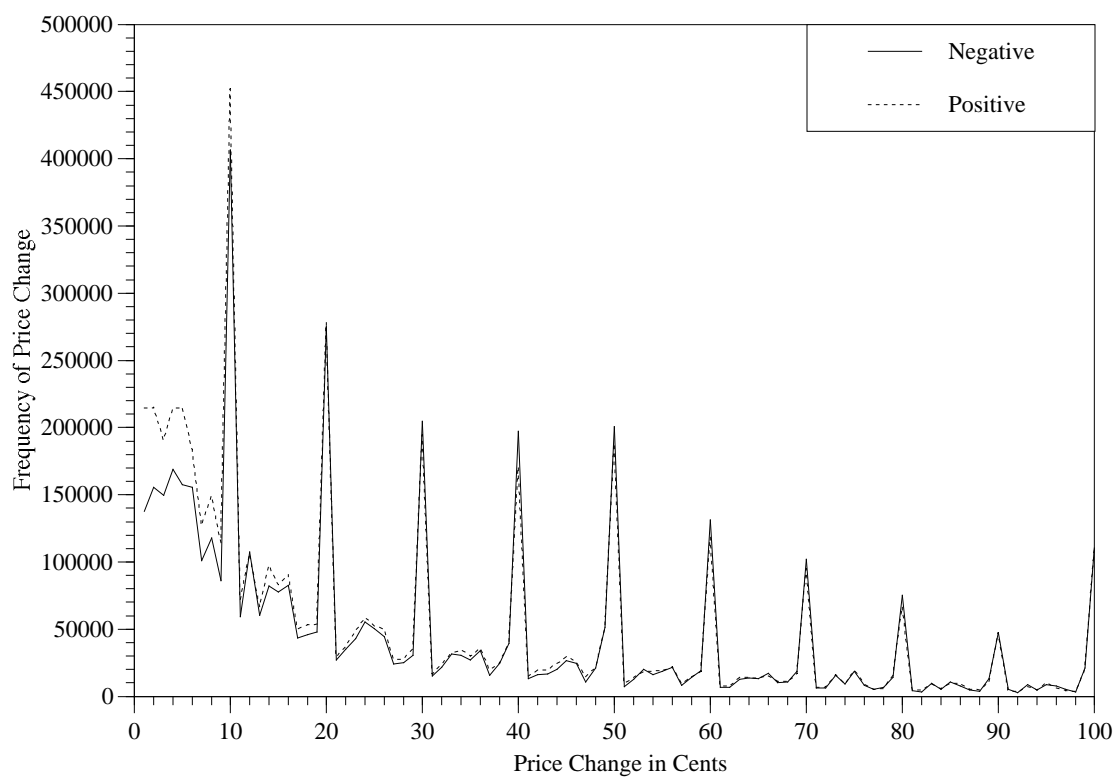


Figure R1a. Frequency of Positive and Negative Retail Price Changes in Cents: All 29 Categories, Low/Zero Inflation Period

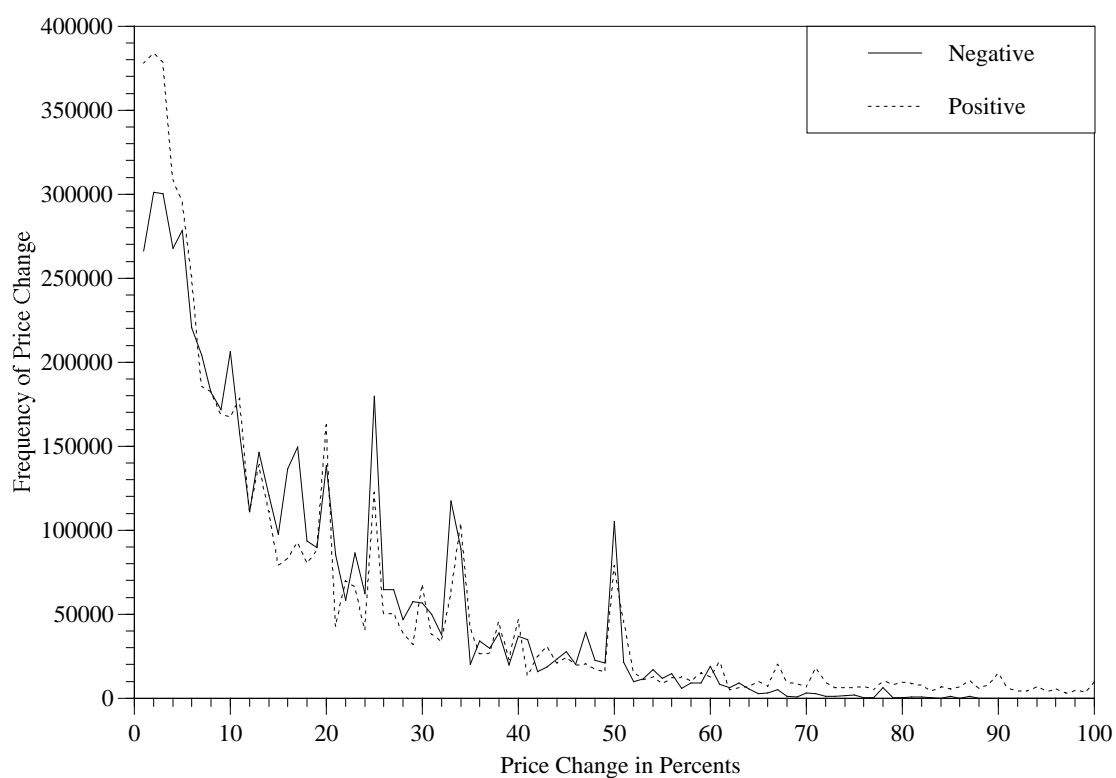


Figure R1b. Frequency of Positive and Negative Retail Price Changes in Percents: All 29 Categories, Low/Zero Inflation Period

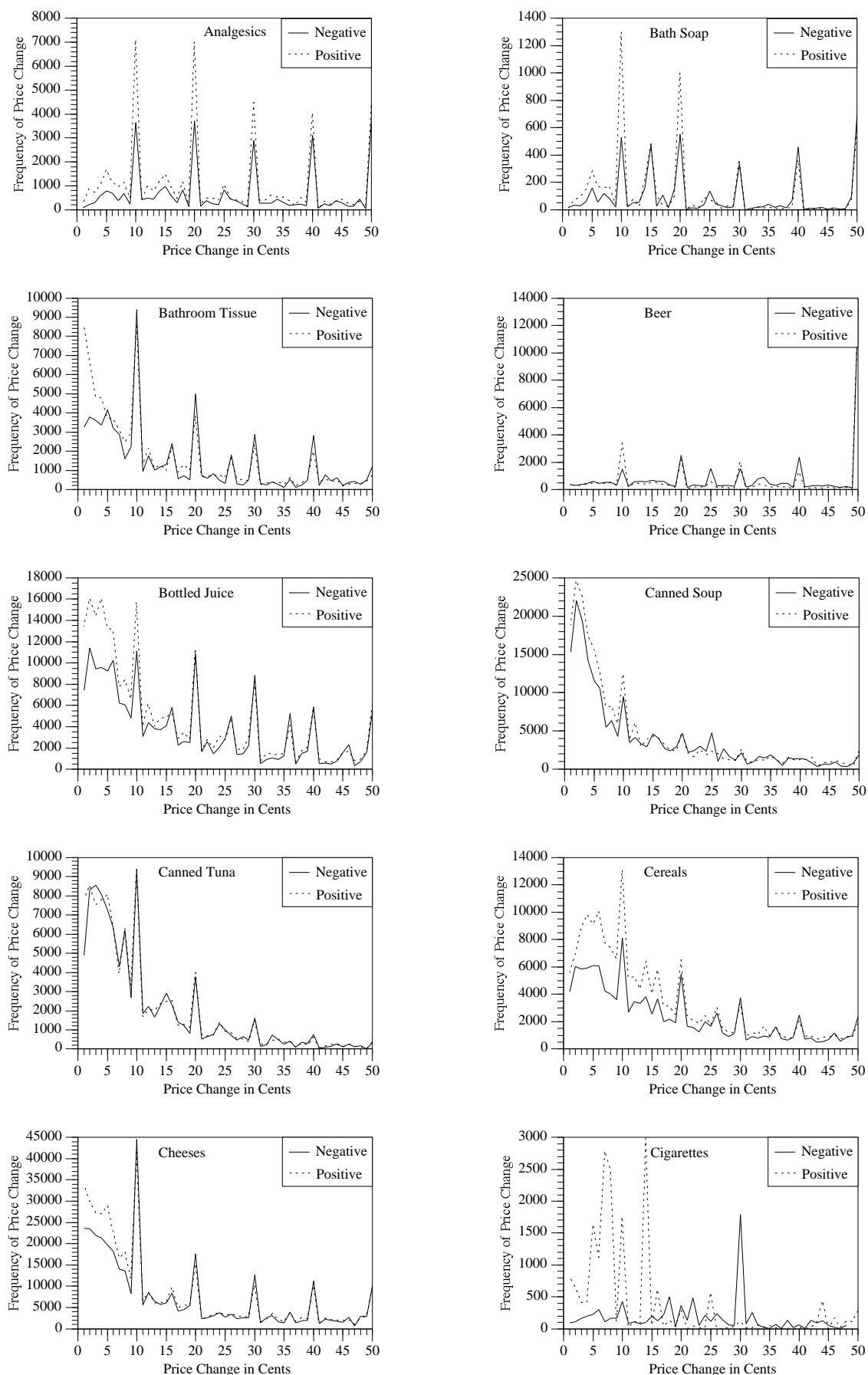


Figure R1.1a. Frequency of Positive and Negative Retail Price Changes in Cents by Category, Low/Zero Inflation Period

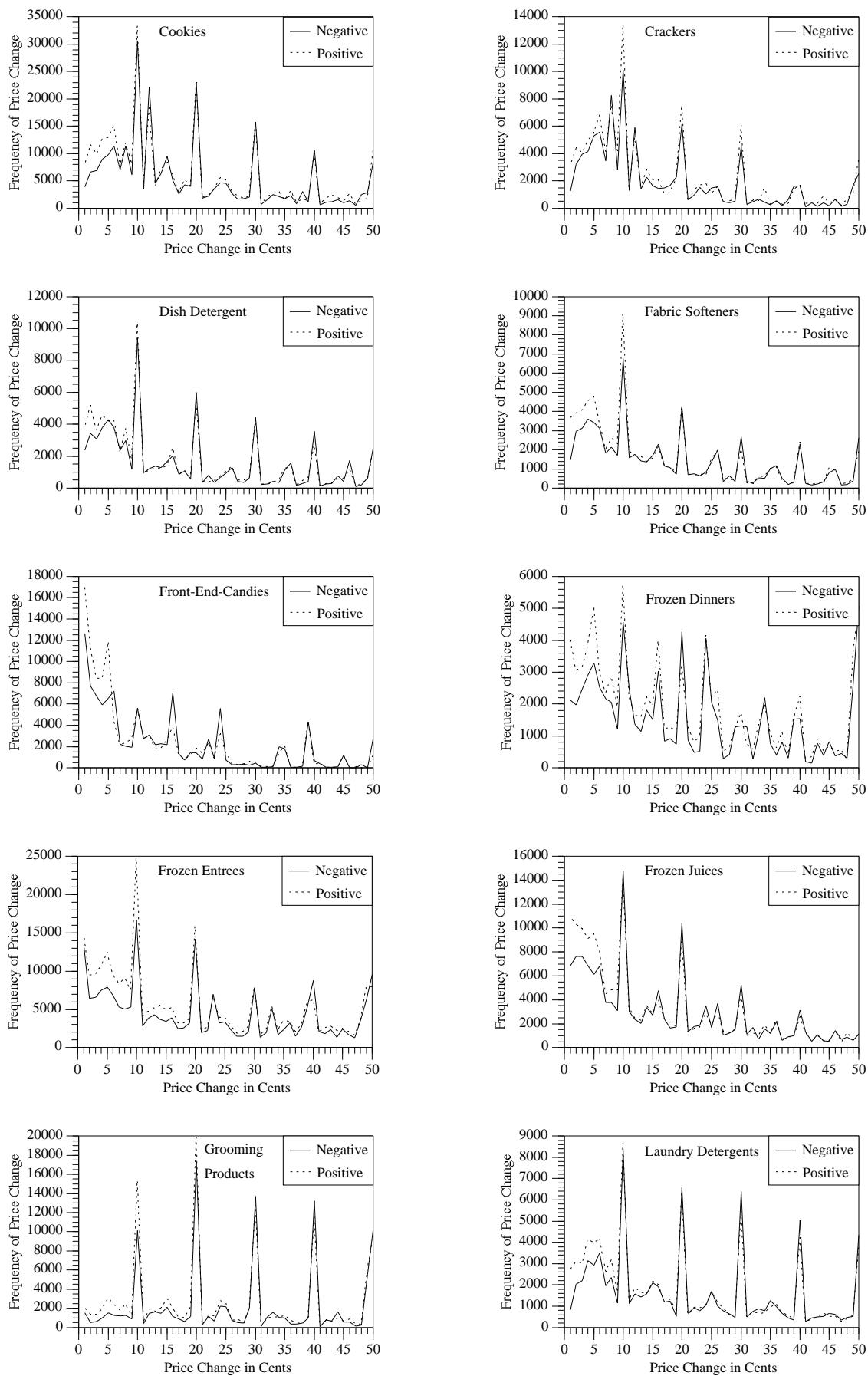


Figure R1.1b. Frequency of Positive and Negative Retail Price Changes in Cents by Category, Low/Zero Inflation Period

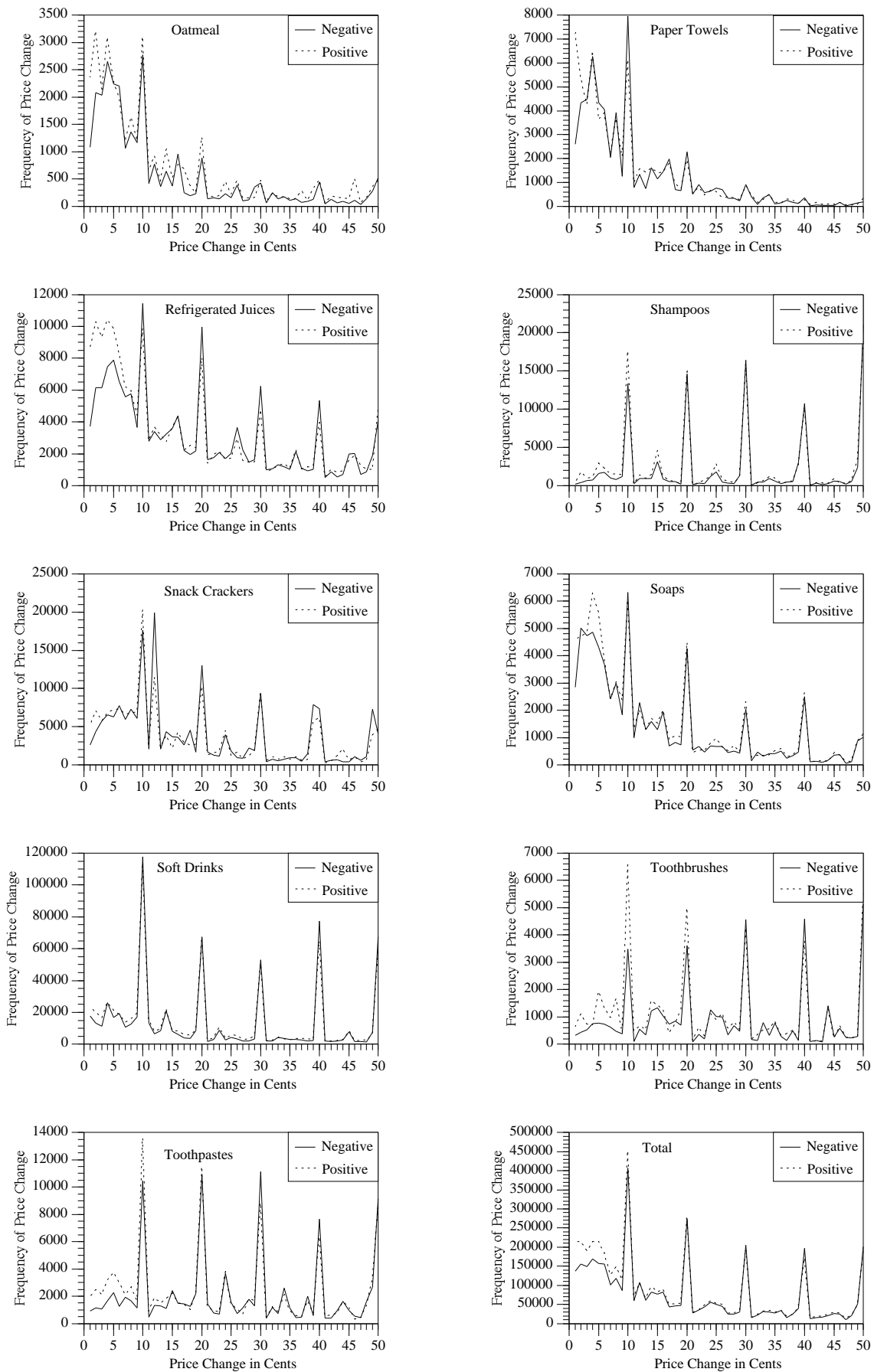


Figure R1.1c. Frequency of Positive and Negative Retail Price Changes in Cents by Category, Low/Zero Inflation Period



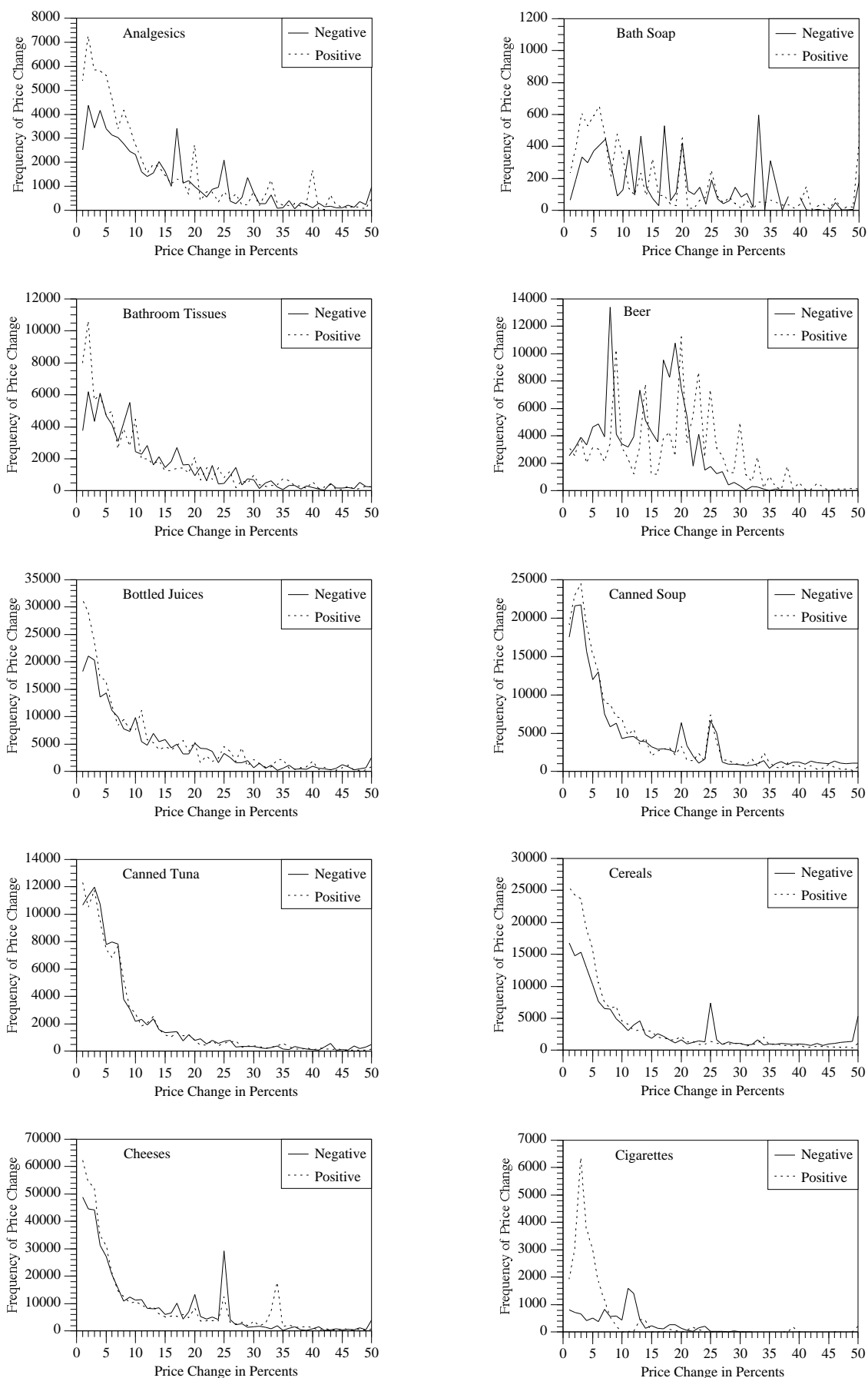


Figure R1.2a. Frequency of Positive and Negative Retail Price Changes in Percents by Category, Low/Zero Inflation Period

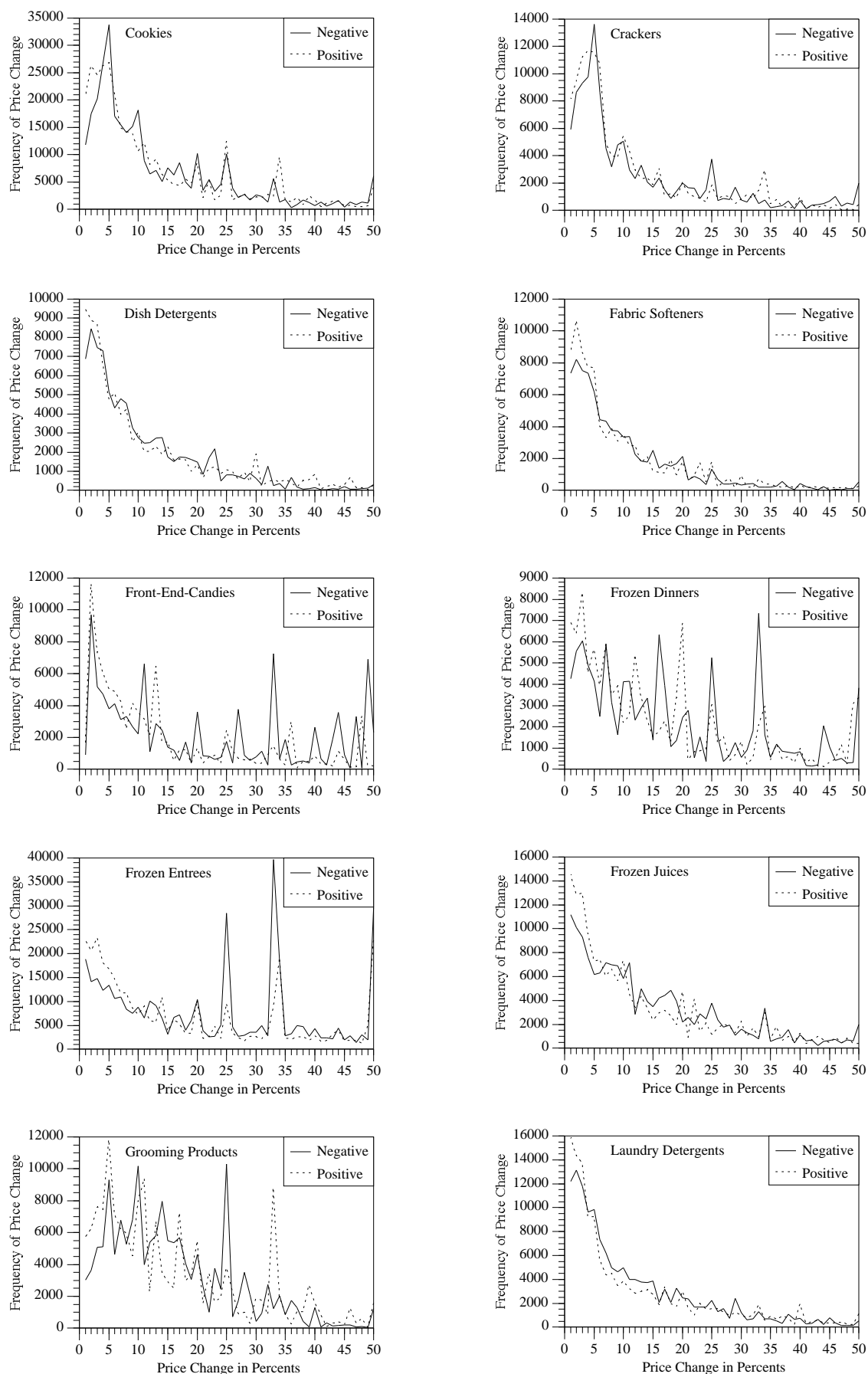


Figure R1.2b. Frequency of Positive and Negative Retail Price Changes in Percents by Category, Low/Zero Inflation Period

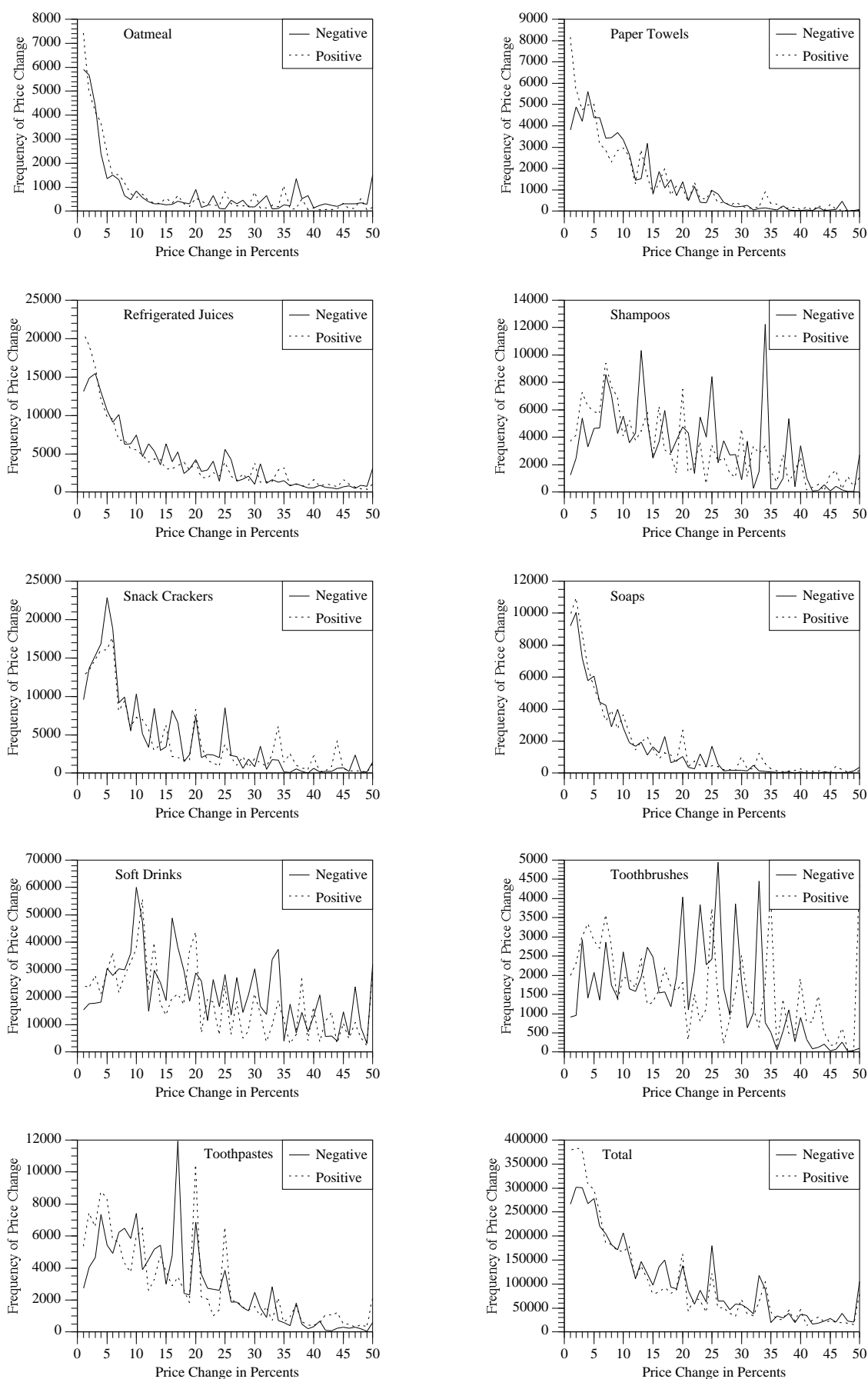


Figure R1.2c. Frequency of Positive and Negative Retail Price Changes in Percents by Category, Low/Zero Inflation Period

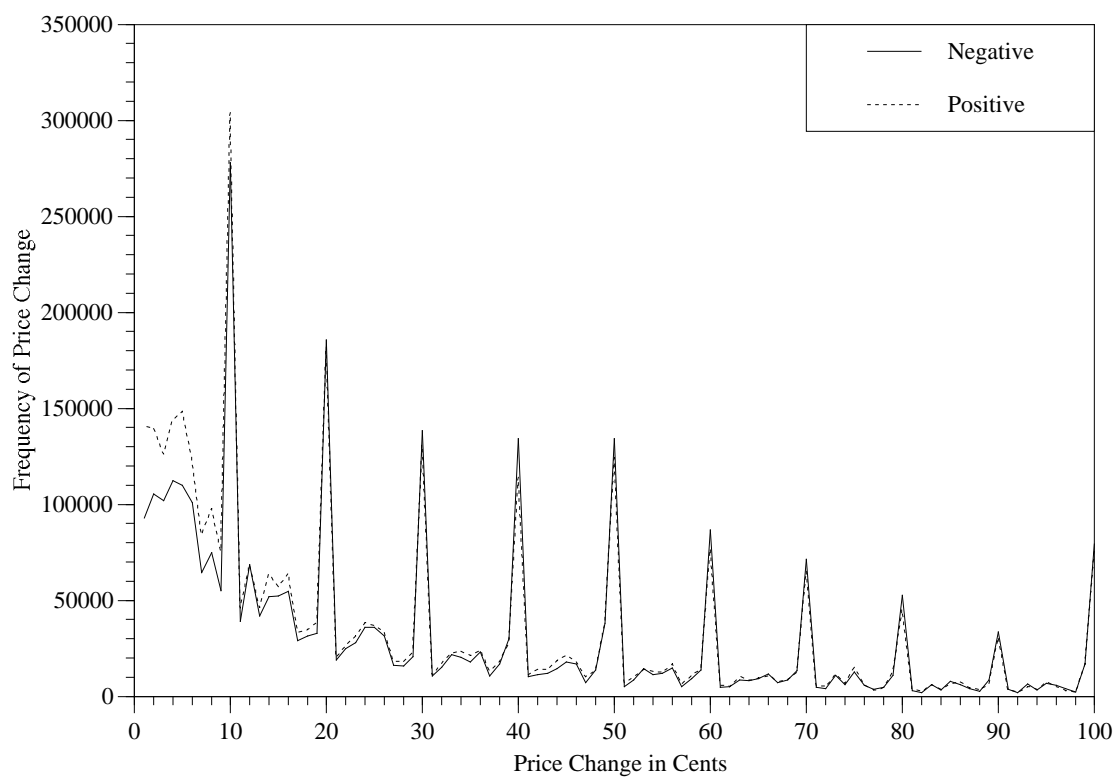


Figure R2a. Frequency of Positive and Negative Retail Price Changes in Cents: All 29 Categories, Deflation Period

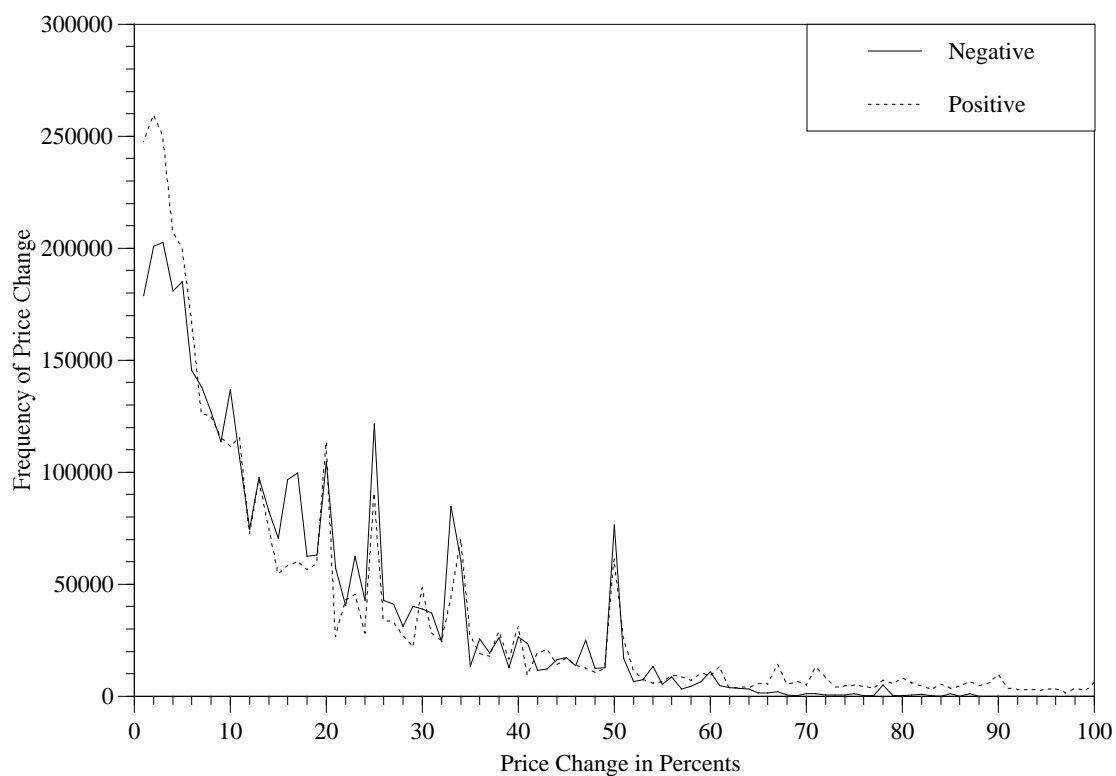


Figure R2b. Frequency of Positive and Negative Retail Price Changes in Percents: All 29 Categories, Deflation Period

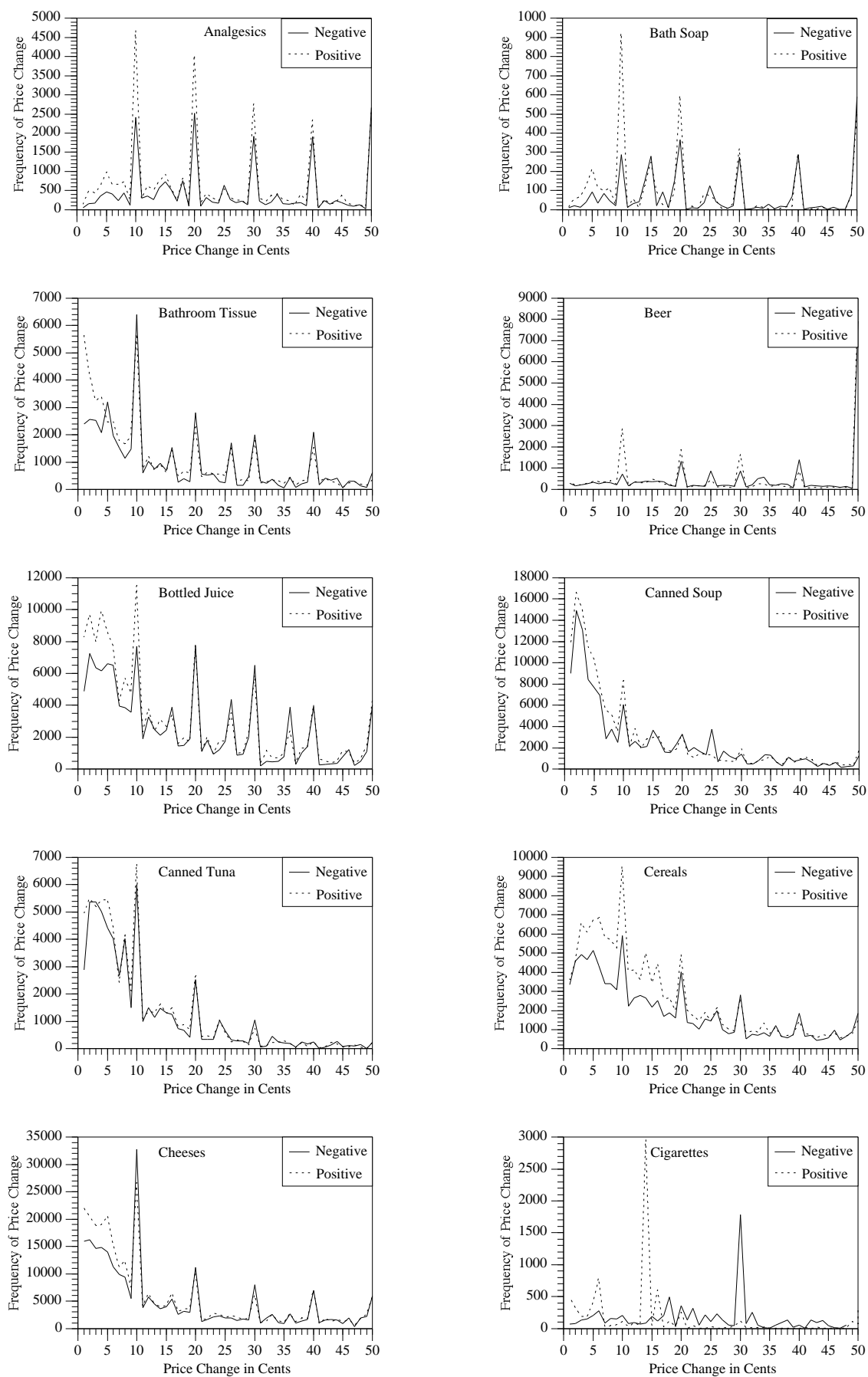


Figure R2.1a. Frequency of Positive and Negative Retail Price Changes in Cents by Category, Deflation Period

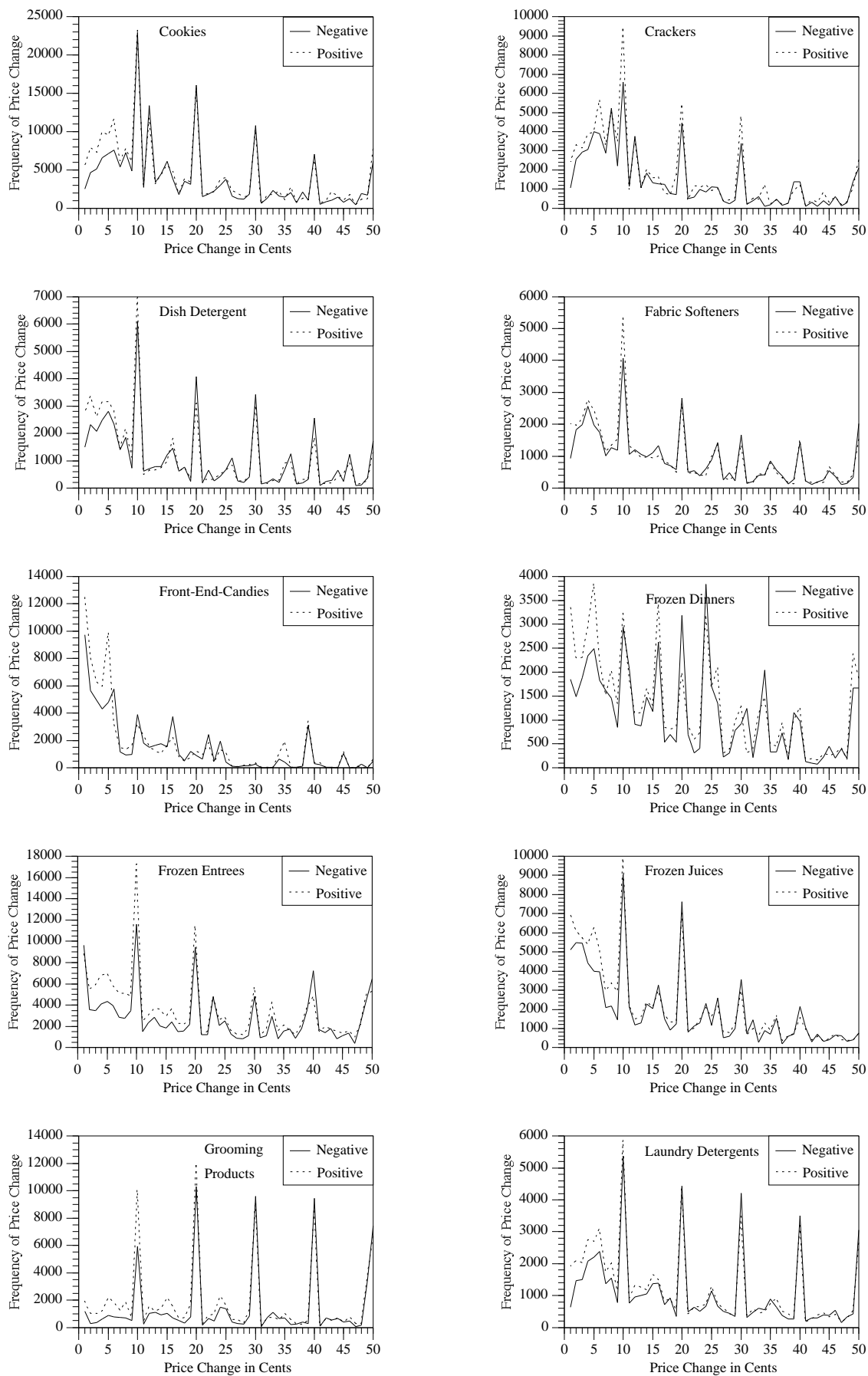


Figure R2.1b. Frequency of Positive and Negative Retail Price Changes in Cents by Category, Deflation Period

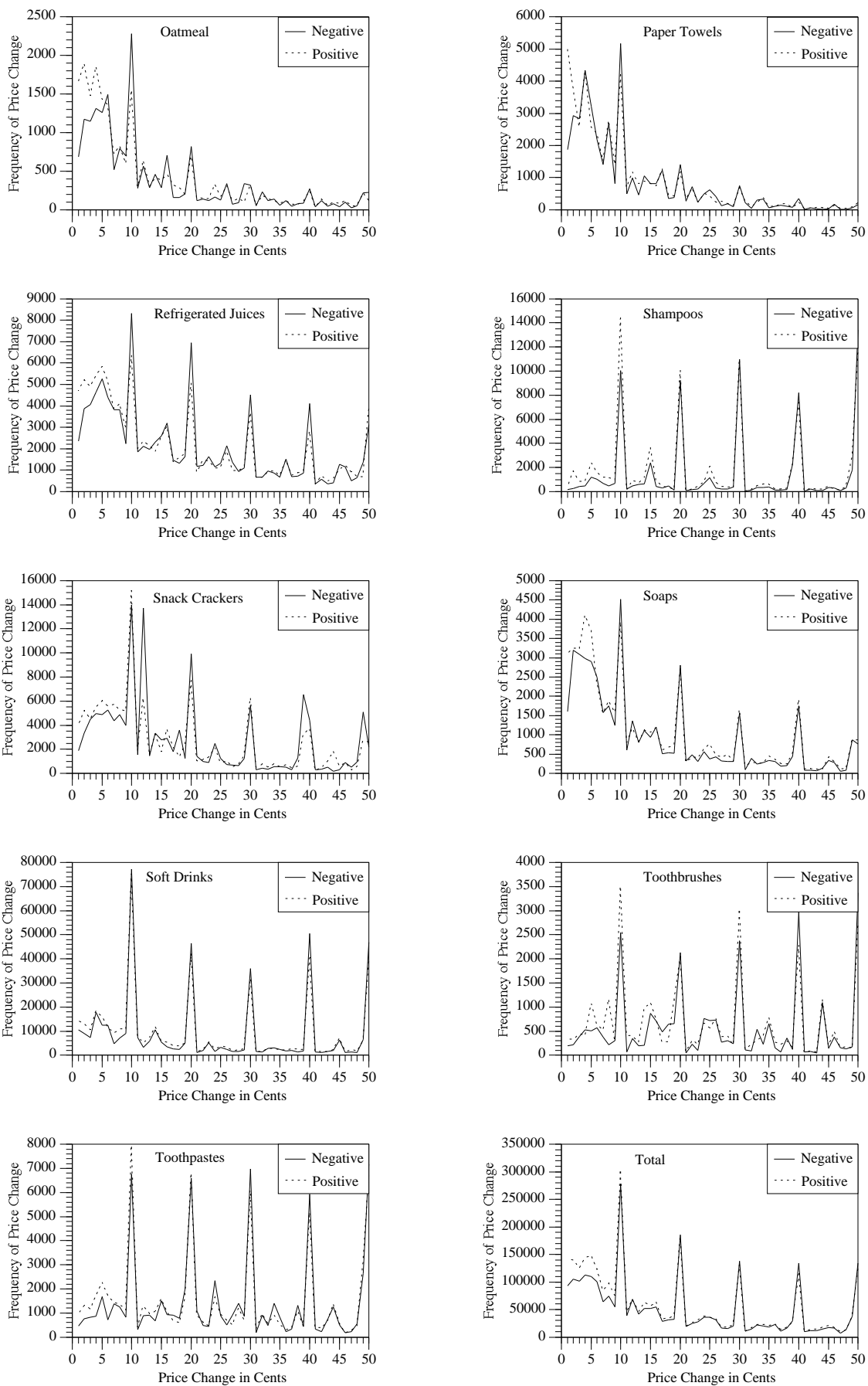


Figure R2.1c. Frequency of Positive and Negative Retail Price Changes in Cents by Category, Deflation Period

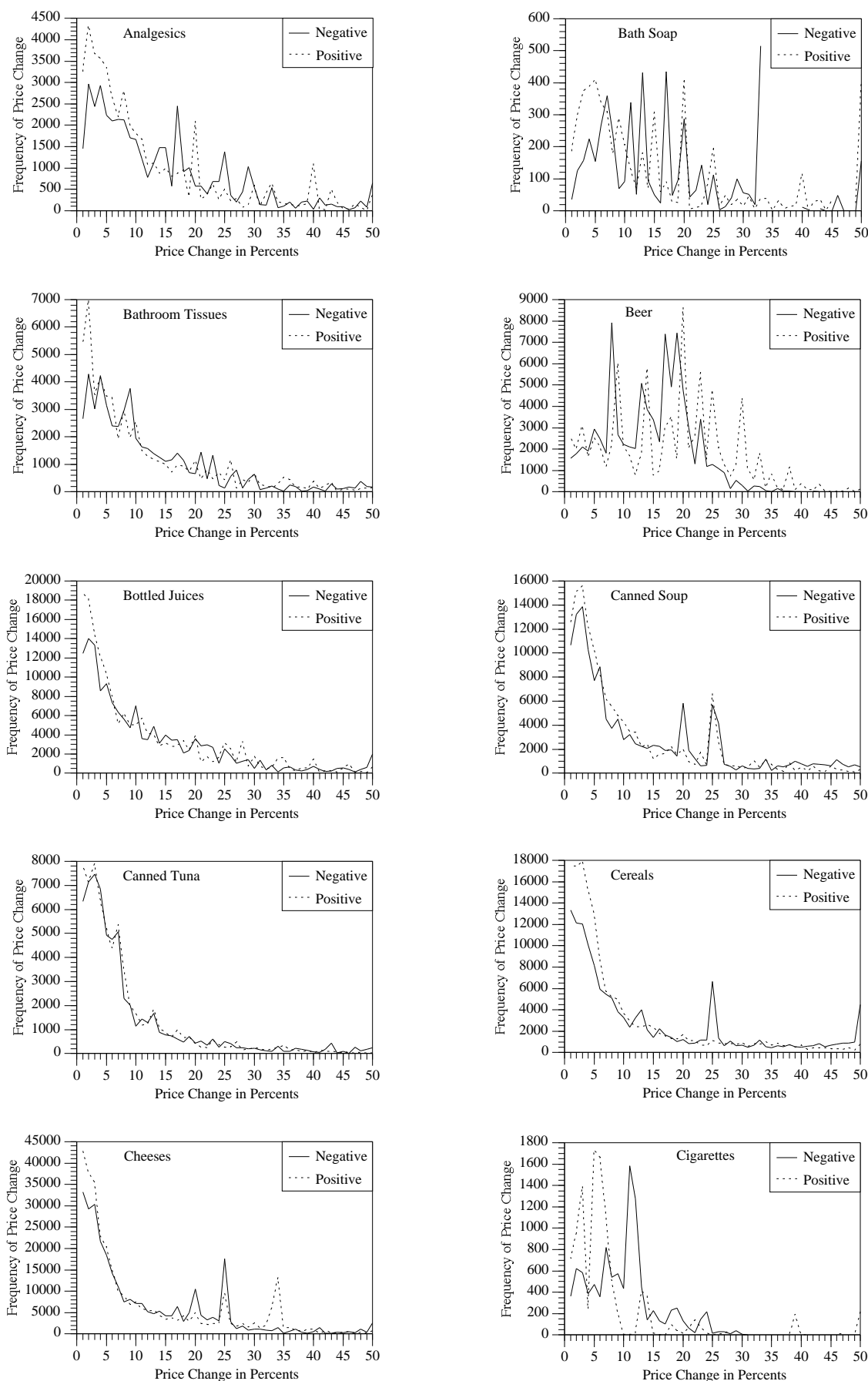


Figure R2.2a. Frequency of Positive and Negative Retail Price Changes in Percents by Category, Deflation Period



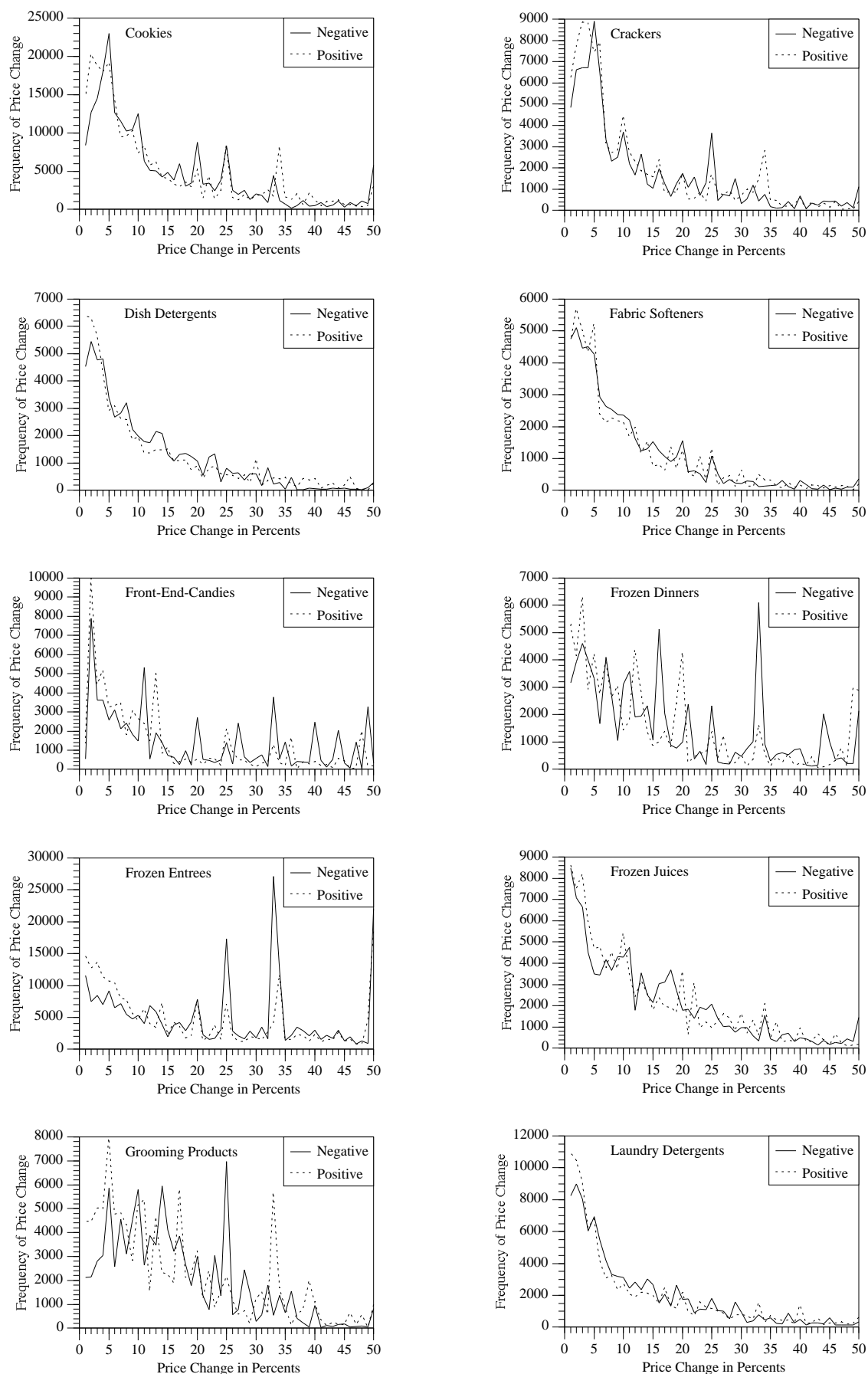


Figure R2.2b. Frequency of Positive and Negative Retail Price Changes in Percents by Category, Deflation Period

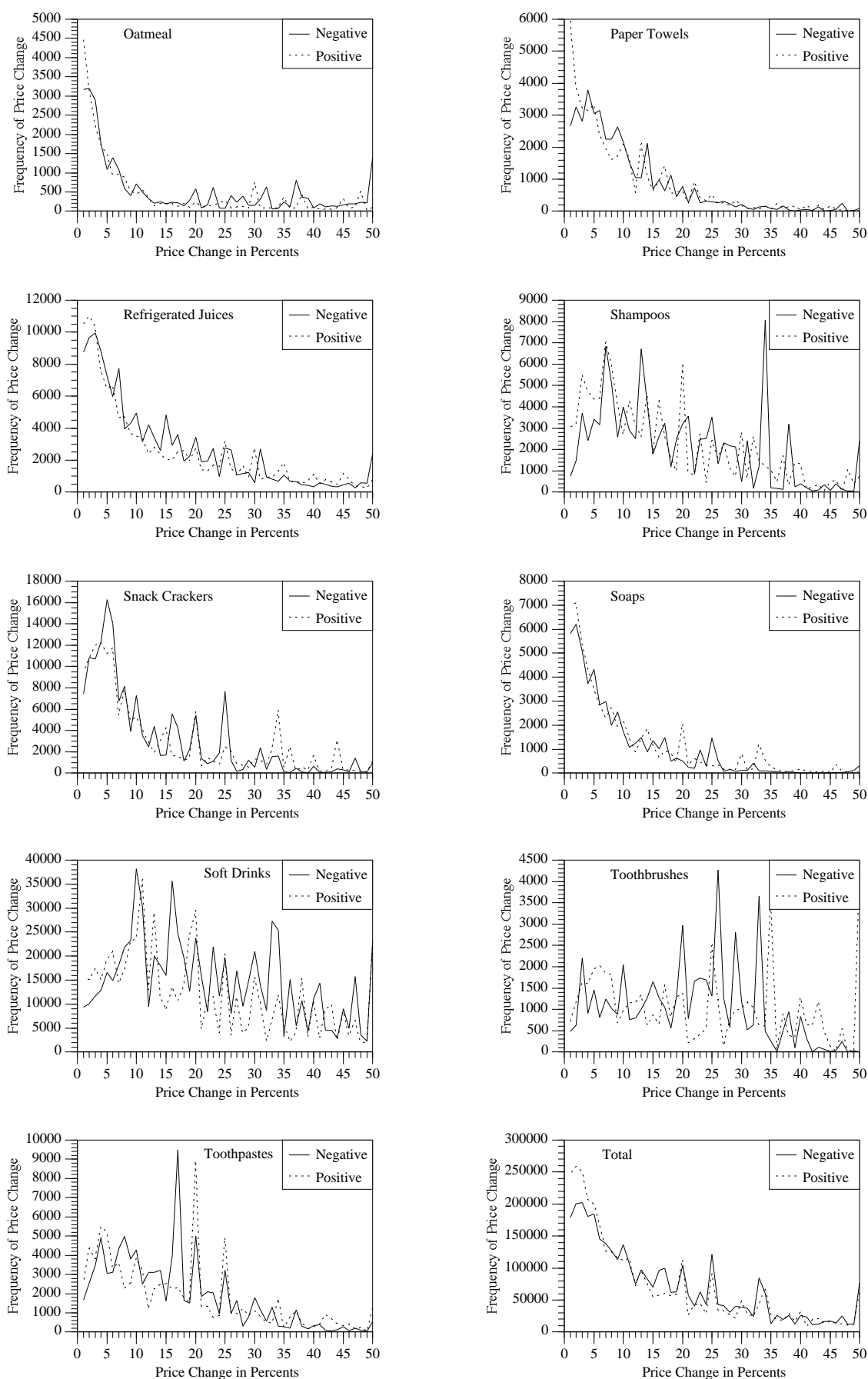


Figure R2.2c. Frequency of Positive and Negative Retail Price Changes in Percents by Category, Deflation Period