



## Marketing Science

Publication details, including instructions for authors and subscription information:  
<http://pubsonline.informs.org>

### Asymmetric Wholesale Pricing: Theory and Evidence

Sourav Ray, Haipeng (Allan) Chen, Mark E. Bergen, Daniel Levy,

To cite this article:

Sourav Ray, Haipeng (Allan) Chen, Mark E. Bergen, Daniel Levy, (2006) Asymmetric Wholesale Pricing: Theory and Evidence. Marketing Science 25(2):131-154. <https://doi.org/10.1287/mksc.1050.0138>

Full terms and conditions of use: <https://pubsonline.informs.org/Publications/Librarians-Portal/PubsOnLine-Terms-and-Conditions>

This article may be used only for the purposes of research, teaching, and/or private study. Commercial use or systematic downloading (by robots or other automatic processes) is prohibited without explicit Publisher approval, unless otherwise noted. For more information, contact [permissions@informs.org](mailto:permissions@informs.org).

The Publisher does not warrant or guarantee the article's accuracy, completeness, merchantability, fitness for a particular purpose, or non-infringement. Descriptions of, or references to, products or publications, or inclusion of an advertisement in this article, neither constitutes nor implies a guarantee, endorsement, or support of claims made of that product, publication, or service.

Copyright © 2006, INFORMS

Please scroll down for article—it is on subsequent pages



With 12,500 members from nearly 90 countries, INFORMS is the largest international association of operations research (O.R.) and analytics professionals and students. INFORMS provides unique networking and learning opportunities for individual professionals, and organizations of all types and sizes, to better understand and use O.R. and analytics tools and methods to transform strategic visions and achieve better outcomes.

For more information on INFORMS, its publications, membership, or meetings visit <http://www.informs.org>

# Asymmetric Wholesale Pricing: Theory and Evidence

Sourav Ray

DeGroote School of Business, McMaster University, 1280 Main Street, Hamilton, Ontario L8S-4M4, Canada,  
sray@mcmaster.ca

Haipeng (Allan) Chen

Department of Marketing, University of Miami, Coral Gables, Florida 33124, hchen@miami.edu

Mark E. Bergen

Department of Marketing and Logistics Management, Carlson School of Management, University of Minnesota,  
Minneapolis, Minnesota 55455, mbergen@csom.umn.edu

Daniel Levy

Department of Economics, Bar-Ilan University, Ramat-Gan 52900, Israel, levyda@mail.biu.ac.il

Asymmetric pricing or asymmetric price adjustment is the phenomenon where prices rise more readily than they fall. We offer and provide empirical support for a new theory of asymmetric pricing in wholesale prices. Wholesale prices may adjust asymmetrically in the small but symmetrically in the large, when retailers face cost of price adjustment. Such retailers will not adjust prices for small changes in their costs. Manufacturers then see a region of inelastic demand where small wholesale price changes do not translate into commensurate retail price changes. The implication is asymmetric—a small wholesale price increase is more profitable because manufacturers will not lose customers from higher retail prices; yet, a small decrease is less profitable, because it will not lower retail prices; hence, there is no extra revenue from greater sales. For larger changes, this asymmetry in the behavior of wholesale price vanishes as the price adjustment cost is compensated by the increase in retailers' revenue resulting from correspondingly large retail price changes. We present a formal economic model of a channel with forward-looking retailers and cost of price adjustment, test the derived propositions on the behavior of manufacturer prices using a large supermarket scanner data set, and find that the results are consistent with the predictions of our theory. We then discuss the implications for asymmetric pricing, channels, and cost of price adjustment literatures, as well as public policy.

*Key words:* asymmetric pricing; asymmetric price adjustment; channel pricing; cost of price adjustment; menu cost; wholesale price; channel of distribution; retailing; economic model; scanner data

*History:* This paper was received February 10, 2003, and was with the authors 13 months for 3 revisions; processed by Subrata Sen.

## 1. Introduction

Asymmetric pricing or what is also known as asymmetric price adjustment is a phenomenon where prices rise readily but fall slowly. Frequent reports in the popular press lament the fact that prices are asymmetric. It is not uncommon to read headlines about prices “rising like rockets... (but)... falling like feathers” (*Octane Week* 1999); retail pork prices not coming down even if hog prices do (*New York Times* 1999); and government subsidies to dairy farmers not lowering dairy products prices, even if a hike in the price of industrial milk paid to farmers, raises such prices at the store (*Canadian Press Newswire* 2000). The resulting public interest in the phenomenon has spawned a large academic literature devoted to the issue. Asymmetry has been studied across a broad range of product markets (Peltzman 2000), including

gasoline (Bacon 1991, Borenstein and Shepard 1996, Karrenbrock 1991); fruit and vegetables (Pick et al. 1991, Ward 1982); pork (Boyde and Brorsen 1988); and banking (Hannan and Berger 1991, Neumark and Sharpe 1992).

Yet, despite the substantial research in asymmetric pricing, the theoretical literature in the area is still in its nascent stages. Peltzman (2000), for example, comments that “Economic theory suggests no pervasive tendency for prices to respond... (asymmetrically)...” Most existing research is empirically driven, attempting to establish the scale and scope of asymmetry. Only a few papers develop formal theories. These include explanations based on monopoly power (Benabou and Gertner 1993, Borenstein and Shepard 1996), inflation with costs of price adjustment (Ball and Mankiw 1994), elasticity differences

in a channel with costs of price adjustment (Madsen and Yang 1998), and information processing costs of consumers (Chen et al. 2005). Yet, in the context of the broad evidence of asymmetric pricing, the theoretical field is still largely unexplored. For authors like Peltzman (2000), this represents a “serious gap in a fundamental area of economic theory.” Similar sentiments are echoed by Ball and Mankiw (1994), Borenstein et al. (1997), and Blinder et al. (1998), all calling for further theory development to close this gap. Surprisingly, given the ubiquity of the phenomenon and the rich marketing literature in pricing (cf. DeSarbo et al. 1987, Hess and Gerstner 1987, Ratchford and Srinivasan 1993, Tellis and Zufryden 1995, Kadiyali et al. 2000), marketing’s contribution to research in asymmetric pricing has been marginal till date. To the best of our knowledge, marketing has not directly studied asymmetric pricing.<sup>1</sup>

In this paper, we hope to address this gap by offering, and providing empirical support for, a theory of asymmetric pricing. Our theory combines insights from the literature on channels of distribution with insights from the literature on costs of price adjustment to suggest why wholesale prices may be asymmetric. This is a natural direction to explore for two very important reasons.

First, we know little about the role played by the distribution channel and the business-to-business linkages implied therein, in determining asymmetric pricing at any level of the channel. Yet, such linkages have been consistently argued to have important influences on the channel’s pricing practices.<sup>2</sup> There is no reason to believe asymmetric pricing will be an exception. Quite to the contrary, Peltzman (2000) suggests, “an explanation for asymmetry may require a fuller understanding of those vertical market linkages.” By focusing on asymmetry in wholesale prices in the context of a distribution channel, we help to clarify the role of such vertical linkages.

Second, while there is a large literature on the importance of costs of price adjustment for price rigidity, we are only beginning to develop our understanding of the implications of these costs on both pricing decisions of other members of the distribution channel and asymmetric pricing.<sup>3</sup> For example,

Levy et al. (1997) attempt to calibrate the source and magnitude of these costs, but do not explore asymmetry or the implications for channel pricing. On the other hand, Ball and Mankiw (1994) combine costs of price adjustment with inflation to offer an explanation of asymmetric pricing. There are also authors who combine channels of distribution and costs of price adjustment. For example, Basu (1995) has addressed both price adjustment costs and channels of distribution in his work on stages of processing, although he focuses on the implications for price rigidity rather than any asymmetry issues in his paper. Madsen and Yang (1998) look at differences in price elasticities in channels of distribution with costs of price adjustment to offer an explanation for asymmetric pricing. We develop this literature to increase our understanding of the implications of costly price adjustment on prices throughout the channel of distribution and asymmetry.

We suggest that retail costs of price adjustment may result in asymmetric pricing by manufacturers. If retailers face costs of price adjustment, they will not adjust retail prices for small changes in wholesale prices. This changes the demand curve faced by the manufacturers. In essence, they then see a region of inelastic demand where small wholesale price changes do not translate into commensurate retail price changes. The implication is asymmetric for manufacturers—it will make small wholesale price increases more profitable because they will not lose customers from higher retail prices. Yet, they will find it less profitable to make small wholesale price decreases, because these will not translate into lower retail prices, and therefore no extra revenue will be generated by these wholesale price cuts.

For larger wholesale price changes, however, retail prices move readily because the cost of changing prices is compensated by increases in retailers’ revenue. As a result, wholesale prices adjust symmetrically to large changes. To formalize this idea, we present an economic model with costly price adjustment in a distribution channel where members have rational expectations because they are forward looking, and therefore behave with foresight. In using the model, we derive testable predictions about patterns of wholesale price adjustment.

To test this theory, we need data on upstream prices in a channel, where we believe price adjustment is costly for the retailer. A natural place to look is in the grocery industry, where these costs have been shown to exist (Levy et al. 1997, 1998; Dutta et al. 1999). Specifically, we use the Dominick’s Finer Food (DFF) scanner data set because it has a measure of

<sup>1</sup> The marketing literature on price adjustment costs is limited. See the paper on haggling by Desai and Purohit (2004) as an example of how these costs might impact marketing strategy. On asymmetry, see Greenleaf (1995), Kopalle et al. (1996), etc. for their consideration of asymmetric reference price effects, which is the closest related work.

<sup>2</sup> See Jeuland and Shugan (1983), Moorthy (1988), Choi (1991), Messinger and Narasimhan (1995), Ingene and Parry (1995), Bergen et al. (1996), etc.

<sup>3</sup> For the literature on these costs, see Mankiw (1985), Ball and Mankiw (1994, 1995), Danziger (1987), Levy et al. (1997), Basu

(1995), Blinder et al. (1998), Dutta et al. (1999), Slade (1998), Zbaracki et al. (2004), etc.

upstream prices that the retailer paid for its products (wholesale prices), and because the existence of retail costs of price adjustment in this industry has been documented in the earlier studies. The data consist of up to 400 weekly observations of this measure of wholesale prices in 29 different product categories, covering the period of about eight years between 1989 and 1997.

We conduct the analysis for each of the 29 categories and find almost uniform support for our theoretical propositions—asymmetry in the small, but symmetry in larger wholesale price changes. To check if our results are because of inflation, we redo each category-level analysis, first for noninflationary, and then for deflationary periods in the data set. In both cases, we find our results to be robust across the categories considered. Yet, one limitation of DFF's data set is that the reported wholesale numbers are not actual wholesale prices but are based on the average acquisition cost. Therefore we also check if the results could be an artifact of the manner in which wholesale prices have been calculated, and conclude that this cannot explain our results.

In the rest of this paper, we first present the model, followed by an account of the data, analysis, and the results. We then discuss the theoretical and managerial implications for the literatures spanning asymmetric pricing, distribution channels, and costs of price adjustment. The implications for public policy are discussed next. We finish this paper by highlighting the principal conclusions, important limitations, and opportunities for future research.

## 2. Theoretical Model

In this section, we offer a theory where asymmetric pricing at wholesale level is driven by the presence of downstream costs of price adjustment. Thus, at a minimum, we need to consider a two-level distribution channel, with pricing decisions for each member, and downstream costs of price adjustment.

Specifically, we model a channel with one manufacturer selling through one retailer to end customers. The customer demand is a continuously differentiable function, decreasing in  $p$ :  $D(p)$ , in each period. For feasibility, we assume the demand function is such that there is at least one price above cost at which demand is positive. We let the manufacturer set the wholesale price  $w_i$  and retailer set the retail price  $p_i$  in each period  $i$ . Both manufacturer and retailer choose prices to maximize their profits. To explore price adjustment from one period to the other, we need to consider at least two periods. We denote the initial pricing period as  $t_0$ , where channel members set the initial price of the product. The second, or the "adjustment period" is denoted  $t_1$ . In the adjustment period, firms will decide

whether, and how much, to adjust prices given the costs of price adjustment and any changes in market conditions.

We assume that the retailers must bear a fixed cost  $x$  whenever they change retail prices. Thus, in period  $t_1$ , if the retailer decides to change prices from those they set in the initial period  $t_0$ , they must incur a cost of  $x$ . If the retailer chooses not to adjust prices in period  $t_1$ , then they do not have to bear this cost.

The manufacturers are also assumed to have a fixed cost  $y$  whenever they change wholesale prices. They can avoid this cost in period  $t_1$  by not changing their  $t_0$  period prices.<sup>4</sup>

The impetus for price changes comes from changing market conditions. We focus on changes in manufacturers' costs as a proxy for such an impetus.<sup>5</sup> More specifically, the manufacturer faces a unit production cost  $c$  in the initial period  $t_0$ , and this cost changes by an amount  $\Delta c$  in the adjustment period  $t_1$ . We assume  $\Delta c$  is a single-peaked symmetric distribution with mean zero.<sup>6</sup>

In terms of how the channel prices are set in each period, we will assume a Stackelberg game with the manufacturers as price leaders, i.e., they set wholesale prices anticipating the retailers' reactions to these prices. The retailers then take the wholesale prices as given and set retail prices. In setting these prices across periods, we let both the retailer and manufacturer act with foresight, i.e., in period  $t_0$ , both consider the pricing actions they will take in  $t_1$ .

In this setup, asymmetric pricing occurs when the likelihood of positive price adjustments are systematically greater than those of negative ones given similar changes in market conditions. For example, given  $\Delta c \neq 0$  of a given magnitude, asymmetric pricing is exhibited if the likelihood of prices rising following  $\Delta c > 0$  is greater than the likelihood of prices falling following  $\Delta c < 0$ . Asymmetry is also exhibited if the magnitude of the positive price adjustment is greater than the magnitude of the negative adjustment. For  $\Delta c = 0$ , asymmetric pricing would be exhibited if the likelihood of prices rising is greater than the likelihood of prices falling or remaining the same.

In the following paragraphs, we first set up the general problem. We then explore a model of this channel without any costs of price adjustment to illustrate

<sup>4</sup> In the analysis, we consider a case with  $y = 0$  for expositional simplicity. The general case with  $y > 0$  is dealt with in the appendix.

<sup>5</sup> There are many other ways market conditions can change. These include changing demand, entry or exit of competitors, change in the macroeconomy (inflation or recession), change in government regulation (price or produce control), as well as acts of God (unseasonal weather patterns), etc. The spirit of these results would remain unchanged, regardless of the specific situation.

<sup>6</sup> Note that if there are inflationary trends, the expected value of  $\Delta c$  would be nonzero. So, our results are essentially derived for a zero inflation scenario.

that asymmetric pricing is not a result of the vertical separation in a channel setting per se. Subsequently, we investigate this model with only retail costs of price adjustment ( $x$ ). This illustrates that by itself, costly price adjustment leads to price rigidity but not asymmetry. However, this also allows us to illustrate how these downstream costs of adjustment lead to upstream asymmetry in wholesale prices during the adjustment period. In the appendix, we explore the general model with the manufacturer costs of adjustment ( $y$ ) to investigate its effects on our results.

## 2.1. General Case of Channel with Costs of Price Adjustment

The retail profit functions in the initial period  $t_0$  and in the adjustment period  $t_1$  are, respectively,

$$\begin{aligned}\Pi_{r0} &= \text{Max}(p_0): \{(p_0 - w_0)D(p_0)\} \\ \Pi_{r1} &= \text{Max}(p_1, \delta): \{(p_1 - w_1)D(p_1) - \delta x\}, \quad (1) \\ &\text{where } \delta = 1 \text{ if } p_1 \neq p_0, 0 \text{ otherwise.}\end{aligned}$$

Similarly, the manufacturer profit functions are, respectively,

$$\begin{aligned}\Pi_{m0} &= \text{Max}(w_0): \{(w_0 - c)D(p_0)\} \\ \Pi_{m1} &= \text{Max}(w_1, \delta): \{(w_1 - c - \Delta c)D(p_1) - \delta y\}, \quad (2) \\ &\text{where } \delta = 1 \text{ if } w_1 \neq w_0, 0 \text{ otherwise,}\end{aligned}$$

where  $w_i$  and  $p_i$  are the wholesale and retail prices in period  $i$  and  $\Pi_{mi}$ ,  $\Pi_{ri}$  being the corresponding profits.

Both the manufacturer and retailer maximize total profits over the two periods. We assume that the feasibility conditions of profit maximization are satisfied, i.e., positive profit-maximizing prices are feasible and that demand is positive at such prices.

The retailer and the manufacturer must take their expected  $t_1$  period solutions into account in solving for their initial ( $t_0$ ) period prices. These  $t_0$  prices are then considered when solving for the adjustment ( $t_1$ ) period prices. Our solution process, therefore, is to proceed backward by first solving for the  $t_1$  period prices  $w_1$  and  $p_1$ , given the  $t_0$  prices  $p_0$  and  $w_0$ . We then derive the equilibrium  $t_0$  prices using the  $t_1$  period solutions. The equilibrium  $t_1$  prices can then be obtained by substituting these  $t_0$  solutions.

Additionally, in each period, we solve for the prices in a Stackelberg fashion where the manufacturer takes into account the retail reaction function  $p(w)$  in setting its wholesale price. For example, the  $t_0$  period solutions are derived in two stages.

First, the retail reaction function  $p_0(w_0)$  is obtained from<sup>7</sup>

$$\text{Max}(p_0; p_1^e): \{(p_0 - w_0)D(p_0)\} + \{(p_1^e - w_1^e)D(p_1^e)\}, \quad (3)$$

<sup>7</sup> We do not include a discount factor for the second-period profits. Such a factor does not affect our central results, but makes the notations more complex.

where  $p_1^e = p_0 + \Delta p^e$  and  $w_1^e = w_0 + \Delta w^e$ , the superscript “e” denoting the prices expected by the retailer in the adjustment period. Next, this is substituted into the manufacturer problem to solve

$$\begin{aligned}\text{Max}(w_0; w_1^e): &\{(w_0 - c)D(p_0(w_0))\} \\ &+ \{(w_1^e - c - E(\Delta c))D(p_1^e)\}, \quad (4)\end{aligned}$$

where  $E(\Delta c)$  is the expectation of  $\Delta c$  based on the distributional assumptions made earlier.

Having set up the general problem, we now consider below the implications for asymmetric pricing.

## 2.2. Channel Pricing Without Costs of Price Adjustment

We begin by exploring the pricing decisions of channel members when there are no costs of price adjustment ( $x = 0$ ,  $y = 0$ ).

**Adjustment Period  $t_1$ .** With no costs of price adjustment in  $t_1$ , from (1),  $\delta$  is not a factor in the retail problem. Hence the initial period price has no affect on the adjustment period solutions and we can directly solve for the equilibrium adjustment period prices. The retailer sets  $p$  to maximize  $(p - w_1) \cdot D(p)$ , which gives the retailer’s price reaction function  $p_1(w_1)$  that solves

$$\begin{aligned}p_1(w_1) &= p(w_1) \quad \text{s.t.} \quad p = \frac{w_1}{1 - 1/\varepsilon_{r1}}, \\ &\text{where } \varepsilon_{r1} = \varepsilon_{r1}(w_1) = -\frac{\partial \log D}{\partial \log p}. \quad (5)\end{aligned}$$

Similarly, from (2), the manufacturer sets  $w$  to maximize  $\{(w - (c + \Delta c))D(p_1(w))\}$ . This gives the wholesale price  $w_1^*$ , which solves<sup>8</sup>

$$w = \frac{c + \Delta c}{1 - 1/\varepsilon_{m1}}, \quad \text{where } \varepsilon_{m1} = \varepsilon_{m1}(p_1(w)) = -\frac{\partial \log D}{\partial \log w}. \quad (6)$$

The equilibrium retail price  $p_1^*$  is then given by  $p_1^* = p_1(w_1^*)$ .

From (5) and (6), in equilibrium,

$$w_1^* = \frac{c + \Delta c}{1 - 1/\varepsilon_{m1}^*} \quad \text{and} \quad p_1^* = \frac{c + \Delta c}{(1 - 1/\varepsilon_{r1}^*)(1 - 1/\varepsilon_{m1}^*)}. \quad (7)$$

**Initial Period  $t_0$ .** In the initial period, because there are no costs of price adjustment, neither the manufacturer nor retailer needs to take into account the impact of initial pricing decisions on later adjustment period actions. The maximization problems therefore become identical to that of the adjustment period, except that costs will be  $c + E(\Delta c)$  rather than  $c + \Delta c$ .

<sup>8</sup> Subsequently, the superscript “\*” will be used to denote equilibrium solutions.

By our distributional assumption of  $\Delta c$ ,  $E(\Delta c) = 0$ . Hence the equilibrium solutions with the appropriate notations are

$$w_0^* = \frac{c}{1 - 1/\varepsilon_{m0}^*} \quad \text{and} \quad p_0^* = \frac{c}{(1 - 1/\varepsilon_{r0}^*)(1 - 1/\varepsilon_{m0}^*)}. \quad (8)$$

Notice from (7) that both  $w_1^*$  and  $p_1^*$  exhibit a symmetric pricing pattern—both negative and positive cost changes of similar magnitudes elicit the same magnitude of wholesale and retail price changes. Hence *the channel per se does not lead to any asymmetric price adjustment*.

### 2.3. Channel Pricing with Downstream Costs of Price Adjustment

Consider now the case when we allow for downstream costs of price adjustment,  $x$  in the earlier setup. In the context of the vertical separation of a distribution channel, these costs lead to asymmetric adjustment of prices. For ease of exposition, we keep  $y = 0$  in the following discussion. When  $x > 0$ , the price adjustment decision of the retailer changes. In the adjustment period  $t_1$ , the retailer will not change prices unless market forces change sufficiently to make such price adjustment worthwhile.

**Adjustment Period  $t_1$ .** The retailer's objective function in  $t_1$ , given the initial pricing decision  $p_0$  is

$$\Pi_{r1} = \text{Max}(p, \delta): \{(p - w_1)D(p) - \delta x\},$$

where  $\delta = 1$  if  $p_1 \neq p_0$ , 0 otherwise. (9)

Here, it incurs a cost  $x$  when it changes price ( $\delta = 1$ ) from the  $t_0$  period price  $p_0$ . When it does not change price ( $\delta = 0$ ), it does not incur this cost.

The solutions are obtained first by solving for  $\delta = 1$  and then for  $\delta = 0$ . In the first case,  $x$  is a fixed exogenous parameter, and does not affect the first-order conditions. So, the retailer's *desired* price in the adjustment period is the same as previously solved in (7). The retailer's solution is a price reaction function  $p_1(w_1)$  that solves

$$p_1(w_1) = p(w_1) \quad \text{s.t.} \quad p = \frac{w_1}{1 - 1/\varepsilon_{r1}},$$

where  $\varepsilon_{r1} = \varepsilon_{r1}(w_1) = -\frac{\partial \log D}{\partial \log p}$ . (10)

Now, the retailer will implement a new price ( $\delta = 1$ ) only if, by doing so, it is going to be better off than by staying at  $p_0$ . Therefore it will not change price ( $\delta = 0$ ) if  $(p_1(w_1) - w_1)D(p_1(w_1)) - x \leq (p_0 - w_1)D(p_0)$ . The retailer's solution therefore is

$$p_1(w_1) = \begin{cases} p_1(w_1) & \text{if } \Gamma(p_1(w_1), p_0, x) \\ p_0 & \text{otherwise} \end{cases}, \quad (11)$$

where  $\Gamma(p_1(w_1), p_0, x)$  denotes that the following condition is satisfied:

$$\{\Pi_R(p_1(w_1)) - x > \Pi_R(p_0)\} \quad \text{with } \Pi_R(p) = (p - w)D(p).$$

$\Gamma^C(\cdot)$  therefore denotes complementary condition

$$\{\Pi_R(p_1(w_1)) - x \leq \Pi_R(p_0)\}. \quad (12)$$

To solve the manufacturer problem, recall from (7) that if the retailer reacts to the manufacturer's price change, the optimal wholesale price will be  $w_1 = (c + \Delta c)/(1 - 1/\varepsilon_{m1})$ . But the existence of downstream costs of price adjustment creates a region defined by  $\Gamma^C(\cdot)$  above, where the retailer does not change its own price. Hence demand would be inelastic to any wholesale price change in that region and the manufacturer will not find it optimal to price as in (7). For wholesale price changes where  $\Gamma(\cdot)$  is satisfied, however, the retailer will change its price and the manufacturer will find it optimal to price as in (7). By taking this into account, the manufacturer's wholesale pricing decision in the adjustment period is

$$w_1 = \begin{cases} w_1 = \arg \max_w (w - (c + \Delta c))D(p_1(w)) & \text{if } \Gamma(p_1(w_1), p_0, x) \\ w_{11} = \arg \max_w (w - (c + \Delta c))D(p_0) & \text{otherwise} \end{cases}. \quad (13)$$

Since  $\delta \neq 0$  from (9), the  $t_1$  period solutions are a function of the  $t_0$  period prices. We therefore first solve for the  $t_1$  prices given the  $t_0$  prices  $p_0$  and  $w_0$ . Subsequently, the  $t_0$  solutions  $p_0^*$  and  $w_0^*$  are derived by incorporating the  $t_1$  results. These are substituted back, to get the final  $t_1$  solutions  $p_1^*$  and  $w_1^*$ . In the following, we discuss these price adjustment decisions.

**Retailer Price Adjustment Decision—Rigidity, but Not Asymmetry.** Equation (11) implies that there exists a region of small wholesale price changes around zero where retail prices are rigid. To see this, consider the retail solution in (11). Substituting  $w_0^*$  and  $p_0^*$ , the  $\Gamma^C(p_1(w_1), p_0, x)$  condition can be written as  $\{\Pi_R(p_1(w_1)) - x \leq \Pi_R(p_0^*)\}$  or

$$(p_1(w_1) - w_1)D(p_1(w_1)) - x \leq (p_0^* - w_1)D(p_0^*).$$

Substituting  $w_1 = w_0^* + \Delta w$  and rearranging

$$(p_1(w_1) - w_0^*)D_1 - (p_0^* - w_0^*)D_0 + (D_0 - D_1)\Delta w - x \leq 0,$$

where  $D_0 = D(p_0^*)$  and  $D_1 = D(p_1(w_1))$ .

Now, let  $K = (p_1(w_1) - w_0^*)D_1 - (p_0^* - w_0^*)D_0$ . It must be the case that  $K < 0$ . This is because  $p_0^*$  being the profit-maximizing price; the profit  $(p_0^* - w_0^*)D_0$  must be greater than profit determined by any other retail

price. Therefore, rewrite the  $\Gamma^C(\cdot)$  condition as  $-|K| + (D_0 - D_1)\Delta w - x \leq 0$ .

For  $\Delta w = 0$ , the condition is identically satisfied.

For  $\Delta w > 0$ , by assumptions of a well-behaved profit function,  $p_1(w_1) > p_0^*$ . Consequently,  $D_0 > D_1$ , since the demand function is downward sloping. We can then rewrite the  $\Gamma^C(\cdot)$  condition as  $-|K| + (D_0 - D_1)\Delta w - x \leq 0$ . Clearly, therefore, there exists a  $\Delta w_r = (|K| + x)/|D_0 - D_1| > 0$  such that the  $\Gamma^C(\cdot)$  condition is satisfied only if  $\Delta w \leq \Delta w_r$ .

For  $\Delta w < 0$ , by similar logic as above,  $p_1(w_1) < p_0^*$  and, consequently,  $D_0 < D_1$ . The  $\Gamma^C(\cdot)$  condition can then be rewritten as  $-|K| - (D_0 - D_1)\Delta w - x \leq 0$ . Therefore, there exists a  $\Delta w_r = -(|K| + x)/|D_0 - D_1| < 0$  such that the  $\Gamma^C(\cdot)$  condition is satisfied only if  $\Delta w \geq \Delta w_r$ .

Taken together, the  $\Gamma^C(\cdot)$  condition implies a region of small wholesale price changes where the retailer does not change its price. This is given by  $-|\Delta w_r| \leq \Delta w \leq |\Delta w_r|$ , where

$$\Delta w_r = \frac{|(p_1(w_1) - w_0^*)D(p_1(w_1)) - (p_0^* - w_0^*)D(p_0^*)| + x}{|D(p_0^*) - D(p_1(w_1))|}. \quad (14)$$

Since the retail reaction function is of the form  $p_1(\Delta w) = (w_0^* + \Delta w)/(1 - 1/\varepsilon_{r1})$ , this region of price rigidity still does not suggest asymmetry. In fact, when  $|\Delta w| > |\Delta w_r|$ , the retail price adjustment is symmetric in that both negative and positive  $\Delta w$  will elicit matching positive and negative retail price adjustments. If we abstract away from the channel and look at the price adjustment decisions of the retailer as an individual economic agent, we are led to conclude that *while it leads to price rigidity, price adjustment cost per se does not lead to asymmetric pricing*. This is a standard result in the costs of adjustment literature (cf. Carlton 1986, Danziger 1987, Kashyap 1995, etc.).

**Manufacturer Decision—Asymmetry.** When the retail solutions are folded back into the manufacturer problem, the region of retail rigidity can now be obtained as  $-|\Delta w_r^*| \leq \Delta w^* \leq |\Delta w_r^*|$ , where

$$\Delta w_r^* = \frac{|(p_1^* - w_0^*)D(p_1^*) - (p_0^* - w_0^*)D(p_0^*)| + x}{|D(p_0^*) - D(p_1^*)|}. \quad (15)$$

Substituting this, the manufacturer solution is

$$w_1 = \begin{cases} w_1^* & \text{if } |\Delta w^*| > |\Delta w_r^*|, \text{ where } w_1^* = w_0^* + \Delta w^* \\ w_{11}^* & \text{if } |\Delta w^*| \leq |\Delta w_r^*|, \\ & \text{where } w_{11}^* = \arg \max_w (w - c - \Delta c)D(p_0^*) \end{cases}. \quad (16)$$

Notice in solving for  $w_{11}^*$ , that demand  $D(p_0^*)$  is unaffected by changes in wholesale costs. Consequently, the maximization problem reduces to one of

maximizing  $w$ , which gives  $w_{11}^* = w_0^* + |\Delta w_r^*|$  as the solution.

Consider now the nature of the region defined by  $|\Delta w^*| \leq |\Delta w_r^*|$ . First, note that  $\Delta w^*$  is the wholesale price adjustment that the manufacturer would make in the absence of any retail costs of price adjustment. Now, if  $\Delta c = 0$ , we have  $\Delta w^* = 0$ , and therefore  $w_1^* = w_0^*$ . Therefore, since  $w_1^* = (c + \Delta c)/(1 - 1/\varepsilon_{m1}^*)$ , we can write  $\Delta w^* = \Delta c/(1 - 1/\varepsilon_{m1}^*)$ . Since  $(1 - 1/\varepsilon_{m1}^*) > 0$ ,  $|\Delta w^*| \leq |\Delta w_r^*|$  can now be rewritten in terms of  $\Delta c$  as

$$-|\Delta c_r| \leq \Delta c \leq |\Delta c_r|, \quad \text{where } |\Delta c_r| = |\Delta w_r^*|(1 - 1/\varepsilon_{m1}^*). \quad (17)$$

Substituting this, the manufacturer solutions can now be expressed as

$$w_1 = \begin{cases} \frac{c + \Delta c}{1 - 1/\varepsilon_{m1}^*} & \text{if } |\Delta c| > |\Delta c_r| \\ w_0^* + |\Delta w_r^*| & \text{if } -|\Delta c_r| \leq \Delta c \leq |\Delta c_r| \end{cases}. \quad (18)$$

Consider the implication of the above solution for wholesale prices. For changes in costs that are large, whether positive or negative, i.e., when  $|\Delta c| > |\Delta c_r|$ , we have *symmetric adjustment* because wholesale price changes by commensurate amounts in either directions.

However, for changes in costs that are small, i.e., in the range  $-|\Delta c_r| \leq \Delta c \leq |\Delta c_r|$ , we have *asymmetric adjustment*. The asymmetry can be seen from the following: when the cost change is nonnegative ( $0 \leq \Delta c \leq \Delta c_r$ ), the wholesale price goes up by the amount  $|\Delta w_r^*|$ , but when the cost change is negative ( $-\Delta c_r \leq \Delta c < 0$ ), not only does the wholesale price not come down, but it actually increases by the same magnitude. To relate it back to our earlier definitions of asymmetry, given identical magnitudes of small positive and negative cost changes in the range  $-|\Delta c_r| \leq \Delta c \leq |\Delta c_r|$ , the likelihood of prices rising following  $\Delta c \geq 0$  is greater than the likelihood of prices falling following  $\Delta c < 0$ .

The asymmetry above is driven by the retail costs of price adjustment,  $x$  and the concomitant retail rigidity. If the manufacturer knows that the retailer's price adjustment is costly, it will have an incentive to raise wholesale prices, and a disincentive to lower them, in the region of rigidity for the retailers. The incentives that these retail costs of price adjustment create for asymmetric pricing by manufacturers is the heart of our argument in this paper.

**Initial Period  $t_0$ .** In the initial period, the retailer's solution would take into account the expected wholesale prices in the next period,  $w_1^e = w_0 + \Delta w^e$ . In equilibrium,  $w_1^e = w_0^* + |\Delta w_r^*|$ . The retailer changes price in  $t_1$  only if  $|\Delta w| > |\Delta w_r^*|$ , otherwise its price remains unchanged. Hence the retailer solves for the price that

will maximize profits over the two periods  $t_0$  and  $t_1$  as per the following:

$$\Pi_r = \max_p \{(p - w_0^*)D(p(w)) + (p - w_0^* - |\Delta w_r^*|)D(p(w))\}. \quad (19)$$

The solution gives  $p_0^*$ , which gives

$$p_0^* = \frac{2w_0^* + |\Delta w_r^*|}{2(1 - 1/\varepsilon_{r0}^*)}, \quad \text{where } \varepsilon_{r0}^* = \varepsilon_0(p_0^*) = -\frac{\partial \log D}{\partial \log p}. \quad (20)$$

The forward-looking retailer therefore compensates for its cost of adjustment by charging  $|\Delta w_r^*|/(2(1 - 1/\varepsilon_{r0}^*))$  more in the initial period than what it would charge if it did not have any such costs.

To derive the manufacturer price  $w_0^*$ , we fold the retail solution into the manufacturer problem. Now, the manufacturer's wholesale prices change in both directions in  $t_1$  only for large enough cost changes ( $|\Delta c| > |\Delta c_r|$ ). For smaller cost changes, however, wholesale prices change only upwards by  $|\Delta w_r^*|$ . In fact, this is true even if there is no change in costs. Since  $E(\Delta c) = 0$ , in equilibrium, the manufacturer solution must incorporate this upwards adjustment in  $t_1$ .

To set  $w_0^*$ , therefore the manufacturer maximizes over the two periods as

$$\Pi_m = \max_w \{(w - c)D(p_0(w)) + (w + |\Delta w_r^*| - c)D(p_0(w))\}. \quad (21)$$

The solution gives

$$w_0^* = \frac{2c - |\Delta w_r^*|}{2(1 - 1/\varepsilon_{m0}^*)}, \quad \text{where } \varepsilon_{m0}^* = \varepsilon_0(p_0^*(w_0^*)) = -\frac{\partial \log D}{\partial \log w}. \quad (22)$$

Notice that the  $t_0$  prices of the manufacturer are  $|\Delta w_r^*|/(2(1 - 1/\varepsilon_{m0}^*))$  less than the price that would be if there were no costs of price changes in the channel.

To summarize, the equilibrium channel prices are

$$(p_1, w_1) = \begin{cases} \left( \frac{c + \Delta c}{(1 - 1/\varepsilon_{r1}^*)(1 - 1/\varepsilon_{m1}^*)}, \frac{c + \Delta c}{(1 - 1/\varepsilon_{m1}^*)} \right) & \text{if } |\Delta c| > |\Delta c_r| \\ (p_0^*, w_0^* + |\Delta w_r^*|) & \text{if } -|\Delta c_r| \leq \Delta c \leq |\Delta c_r| \end{cases}$$

$$(p_0^*, w_0^*) = \left( \frac{2c - |\Delta w_r^*|(1/\varepsilon_{m0}^*)}{2(1 - 1/\varepsilon_{r0}^*)(1 - 1/\varepsilon_{m0}^*)}, \frac{2c - |\Delta w_r^*|}{2(1 - 1/\varepsilon_{m0}^*)} \right). \quad (23)$$

In the adjustment period, for retail prices, the solutions imply *symmetric* adjustment for large cost changes ( $|\Delta c| > |\Delta c_r|$ ), but *rigidity* when cost changes are small enough ( $-|\Delta c_r| \leq \Delta c \leq |\Delta c_r|$ ). For wholesale prices, however, the implications are different. While

for large cost changes, the adjustments are *symmetric*, for small changes, we now have *asymmetry*. Retailers take this into account in setting their initial prices and manufacturers take retailers into account in setting the initial wholesale price as well. Thus we have rational expectations for all channel participants.

The above discussions lead to the following research proposition.

**PROPOSITION 1.** *There is a range of cost changes for which the manufacturer will adjust its wholesale prices asymmetrically. In particular, the manufacturer will only adjust its prices upwards regardless of the direction of cost changes, in a region of cost changes of small magnitudes:  $-|\Delta c_r| \leq \Delta c \leq |\Delta c_r|$ . For cost changes of larger magnitudes, the wholesale prices will adjust symmetrically.*

We address the consequences of upstream costs of price adjustment,  $y$  in the appendix. These costs imply regions of wholesale price rigidity, but not asymmetry. Our main results are robust to reasonable specifications of  $y$ . More specifically, when  $y$  is small relative to  $x$  ( $y \ll x$ ) and does not cause wholesale prices to remain unchanged, the asymmetry results are identical.

### 3. Empirical Validation

Our general empirical approach is to test the main implications of the model using upstream price data. Typically, however, upstream data are difficult to get. Therefore we first choose a context that broadly satisfies some of the key assumptions of the model and then use the available scanner data that also have upstream prices. Specifically, we use scanner data from a large Midwestern supermarket chain.

**3a. Implications of the Model.** Our theory predicts that for small cost changes (indirectly observed by small wholesale changes), wholesale prices are more likely to change in the positive direction than in the negative, but for large cost changes (indirectly observed by large wholesale changes), wholesale prices should not exhibit any such systematic pattern. It follows, therefore, that positive wholesale price changes are more likely than negative wholesale price changes when the magnitude of change is small, but they are equally likely when the magnitude of change is large. In other words, wholesale prices will exhibit asymmetry *in the small*, but not in the large.

Moreover, recall that our results were derived in the absence of inflationary trends. Therefore, this pattern should be independent of inflation. In other words, we expect that the pattern of asymmetry in the small will be observed in noninflationary periods as well.<sup>9</sup>

<sup>9</sup> Note that we abstain from defining what might constitute a "small" price change because its precise magnitude will vary with



The availability of data that cover a long time span enables us to examine this implication by separating the data into inflation-period, low-inflation-period, and deflation-period subsamples.

**3b. Data.** To examine the empirical validity of the model's implications, we use data from DFF, which is one of the largest retail supermarket chains in the larger Chicago metropolitan area, operating 94 stores with a market share of about 25%. Large multistore U.S. supermarket chains of this type made up about \$310,146,666,000 in total annual sales in 1992, which was 86.3% of total retail grocery sales (*Supermarket Business* 1993). In 1999, the retail grocery sales has reached \$435 billion. Thus the chain we study is a representative of a major class of the retail grocery trade. Moreover, DFF's-type multistore supermarket chains' sales constitute about 14% of the total retail sales of about \$2,250 billion in the United States. Since retail sales account for about 9.3% of the GDP, our data set is a representative of as much as 1.28% 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 wholesale prices covering the period from September 14, 1989 to May 8, 1997.<sup>10</sup> The length of individual product's price time series, however, varies depending on when the data collection for the specific category began and ended. Note that DFF's UPC-level database does not include all products the chain sells. The database includes 29 different product categories, representing approximately 30% of DFF's revenues (see Table 4).<sup>11</sup>

DFF sets its prices on a chainwide basis at the corporate headquarters, but there may still be some price variation across the chain's stores, depending on the competitive market structure in and around the location of the individual stores (Levy et al. 2002, Dutta et al. 2002). According to Barsky et al. (2003), DFF, in general, maintains three price zones depending on the local market conditions. 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 have used all the data available from all stores.

The wholesale price data we have is not direct. Rather, they are calculated indirectly, from the retail prices reported in the chain's scanner database, which are the actual retail transaction prices (i.e., the price customers paid at the cash register each week), and the profit margin the supermarket makes on each product. Thus the wholesale price series we use are calculated according to the formula  $P_w = (1 - m)P_r$ , where  $P_w$  denotes the wholesale price,  $m$  denotes the gross margin measured as a percentage of the retail price, and  $P_r$  denotes the retail price.<sup>12</sup>

**3c. Relevance of the Empirical Context.** Before discussing the data analysis results, let us briefly consider the similarity of the data we are studying—wholesale price data, and their source—a large retail supermarket chain, to the environment envisioned by the model described in the theoretical section of the paper. In particular, we want to assess the empirical validity of some of the assumptions on which the model is based.

The first assumption of the model is that the retailer faces costs of price adjustment. How valid is this assumption? In a recent series of papers, a group of scholars from marketing, economics, and organizational behavior study price change process and its cost at five large U.S. supermarket chains each operating between 100 to more than 1,000 stores, and demonstrate "... that changing prices in these establishments is a complex process, requiring dozens of steps, and non-trivial amount of resources" (Levy et al. 1997, p. 791). They provide direct measures of these costs, finding that they lead to more than \$100,000 per store annually (more than 35% of the net margin) at major grocery chains like the one examined in this study.<sup>13</sup> Slade (1998) also estimates these costs to be as high as \$2.72 per price change in grocery store chains of similar characteristics. Thus it has been documented in these studies that retail supermarket chains not only face costs of price adjustment, but that the costs are quite substantial.

A second assumption concerns the relative magnitudes of the manufacturer and retailer costs of price adjustment ( $y \ll x$ ). Although manufacturers also face costs of price adjustment, they may not be as substantial in this industry because of the Robinson-Patman

---

the size of the price adjustment cost as well as with various demand factors. Instead, we focus on what it implies in terms of the observable behavior of the wholesale price by letting the data tell us what may constitute a "small" price change. See the results in the Discussion section.

<sup>10</sup> The wholesale prices here are the average acquisition costs (AAC)—see a later section for a discussion.

<sup>11</sup> Note that the data for Beer and Cigarettes categories may be problematic. Unlike the others, they are subject to various kinds of tax rules and government regulations such as restrictions on sales and promotional practices. We, nevertheless, present the results for all 29 categories for the sake of completeness.

<sup>12</sup> The data set reports the variable "profit," which is defined as "the gross margin in percent that DFF makes on the sale of the UPC." See Peltzman (2000, p. 501) for a discussion.

<sup>13</sup> The followup studies by Levy et al. (1998), Dutta et al. (1999), and Zbaracki et al. (2004), which explore other retail and wholesale settings, further confirm and reinforce the original findings. See also Blinder et al. (1998).

Act. This requires that all retailers have access to the same terms and conditions for goods of like grade and quality. Branded consumer packaged goods are often of like grade and quality in this industry (for consumer and logistical reasons). As such, much of the manufacturer pricing is setting the schedule in which all retailers have access. Although this may require a large amount of resources in aggregate, the costs for any particular retailer would be minimal.<sup>14</sup>

Our third assumption is about the fixed nature of the costs of price adjustment. In this regard, we have followed the existing theoretical studies of costly price adjustment models, which typically treat the costs as fixed.<sup>15</sup> But more importantly, the studies by Levy et al. (1997, 1998), Dutta et al. (1999), and Slade (1998) find that the price adjustment costs the supermarkets face are indeed fixed.<sup>16</sup> In fact, Slade (1998) estimates that the magnitude of the fixed component of these costs exceed that of any variable component by a magnitude of about 15 times. According to Levy et al. (1997), the major steps required to change shelf prices include: tag change preparation, tag change itself, tag change verification, and resolution of price mistakes at the store, zone, or corporate level (pp. 798–799; also see their Figure 1). Therefore, many of the cost components, such as the labor time spent during the price tag change process, the cost of printing and delivering new price tags, and the cost of the in-store supervision time, do not change with the size of price change. Thus our assumption that price adjustment costs the supermarkets face are fixed (as opposed to convex) is consistent with the existing evidence on the nature of such costs in the retail supermarket setting.<sup>17</sup>

Our fourth assumption is that the manufacturers are aware of the existence of the retail price adjustment costs. This assumption seems reasonable. The retail price change processes and procedures are common knowledge amongst the practitioners. For example, dozens of articles have been published in numerous trade publications covering the supermarket industry on electronic shelf label systems and how they can reduce the price adjustment costs faced by

retail supermarket chains, especially in states with item-pricing laws. Moreover, many manufacturers of direct store delivery products are themselves engaged in price change management and implementation in these retail stores. These manufacturers are, therefore, intimately familiar with price adjustment complexities and their costs.

Finally, we believe the assumption on demand stability is also reasonable. Most of the product categories included in our data set are mature categories, which have likely reached the limit of their market growth. Moreover, most of the products in these categories are staple goods, which suggest that large demand variations, which would be typical to fashion or fad goods, are unlikely.<sup>18</sup>

**3d. Empirical Findings.** Below we analyze the predictions of our theory for the entire data set as well as for each of the individual categories. In each case, we consider the entire sample period as well as two subsamples. One subsample includes only those weeks in which the monthly inflation rate was below 0.1%, which we call the *low-inflation-period sample*. The other subsample includes only those weeks in which the monthly inflation rate was 0% or less, which we call the *deflation-period sample*. For each subsample, we first consider price changes in cents (i.e., in absolute terms) and then in percent (i.e., in relative terms).<sup>19</sup>

**Analysis of the Data for the Entire Sample Period.** Recall that according to our theory, we expect to see more positive price changes “in the small.” That is, we expect to see more small price increases than decreases. However, as the magnitude of the price change gets larger, we expect these differences to disappear.

The question that naturally arises is: What do we mean by “small”? Because the answer is not obvious, we have chosen to let the data tell us what may constitute a “small” price change in this market. To accomplish this, we have calculated the frequency of positive and negative price changes for each possible size of price change in cents: 1 cent, 2 cents, 3 cents, etc., up to 100 cents; as well as in percents: 1%, 2%, 3%, etc., up to 100%. The results are displayed in Figures 1–3 and Tables 1–3, corresponding to the entire sample, the low inflation subsample, and the deflation subsamples, respectively.

In Figure 1, we report the frequency of positive and negative price changes found in the entire DFF’s

<sup>14</sup> See Levy et al. (1997) for a discussion of the impact of centralized pricing to reduce the costs of price adjustment.

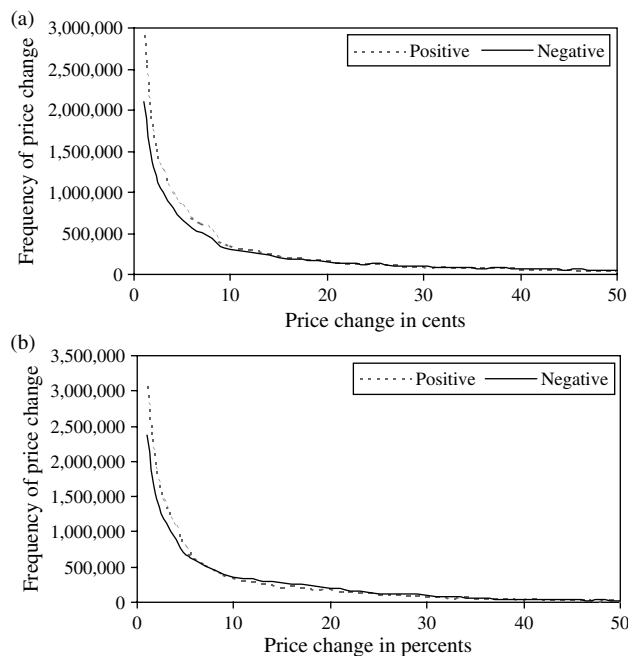
<sup>15</sup> See, for example, Mankiw (1985) and Danziger (1987).

<sup>16</sup> Alternatively, these costs could vary with the size of price change (i.e., the bigger the price change, the larger is its cost), which is known as “convex price adjustment cost.”

<sup>17</sup> However, these costs of price adjustments could be a function of such variables as market share of the products, whether a brand is a national brand or private label, and whether item pricing law is required in the areas where the retailer is operating (Levy et al. 2005). Examining how retailer’s menu cost varies with these variables and its implications on asymmetric pricing are interesting avenues for future research. We thank an anonymous reviewer for pointing us in that direction.

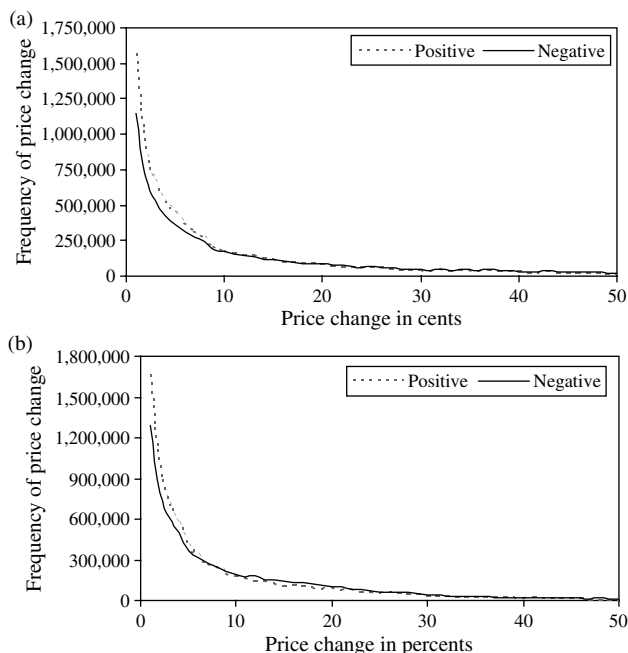
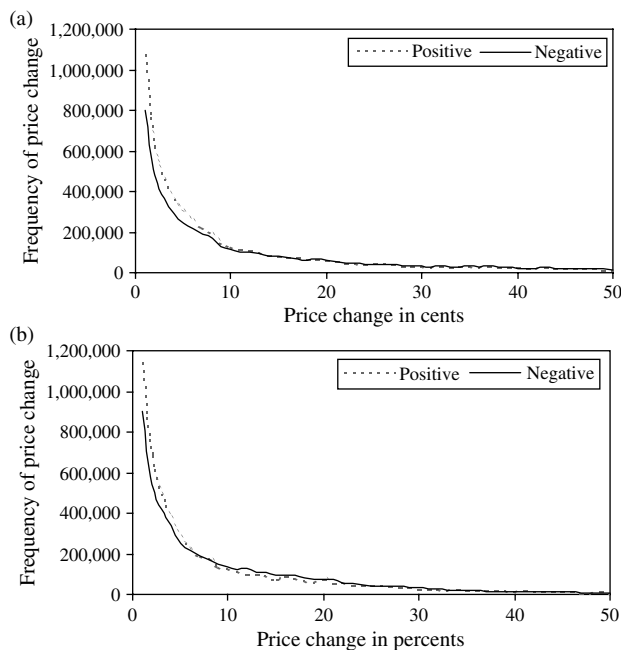
<sup>18</sup> See Cagan (1974), Roll (1984), and Dutta et al. (2002).

<sup>19</sup> The statistical analysis of these various combinations of sample periods/categories/units of measurement has yielded a total of 180 tables of 50 rows each (29 categories + 1 all categories combined × 3 samples/subsamples × 2 units of measurement = 180). While these tables are too many to be included even in the referee’s appendix, they are available to interested readers upon request.

**Figure 1** Frequency of Positive and Negative Wholesale Price Changes: All 29 Categories, Entire Period

database of wholesale prices; that is, when we use all available wholesale price series for all products and all 29 categories, during the entire eight-year sample period. Figure 1(a) displays the frequency of price changes in cents, while Figure 1(b) displays the frequency of price changes in percents.

According to Figure 1(a), indeed, for small price changes, we find systematically more price increases

**Figure 2** Frequency of Positive and Negative Wholesale Price Changes: All 29 Categories, Low Inflation Period**Figure 3** Frequency of Positive and Negative Wholesale Price Changes: All 29 Categories, Deflation Period

than decreases. The difference appears particularly large for price changes of up to about 30 cents. Beyond that, the difference between the frequency of positive and negative price changes quickly disappears as the size of price changes increases. In fact, the two series become virtually indistinguishable beyond that point, at least visually. According to Table 1a, the frequency of price increases exceeds the frequency of price decreases in statistical terms as well: the higher frequency of positive price changes is systematically significant for absolute price changes of up to 36 cents. Beyond that, the two series crisscross each other without any systematic pattern.

A similar pattern is observed when we consider the frequency of price changes in relative terms, i.e., in percents. For price changes of up to about 8%–10%, we indeed see more price increases than decreases. Beyond that point, the two series do not exhibit a clear systematic pattern, as they crisscross each other. Further, the differences between positive and negative price changes slowly disappear. According to the figures in Table 1b, the higher frequency of positive price changes is systematically significant for relative price changes of up to 8%. Beyond that, the two series crisscross each other without any systematic pattern. Thus the results we find in terms of both absolute as well as relative terms are consistent with the model's prediction: for small price changes, there are more price increases than decreases. The asymmetry disappears for larger price changes.

Next, we consider the behavior of the wholesale price data for individual categories. We looked at the

**Table 1a** All Categories Combined, Entire Sample,  
Price Changes in Cents

Price change in cents	Positive	Negative	Z-value
1	2,895,106	2,098,539	356.46
2	1,676,572	1,300,313	218.07
3	1,247,860	1,001,943	163.95
4	986,016	810,011	131.33
5	836,345	662,900	141.65
6	702,145	564,634	122.18
7	619,595	514,363	98.82
8	520,394	448,388	73.16
9	409,297	345,331	73.63
10	357,570	305,687	63.71
11	317,809	282,220	45.94
12	297,657	274,928	30.04
13	283,681	255,998	37.68
14	256,040	233,362	32.42
15	234,609	207,550	40.69
16	204,458	194,157	16.32
17	198,795	177,999	33.88
18	179,168	167,727	19.43
19	182,573	172,934	16.17
20	163,876	154,406	16.79
21	147,867	138,684	17.15
22	140,236	136,270	7.54
23	132,603	127,776	9.46
24	127,366	118,553	17.77
25	132,680	127,664	9.83
26	120,090	112,526	15.68
27	114,587	106,147	17.96
28	98,560	94,870	8.39
29	98,055	94,940	7.09
30	97,295	96,314	2.23
31	89,961	89,116	2.00
32	101,094	92,851	18.72
33	86,914	83,416	8.48
34	85,815	81,700	10.05
35	89,367	85,005	10.45
36	80,315	75,532	12.12
37	85,957	88,666	−6.48
38	85,041	80,912	10.14
39	78,067	72,677	13.88
40	70,122	65,406	12.81
41	64,565	60,255	12.20
42	63,398	61,014	6.76
43	70,939	69,516	3.80
44	62,361	61,711	1.85
45	60,022	59,303	2.08
46	58,291	63,867	−15.95
47	51,194	51,552	−1.12
48	51,733	54,594	−8.77
49	46,529	47,104	−1.88
50	45,186	46,693	−4.97

**Table 1b** All Categories Combined, Entire Sample,  
Price Change in Percents

Price change in percents	Positive	Negative	Z-value
1	3,040,097	2,369,790	288.19
2	1,833,178	1,467,749	201.13
3	1,340,358	1,117,787	141.96
4	1,072,180	899,292	123.13
5	765,355	668,618	80.78
6	631,352	592,735	34.90
7	524,601	506,774	17.55
8	480,713	452,409	29.30
9	393,397	393,734	−0.38
10	351,780	362,894	−13.15
11	322,287	331,016	−10.80
12	288,412	326,835	−48.99
13	280,326	291,078	−14.22
14	250,000	300,384	−67.91
15	225,027	271,375	−65.78
16	242,802	249,251	−9.19
17	221,687	252,551	−44.82
18	201,737	234,925	−50.22
19	180,080	214,481	−54.77
20	201,395	196,250	8.16
21	160,135	192,749	−54.90
22	163,640	163,501	0.24
23	144,710	152,282	−13.89
24	142,030	138,348	6.95
25	123,762	126,999	−6.46
26	126,984	113,861	26.74
27	116,047	111,207	10.15
28	102,891	113,362	−22.52
29	97,362	118,163	−44.81
30	86,047	90,755	−11.20
31	76,570	88,536	−29.45
32	77,578	79,606	−5.12
33	65,036	72,268	−19.52
34	69,211	63,321	16.18
35	63,195	58,258	14.17
36	60,660	54,383	18.51
37	58,841	44,385	44.99
38	55,280	43,987	35.84
39	53,907	38,740	49.83
40	46,866	41,935	16.55
41	67,823	40,201	84.04
42	43,074	35,005	28.88
43	45,052	34,840	36.13
44	40,879	35,856	18.13
45	41,584	39,883	5.96
46	41,443	31,647	36.23
47	30,251	28,806	5.95
48	29,130	31,172	−8.32
49	33,433	24,716	36.15
50	28,534	27,389	4.84

frequency of negative and positive price changes first as a function of the size of price change in cents, and then in percents.<sup>20</sup>

<sup>20</sup> Only the plots for Toothpastes are given in Figure 5. Because of sheer volume, the rest of the category-level plots are included in the Technical Appendix available at [mktsci.pubs.informs.org](http://mktsci.pubs.informs.org).

We find that the frequency of positive price changes exceeds the frequency of negative price changes “in the small” for all 29 categories displayed. For most categories, the difference appears particularly strong for price changes of up to 10–15 cents. Beyond that, the two time series exhibit a very similar behavior, often merging with each other. We have con-

**Table 2a** All Categories Combined, Low Inflation,  
Price Changes in Cents

Price change in cents	Positive	Negative	Z-value
1	1,563,081	1,145,605	253.66
2	901,586	703,395	156.44
3	670,891	538,954	119.95
4	521,048	430,541	92.78
5	449,189	356,776	102.94
6	374,921	306,464	82.93
7	324,646	273,707	65.85
8	276,121	244,961	43.17
9	214,997	186,572	44.86
10	186,824	171,666	25.32
11	166,624	152,614	24.80
12	155,122	148,049	12.85
13	151,697	140,288	21.11
14	132,013	121,424	21.03
15	123,295	114,419	18.20
16	108,076	106,859	2.63
17	102,463	95,490	15.67
18	95,988	89,244	15.67
19	93,151	92,083	2.48
20	83,270	82,713	1.37
21	79,235	74,453	12.20
22	72,416	74,441	-5.28
23	68,190	72,591	-11.73
24	66,608	62,577	11.22
25	67,569	64,884	7.38
26	64,555	58,527	17.18
27	60,430	57,106	9.70
28	50,378	49,997	1.20
29	50,175	51,220	-3.28
30	48,271	49,089	-2.62
31	42,759	42,361	1.36
32	53,628	50,100	10.95
33	42,734	42,949	-0.73
34	46,418	44,567	6.14
35	51,159	47,374	12.06
36	41,091	37,720	12.01
37	45,209	46,517	-4.32
38	43,291	41,026	7.80
39	39,149	40,027	-3.12
40	36,733	33,959	10.43
41	33,701	31,924	6.94
42	33,457	33,174	1.10
43	35,269	35,536	-1.00
44	32,423	32,049	1.47
45	29,096	30,832	-7.09
46	29,609	33,998	-17.40
47	26,487	27,952	-6.28
48	25,263	27,273	-8.77
49	22,910	23,985	-4.96
50	20,586	23,218	-12.58

**Table 2b** All Categories Combined, Low Inflation,  
Price Changes in Percents

Price change in percents	Positive	Negative	Z-value
1	1,654,535	1,292,877	210.66
2	987,127	792,036	146.26
3	714,404	610,636	90.15
4	572,131	494,293	75.37
5	404,874	363,633	47.04
6	330,664	314,028	20.72
7	278,831	273,952	6.56
8	256,257	242,442	19.56
9	206,590	214,455	-12.12
10	186,363	196,416	-16.25
11	168,146	176,572	-14.35
12	151,629	179,133	-47.82
13	147,464	154,627	-13.03
14	129,467	152,450	-43.29
15	115,764	141,946	-51.57
16	122,650	130,178	-14.97
17	116,947	133,105	-32.31
18	103,816	123,467	-41.22
19	90,744	108,787	-40.39
20	98,804	104,223	-12.03
21	81,917	101,902	-46.61
22	88,062	77,087	27.01
23	72,590	79,946	-18.83
24	68,782	73,531	-12.59
25	64,974	60,265	13.31
26	66,998	58,793	23.13
27	58,916	56,068	8.40
28	50,181	61,586	-34.11
29	49,239	55,522	-19.41
30	42,851	44,625	-6.00
31	38,489	42,770	-15.02
32	37,532	34,864	9.92
33	29,729	33,741	-15.92
34	33,954	31,617	9.13
35	31,013	26,232	19.98
36	28,902	27,289	6.80
37	29,610	19,209	47.07
38	27,315	22,345	22.30
39	26,582	18,427	38.44
40	21,786	21,579	0.99
41	30,072	20,970	40.29
42	21,894	17,748	20.82
43	22,440	16,368	30.82
44	19,791	17,235	13.28
45	21,168	19,614	7.70
46	16,818	16,723	0.52
47	13,292	15,199	-11.30
48	13,875	16,580	-15.50
49	14,877	14,002	5.15
50	13,145	14,266	-6.77

ducted formal statistical significance tests for each of the 29 individual categories, and they confirm our interpretation of the results: the frequency of positive price changes exceeds the frequency of negative price changes for all 29 categories included in our sample. According to these tests, for most categories, the asymmetry holds for absolute price changes of

between 5–20 cents. Table 4 reports these cutoff points for each category.

Now, consider the price change behavior in percents. We find that for all categories considered (the category of Beer being the only exception), the frequency of positive price changes exceeds the frequency of negative price changes “in the small.” In most cases, “small” visually appears to mean about

**Table 3a** All Categories Combined, Deflation, Price Changes in Cents

Price change in cents	Positive	Negative	Z-value
1	1,072,926	797,687	201.24
2	614,350	482,632	125.76
3	463,687	368,254	104.63
4	359,824	292,415	83.47
5	307,434	244,947	84.08
6	256,657	215,861	59.35
7	221,610	188,616	51.51
8	187,334	167,618	33.09
9	149,559	127,189	42.52
10	129,117	115,699	27.12
11	112,853	103,478	20.16
12	106,162	100,130	13.28
13	103,670	95,437	18.45
14	89,093	84,736	10.45
15	84,646	78,955	14.07
16	72,653	72,355	0.78
17	73,377	64,770	23.16
18	65,118	61,508	10.14
19	66,383	65,638	2.05
20	57,643	57,811	−0.49
21	56,121	52,181	11.97
22	49,908	50,648	−2.33
23	45,871	49,709	−12.41
24	43,987	42,410	5.37
25	46,329	43,533	9.33
26	44,724	41,961	9.38
27	39,843	41,019	−4.14
28	35,051	34,816	0.89
29	34,420	33,976	1.70
30	34,884	33,819	4.06
31	28,460	29,459	−4.15
32	36,880	35,455	5.30
33	29,696	30,226	−2.17
34	32,330	29,349	12.00
35	35,189	32,447	10.54
36	27,945	24,826	13.58
37	31,099	31,584	−1.94
38	28,197	25,999	9.44
39	26,146	26,556	−1.79
40	25,296	23,063	10.15
41	22,027	22,258	−1.10
42	21,223	21,430	−1.00
43	24,978	25,848	−3.86
44	20,919	20,625	1.44
45	19,661	19,357	1.54
46	21,522	23,253	−8.18
47	17,895	18,064	−0.89
48	18,622	18,908	−1.48
49	16,249	17,575	−7.21
50	14,401	15,968	−8.99

**Table 3b** All Categories Combined, Deflation, Price Changes in Percents

Price change in percents	Positive	Negative	Z-value
1	1,141,220	898,901	169.65
2	681,315	540,571	127.33
3	496,515	418,860	81.17
4	382,480	340,023	49.95
5	283,179	250,915	44.15
6	225,844	213,743	18.25
7	190,062	188,157	3.10
8	172,890	166,784	10.48
9	138,369	147,775	−17.58
10	125,667	133,492	−15.37
11	117,385	122,344	−10.13
12	104,715	128,934	−50.10
13	103,438	109,879	−13.95
14	91,527	106,677	−34.03
15	77,789	95,260	−42.00
16	85,445	92,440	−16.59
17	78,764	94,632	−38.11
18	68,349	84,438	−41.16
19	61,441	74,405	−35.17
20	71,493	73,817	−6.10
21	53,955	71,276	−48.95
22	58,647	54,368	12.73
23	48,101	54,147	−18.91
24	46,712	50,332	−11.62
25	46,113	41,600	15.24
26	48,012	41,220	22.74
27	39,136	38,728	1.46
28	35,798	43,910	−28.73
29	33,218	37,130	−14.75
30	29,206	30,894	−6.89
31	25,421	29,572	−17.70
32	26,895	25,625	5.54
33	21,690	23,114	−6.73
34	25,150	21,731	15.79
35	21,084	18,316	13.94
36	20,576	20,044	2.64
37	21,365	12,417	48.68
38	19,234	15,076	22.45
39	18,150	12,685	31.12
40	15,093	14,572	3.02
41	20,177	13,296	37.61
42	16,177	10,801	32.73
43	14,710	11,249	21.48
44	13,787	11,451	14.70
45	14,500	11,752	16.96
46	12,246	10,721	10.06
47	9,181	9,836	−4.75
48	9,559	9,216	2.50
49	10,395	9,177	8.71
50	8,778	9,945	−8.53

5%–8% change. The results of a formal statistical testing of the hypothesis of asymmetry confirm this conclusion: they indicate that the asymmetry in relative terms holds for price changes in the range of 2%–9% with the majority of the categories falling in the range of 5%–8%. Table 4 reports these cutoff points for each category. Thus the analysis of asymmetry in relative terms reveals a greater homogeneity

across the 29 product categories. Overall, we conclude that the wholesale prices of every product category exhibit asymmetric pricing in the small, in both absolute and relative terms.

**Analysis of the Data for Low Inflation and Deflation Periods.** A possible criticism of the findings we have reported so far, however, is the fact that during the sample period covered in this study, the United

**Table 4** What Might Constitute a “Small” Price Change Statistical Analysis of the Data by Product Category in Absolute (Cents) and Relative (Percentage) Terms

	Entire sample period		Low/zero inflation period		Deflation period	
	Absolute (cents)	Relative (%)	Absolute (cents)	Relative (%)	Absolute (cents)	Relative (%)
Analgesics	30	8	21	10	3	7
Bath soap	10	2	2	1	2	1
Bathroom tissues	11	4	9	1	10	1
Beer	3	0	0	2	0	2
Bottled juices	13	5	21	11	9	5
Canned soup	13	8	9	7	6	8
Canned tuna	3	2	3	1	4	2
Cereals	33	9	19	9	19	9
Cheeses	18	6	9	3	5	3
Cigarettes	14	8	1	8	1	3
Cookies	11	6	11	6	11	8
Crackers	15	6	15	5	15	8
Dish detergent	4	2	4	1	4	1
Fabric softeners	5	2	8	3	2	3
Front-end candies	7	9	6	8	6	5
Frozen dinners	6	1	3	1	3	1
Frozen entrees	30	5	17	8	8	6
Frozen juices	9	5	7	6	9	7
Grooming products	12	8	15	8	13	8
Laundry detergents	8	2	8	2	6	2
Oatmeal	7	7	2	1	2	1
Paper towels	1	2	3	4	10	4
Refrigerated juices	10	6	8	4	4	2
Shampoos	13	7	10	6	13	7
Snack crackers	7	5	7	5	7	3
Soaps	7	4	9	4	5	3
Soft drinks	23	9	14	11	14	8
Toothbrushes	9	8	9	7	11	7
Toothpastes	16	5	10	4	10	4
Total (all 29 categories combined)	36	8	19	8	15	8

*Notes.* (1) The figures reported in the table are the cutoff points of what might constitute a “small” price change for each category. 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. (2) In all tables, the critical values for 1%, 5%, and 10% significance are 2.575, 1.96, and 1.645, respectively.

States was experiencing inflation. In Figure 4, we plot the monthly inflation rate in the United States as measured by the *Producer Price Index*. We use the *Producer Price Index* because it is likely to be a better indicator of the wholesalers’ costs than the more com-

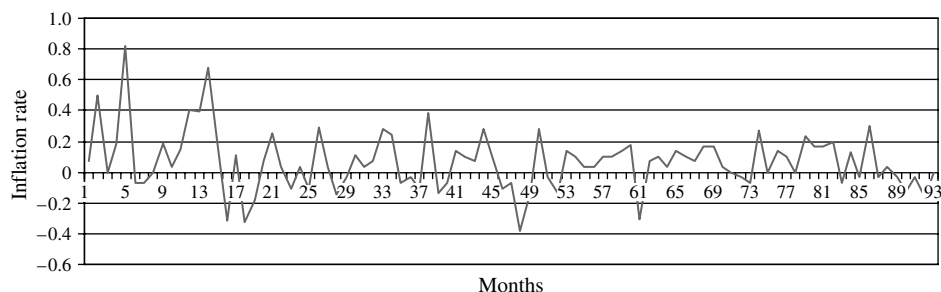
monly used *Consumer Price Index*. Given that, during the period we study, there was inflation in the United States, it is possible that the finding we are documenting is merely a reflection of that fact. That is, during an inflation period, even if prices go up and down, we would expect that *ceteris paribus*, prices will go up more often than down.

One possible answer to this criticism, however, 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.

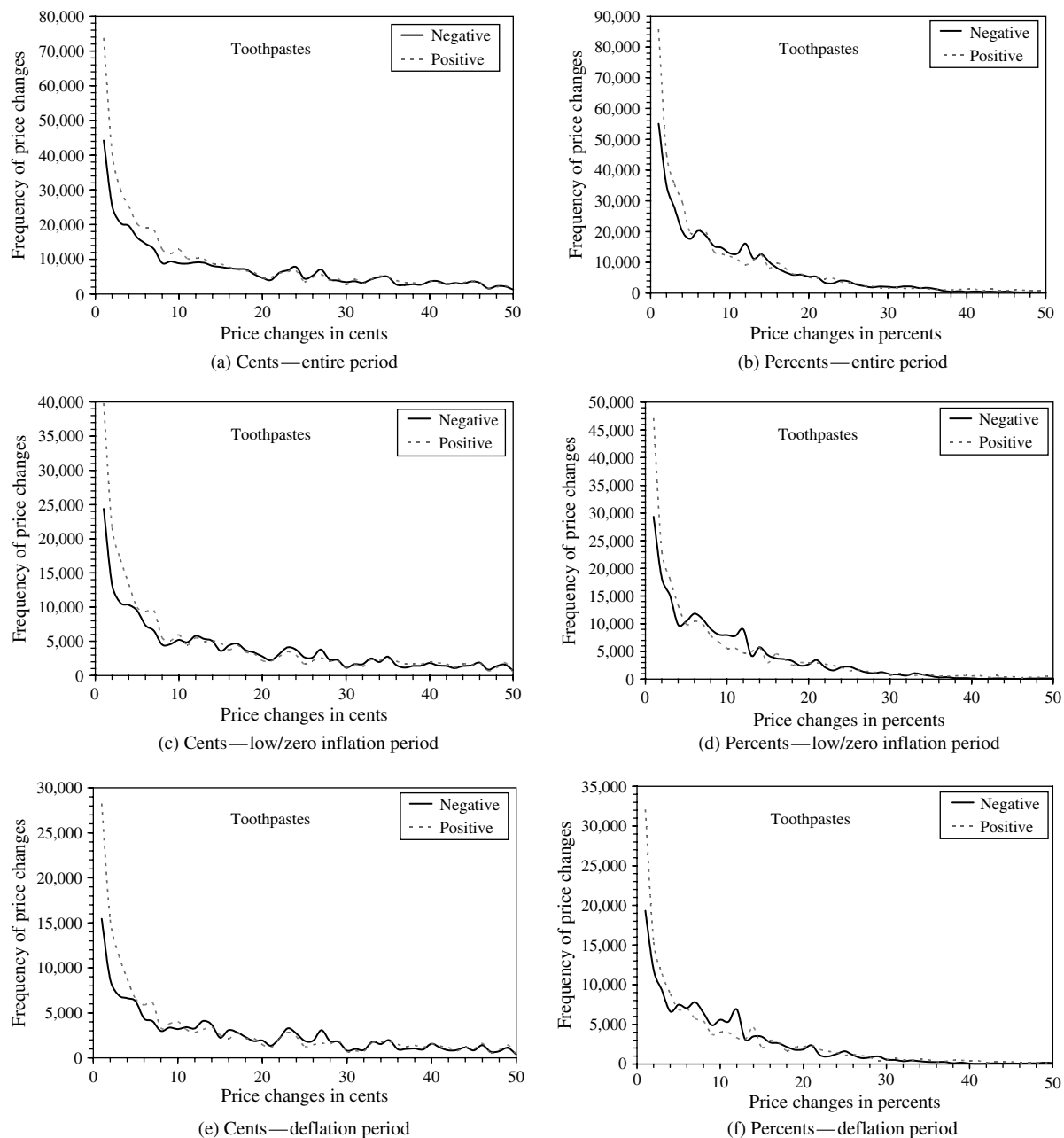
A direct, and perhaps more methodical, response to the above criticism can be given by conducting the following analysis. Let us try and see whether the asymmetric pricing we document “in the small” for the entire sample period also exists in the data when the observations pertaining to the inflationary periods are excluded from the analysis. Given our large sample of observations, such an analysis is possible.

We have conducted two versions of such an analysis. In the first, we included only those observations during which the monthly *Producer Price Index* inflation rate did not exceed 0.1%, a very low inflation rate by any historical standard. We call this a low/zero inflation sample. In the second version, we took an even more conservative stand by including in the analysis only these observations in which the monthly inflation rate was zero or negative. We call this a deflation-period sample.

In Figures 2(a) and 2(b), we report the frequency of positive and negative price changes found in the DFF’s wholesale prices during low/zero inflation periods. In Figures 3(a) and 3(b), we report the frequency of positive and negative price changes during deflation periods. Figures 2(a) and 3(a) display the frequency of price changes in cents, and Figures 2(b) and 3(b) in percents. In both low inflation and deflation periods, our substantive conclusions remain the same—we find significantly more price increases than decreases for small price changes. For absolute changes, the difference appears especially big for price changes of up to about 10–15 cents. For percentage changes, the difference appears large for

**Figure 4** Monthly Inflation Rate Based on *Producer Price Index*, September 1989–May 1997

**Figure 5** Frequency of Positive and Negative Wholesale Price Changes: Toothpaste



changes up to about 5%. Beyond these, the difference in the frequency of positive and negative price changes quickly disappears as the size of price change increases.

The findings remain unchanged for individual categories as well. The results are very similar to the findings reported for the entire data set. With the exception of Beer, the frequency of positive price changes exceeds the frequency of negative price changes “in the small” for all others. Formal statistical significance tests for each of the 28 categories confirmed that the asymmetry holds for absolute price changes of between 5–20 cents, with the difference

being particularly strong between 10–15 cents. In terms of percentage changes, the asymmetry holds for price changes of 11% or less, with the majority of the categories falling in the range of 5%–8%. Beyond these, the two time series exhibit a very similar behavior, often merging with each other, in both (cents and percents) cases. Thus the analysis of asymmetry in relative terms again reveals a greater homogeneity across the 29 product categories. Table 4 reports these cutoff points for each category.

**Could the Results Be an Artifact of How the Wholesale Prices Are Calculated?** Yet, another criti-



cism of our results could be that our findings are a direct result of the manner in which the wholesale prices are calculated. Our wholesale price, as reported in the DFF database, is based on the AAC. The AAC per unit is calculated as follows:

$$\begin{aligned} AAC(t) = & \{Purch(t) \times price(t)\} \\ & + \{EndInventory(t-1) - sales(t)\} \\ & \times AAC(t-1)) \cdot (TotalInventory(t))^{-1}, \end{aligned}$$

where

$Purch(t)$  = inventory bought in  $t$ ;

$price(t)$  = per unit wholesale price paid in  $t$ ;

$EndInventory(t-1)$  = inventory at end of  $t-1$ ;

$sales(t)$  = retail sales at  $t$ ;

$TotalInventory(t)$  = total inventory at  $t$

**The Role of Forward Buying by Retailers.** Can it be claimed that our results could be just an artifact of the manner in which AAC is calculated? Manufacturers often inform the retailer in advance of an impending temporary price reduction, permitting the retailer to completely deplete its inventory and then “forward buying” to overstock at the lower price (Peltzman 2000). Because new purchases form a large proportion of the total inventory in this case, the large discount shows up as a commensurately large reduction in AAC. On the other hand, a retailer buys *less* when the wholesale price goes up. Consequently, a wholesale price *increase* of the same large magnitude as the decrease considered earlier, will translate into a relatively smaller increase in AAC. *Ceteris paribus*, it is reasonable to expect that the observed asymmetry in the small therefore may be driven by such a forward-buying phenomenon.<sup>21</sup>

In the absence of actual wholesale prices, how do we conduct a direct test to check for the above effect? Note that the forward-buying rationale suggests that *if the manner of calculating AAC was the major driver of the observed asymmetry, it should be more pronounced for products that are subjected to greater degree of forward buying*. For products not subject to major fluctuations in its purchases driven by promotional prices, we should expect much lesser degree of such systematic distortion. This leads to the following null proposition, which holds true if the manner of computing AAC was the major driver of our results.<sup>22</sup>

**FORWARD-BUYING PROPOSITION.** *Products subject to greater degree of forward buying will exhibit greater asymmetry than products that are subject to lesser degree of forward buying.*

<sup>21</sup> We thank an anonymous reviewer for alerting us to this potential rival explanation of our results.

<sup>22</sup> This is not to be confused with our theoretical proposition earlier. Here, we intend to check if the “null” (forward buying is a key driver of the observed asymmetry) can be rejected in favor of the “alternate” (that it is not).

Unfortunately, we do not have direct data on the degree of forward buying. However, several authors (Hoch and Banerji 1993, Rao 1991, Lal 1990) have suggested that, in general, private labels are not promoted as heavily, and hence are likely to be forward bought less than national brands.<sup>23</sup> Therefore, a comparison of national brands to private labels provides a natural context to test the above proposition. In essence, if forward buying is the main driver of our results, the predicted asymmetry should be stronger for national brands than for private labels. We therefore undertook two additional analyses to explore whether, and to what extent, can our results be attributed to the method of computing AAC. In the paragraphs below, we discuss the data used for the test and briefly summarize the findings.

**National Brand vs. Private Label Data.** For the purposes of the test, we need data on comparable national brand (NB)–private label (PL) product pairs. We base our identification of such NB–PL pairs on a recently published study of Barsky et al. (2003), who use the same DFF data to investigate the size of markups for nationally branded products sold in the U.S. retail grocery industry. Their measure of markup is based on a comparison of the prices of matched pairs of NB–PL products. To implement their strategy, therefore, Barsky et al. (2003) had to identify the product pairs based on several comparability criteria, which included, among other attributes, product’s quality, size, packaging, etc. For quality comparison, they used Hoch and Banerji’s (1993) PL product quality rankings.

After filtering out the product pairs that were not comparable for various reasons (for example, size differences, quality differences, insufficient number of observations, etc.), Barsky et al. (2003) were left with 231 matched NB–PL product pairs of comparable size and quality, covering 19 product categories.<sup>24</sup> These categories are Analgesics, Bottled Juices, Cereals, Cheeses, Cookies, Crackers, Canned Soups, Dish Detergent, Frozen Entrees, Frozen Juices, Fabric Softeners, Grooming Products, Laundry Detergents, Oatmeal, Snack Crackers, Toothpastes, Toothbrushes, Soft Drinks, and Canned Tuna. However, Barsky et al.

<sup>23</sup> Hoch and Banerji (1993, p. 61) suggest national brands will promote more to reduce private label market share. Also, see Pauwels and Srinivasan (2004). Rao (1991, Table 1, p. 140) presents evidence from three product categories that shows private labels are promoted less frequently than national brands. Lal (1990) argues based on his theoretical model that “... (the private label) has a constant retail price—that is, it is never promoted” (p. 433) and that “... (the empirical evidence) do not contradict the second hypothesis that the local/store brand is promoted less often than the national brands” (p. 439).

<sup>24</sup> See Barsky et al. (2003, Tables 7A.1–7A.19) for a detailed list of the NB–PL product pairs.

(2003) argue that Toothbrushes category is an outlier for its unusually high markup ratio, in comparison to the remaining 18 categories. Consequently, they omit the Toothbrushes category from much of their analysis.<sup>25</sup> Following their strategy, therefore, we also exclude the category of Toothbrushes from our analysis, which leaves us with 18 categories of matched NB–PL pairs for the analysis.

The first analysis compared the aggregate asymmetries between national brands and private labels. No significant difference was found either in the absolute (cents) or relative (percents) asymmetry thresholds. We also did not find any statistical difference in the degrees of asymmetry when we considered the difference between the number of positive and negative changes expressed as a percentage of the number of positive changes.

The second analysis compared category-level asymmetries between national brands and private labels. Again, we found no evidence to suggest that there is a significant difference between the two groups either in absolute (cents) or relative (percents) terms.<sup>26</sup>

**Forward Buying Is Not a Key Driver of the Observed Asymmetry in the Small.** To conclude, it is unlikely that our empirical results are an artifact of the manner in which the wholesale prices have been calculated. We subject the data to a series of tests to check if there are patterns consistent with the forward-buying hypotheses. None of the analyses, whether descriptive, or statistical, provide support for these hypotheses.

Such a conclusion must, however, be tempered with the knowledge that we are after all dealing with a derived measure of wholesale prices, and a better test of our theory would be with actual wholesale prices. Unfortunately, such data are not available. We are not unique in dealing with this problem. A number of other authors who have dealt with it bemoan the lack of proper wholesale price data (cf. Cecchetti 1986, Peltzman 2000, Chintagunta 2002, Levy et al. 2002, Chevalier et al. 2003, etc.). Creative approaches like estimating wholesale prices from regression, which is particularly common in the empirical industrial organization literature (see Carlton and Perloff 1994), using aggregate price indexes as a proxy, such as *Wholesale Price Index* (Cecchetti 1986), rough accounting estimates (Nevo 2001), and even simulation (Tellis and Zufryden 1995) are the norm in such cases. Others may ignore explicit consideration of wholesale prices altogether (Gerstner et al. 1994, Pesendorfer 2002).

<sup>25</sup> See Barsky et al. (2003, p. 194).

<sup>26</sup> Details of these tests are in a technical appendix available at [mktsci.pubs.informs.org](http://mktsci.pubs.informs.org).

While the lack of accurate wholesale price data is unfortunate, we believe that should not hinder theory building in the domain of wholesale prices. Nevertheless, the onus is on the researcher to ensure that any empirical test of theory using weak wholesale data is actually robust to the weakness of the data. It is in that spirit that we conducted these additional checks.

To keep things in perspective, therefore it is necessary to understand that while we stand behind the spirit of our results, we recognize that the verity of the exact magnitudes of the asymmetry we report is subject to some uncertainty.

Overall, by ruling out inflation and forward buying as potential rival explanations of our results, we conclude that our theory offers the most consistent explanation of the observed asymmetry in the small.<sup>27</sup>

## 4. Discussion

Our primary goal in this paper is to offer and empirically validate a theory of asymmetric pricing. To this end, we offer a channel-based theory of asymmetric pricing—that costs of price adjustment for downstream channel members can create an incentive for asymmetric pricing by upstream channel members. We go on to present evidence of asymmetric wholesale pricing “in the small” with symmetric wholesale pricing “in the large,” which is consistent with this theory. To the best of our knowledge, no other paper reports such patterns of asymmetries at the wholesale level.

Theoretically, this paper merges two different lines of research: (1) costs of price adjustment in economics and (2) distribution channels in marketing. By themselves, neither implies asymmetry. Traditional economic theories based on costs of price adjustment suggest that nominal rigidities are usually symmetric, with “prices (responding) similarly to positive and negative shocks” (Ball and Mankiw 1994, p. 247). Similarly, channels of distribution are often argued to be a source of many pricing distortions, (e.g., double marginalization—Jeuland and Shugan 1983, free riding—Bergen and John 1997), but not asymmetry. Taken together, however, costs of price adjustment and channels of distribution suggest ranges of asymmetric pricing by the upstream firm.

<sup>27</sup> Other authors using this data set (e.g., Peltzman 2000) restrict their sample till September 1994 because of a change in manufacturers’ pricing policies from that point in time. To maintain comparability and to rule out this policy change as a driver of our results, we conduct an additional analysis by restricting our sample to the pre-September 1994 period. The details of this test are in the technical appendix available at [mktsci.pubs.informs.org](http://mktsci.pubs.informs.org). Our central result remains unaffected by this change, thereby ruling it out as a central driver of our results. We thank an anonymous reviewer for suggesting this additional check.

Because most of the existing research has focused on asymmetric pricing by a single decision maker (primarily, the retailer), we expand the scope of asymmetry research by explicitly exploring the implications of the business-to-business linkages in a channel. This builds on a long tradition in marketing of using the distribution channel to improve our understanding of a variety of marketing issues beyond the traditional scope of the channels literature.<sup>28</sup>

By combining a channels perspective with the costs of price adjustment perspective, we generate predictions and empirical findings that cannot be easily explained by the existing theories of asymmetric pricing. For example, asymmetry that is driven by inflation (Ball and Mankiw 1994) cannot account for asymmetry in noninflationary periods, or deflationary periods that we observe in our data. Similarly, market power-based explanations for wholesale asymmetry suggest that asymmetric adjustments may be a means to extract monopoly rent from retailers (Benabou and Gertner 1993, Borenstein and Shepard 1996). Yet, this does not explain why we observe asymmetry in small, but not in large wholesale price changes. In the same way, the differences in elasticities and costs across levels of the distribution channel, required to explain asymmetry in Madsen and Yang (1998), does not explain why asymmetry occurs in the small, but not in the large. More generally, Peltzman (2000) concludes, "... attributing asymmetries to imperfect competition is unlikely to be rewarding."

There are also some promising cross-disciplinary theoretical directions that this paper suggests. We extend the marketing literature on channels of distribution to explicitly considering the costs of price adjustment and its implications on channels pricing behavior. Traditionally, these costs of price adjustment have been known as "menu costs" (Ball and Mankiw 1994) and are associated primarily with price rigidity. Although we focus on asymmetric pricing issues, there are many other natural applications for marketers to explore. One direction is how these costs of price adjustment impact pass-through of manufacturer price changes (cf. Kim and Staelin 1999, Tyagi 1999). There is a literature in economics called "stages of processing" that is related to channels of distribution. It has considered the extent of pass-through in the context of studying price rigidity/flexibility in stages of processing, but has not explored price asymmetry. The main focus of these studies has been on the effect of the number of stages of processing on the degree of price flexibility. For example, Blanchard (1983) focuses on the role of price adjustment costs on

the degree of price rigidity in markets with a stages of processing structure (which though not identical, quite resembles the channels structure), and Basu (1995) who studies the role of price adjustment costs in economies with the input-output structure, which is an alternative way of looking at the organization of production in market economies (see also Gordon 1990).

In expanding the costly price adjustment theory to include channels of distribution, we explore how the presence of these costs may fundamentally alter the nature of transactions within the channel as well. The implications are not just price rigidity, which is a direct effect of these costs, but asymmetric pricing, which is more strategic in nature. This suggests that this literature broadens its consideration to look at the impacts of these costs on the incentives and actions of related parties to transactions.

Empirically, we document systematic evidence of asymmetric pricing that, taken in the context of previous empirical research, is particularly surprising. Specifically, Peltzman (2000) studies the same DFF's data set and reports finding *no systematic evidence of asymmetry*. Yet, our results are actually more complementary than contradictory to Peltzman's (2000). The key differences between the papers are the *location* and *size* of asymmetry within the distribution channel. While Peltzman (2000) looked downstream, we look for asymmetry in upstream channel prices. This, in turn, addresses one of Peltzman's (2000) own conclusions that the "vertical market linkages" of a distribution channel may be key factors in asymmetric adjustment. Additionally, Peltzman (2000) looks for asymmetry overall, both the large and the small without distinguishing between the two. Our results suggest the need to consider differences in asymmetry within the magnitude continuum as well.

Finally, our paper has public policy implications. Generally speaking, marketing scholars over the years have consistently called for greater involvement of marketers in shaping public policy (cf. Alderson 1937, Guiltinan and Gundlach 1996). More specifically, policy implications of pricing strategies have been a central concern for a number of marketing researchers (Gerstner and Hess 1990, Wilkie et al. 1998, etc.). Yet, the literature is relatively sparse and in a recent editorial, Grewal and Compeau (1999) point out that "... (there is a need for) ... marketing researchers to examine the public policy issues raised by the strategic pricing practices firms employ." Asymmetric pricing is such a strategy and has not escaped the view of policymakers who worry about prices that are too quick to rise, but are not clear about the central causes. This is evidenced in headlines such as: "California politicians ask for price caps on electricity" (CNN.com 2001), or in comments such as

<sup>28</sup> Examples include product introduction and design (Rao and McLaughlin 1989, Villas-Boas 1998), unbundling (Wilson et al. 1990), advertising (Bergen and John 1997), etc.

U.S. Vice President Dick Cheney's: "We get politicians who want to go out and blame somebody and allege there is some kind of conspiracy, instead of dealing with the real issues" (CNN.com 2001). Our perspective suggests that there may be asymmetric pricing upstream in the channel. But this upstream asymmetry may be bounded by the size of the costs of price adjustment of downstream channel members. Any concern with asymmetric pricing must therefore factor in the efficiency issues inherent in such costs. For example, asymmetric pricing is less likely to be a significant concern for channels that invest in reducing such costs.

## 5. Conclusions

This paper is only another step in our understanding of asymmetric pricing. It does suggest future theoretical work to explore additional implications of costs of price adjustment on pricing, contracting, and design of channels of distribution. Presently, this theory is only applicable in upstream channel pricing. The logic of asymmetric pricing may be extended to retail pricing decisions as well. A couple of recent papers (Chen et al. 2005, Müller and Ray 2006) explore the implications for retail pricing decisions. We call for more investigations in the same vein. We did not have access to wholesaler's cost data. If such data were to become available, future empirical work could take advantage of it to directly assess the implications of this theory. In addition, future work could explore the cross-category differences (Hoch et al. 1995) in the extent of asymmetry.

On another note, recall that we show asymmetric adjustment of wholesale prices is a subgame-perfect equilibrium in a two-period model. One especially promising area of future theoretical research would be to explore the implications for the results if we extend the model to longer time horizons. Such an extension can be done in several ways. If we merely extend the game to  $n$  periods, the results are unlikely to be substantively different from the conclusions we draw from our simpler model. However, the outcomes are not intuitive in a model with *repeated* strategic interactions between manufacturers and retailers. In this context, note that a benefit of having forward-looking retailers in our current model is that—equilibrium retailers are not disadvantaged by asymmetric pricing in the small—they adjust their initial pricing decisions to reflect this economic reality. So, it is not clear that a richer space of punishments, relationships, or prices would necessarily be of any improvement to the retailer in this situation. The costs are real, and as such, any solution would have to factor them into the equilibrium. Nevertheless, while we suspect that

asymmetry will still be an equilibrium outcome, more rigorous theoretical efforts are needed before a definitive answer can be given.

Finally, we hope this paper reinforces the value of bringing scholars in marketing and economics together to study issues of common interest. This paper brings a marketing perspective to this dialog by conducting this investigation in the context of a distribution channel and by considering store-level marketing data. We believe this is the first paper in marketing to incorporate costs of price adjustment explicitly into their analysis. There are a variety of issues in marketing that may benefit from a consideration of these costs of price adjustment in the area of pass-through, promotional pricing, everyday low pricing, etc. It also brings an economic perspective to this dialogue in the work on asymmetric pricing and costs of price adjustment, areas where marketing researchers are relative newcomers but may have important insights and evidence to bring to these areas of inquiry. We feel that both disciplines can benefit greatly from these kinds of cross-disciplinary explorations.

## Acknowledgments

The authors thank the two anonymous reviewers, area editor and the editor, and Steve Shugan, for their constructive comments, suggestions, and guidance through the revision process. Special thanks to our discussant, Justin Johnson, and the participants at the 2002 INFORMS–Cornell Conference on Pricing Research in Ithaca, New York; the 2002 Marketing Science Conference in Edmonton, Alberta; the marketing department seminars at JMSB–Concordia University, HEC, and McGill University, all in Montreal; and at CSOM–University of Minnesota, Minneapolis for their feedback. They also thank Bianca Grohmann for her valuable feedback. Research assistance by Manish Aggarwal is gratefully acknowledged. Parts of this research have been funded by FRDP of Concordia University and by the INE program of SSHRC, Canada. All authors contributed equally. The usual disclaimer applies.

## Appendix

### A.0. General Case of Channel with Costs of Price Adjustment

The general setup of the model is given in the main body of this paper. The solution proceeds by first solving for the  $t_1$  prices  $w_1$  and  $p_1$ , given any  $t_0$  prices  $p_0$  and  $w_0$ . Subsequently, the  $t_0$  results are obtained by incorporating the  $t_1$  solutions. Substituting these back into the  $t_1$  period solutions gives the final results.

**Adjustment Period  $t_1$ .** The solutions are obtained first by solving for  $\delta = 1$  and then for  $\delta = 0$ . In the first case,  $x$  is a fixed exogenous parameter and does not affect the first-order conditions: Hence  $\arg \max_p \{(p - w)D(p) - x\} = \arg \max_p (p - w)D(p)$ . The retailer's price reaction function  $p_1(w)$  solves

$$p(w) = p_1(w) \quad \text{s.t.} \quad p = \frac{w}{1 - 1/\varepsilon_{r1}},$$

$$\text{where} \quad \varepsilon_{r1} = \varepsilon_{r1}(w) = -\frac{\partial \log D}{\partial \log p}. \quad (\text{A.1})$$

Now, the retailer will implement a new price ( $\delta = 1$ ) only if by doing so it is going to be better off than by staying at  $p_0$ . It will not change price ( $\delta = 0$ ) if  $(p_1(w) - w)D(p_1(w)) - x \leq (p_0 - w)D(p_0)$ . The retailer's solution therefore is

$$p(w) = \begin{cases} p_1(w) & \text{if } \Gamma(p_1(w), p_0, x) \\ p_0, & \text{otherwise} \end{cases}, \quad (\text{A.2})$$

where

$$\Gamma(p_1(w), p_0, x) \equiv [\Pi_R(p_1(w)) - x > \Pi_R(p_0)] \quad \text{and}$$

$$\Pi_R(p) = (p - w)D(p).$$

The  $t_1$  period wholesale prices for the manufacturer is obtained by solving

$$\Pi_{m1} = \max(w_1, \delta): \{(w_1 - c - \Delta c)D(p_1) - \delta y\}. \quad (\text{A.3})$$

The manufacturer incurs a cost  $y$  when it changes price ( $\delta = 1$ ) from  $w_0$ . When it does not change price,  $\delta = 0$ .

The manufacturer solutions must also internalize the effects of  $x$ . There are three possible outcomes: (1) both the manufacturer and the retailer readjust their prices, (2) the manufacturer does but the retailer does not readjust, and (3) neither readjusts.<sup>29</sup>

The wholesale solutions then are expressed as

$$w_1 = \begin{cases} w_1 & \text{if } \Gamma(p_1(w_1), p_0, x) \text{ and } \Phi(w_1, w_0, p(w_1), y) \\ w_{11} & \text{if } \Gamma^C(p_1(w_{11}), p_0, x) \text{ and } \Phi(w_{11}, w_0, p(w_{11}), y) \\ w_0 & \text{if } \Phi^C(w_{11}, w_0, p(w_0), y) \end{cases}, \quad (\text{A.4})$$

where  $p(w)$  is the retail reaction function to wholesale prices

$$\begin{aligned} \Gamma(p_1(w), p_0, x) &\equiv [\Pi_R(p_1(w)) - x > \Pi_R(p_0)]; \\ \Gamma^C(\cdot) &\equiv [\Pi_R(p_1(w)) - x \leq \Pi_R(p_0)]; \\ \Phi(w_1, w_0, p(w), y) &\equiv [\Pi_M(w_1) - y > \Pi_M(w_0)]; \\ \Phi^C(\cdot) &\equiv [\Pi_M(w_1) - y \leq \Pi_M(w_0)]; \\ \Pi_R(p) &= (p - w)D(p); \\ \Pi_M(w) &= (w - c - \Delta c)D(p(w)); \\ w_1 &= \arg \max_w \{(w - (c + \Delta c))D(p_1(w))\} \quad \text{s.t.} \\ &\Gamma(p_1(w_1), p_0, x) \text{ and } \Phi(w_1, w_0, p(w_1), y); \\ w_{11} &= \arg \max_w \{(w - (c + \Delta c))D(p_0)\} \quad \text{s.t.} \\ &\Gamma^C(p_1(w_{11}), p_0, x) \text{ and } \Phi(w_{11}, w_0, p(w_{11}), y). \end{aligned} \quad (\text{A.5})$$

The corresponding retail prices are given by

$$p_1 = \begin{cases} p_1 & \text{if } \Gamma(p_1(w_1), p_0, x) \text{ and } \Phi(w_1, w_0, p(w_1), y). \\ p_0, & \text{otherwise} \end{cases} \quad (\text{A.6})$$

<sup>29</sup> The alternative where the retailer readjusts but the manufacturer does not is not feasible in our setup, because if the wholesale prices do not change, retail prices remain unchanged as well.

The  $\Gamma$  and  $\Phi$  conditions in the first rows of both the manufacturer and retailer solutions can now be redefined in terms of the cost changes. In particular, using procedures similar to that used earlier in the main paper, we can show the existence of  $\Delta c_r$  and  $\Delta c_m$  with properties  $\partial|\Delta c_r|/\partial x > 0$  and  $\partial|\Delta c_m|/\partial y > 0$ , respectively, such that

$$\Gamma(\cdot) \Rightarrow |\Delta c| > |\Delta c_r| \quad \text{and} \quad \Phi(\cdot) \Rightarrow |\Delta c| > |\Delta c_m|. \quad (\text{A.7})$$

**Initial Period  $t_0$ .** The  $t_1$  solutions are then incorporated into the  $t_0$  problem to solve for  $p_0^*$  and  $w_0^*$ . First, the retail reaction function  $p_0(w_0)$  is obtained from

$$\text{Max}(p_0; p_1^e): \{(p_0 - w_0)D(p_0)\} + \{(p_1^e - w_1^e)D(p_1^e)\}, \quad (\text{A.8})$$

where  $p_1^e = p_0 + \Delta p^e$  and  $w_1^e = w_0 + \Delta w^e$ , the superscript “e” denoting the prices expected by the retailer in the adjustment period. Next, this is substituted into the manufacturer problem to solve

$$\begin{aligned} \text{Max}(w_0; w_1^e): \{(w_0 - c)D(p_0(w_0))\} \\ + \{(w_1^e - c - E(\Delta c))D(p_1^e)\}, \end{aligned} \quad (\text{A.9})$$

where  $E(\Delta c)$  is the expectation of  $\Delta c$  based on the distributional assumptions made earlier.

The solutions  $p_0^*$  and  $w_0^*$  are then substituted back into the  $t_1$  solutions to get  $p_1^*$  and  $w_1^*$ .

With this general problem as the background, we will now consider the role of the upstream costs of price adjustment,  $y$  for our results.<sup>30</sup>

### A.1. Pricing with Only Upstream Costs of Price

#### Adjustment ( $y > 0$ , $x \approx 0$ ): Rigidity

We start by exploring the role of  $y$  in isolation of any channel effects. For this, we set  $x \approx 0$  and let  $y > 0$ . The results show that  $y$  by itself only leads to price rigidity but not asymmetry.

**Adjustment Period  $t_1$ .** The manufacturer will not implement a new price if it is better off by staying at  $w_0^*$ . Since  $p_0^*$  remains the profit-maximizing retail price if wholesale prices remain at  $w_0^*$ , the condition when the wholesale does not change can be written as

$$\{w_1^* - (c + \Delta c)\}D(p_1(w_1^*)) - y \leq \{w_0^* - (c + \Delta c)\}D(p_0^*). \quad (\text{A.10})$$

The equilibrium channel prices can then be expressed as

$$(w_1, p_1) = \begin{cases} (w_1^*, p_1^*) & \text{if } \Phi(w_1^*, w_0^*, p(w), y) \\ (w_0^*, p_0^*), & \text{otherwise} \end{cases}, \quad (\text{A.11})$$

where  $w_1^*$  solves  $w = (c + \Delta c)/(1 - 1/\varepsilon_{m1})$ ;  $p_1^* = p_1(w_1^*)$ ;  $\Phi$  as defined earlier in (A.5), is given by

$$\begin{aligned} \Phi(w_1, w_0, p(w), y) &\equiv [\Pi_M(w_1) - y > \Pi_M(w_0)] \\ \text{with } \Pi_M(w) &= (w - c - \Delta c)D(p(w)). \end{aligned}$$

Using procedures similar to earlier, it follows from (A.10) and (A.11) that there exists a  $\Delta c_{x0}$  with the

<sup>30</sup> For ease of exposition and notational economy, we will henceforth derive the  $t_1$  period solutions as functions of  $w_0^*$  and  $p_0^*$  and solve for the functional forms of  $w_0^*$  and  $p_0^*$  later when solving the  $t_0$  period problem.

property  $\partial|\Delta c_{x0}|/\partial y > 0$  such that prices are unchanged for  $|\Delta c| \leq |\Delta c_{x0}|$ . (A.12)

Hence the primary contribution of price adjustment costs at the manufacturer end in this setup is *price rigidity at both wholesale and retail when cost changes are small enough*. For  $|\Delta c| > |\Delta c_{x0}|$ , wholesale prices adjust to  $w_1^*$  and retail prices to  $p_1^*$ . Notice that this adjustment pattern is symmetric in that both negative and positive  $\Delta c$  will elicit matching positive and negative price adjustments. In fact, if we abstract away from the channel and look at the price adjustment decisions of an individual economic agent (i.e., when  $p(w) = w$ ),<sup>31</sup> we are led to conclude that *while it leads to price rigidity, price adjustment cost per se does not lead to asymmetric pricing*. This is a standard result in the costs of adjustment literature (cf. Carlton 1986, Danziger 1987, Kashyap 1995, etc.).

**Initial Period  $t_0$ .** Now, note that the rigidity imposed by  $y$  creates a potential marginal distortion for the manufacturer of magnitude  $|\Delta c_{x0}|$ . In this region of small costs changes, there would be no change in demand as there would be no change in manufacturer prices. In other words, even if costs were to go up by  $|\Delta c_{x0}|$  (with the commensurate negative effect on profits), the manufacturer will not adjust its prices in  $t_1$ . A profit-maximizing manufacturer would incorporate this in its  $t_0$  solution. The  $t_0$  solution for manufacturer prices therefore is obtained by setting  $E(\Delta c) = |\Delta c_{x0}|$ :

$$\max(w): \{(w - c)D(p_0^*) + (w - c - |\Delta c_{x0}|)D(p_0^*)\}. \quad (\text{A.12})$$

The solution gives  $w_0^*$ , which solves

$$w = \frac{2c + |\Delta c_{x0}|}{2(1 - 1/\varepsilon_{m0})}, \quad \text{where } \varepsilon_{m0} = \varepsilon_0(p_0(w)) = -\frac{\partial \log D}{\partial \log w}. \quad (\text{A.13})$$

This price would remain in effect in  $t_1$  unless  $|\Delta c| > |\Delta c_{x0}|$ , when as per the  $t_1$  period solutions, prices will adjust symmetrically. The manufacturer acting in a forward-looking manner therefore compensates for its cost of adjustment by charging  $|\Delta c_{x0}|/(2(1 - 1/\varepsilon_{m0}))$  more in the initial period than what it would charge if it did not have any such costs.

## A.2. Pricing with Both Up and Downstream Costs of Price Adjustment ( $y > 0, x > 0$ )

We now consider the more general case discussed earlier ( $x > 0, y > 0$ ). This explores how  $y$  may affect the asymmetry results obtained earlier. The main conclusion is that  $y$  implies regions of wholesale price rigidity, but not asymmetry. We start by considering the different cases dependent on the relative magnitude of  $y$ .

First, for convenience, we present the general solution for period  $t_1$  in terms of the ranges of cost changes

$$(w_1, p_1) = \begin{cases} (w_1^*, p_1^*) & \text{if } |\Delta c| > |\Delta c_r| \text{ and } |\Delta c| > |\Delta c_m| \\ (w_{11}^*, p_0^*) & \text{if } |\Delta c| \leq |\Delta c_r| \text{ and } |\Delta c| > |\Delta c_m| \\ (w_0^*, p_0^*) & \text{if } |\Delta c| \leq |\Delta c_m| \end{cases} \quad (\text{A.14})$$

### 1. Large $y$ : Rigidity

Suppose now,  $y$  is large ( $y \gg x$ ). In particular, let  $y$  be large enough such that  $|\Delta c_m| \geq |\Delta c_r|$ .<sup>32</sup>

**Adjustment Period  $t_1$ .** When  $|\Delta c_m| \geq |\Delta c_r|$ , the condition in the second row of the manufacturer solution is not feasible. We can then rewrite the equilibrium channel prices in  $t_1$  as

$$(w_1, p_1) = \begin{cases} (w_1^*, p_1^*) & \text{if } |\Delta c| > |\Delta c_m| \\ (w_0^*, p_0^*), & \text{otherwise} \end{cases} \quad (\text{A.15})$$

Hence, for large  $y$ , the main implication of price adjustment costs is still one of rigidity in channel prices for small enough cost changes.

**Initial Period  $t_0$ .** In  $t_0$ , the retailer solution is simply  $p_0^* = w_0^*/(1 - 1/\varepsilon_{r0})$ .

The manufacturer solution, on the other hand, is obtained in a manner similar to the earlier subsection, by considering  $\Delta c_m$  instead of  $\Delta c_{x0}$ :

$$w_0^* = \frac{2c + |\Delta c_m|}{2(1 - 1/\varepsilon_{m0}^*)}, \quad \text{where } \varepsilon_{m0}^* = \varepsilon_0(p_0^*(w_0^*)) = -\frac{\partial \log D}{\partial \log w}. \quad (\text{A.16})$$

### 2. Small $y$ : Asymmetry

Let  $y$  be small:  $y \ll x$ . In particular, let  $y$  be small enough such that  $|\Delta c_m| < |\Delta c_r|$ . In this subsection, we will first solve the  $t_1$  prices and derive the  $t_0$  prices for the special cases of different magnitudes of  $y$  discussed subsequently.

The  $t_1$  equilibrium prices can be derived from (A.4) and (A.15), which are equivalent. From (A.15), if  $|\Delta c_m| < |\Delta c_r|$ , then  $|\Delta c| > |\Delta c_m|$  is identically satisfied whenever  $|\Delta c| > |\Delta c_r|$  and  $(w_1^*, p_1^*)$  are the equilibrium prices. Then,  $w_1^* = (c + \Delta c)/(1 - 1/\varepsilon_{m1}^*)$  is the solution to  $\max_w \{(w - (c + \Delta c))D(p_1(w))\}$  s.t.  $|\Delta c| > |\Delta c_r|$ .

From the functional form, it is clear that *given small  $y$ , for large enough cost changes ( $|\Delta c| > |\Delta c_r|$ ), the wholesale price here is still symmetric with respect to positive and negative directions of cost changes*.

$p_1^*$  can be obtained from the retail reaction function  $p_1^* = w_1^*/(1 - 1/\varepsilon_{r1}^*)$ .

Now, what happens when the costs changes are small—specifically,  $|\Delta c| \leq |\Delta c_r|$ ? From (A.15),  $w_{11}^*$  is the solution to  $\max_w \{(w - (c + \Delta c))D(p_0^*)\}$ . Using the equivalency between (A.4) and (A.15), since demand is independent of  $w$ , this maximization boils down simply to maximizing  $w$  subject to the conditions  $\Gamma^C(\cdot)$  and  $\Phi(\cdot)$  in (A.4). The  $\Gamma^C(\cdot)$  implies  $(p_1^* - w_{11})D(p_1^*) - x \leq (p_0^* - w_{11})D(p_0^*)$ . Using procedures similar to that employed earlier, we can express this as

$$-|\Delta w_r^*| \leq \Delta w^* \leq |\Delta w_r^*|, \quad \text{where } \Delta w_r^* = \frac{(p_1^* - w_0^*)D(p_1^*) - (p_0^* - w_0^*)D(p_0^*) + x}{|D(p_0^*) - D(p_1^*)|}. \quad (\text{A.17})$$

Since the maximization exercise involves maximizing the wholesale price,  $w_{11}^* = w_0^* + |\Delta w_r^*|$  is the profit-maximizing

<sup>31</sup> Essentially, completely ignoring the existence of the retailer in the above case.

<sup>32</sup> Recall that  $\partial|\Delta c_m|/\partial y > 0$ .

solution.<sup>33</sup> The corresponding  $\Phi$  condition can therefore be written as  $(w_0 + |\Delta w_r^*| - c - \Delta c)D(p_0^*) - y > (w_0^* - c - \Delta c) \cdot D(p_0^*)$  or

$$|\Delta w_r^*|D(p_0^*) > y. \quad (\text{A.18})$$

So, as expected, for small cost changes ( $|\Delta c| \leq |\Delta c_r|$ ), the results predict asymmetry. However, this asymmetry appears contingent on certain magnitudes of  $y$ . So, now let us consider the implication the magnitude of  $y$  has on the final solutions. Let

$$y^* = |\Delta w_r^*|D(p_0^*) \quad (\text{A.19})$$

**Case A**  $y > y^*$ .

**Adjustment Period  $t_1$ .** If  $y > y^*$ , the corresponding  $\Phi$  condition (A.19) is always violated ( $|\Delta c| \leq |\Delta c_m|$ ) and manufacturer prices remain unchanged at  $w_0^*$ . Without any change in wholesale prices, the retail prices also remain unchanged at  $p_0^*$ .

Hence, when  $y$  is large enough, the results predict rigidity for both upstream and downstream prices.

**Initial Period  $t_0$ .** Since  $|\Delta c_m|$  represents the marginal distortion because of its costs of price changes, the manufacturer sets the  $w_0^*$  that maximizes

$$\Pi_m = \max_w \{(w - c)D(p(w)) + (w - c - |\Delta c_m|)D(p(w))\}.$$

The solution gives  $w_0^*$ , which solves

$$w_0^* = \frac{2c + |\Delta c_m|}{2(1 - 1/\varepsilon_{m0}^*)}, \quad \text{where } \varepsilon_{m0}^* = \varepsilon_0(p_0(w_0^*)) = -\frac{\partial \log D}{\partial \log w}. \quad (\text{A.20})$$

As before, the manufacturer, acting in a forward-looking manner, therefore compensates for its cost of adjustment by charging  $|\Delta c_m|/(2(1 - 1/\varepsilon_{m0}^*))$  more in the initial period than what it would charge if it did not have any such costs.

$p_0^*$  is obtained by substituting  $w_0^*$  into the retail reaction function  $p_0^* = w_0^*/(1 - 1/\varepsilon_{r1}^*)$ .

**Case B**  $0 \leq y \leq y^*$ .

**Adjustment Period  $t_1$ .** If  $y$  is quite small, in particular, if  $y \leq y^*$ , the  $\Phi$  condition (A.19) is identically satisfied for all  $\Delta c$ . When (A.19) is thus satisfied,  $w_{11}^* = w_0^* + |\Delta w_r^*|$  is the solution.

The equilibrium channel prices when  $0 < y \leq y^*$  then are

$$(w_1, p_1) = \begin{cases} (w_1^*, p_1^*) & \text{if } |\Delta c| > |\Delta c_r| \\ (w_0^* + |\Delta w_r^*|, p_0^*), & \text{otherwise} \end{cases}. \quad (\text{A.21})$$

$p_1^*$  can be derived by substituting  $w_1^*$  in the reaction function  $p_1^*(w_1^*) = w_1^*/(1 - 1/\varepsilon_{r1}^*)$ , which would be symmetric to any changes in wholesale prices.

Hence, when  $y$  is small enough, the results predict asymmetry for upstream prices. This is very similar to the effect illustrated in the main paper.

<sup>33</sup>  $w_{11} > w_{11}^*$  is not profit maximizing here. In that case,  $\Delta w > \Delta w_r^*$  and the  $\Gamma^C$  condition is violated—in other words, the retail price will change and our maximization exercise will be different, with  $w_1^*$  as the profit-maximizing outcome.

**Initial Period  $t_0$ .** The initial period solutions are obtained as solved in the main paper. Essentially, the retailer's solution would take into account the expected wholesale prices in the next period. This price would remain in effect unless  $|\Delta w| > |\Delta w_r^*|$ . The equilibrium retail price at  $t_0$  therefore is obtained from

$$\Pi_r = \max_p \{(p - w_0^*)D(p(w)) + (p - w_0^* - |\Delta w_r^*|)D(p(w))\}. \quad (\text{A.22})$$

The solution gives  $p_0^*$

$$p_0^* = \frac{2w_0^* + |\Delta w_r^*|}{2(1 - 1/\varepsilon_{r0}^*)}, \quad \text{where } \varepsilon_{r0}^* = \varepsilon_0(p_0^*) = -\frac{\partial \log D}{\partial \log p}. \quad (\text{A.23})$$

To derive the manufacturer prices, we fold the retail solution back into the manufacturer problem. In doing so, we consider the magnitude of the expected cost change and the upward adjustment of the wholesale prices as discussed earlier in the main paper. To set  $w_0^*$ , therefore, the manufacturer maximizes over the two periods as

$$\Pi_m = \max_w \{(w - c)D(p_0(w)) + (w + |\Delta w_r^*| - c)D(p_0(w))\}. \quad (\text{A.24})$$

The solution gives

$$w_0^* = \frac{2c - |\Delta w_r^*|}{2(1 - 1/\varepsilon_{m0}^*)}, \quad \text{where } \varepsilon_{m0}^* = \varepsilon_0(p_0^*(w_0^*)) = -\frac{\partial \log D}{\partial \log w}. \quad (\text{A.25})$$

These  $t_0$  prices remain in effect unless the magnitude of the cost change is large enough ( $|\Delta c| > |\Delta c_r|$ ) to effect a change in channel prices.

Consider now the implications of the solutions for channel prices. For retail prices, we still predict *symmetric adjustment* for large cost changes ( $|\Delta c| > |\Delta c_r|$ ), but (symmetric) *rigidity* when cost changes are small enough ( $|\Delta c| \leq |\Delta c_r|$ ).

For wholesale prices, the results are a function of the magnitude of  $y$ . When  $y$  is large ( $y > y^*$ ), we get (symmetric) rigidity for small costs changes ( $|\Delta c| \leq |\Delta c_r|$ ). When the cost change is large enough ( $|\Delta c| > |\Delta c_r|$ ), we get symmetric adjustment. When  $y$  is small ( $y \leq y^*$ ), however, we get asymmetry for small costs changes ( $|\Delta c| \leq |\Delta c_r|$ ) and symmetric adjustment for large ones ( $|\Delta c| > |\Delta c_r|$ ).

The intuition behind the asymmetry results is derived from the impact of the retailer's costs of price adjustment,  $x$  and the resulting retail price rigidity. This creates a region of wholesale price changes (both positive and negative) where the demand is inelastic, leading to the asymmetric adjustment of wholesale prices. The manufacturer costs,  $y$ , however, does not play any direct role in this asymmetry. Its primary role in this setup is to determine when the manufacturer will not find it profitable to change its wholesale prices. Since retail prices only change following wholesale price changes, this implies that  $y$ 's primary contribution is in determining regions of wholesale, and by corollary, retail price rigidity.

Interestingly, wholesale asymmetry (when wholesale price changes in the adjustment period) persists even for very small cost changes in spite of the fact that manufacturer costs of price adjustment  $y > 0$ . This happens because, in the region of retail rigidity, the manufacturer can compensate  $y$  by the increase in profits that follows asymmetric

positive adjustment. However, this is only true for small enough  $y$ . For large enough  $y$ , this asymmetry will not happen because the manufacturer cannot compensate  $y$  by the increase in profits because of the asymmetric adjustment. If  $y$  is so large that the manufacturer will implement only a large wholesale price change, we may not see any rigidity at retail because the magnitude of wholesale price change may be larger than the region of retail rigidity.

It is worthwhile to note that even if wholesale asymmetry is a direct result of retail rigidity, it does not imply that retailers will be taken advantage of. The fact that forward-looking retailers will take these costs into account when setting initial and future prices is a standard result in the economics literature. In our case, the nature of the expected distortions in the adjustment period, introduced by these costs, is incorporated in the initial period prices.

In conclusion, when  $y$  is large ( $y \gg x$ ), the main prediction is rigidity in channel prices for small enough cost changes. However, generally speaking,  $y \ll x$ .<sup>34</sup> In this case, wholesale price changes are *symmetric* with respect to large positive and negative cost changes. However, for *small* cost changes, the results predict *asymmetry*, depending on the magnitude of  $y$ . Specifically, when  $y > y^*$ , where  $y^* = |\Delta w_r|/D(p_0^*)$ , the results predict rigidity for both upstream and downstream prices. However, when  $y \leq y^*$ , the results predict *asymmetry* for upstream prices. This is stated in the following research proposition.

**PROPOSITION 1A.** *When  $y$  is small ( $0 < y \leq y^*$ ), there is a range of cost changes for which the manufacturer will adjust its wholesale prices asymmetrically. In particular, the manufacturer will only adjust its prices upwards regardless of the direction of cost changes, in a region of cost changes of small magnitudes:  $-\lvert\Delta c_r\rvert \leq \Delta c \leq \lvert\Delta c_r\rvert$ . For cost changes of larger magnitudes, the wholesale prices will adjust symmetrically.*

## References

- Alderson, W. 1937. A marketing view of competition. *J. Marketing* 1(3) 189–190.
- Bacon, R. W. 1991. Rockets and feathers: The asymmetric speed of adjustment of U.K. retail gasoline prices to cost changes. *Energy Econom.* 13(3) 211–218.
- Ball, L., N. G. Mankiw. 1994. A sticky-price manifesto. *Carnegie-Rochester Conference Series on Public Policy*, Vol. 41. Pittsburgh, PA, 127–152.
- Ball, L., N. G. Mankiw. 1995. Relative price changes as aggregate supply shocks. *Quart. J. Econom.* 110(1) 161–193.
- Barboya, David. 1997. The great pork gap: Hog prices have plummeted. Why haven't store prices? *New York Times* (January 7), Sect. C, Col. 2, 1.
- Barsky, R., M. Bergen, S. Dutta, D. Levy. 2003. What can the price gap between branded and generic products tell us about markups? R. Feenstra, M. Shapiro, eds. *Scanner Data and Price Indexes*. National Bureau of Economic Research, University of Chicago Press, Chicago, IL, 165–225.
- Basu, S. 1995. Intermediate goods and business cycles: Implications for productivity and welfare. *Amer. Econom. Rev.* 85(3) 512–531.
- Benabou, R., R. Gertner. 1993. Search with learning from prices—Does increased inflationary uncertainty lead to higher markups? *Rev. Econom. Stud.* LX 69–93.
- Bergen, M., G. John. 1997. Understanding cooperative advertising participation rates in conventional channels. *J. Marketing Res.* XXXIV(Aug.) 357–369.
- Bergen, M., S. Dutta, S. M. Shugan. 1996. Branded variants: A retail perspective. *J. Marketing Res.* XXXIII 9–19.
- Blanchard, O. J. 1983. Price asynchronization and price-level inertia. R. Dornbusch, M. Simonsen, eds. *Inflation, Debt, and Indexation*. MIT Press, Cambridge, MA, 3–24.
- Blinder, A. S., E. R. D. Canetti, D. E. Lebow, J. B. Rudd. 1998. *Asking about Prices: A New Approach to Price Stickiness*. Russell Sage Foundation, New York.
- Borenstein, S., A. Shepard. 1996. Dynamic pricing in retail gasoline markets. *RAND J. Econom.* XXVII 429–451.
- Borenstein, S., C. A. Cameron, R. Gilbert. 1997. Do gasoline prices respond asymmetrically to crude oil price changes? *Quart. J. Econom.* 112(1) 305–339.
- Boyde, M. S., W. B. Brorsen. 1988. Price asymmetry in the U.S. pork marketing channel. *North Central J. Agricultural Econom.* 10(1) 103–109.
- Cagan, P. 1974. The hydra-headed monster: The problem of inflation in the United States. Domestic affairs case study no. 26, American Enterprise Institute, Washington, D.C.
- Canadian Press Newswire. 2000. Cheesed off: Retail price of cheese, ice cream may rise with wholesale hike. December 18, Section D 8'00.
- Carlton, D. W. 1986. The rigidity of prices. *Amer. Econom. Rev.* 76(4) 637–658.
- Carlton, D., J. Perloff. 1994. *Modern Industrial Organisation*. Harper-Collins, New York.
- Cecchetti, S. 1986. The frequency of price adjustment: A study of the newsstand prices of magazines. *J. Econometrics* 31 255–274.
- Chen, H., S. Ray, M. Bergen, D. Levy. 2005. Asymmetric price adjustment in the small: An implication of rational inattention. Working paper, Winter 2002 North American Meeting of the Econometric Society, Atlanta, GA.
- Chevalier, J., A. Kashyap, P. Rossi. 2003. Why don't prices rise during periods of peak demand? Evidence from scanner data. *Amer. Econom. Rev.* 93(1) 15–37.
- Chintagunta, P. 2002. Investigating category pricing behavior in a retail chain. *J. Marketing Res.* 39(2) 141–154.
- Choi, S. C. 1991. Price competition in a channel with a common retailer. *Marketing Sci.* 10(4) 271–296.
- Danziger, L. 1987. Inflation, fixed cost of price adjustments, and measurement of relative price variability. *Amer. Econom. Rev.* 77(4) 704–713.
- Desai, P. S., D. Purohit. 2004. "Let me talk to my manager:" Haggling in a competitive environment. *Marketing Sci.* 23(2) 219–233.
- DeSarbo, W. S., V. R. Rao, J. H. Steckel, J. Wind, R. Colombo. 1987. A friction model for describing and forecasting price changes. *Marketing Sci.* 6(4) 299–319.
- Dutta, S., M. Bergen, D. Levy. 2002. Price flexibility in channels of distribution: Evidence from scanner data. *J. Econom. Dynam. Control* 26(11) 1845–1900.
- Dutta, S., M. Bergen, D. Levy, R. Venable. 1999. Menu costs, posted prices, and multiproduct retailers. *J. Money, Credit, and Banking* 31(4) 683–703.
- Gerstner, E., J. D. Hess. 1990. Can bait and switch benefit consumers? *Marketing Sci.* 9(2) 114–124.
- Gerstner, E., J. D. Hess, D. M. Holthausen. 1994. Price discrimination through a distribution channel: Theory and evidence. *Amer. Econom. Rev.* 84(5) 1437–1445.
- Gordon, R. J. 1990. What is new-Keynesian economics? *J. Econom. Literature* 28(3) 1115–1171.
- Greenleaf, E. A. 1995. The impact of reference price effects on the profitability of price promotions. *Marketing Sci.* 14(1) 82–104.
- Grewal, D., L. D. Compeau. 1999. Pricing and public policy: A research agenda and an overview of the special issue. *J. Public Policy and Marketing* 18(1) 3–10.

<sup>34</sup> See the empirical section of the main paper for a discussion.



- Guiltinan, J. P., G. T. Gundlach. 1996. Aggressive and predatory pricing: A framework for analysis. *J. Marketing* 60(3) 87–102.
- Hannan, T. H., A. N. Berger. 1991. The rigidity of prices: Evidence from the banking industry. *Amer. Econom. Rev.* 81(4) 938–945.
- Hess, J. D., E. Gerstner. 1987. Loss leader pricing and rain check policy. *Marketing Sci.* 6(4) 358–374.
- Hoch, S., S. Banerji. 1993. When do private labels succeed? *Sloan Management Rev.* 34(4) 57–67.
- Hoch, S. J., B. D. Kim, A. L. Montgomery, P. E. Rossi. 1995. Determinants of store-level price elasticity. *J. Marketing Res.* 32 17–29.
- Ingene, C. A., M. E. Parry. 1995. Channel coordination when retailers compete. *Marketing Sci.* 14(4) 360–377.
- Jeuland, A. P., S. M. Shugan. 1983. Managing channel profits. *Marketing Sci.* 2(3) 239–272.
- Kadiyali, V., P. Chintagunta, N. Vilcassim. 2000. Manufacturer-retailer channel interactions and implications for channel power: An empirical investigation of pricing in a local market. *Marketing Sci.* 19(2) 127–148.
- Karrenbrock, J. D. 1991. The behavior of retail gasoline prices: Symmetric or not? *Federal Reserve Bank of St. Louis Rev.* 73(4) 19–29.
- Kashyap, A. K. 1995. Sticky prices: New evidence from retail catalogues. *Quart. J. Econom.* 110(1) 245–274.
- Kim, S. Y., R. Staelin. 1999. Manufacturer allowances and retailer pass-through rates in a competitive environment. *Marketing Sci.* 18(1) 59–76.
- Kopalle, P. K., A. G. Rao, J. L. Assuncao. 1996. Asymmetric reference price effects and dynamic pricing policies. *Marketing Sci.* 15(1) 60–85.
- Lal, R. 1990. Manufacturer trade deals and retail price promotions. *J. Marketing Res.* 27 428–444.
- Levy, D., S. Dutta, M. Bergen. 2002. Heterogeneity in-price rigidity: Evidence from a case study using micro-level data. *J. Money, Credit, and Banking* 34(1) 197–220.
- Levy, D., M. Bergen, S. Dutta, R. Venable. 1997. The magnitude of menu costs: Direct evidence from large U.S. supermarket chains. *Quart. J. Econom.* 112 791–825.
- Levy, D., S. Dutta, M. Bergen, R. Venable. 1998. Price adjustment at multiproduct retailers. *Managerial Decisions Econom.* 19(2) 81–120.
- Levy, D., B. Zelig, P. Rubin, S. Ray, M. Bergen. 2005. When little things mean a lot: On the inefficiency of item pricing laws. Working paper, Law and Economics Workshop, Summer 2003 NBER, Cambridge, MA.
- Litwak, David, Nancy Maline. 1993. A year of learning to play the new game. *Supermarket Bus.* 48(9) 47–70.
- Madsen, J. B., B. Z. Yang. 1998. Asymmetric price adjustment in a menu-cost model. *J. Econom.* 68(3) 295–309.
- Mankiw, N. G. 1985. Small menu costs and large business cycles: A macroeconomic model of monopoly. *Quart. J. Econom.* 100(May) 529–539.
- Messinger, P. R., C. Narasimhan. 1995. Has power shifted in the grocery channel? *Marketing Sci.* 14(2) 189–223.
- Moorthy, K. S. 1988. Strategic decentralization in channels. *Marketing Sci.* 7(4) 335–355.
- Müller, G., S. Ray. 2006. Asymmetric price adjustments: Evidence from weekly product-level scanner price data. *Managerial Decision Econom.* Forthcoming.
- Neumark, D., S. A. Sharpe. 1992. Market structure and the nature of price rigidity: Evidence from the market for consumer deposits. *Quart. J. Econom.* 107(2) 657–680.
- Nevo, A. 2001. Measuring market power in the ready-to-eat cereal industry. *Econometrica* 69(2) 307–342.
- Octane Week. 1999. June 13 (6–7).
- Pauwels, K., S. Srinivasan. 2004. Who benefits from store brand entry? *Marketing Sci.* 23(3) 364–390.
- Peltzman, S. 2000. Prices rise faster than they fall. *J. Political Econom.* 108(3) 466–502.
- Pesendorfer, M. 2002. Retail sales: A study of pricing behavior in supermarkets. *J. Bus.* 75(1) 33–66.
- Pick, D. H., J. Karrenbrock, H. F. Carmen. 1991. Price asymmetry and marketing margin behavior: An example for California-Arizona citrus. *Agribusiness* 6(1) 75–84.
- Rao, R. C. 1991. Pricing and promotions in asymmetric duopolies. *Marketing Sci.* 10(2) 131–144.
- Rao, V. R., E. W. McLaughlin. 1989. Modeling the decision to add new products by channel intermediaries. *J. Marketing* 53(Jan.) 80–88.
- Ratchford, B. T., N. Srinivasan. 1993. An empirical investigation of returns to search. *Marketing Sci.* 12(1) 73–87.
- Roll, R. 1984. Orange juice and weather. *Amer. Econom. Rev.* 74 861–880.
- Slade, M. E. 1998. Optimal pricing with costly adjustment: Evidence from retail-grocery prices. *Rev. Econom. Stud.* 65 87–107.
- Tellis, G. J., F. S. Zufryden. 1995. Tackling the retailer decision maze: Which brands to discount, how much, when and why? *Marketing Sci.* 14(3) 271–299.
- Tyagi, R. K. 1999. A characterization of retailer response to manufacturer trade deals. *J. Marketing Res.* 36(4) 510–516.
- Villas-Boas, J. M. 1998. Product line design for a distribution channel. *Marketing Sci.* 17(2) 156–169.
- Ward, R. W. 1982. Asymmetry in retail, wholesale and shipping point pricing for fresh vegetables. *Amer. Agricultural Econom. Association* 14(May) 205–215.
- Wilkie, W. L., C. F. Mela, G. T. Gundlach. 1998. Does “bait and switch” really benefit consumers? *Marketing Sci.* 17(3) 273–282.
- Wilson, L. O., A. M. Weiss, G. John. 1990. Unbundling of industrial systems. *J. Marketing Res.* XXVII 123–138.
- Zbaracki, M., M. Ritson, D. Levy, S. Dutta, M. Bergen. 2004. The managerial and customer costs of price adjustment: Direct evidence from industrial markets. *Rev. Econom. Statist.* 86(2) 514–533.