

# Consumption Inertia and Asymmetric Price Transmission

Tian Xia and Xianghong Li

We propose consumption inertia as a new explanation for asymmetric price transmission. Inertia in consumer demand enlarges retailers' gains in gross profits from raising prices in response to higher wholesale prices and reduces gains from decreasing prices in response to lower wholesale prices. Thus, consumption inertia can cause asymmetries in price transmission whereby retailers are more willing to change their prices, and change them more quickly, in response to wholesale price increases as opposed to wholesale price decreases.

*Key Words:* asymmetric price transmission, consumption inertia, market power, retail pricing

## Introduction

Price transmissions along many agricultural product market chains are asymmetric in that input price increases are often more quickly or fully transmitted to output prices than price decreases (Meyer and von Cramon-Taubadel, 2004; Frey and Manera, 2007). Asymmetry of price transmission from wholesale to retail markets prevents consumers from enjoying earlier and greater reductions in retail prices and prevents wholesalers from benefiting from faster and larger increases in retail sales as wholesale prices decrease. Thus, this asymmetry harms the interests of both consumers and wholesalers. Some of these effects may be transferred to farmers through the procurement of agricultural commodities. Understanding the reasons for asymmetric price transmission (APT) can have significant welfare and policy implications.

Consumption inertia refers to a gradual adjustment of consumption levels in response to retail price changes. The gradual adjustment occurs primarily because of existing consumption habits. Specifically, consumption inertia implies consumption changes are smaller in the short run than in the long run. We develop a simple conceptual framework to examine the effects of consumption inertia on asymmetries in price transmission from wholesale to retail markets. We show that this inertia increases retailers' profits from raising prices in response to wholesale price increases and reduces profits from lowering prices in response to wholesale price decreases. Hence, consumption inertia can cause asymmetries in price transmission, where retailers change their prices faster in response to wholesale price increases than decreases.

Consumption inertia can cause faster transmission of wholesale price increases to retail markets. This asymmetry has been investigated in previous empirical studies, but appears to conflict with theoretical predictions (Meyer and von Cramon-Taubadel, 2004). Empirical studies that find asymmetries in the speed of price transmission provide evidence of unidirectional APT; i.e., wholesale or farm price increases are transmitted faster to retail markets than price decreases (Kinnucan and Forker, 1987; Frigon, Doyon, and Romain, 1999; Peltzman, 2000; Miller and Hayenga, 2001).

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### Literature Review

Asymmetric price transmission occurs primarily in agricultural and food industries. In their survey of literature, Meyer and von Cramon-Taubadel (2004) found that 27 of 40 empirical studies on APT investigate agricultural and food markets. Frey and Manera's (2007) survey of 70 studies on the subject confirmed that APT exists widely in agricultural, food, and gasoline markets. As reported by Peltzman (2000), in more than two-thirds of examined markets, including many agricultural and food markets, output prices rise faster than they fall in response to input price changes. Table 1 provides a summary of APT studies on individual agricultural and food industries.

Imperfect competition offers one explanation for asymmetric price transmission (Bailey and Brorsen, 1989; Borenstein, Cameron, and Gilbert, 1997; Azzam, 1999). Retailers and processors with market power may quickly raise output prices in response to input price increases to minimize profit losses. However, input price decreases extend profit margins if transmitted slowly to output prices. Based on findings of a group of theoretical studies (Barro, 1972; Blinder, 1982; Reagan and Weitzman, 1982; Ball and Mankiw, 1994; Balke, Brown, and Yücel, 1998), APT may result from asymmetry in firms' adjustment costs with respect to increasing or decreasing prices, production levels, and inventory. Several studies (Azzam, 1999; Fousekis, 2008; Xia, 2009) found that consumer demand and farm supply function curvature can cause asymmetries in the magnitude of price transmission from farm or wholesale to retail markets.

Existing theoretical studies provide ambiguous or conflicting results regarding the directionality of price transmission asymmetries. Some results offer explanations for faster or more complete transmission of farm or wholesale price increases to the retail level. Other results suggest farm or wholesale price increases are transmitted more slowly or less completely to the retail level than are price decreases. Levy et al. (2004) consider consumer inattention to small price changes as an explanation for asymmetric price adjustment at the retail level when input prices remain constant over time.<sup>1</sup> Hence, the existing APT literature is inconclusive regarding both causation and direction (Meyer and von Cramon-Taubadel, 2004).

We propose consumption inertia as a new explanation for APT. Consumers may form habits based on consumption experience, leading to inertia in consumption behavior (Brown, 1952; Pollack, 1970; Bonneuil, 1994; Thunström, 2008). Empirical studies report evidence of these phenomena in aggregate food consumption (Blanciforti and Green, 1983; Heien and Durham, 1991; Carrasco, Labeaga, and Lopez-Salido, 2005). Additionally, studies find habit formation and consumption inertia for specific agricultural and food products, including meat (Pope, Green, and Eales, 1980; Holt and Goodwin, 1997; Karagiannis, Katranidis, and Velentzas, 2000); dairy (Chintagunta, 1993; Erdem, 1996; Karagiannis and Velentzas, 1997; Arnade, Gopinath, and Pick, 2008); fruits and vegetables (Karagiannis and Velentzas, 1997; Stanton, 2007); and breakfast cereal (Thunström, 2008). Table 1 identifies industries in which APT exists and markets for which consumption inertia exists. The two lists show that APT can exist in an industry when consumption inertia is present, suggesting a possible link between the two market phenomena.

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<sup>1</sup> Levy et al. show that consumers may rationally ignore small retail price changes in order to avoid the costs of processing and reacting to new price information. Consumer inattention can explain why small price increases occur more frequently than small price decreases at the retail level.

**Table 1. Industries with Asymmetric Price Transmission, Markets with Consumption Inertia, and Corresponding Studies**

Asymmetric Price Transmission		Consumption Inertia	
Industries	Studies	Markets	Studies
1. Meat Products (cattle/beef, pork, chicken/broilers)	Bailey & Brorsen (1989); Hahn (1990); Appel (1992); Bernard & Willet (1996); von Cramon-Taubadel (1998); Goodwin & Harper (2000); Miller & Hayenga (2001)	1. Meat Products (beef, pork, chicken, turkey, mutton/lamb)	Pope, Green & Eales (1980); Holt & Goodwin (1997); Karagiannis, Katranidis & Velentzas (2000)
2. Dairy Products (milk, butter, cheese, ice cream)	Kinnucan & Forker (1987); Frigon, Doyon & Romain (1999); Chavas & Mehta (2004); Carman & Sexton (2005)	2. Dairy Products (milk, butter, cheese, yogurt)	Chintagunta (1993); Erdem (1996); Karagiannis & Velentzas (1997); Arnade, Gopinath & Pick (2008)
3. Vegetables and Fruits	Ward (1982); Pick, Karrenbrock & Carman (1990); Willett, Hansmire & Bernard (1997); Richards & Patterson (2003)	3. Vegetables and Fruits	Karagiannis & Velentzas (1997); Stanton (2007)
4. Other: <ul style="list-style-type: none"> <li>■ Peanuts</li> <li>■ Maize</li> </ul>	<ul style="list-style-type: none"> <li>■ Zhang, Fletcher &amp; Carley (1995)</li> <li>■ Abdulai (2000)</li> </ul>	4. Other: <ul style="list-style-type: none"> <li>■ Breakfast Cereal</li> <li>■ Aggregate Food</li> </ul>	<ul style="list-style-type: none"> <li>■ Thunström (2008)</li> <li>■ Blanciforti &amp; Green (1983); Heien &amp; Durham (1991); Carrasco, Labeaga &amp; Lopez-Salido (2005)</li> </ul>

### The Model Structure

Food retailers likely possess some market power because of spatial and store differentiation and high concentration in local markets. To facilitate exposition, we consider a model in which local retailers are able to set retail product prices similar to monopolistic behavior.<sup>2</sup> Such products could include agricultural products such as fresh fruits and vegetables or food products. Demand for the product offered by a retailer is represented by a general function,

$$(1) \quad Q = f(P), \text{ with } f' < 0.$$

The retailer procures the product from a competitive wholesale market, so that the wholesale price  $w$  is given.<sup>3</sup> We assume an initial stable wholesale price  $w_0$  in  $m \geq 2$  periods before period 1.<sup>4</sup>

<sup>2</sup> Focusing on the case of monopoly does not imply that consumers cannot shop at a different store or there is no competition among retailers in a specific retail market. Due to high store and spatial differentiation among retailers, this monopoly assumption posits that the customer base of a food retailer is comprised primarily of individuals who live within close proximity and have committed ex ante to do regular grocery shopping in the store(s) of this retailer. For example, Slade (1995) finds most food retailers act as local monopolists in retail markets. The results from this model are robust to oligopoly retailers.

<sup>3</sup> Previous studies (Phlips, 1980; Azzam, 1999) have shown that the existence or nonexistence of market power in the wholesale market has implications for whether price transmission is complete or incomplete, but not for whether price transmission is symmetric or asymmetric. For information about the impact of market power on the completeness (or degree) of price transmission, see McCorrison, Morgan, and Rayner (1998, 2001).

<sup>4</sup> The purpose of specifying the wholesale prices, retail prices, and quantities in two or more periods ( $m \geq 2$ ) before a wholesale price change is to provide the necessary model structure for consumption inertia. In the case of consumption inertia in this model, consumers' experience in at least two periods before period 1 is needed to determine consumers' habit in period 1, when a retail price change could occur.

At the beginning of period 1, we consider a wholesale price increase to  $w_1^+ = w_0 + \alpha$  or decrease to  $w_1^- = w_0 - \alpha$ , where  $\alpha \in (0, w_0)$  and subscript  $t = 1, 2, \dots$  denotes the  $t$ th period since the wholesale price change. This wholesale price change in period 1 can be temporary with a probability  $\theta \in (0, 1)$  or permanent with a probability  $1 - \theta$ .<sup>5</sup> If temporary, the wholesale price will return to its initial level  $w_0$  in period 2 and stay at that level in subsequent periods of the retailer's planning horizon. If the change is permanent, the wholesale price in all subsequent periods of the planning horizon will include the change.

A retail price is set at the beginning of each time period, and the retailer's planning horizon is from period 1 to  $T$ . The retailer has a binary decision to make in each period in response to this wholesale price change. In period 1, she can either change her price or keep it unchanged based on the expected returns of the two choices. Period 2 reveals whether the wholesale price change is temporary or permanent. The retailer decides whether or not to change her price in period 2 and subsequent periods based on this information.

The retailer incurs a constant average and marginal variable selling cost,  $c$ . Without loss of generality, we set  $c = 0$  to facilitate exposition. The profit-maximizing retail price is the solution of  $P$  for  $f(P) + (P - w)f' = 0$ .<sup>6</sup> We denote this solution as a function  $g(w)$  with  $g' > 0$ . In each of the  $m$  periods before the wholesale price change, the equilibrium retail price, quantity, and profit are  $P_0 = g(w_0)$ ,  $Q_0 = f(P_0)$ , and  $\pi_0 = (P_0 - w_0)Q_0$ , respectively. The retailer incurs a repricing cost  $S > 0$  for each price change. Repricing costs are assumed to be symmetric for price increases and decreases.<sup>7</sup>

### The Market Without Consumption Inertia

We use markets for which consumption adjusts instantly to price changes as a benchmark to evaluate consumption inertia effects on price transmission. For the benchmark, consumption in the short run and the long run in response to a retail price change is represented by the same function [equation (1)]. Suppose the wholesale price increases to  $w_1^+$  in period 1. We solve the model backwards to find the retailer's optimal price choices.

#### Price Choices in Periods $t \in [2, T]$

First, we analyze the retailer's price choices in period 2 and subsequent periods assuming retail price was unchanged at  $P_0$  in period 1. If the wholesale price change is temporary and the price returns to  $w_0$  in period 2, the retailer's optimal choice is to continue charging  $P_0$  and receive a per period profit  $\pi_0$  in period 2 and subsequent periods.

<sup>5</sup> We make this distinction in order to capture the fact that some wholesale price changes are caused by fundamental changes in the technology and costs of agricultural production, processing, and wholesaling, as well as market structure in farm markets, while other wholesale price changes are due to temporary fluctuations in the factors related to farm and wholesale markets.

<sup>6</sup> In this model, the retailer is assumed to choose a price to maximize her profit for this product under study, and the coordination of pricing strategies across multiple products in a store is not included. This assumption is standard in the literature on price transmission and retail pricing behavior (e.g., Azzam, 1999; Levy et al., 2004; Villas-Boas, 2007). We acknowledge the possible restrictiveness imposed by this assumption. Future research may be able to examine how relaxing this assumption affects the price transmission analysis.

<sup>7</sup> Repricing costs are a form of adjustment costs. Studies have shown that asymmetry of firms' adjustment costs with respect to increasing or decreasing price, production, and inventory may cause asymmetries in price transmission.

If the wholesale price change is permanent, the retailer has two choices. First, a retailer could continue to charge price  $P_0$ , which would yield a per period profit of  $\pi_u^+ = \pi_0 - \alpha Q_0$ , where subscript  $u$  indicates the retail price is unchanged at  $P_0$ . The present value (period 1 value) of total net profit for periods  $t \in [2, T]$  is:

$$\Phi_i^+ = \sum_{t=2}^T \pi_u^+ \rho^{t-1},$$

where  $\rho = 1/(1+\gamma)$ ,  $\gamma > 0$  is the discount rate, and subscript  $i$  denotes the case when the retail price is unchanged at  $P_0$  in periods 1 and 2.

Second, a retailer could also raise her price and incur a repricing cost  $S$  in period 2 and receive per period profits  $\pi_{op}^+$  for periods  $t \in [2, T]$ . When the wholesale price is  $w_0 + \alpha$ , the retailer's optimal per period profit is  $\pi_{op}^+ = (P_{op}^+ - w_0 - \alpha)Q_{op}^+$ , where  $P_{op}^+ = g(w_0 + \alpha)$ ,  $Q_{op}^+ = f(P_{op}^+)$ , and the subscript  $op$  denotes the optimal value. The present value of the total net profit for periods  $t \in [2, T]$  is then

$$\Phi_{ii}^+ = \sum_{t=2}^T \pi_{op}^+ \rho^{t-1} - S\rho,$$

where subscript  $ii$  denotes the case when the retail price is unchanged at  $P_0$  in period 1 and then changed in period 2.

Comparing  $\Phi_i^+$  and  $\Phi_{ii}^+$  reveals that when the retail price is unchanged in period 1 and the wholesale price change is permanent in period 2, the retailer will continue charging  $P_0$  in period 2 and subsequent periods if  $\alpha \in (0, \varphi_i^+]$ . However, the retailer will raise her price to  $P_{op}^+$  in period 2 and subsequent periods if  $\alpha > \varphi_i^+$ . A detailed specification of  $\varphi_i^+$  is given in appendix A.

We also analyze the retailer's price choices in period 2 and subsequent periods, assuming retail price was immediately raised to  $P_{op}^+$  in period 1. If the wholesale price change is revealed to be temporary, the retailer will reduce the price in period 2 to  $P_0$ , incur repricing cost  $S$ , and receive profit  $\pi_0$  in period 2 and subsequent periods. The present value of the total net profit for periods  $t \in [2, T]$  is:

$$\sum_{t=2}^T \pi_0 \rho^{t-1} - S\rho.$$

If the wholesale price is permanent, however, the retailer will keep the price at  $P_{op}^+$  and receive a per period profit  $\pi_{op}^+$  for period 2 and subsequent periods. For this situation, the retailer's total net profit for periods  $t \in [2, T]$  has a present value of

$$\sum_{t=2}^T \pi_{op}^+ \rho^{t-1}.$$

### Price Choices in Period 1

The choice to not change price from  $P_0$  or immediately raise it to  $P_{op}^+$  must be made prior to knowing if the wholesale price change is temporary or permanent. Based on the price choice in period 2 and subsequent periods, we obtain the expected returns for the two price choices in period 1. If the retailer keeps the price unchanged at  $P_0$  in period 1, the present value of expected total net profit for the planning horizon is:

$$\Pi_{delay}^+ = \begin{cases} \pi_u^+ + \theta \sum_{t=2}^T \pi_0 \rho^{t-1} + (1-\theta) \sum_{t=2}^T \pi_u^+ \rho^{t-1} & \text{if } \alpha \in (0, \varphi_i^+] \\ \pi_u^+ + \theta \sum_{t=2}^T \pi_0 \rho^{t-1} + (1-\theta) \left[ \sum_{t=2}^T \pi_{op}^+ \rho^{t-1} - S\rho \right] & \text{if } \alpha > \varphi_i^+, \end{cases}$$

where the subscript *delay* indicates that a retailer does not change price in period 1 while delaying her final price response to period 2, at which time she would know if the wholesale price change is temporary or permanent. Alternatively, if the retailer immediately raises her price to  $P_{op}^+$  in period 1, the expected total net profit for the planning horizon has a present value of

$$\Pi_{iii}^+ = \pi_{op}^+ - S + \theta \left[ \sum_{t=2}^T \pi_0 \rho^{t-1} - S\rho \right] + (1-\theta) \sum_{t=2}^T \pi_{op}^+ \rho^{t-1},$$

where the subscript *iii* denotes the case in which retail price is immediately changed in period 1 in response to a wholesale price change. Comparing  $\Pi_{delay}^+$  and  $\Pi_{iii}^+$ , we find that the retailer will not change price in period 1 if  $\alpha \leq \varphi_{ii}^+$ , or will immediately raise her price if  $\alpha > \varphi_{ii}^+$  and  $\varphi_{ii}^+ > \varphi_i^+ > 0$ .

In summary, a retailer must decide in each period whether or not to change her price in response to a wholesale price increase. The retailer will immediately raise her price in period 1 when the wholesale price increase of  $\alpha$  is large ( $\alpha > \varphi_{ii}^+$ ). The retailer will not change her price in period 1 when the wholesale price increase is small ( $\alpha \leq \varphi_{ii}^+$ ). If the wholesale price increase is very small ( $0 < \alpha \leq \varphi_i^+$ ), the retailer will always keep her price unchanged in period 2 and subsequent periods. When the wholesale price increase is moderate ( $\varphi_i^+ < \alpha \leq \varphi_{ii}^+$ ), the retailer will raise her price in period 2 if the wholesale price increase is revealed to be permanent, or will continue to keep her price unchanged in period 2 and subsequent periods if the wholesale price change is temporary.

### Price Transmission

We also analyze retailer responses to a wholesale price decrease (appendix A). The boundaries of the magnitude ( $\alpha$ ) for a wholesale price decrease are  $\varphi_i^-$  and  $\varphi_{ii}^-$ . We find  $0 < \varphi_i^- < \varphi_{ii}^-$ ,  $\varphi_i^+ \approx \varphi_i^-$ , and  $\varphi_{ii}^+ \approx \varphi_{ii}^-$  (appendix A).<sup>8</sup> As the results of  $\varphi_i^+ \approx \varphi_i^-$  and  $\varphi_{ii}^+ \approx \varphi_{ii}^-$  show, for equal increments and decrements in the wholesale price, retail price responses are almost identical. Thus, the wholesale-retail price transmission is nearly symmetric in the absence of consumption inertia.

### The Consumption Inertia Model

Consumption inertia is present when consumer habits cause gradual changes in consumption levels in response to retail price changes. Thus, consumption changes are smaller in the short run than in the long run. In our model, the short run is less than or equal to one period. We

<sup>8</sup> Note:  $\varphi_i^+ = \varphi_i^-$  and  $\varphi_{ii}^+ = \varphi_{ii}^-$  when the retailer's per period profit is a quadratic or linear function of the wholesale price (see appendix A for additional discussion).

assume consumers' habits in period  $t$  are based on consumption experiences in the two previous periods,  $t - 1$  and  $t - 2$ .<sup>9</sup> In period  $t$ , consumers' habits can be represented by  $[Q_{min,t}, Q_{max,t}]$ , where  $Q_{min,t} = \text{Min}\{f(P_{t-1}), f(P_{t-2})\}$  and  $Q_{max,t} = \text{Max}\{f(P_{t-1}), f(P_{t-2})\}$ .<sup>10</sup> When consumption inertia exists, retail demand for the product in period  $t$  is represented as:

$$(2) \quad \begin{cases} Q_t = kf(P_t) + (1-k)(Q_{min,t} - \delta) & \text{if } f(P_t) < Q_{min,t} - \delta \\ Q_t = f(P_t) & \text{if } f(P_t) \in [Q_{min,t} - \delta, Q_{max,t} + \delta] \\ Q_t = kf(P_t) + (1-k)(Q_{max,t} + \delta) & \text{if } f(P_t) > Q_{max,t} + \delta, \end{cases}$$

where  $k$  ( $\hat{k} \leq k < 1$ ) measures the difference between consumption changes in the short run and those in the long run, deviations from consumption habits must be greater than  $\delta$  ( $\delta > 0$ ) to trigger a consumption inertia effect.<sup>11</sup> These two parameters provide a measure of consumption inertia strength. Figure 1 illustrates the retail demand specified in equation (2), assuming consumers make smaller consumption changes in the short run than in the long run if a retail price change causes significant deviation ( $> \delta$ ) from the consumers' habit range.

For example, if retail price increases in period  $t$  to  $P_t$  and satisfies  $f(P_t) < Q_{min,t} - \delta$ , this new retail price will lead to a consumption level  $Q_t$  that deviates more than  $\delta$  units from the consumers' habit range  $[Q_{min,t}, Q_{max,t}]$ . Then consumption inertia exists. Thus, the short-run reduction in consumption,  $Q_{t-1} - Q_t$ , is smaller than the long-run reduction,  $Q_{t-1} - Q_{t+1}$ , assuming the retail price remains at  $P_t$  in period  $t + 1$ .

If a retail price change causes only a small (or zero) deviation from consumers' habits,  $Q_t = f(P_t) \in [Q_{min,t} - \delta, Q_{max,t} + \delta]$ , consumers adjust quickly so that the short-run and long-run consumption changes are similar. We use equation (2) to recognize that consumers make small adjustments in their consumption levels quickly, but relatively large adjustments are usually more costly and take longer to complete.

We now investigate retail price responses to wholesale price changes when consumption inertia exists by solving the model backwards. The approach assumes that the wholesale price increases by  $\alpha$  to  $w_1^+$  in period 1.

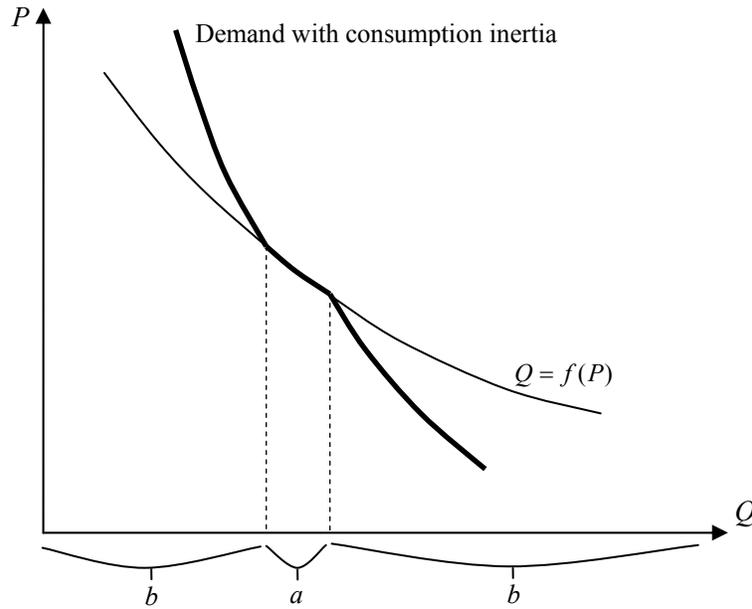
#### Price Choices in Periods $t \in [2, T]$

We first examine retail price choices in period 2 and subsequent periods conditional on an unchanged retail price of  $P_0$  in period 1. The beginning of period 2 reveals whether the wholesale price change is temporary or permanent. If the wholesale price change is temporary, the retailer's optimal choice is to keep the retail price at  $P_0$  in period 2 and subsequent periods. A consumption inertia effect will not be triggered because the retail price remains unchanged in all periods.

<sup>9</sup> Consumption inertia effects on APT in this model are robust to other settings when consumers' habits are based on a longer consumption experience.

<sup>10</sup> In period  $t$ , consumers can fully adjust their consumption levels in response to retail prices ( $P_{t-1}$  and  $P_{t-2}$ ) in the two previous periods based on the consumer demand function  $Q = f(P)$ .

<sup>11</sup> Consumption changes in the short run are smaller than in the long run when consumption inertia is present ( $k$  is less than 1). We assume  $k \geq \hat{k}$  in order to focus on the case of price transmission from wholesale to retail markets, where  $\hat{k}$  ( $\hat{k} > 0$ ) is the value of  $k$  that satisfies  $\pi_w^+(w) = \pi_0(w)$ , and  $\pi_w^+(w)$  is the retailer's profit in one period when a retail price increase triggers a consumption inertia effect. If  $k < \hat{k}$ , the retailer has incentive to adjust her price even if the wholesale price remains constant. This phenomenon is usually called retail price adjustment and it is not price transmission from wholesale to retail.



a: Consumption in the current period is within or deviates a small amount ( $\leq \delta$ ) from the consumers' habit range. Consumption adjustments complete quickly.  
 b: Consumption in the current period deviates a large amount ( $> \delta$ ) from the consumers' habit range. A consumption inertia effect is triggered.

**Figure 1. Consumer demand when consumption inertia exists**

If the wholesale price change is permanent, the retailer faces two price choices. First, if the retail price remains at  $P_0$  in period 2 and subsequent periods, total profit for periods  $t \in [2, T]$  will have a present value of

$$\Psi_i^+ = \sum_{t=2}^T \pi_u^+ \rho^{t-1}.$$

Second, the retailer can also raise her price and incur a repricing cost  $S$  in period 2. This price increase will trigger a consumption inertia effect in period 2 when  $\alpha > g^{-1}[f^{-1}(Q_0 - \delta)] - w_0$ .<sup>12</sup> We use the demand function in (2) to obtain market equilibrium in period 2 as:  $f(P_{ci}^+) + (P_{ci}^+ - w_0 - \alpha)f' + (Q_0 - \delta)(1 - k)/k = 0$ , quantity is  $Q_{ci}^+ = kf(P_{ci}^+) + (1 - k)(Q_0 - \delta)$ , profit is  $\pi_{ci}^+ = (P_{ci}^+ - w_0 - \alpha)Q_{ci}^+$ , and the subscript  $ci$  denotes that a consumption inertia effect is triggered. In period 3, consumers can fully adjust to the retail price change in period 2, resulting in a new habit range of  $[f(P_{ci}^+), f(P_0)]$ . The optimal profit under the consumer demand function  $Q = f(P)$  is  $\pi_{op}^+$  and  $Q_{op}^+ \in [f(P_{ci}^+) - \delta, f(P_0) + \delta]$ . Thus, the consumption inertia effect disappears. The retailer sets her price at  $P_{op}^+$  and receives a per period profit  $\pi_{op}^+$  for period 3 and subsequent periods. The present value of total net profit for periods  $t \in [2, T]$  is

$$\Psi_{ii}^+ = \pi_{ci}^+ \rho - S\rho + \sum_{t=3}^T \pi_{op}^+ \rho^{t-1} - S\rho^2.$$

<sup>12</sup> It is optimal for the retailer to keep her price unchanged in all periods when  $\alpha \leq g^{-1}[f^{-1}(Q_0 - \delta)] - w_0$  (appendix A).

Comparing  $\Psi_i^+$  and  $\Psi_{ii}^+$  shows that a retailer will keep the price at  $P_0$  in period 2 and subsequent periods if  $\alpha \in (0, \eta_i^+]$ , or raise her price to  $P_{ci}^+$  in period 2 and set the price at  $P_{op}^+$  in subsequent periods if  $\alpha > \eta_i^+$  (appendix A).

We analyze the retailer's price choices in period 2 and subsequent periods conditional on the retailer immediately raising her price to  $P_{ci}^+$  in period 1. This retail price increase in period 1 triggers a consumption inertia effect when  $\alpha > g^{-1}[f^{-1}(Q_0 - \delta)] - w_0$ . Again, the consumption inertia effect disappears in period 2. If the wholesale price change is shown to be temporary in period 2, the retailer will reduce her price back to  $P_0$  with a repricing cost and receive a per period profit  $\pi_0$  in period 2 and subsequent periods. The present value of total net profit for periods  $t \in [2, T]$  is then

$$\sum_{t=2}^T \pi_0 \rho^{t-1} - S\rho.$$

If period 2 reveals the wholesale price change to be permanent, the retailer will set the price at  $P_{op}^+$  and receive a per period profit  $\pi_{op}^+$  for period 2 and subsequent periods. The present value of total net profit of this price choice for periods  $t \in [2, T]$  is:

$$\sum_{t=2}^T \pi_{op}^+ \rho^{t-1} - S\rho.$$

### Price Choices in Period 1

In period 1, the retailer chooses between keeping the price unchanged at  $P_0$  and raising the price immediately to  $P_{ci}^+$  based on the relative magnitudes of the expected returns from these two choices. From the analysis of the retailer's price choices in period 2 and subsequent periods, we find the present value of the expected total net profit for the planning horizon of keeping the retail price unchanged in period 1 is:

$$\Omega_{delay}^+ = \begin{cases} \pi_u^+ + \theta \sum_{t=2}^T \pi_0 \rho^{t-1} + (1-\theta) \sum_{t=2}^T \pi_u^+ \rho^{t-1} & \text{if } \alpha \in (0, \eta_i^+] \\ \pi_u^+ + \theta \sum_{t=2}^T \pi_0 \rho^{t-1} + (1-\theta) \left[ \pi_{ci}^+ \rho - S\rho + \sum_{t=3}^T \pi_{op}^+ \rho^{t-1} - S\rho^2 \right] & \text{if } \alpha > \eta_i^+. \end{cases}$$

If the price is raised immediately in period 1, the present value is:

$$\Omega_{iii}^+ = \pi_{ci}^+ - S + \theta \left[ \sum_{t=2}^T \pi_0 \rho^{t-1} - S\rho \right] + (1-\theta) \left[ \sum_{t=2}^T \pi_{op}^+ \rho^{t-1} - S\rho \right].$$

Relative values of  $\Omega_{delay}^+$  and  $\Omega_{iii}^+$  show that the retailer's optimal choice in period 1 is to keep the price unchanged at  $P_0$  if  $\alpha \leq \eta_{ii}^+$ , or to raise her price immediately if  $\alpha > \eta_{ii}^+$  (appendix A).

### Effects on APT

We also analyze the retailer's price choices for wholesale price decreases when consumption inertia exists (appendix A). The boundaries of the magnitude ( $\alpha$ ) of a wholesale price

decrease for the retailer to have different price responses are  $\eta_i^-$  and  $\eta_{ii}^-$ , such that  $0 < \eta_i^- < \eta_{ii}^-$ ,  $\eta_i^- > \eta_i^+$ , and  $\eta_{ii}^- > \eta_{ii}^+$  (appendix A).

Based on these results, we examine price transmission in markets with consumption inertia. We compare the boundaries ( $\eta_i^+$  and  $\eta_{ii}^+$ ) of  $\alpha$  for wholesale price increases with those ( $\eta_i^-$  and  $\eta_{ii}^-$ ) for wholesale price decreases. The results  $\eta_i^- > \eta_i^+$  and  $\eta_{ii}^- > \eta_{ii}^+$  show that the retailer's optimal price choices in response to a wholesale price increase and an equal wholesale price decrease are asymmetric when the magnitudes of wholesale price changes belong to  $(\eta_i^+, \eta_i^-) \cup (\eta_{ii}^+, \eta_{ii}^-)$ . These asymmetries are attributable only to consumption inertia based on the comparison of the market with consumption inertia and the benchmark case. Proposition 1 summarizes the results.

■ **PROPOSITION 1.** *Consumption inertia can cause asymmetries in price transmission from wholesale to retail markets when seller power exists in retail markets. For wholesale price changes at some moderate levels [ $\alpha \in (\eta_i^+, \eta_i^-) \cup (\eta_{ii}^+, \eta_{ii}^-)$ ], consumption inertia causes the following asymmetries:*

- (i) *Retail prices rise immediately in response to a wholesale price increase while their response to an equal wholesale price decrease is slower, or*
- (ii) *Retail prices rise in response to a wholesale price increase while retail prices remain unchanged following an equal wholesale price decrease.*

The intuition behind the results in proposition 1 is straightforward. Consumers reduce consumption levels gradually in response to a retail price increase when consumption inertia exists, but adjust instantly after a retail price increase when there is no consumption inertia. So, raising retail price causes a smaller consumption reduction in the short run for the case of consumption inertia than for the benchmark case. Thus, increasing retail price in response to an increase in wholesale price raises retail profit when consumption inertia exists relative to the benchmark case ( $\pi_{ci}^+ - \pi_u^+ > \pi_{op}^+ - \pi_u^+$ ). On the other hand, consumers also gradually increase consumption levels in response to a retail price reduction when consumption inertia exists. A lower retail price leads to a smaller sales increase in the short run for the case of consumption inertia relative to the benchmark case. Lower retail prices will therefore reduce retail profits when consumption inertia exists relative to markets where it does not ( $\pi_{ci}^- - \pi_u^- < \pi_{op}^- - \pi_u^-$ ). These two opposite consumption inertia effects on gross profit lead to the asymmetries in wholesale-retail price transmission listed in proposition 1.

We can also express the results in terms of different hurdle rates for raising and lowering retail prices in response to wholesale price changes. Two boundaries and three magnitude ranges exist for wholesale price changes. For example,  $\eta_i^+$  and  $\eta_{ii}^+$  are the two boundaries that define three ranges of wholesale price increases when consumption inertia exists. One option of retail price responses exists for each range. First, if a wholesale price change is large, a retailer will immediately change her price. Second, if a wholesale price change is very small, a retailer will not change her price. Third, if a wholesale price change is neither small nor large, a retailer will not change her price, wait to discern whether the wholesale price change is permanent or temporary, and then make her final price response.

When consumption inertia exists, the two boundaries (or hurdle rates) where the option is exercised are different depending on whether the wholesale price increases or decreases. Relatively small wholesale price increases (low hurdle rates) can cause a retailer to immediately raise her price; but relatively large wholesale price decreases (high hurdle rates)

are needed to induce a retailer to immediately reduce her price. This outcome provides structure for empirical tests of the effects of consumption inertia on APT. Rather than using distributed lag structures to determine asymmetric differences and speeds of adjustment, one can measure differences in retailer hurdle rates as a test for APT.

The strength of consumption inertia can affect the range of wholesale price changes that are asymmetrically transmitted to retail prices. Proposition 2 characterizes this relationship (the proof is provided in appendix B).

- PROPOSITION 2. *A stronger consumption inertia effect, represented by a smaller  $k$  or  $\delta$ , leads to a wider range  $(\eta_i^+, \eta_i^-) \cup (\eta_{ii}^+, \eta_{ii}^-)$  of wholesale price changes that are asymmetrically transmitted to retail markets.<sup>13</sup>*

Stronger consumption inertia allows retailers to increase retail prices in response to wholesale price increases and generate higher profits. In addition, profits are declining less as retailers lower prices more slowly in response to wholesale price decreases. Thus, smaller wholesale price increases can cause a retailer to instantly raise her price, but larger wholesale price decreases can induce a retailer to instantly lower her price. Therefore, the range of wholesale price changes that are transmitted asymmetrically to retail markets becomes wider.

Propositions 1 and 2 provide empirical structure for explaining APT behavior. The first empirical issue is that researchers should measure or test for asymmetries in price transmission separately for different levels (magnitudes) of input price changes when the main cause of APT is consumption inertia. Studies using conventional irreversible demand functions (Houck, 1977; Ward, 1982) and cointegration techniques (von Cramon-Taubadel and Fahlbusch, 1994) treat all magnitudes of input price changes as though they transmit identically (symmetrically or asymmetrically) to output prices in the empirical estimation. In studies that use threshold error correction models (e.g., Goodwin and Holt, 1999), input price changes that are smaller than a specific threshold level may not lead to output price responses, but input price changes that exceed a threshold level are assumed to transmit identically to output prices.

Our model shows: (a) large input price changes are symmetrically transmitted, (b) small input price changes cause no responses in output prices, and (c) only moderate input price changes can be asymmetrically transmitted. Empirical tests that assume identical transmission of all magnitudes of input price changes may underestimate the degree of asymmetries in price transmission or incorrectly conclude that symmetric transmission occurs. Estimating and testing APT separately for different magnitudes of input price changes can improve empirical analyses of APT.

The second empirical implication is that APT patterns should be clearer when stronger consumption inertia effects exist. For example, the consumption of addictive substances such as tobacco and alcoholic products exhibits strong consumption inertia effects that can lead to significant asymmetries in price transmission. Although a significant amount of research has been conducted on consumption inertia in markets of addictive substances (e.g., Becker, Grossman, and Murphy, 1994; Grossman, Chaloupka, and Sirtalan, 1998), almost no studies focus on asymmetries in price transmission along the market chain of these addictive products.

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<sup>13</sup> Based on equation (2), the smaller  $k$  or  $\delta$ , the smaller the consumption change that consumers will make in the short run after a retail price change, so the consumption inertia effect is stronger.

### Simulation

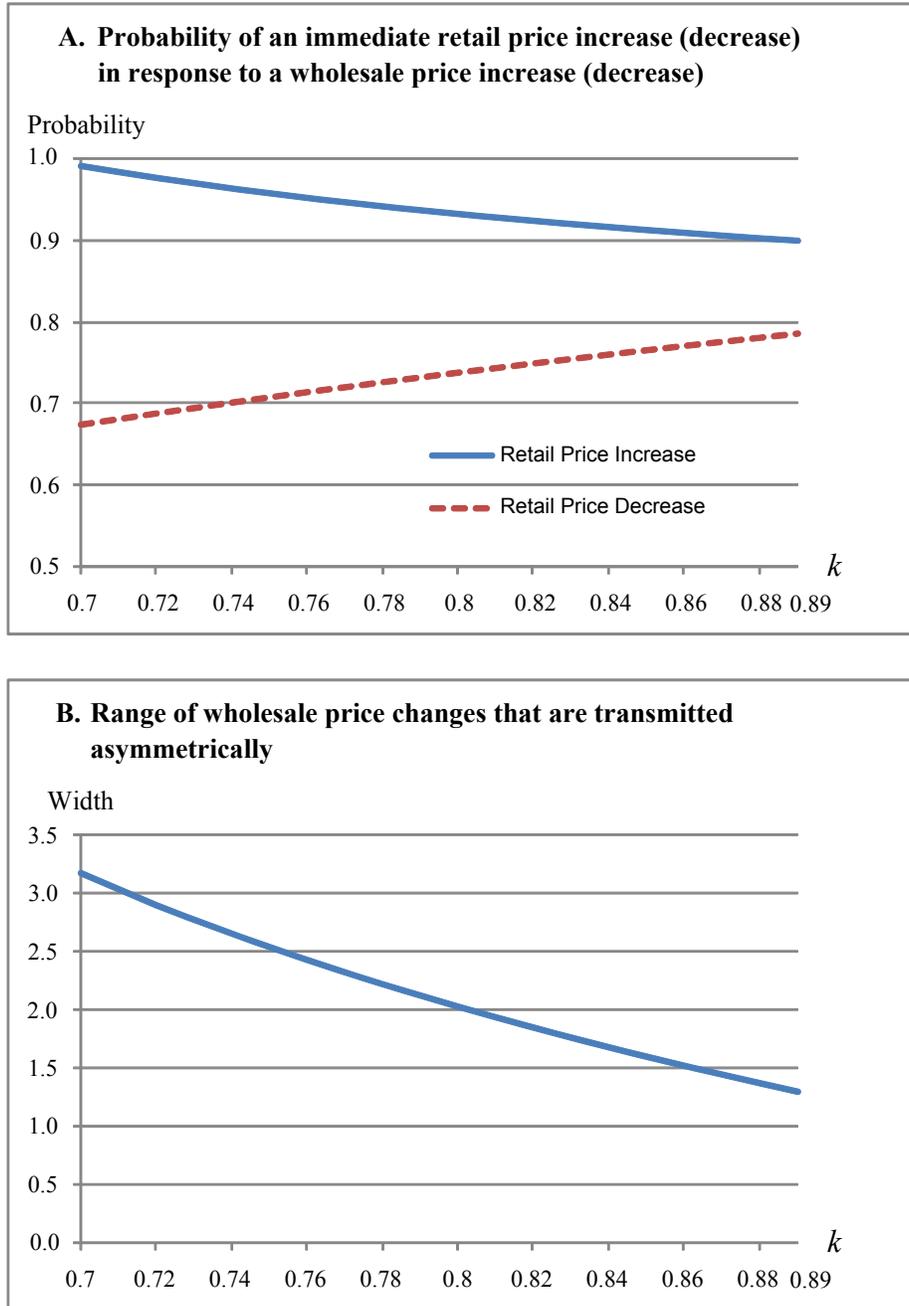
Simulation results shown in figure 2 illustrate asymmetries in price transmission under different levels of consumption inertia effects. We use empirical data and previous research results to model the strength of consumption inertia. Some studies (Heien and Durham, 1991; Karagiannis, Katranidis, and Velentzas, 2000; Carrasco, Labeaga, and Lopez-Salido, 2005) show that the ratios of short-run to long-run demand elasticity for various meat products (beef, pork, chicken, and mutton) and aggregate food consumption fall between 0.70 and 0.89. Based on the model specification in equation (2), the ratio of short-run to long-run demand elasticity is approximately equal to the value of  $k$ , a parameter indicating the strength of consumption inertia. Thus,  $k$  varies from 0.70 to 0.89 in the simulation to represent various levels of consumption inertia in agricultural and food markets.

The simulation specifies functional forms and parameter values based on industry characteristics. We use a quadratic function  $Q = f(P) = P^2 - 50P + 624$  for consumer demand. The initial wholesale price level is  $w_0 = 10$ . The value of  $\theta$  is 0.5, indicating that probabilities for a wholesale price change to be temporary or permanent are the same. Given that retail prices of agricultural and food products are usually set every week, the value of  $\rho$  is probably very close to 1; we therefore set  $\rho = 0.95$ . The number of time periods in the planning horizon is  $T = 4$  based on the condition  $T \geq 3$  in the conceptual model. In the conceptual model,  $\delta$  is small relative to the consumers' habit range, and  $S$  is chosen whereby all three price responses are relevant. Thus, we specify  $\delta = 3$  and  $S = 10$  in the simulation.

We use the analytical results in our conceptual model to calculate values of  $\eta_i^+$ ,  $\eta_{ii}^+$ ,  $\eta_i^-$ , and  $\eta_{ii}^-$  in the simulation analysis. We calculate the probability of an immediate retail price increase (decrease) in response to a wholesale price increase (decrease) when the magnitude of a wholesale price change is uniformly distributed over the interval  $[0, w_0]$ . Figure 2 illustrates that as consumption inertia increases (as  $k$  decreases from 0.89 to 0.70), a retailer is more likely to immediately raise her price in response to a wholesale price increase and less likely to immediately reduce her price when the wholesale price falls. Figure 2 also shows that the range of asymmetric wholesale price changes transmitted to retail markets becomes wider when consumption inertia is stronger.

### Conclusions

Asymmetric price transmission (APT) exists in many agricultural and food industries and can have significant welfare and policy implications. However, mechanisms driving this market phenomenon are not thoroughly understood. This paper suggests consumption inertia explains APT behavior. Consumption inertia makes instantly raising retail prices attractive for retailers with market power when wholesale prices increase because consumers will not significantly reduce their consumption levels in the short run. On the other hand, retailers are less willing to lower prices (and tend to lower them more slowly) in response to wholesale price decreases when consumption inertia exists because of relatively inelastic consumer responses in the short run. Therefore, consumption inertia leads to faster transmission of wholesale price increases to the retail level relative to wholesale price decreases. Our findings also reveal that stronger consumption inertia leads to asymmetries in price transmission over a wider range of wholesale price changes. The results can be applied to various industries because consumption habits exist for many goods. Consumption inertia can therefore help us understand why asymmetry of price transmission is widespread across industries.



Notes: The probability of an immediate retail price increase (or decrease) in response to a wholesale price increase (or decrease) is calculated as  $1 - \eta_{ii}^+ / w_0$  (or  $1 - \eta_{ii}^- / w_0$ ) when the magnitude ( $\alpha$ ) of a wholesale price change is uniformly distributed over the interval  $[0, w_0]$ . The width in panel B is the one of  $(\eta_i^+, \eta_i^-) \cup (\eta_{ii}^+, \eta_{ii}^-)$ .

**Figure 2. Asymmetric price transmission under various consumption inertia levels (smaller  $k$  values indicate stronger consumption inertia)**

The consumption inertia explanation for APT complements other explanations proposed in the literature (e.g., imperfect competition and asymmetry of adjustment costs). Which factor explains the greatest portion of APT in any specific market chain is an empirical question. We are not aware of an all-encompassing model that can measure the APT effects of all the factors that have been proposed—imperfect competition, asymmetry of adjustment costs, and consumption inertia. However, such a model would be useful in empirical studies on asymmetric price transmission and is a topic worthy of future research.

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### Appendix A: Derivations of the Retailer's Optimal Choices

#### *The Market Without Consumption Inertia*

##### ■ A Wholesale Price Increase

Comparing the two present values,  $\Phi_i^+$  and  $\Phi_{ii}^+$ , yields:

$$(A.1) \quad \Phi_{ii}^+ > \Phi_i^+ \Leftrightarrow H_i(\alpha) = (\pi_{op}^+ - \pi_u^+) (1 - \rho^{T-1}) / (1 - \rho) - S > 0.$$

We define  $\phi_i^+ = H_i^{-1}(0)$ , where  $H_i^{-1}(\bullet)$  is the inverse function of  $H_i(\alpha)$ . Then we obtain

$$(A.2) \quad \Pi_{iii}^+ > \Pi_{delay}^+ \Leftrightarrow H_{ii}(\alpha) = \pi_{op}^+ - \pi_u^+ - (1 - \rho + 2\rho\theta)S > 0 \quad \text{when } \Phi_{ii}^+ > \Phi_i^+$$

and define  $\phi_{ii}^+ = H_{ii}^{-1}(0)$ , where  $H_{ii}^{-1}(\bullet)$  is the inverse function of  $H_{ii}(\alpha)$ .

Using the envelope theorem, we find

$$(A.3) \quad \partial H_i(\alpha) / \partial \alpha = (Q_0 - Q_{op}^+) (1 - \rho^{T-1}) / (1 - \rho) > 0$$

and

$$(A.4) \quad \partial H_{ii}(\alpha) / \partial \alpha = Q_0 - Q_{op}^+ > 0.$$

In real industry practice, retail prices may remain unchanged for a short time before changing in response to a wholesale price change. We find the condition

$$(A.5) \quad (1 + \rho)\theta - \rho > 0$$

can ensure all four conditions: (1)  $H_{ii}(\alpha) < H_i(\alpha)$  for the scenario of a wholesale price increase in the benchmark, (2)  $J_{ii}(\alpha) < J_i(\alpha)$  for the scenario of a wholesale price decrease in the benchmark, (3)  $V_{ii}(\alpha) < V_i(\alpha)$  for the scenario of a wholesale price increase in the market with consumption inertia, and (4)  $Z_{ii}(\alpha) < Z_i(\alpha)$  for the scenario of a wholesale price decrease in the market with consumption inertia. The four conditions can guarantee the possibility that it is optimal for the retailer to first keep the price unchanged in period 1 and then change her price in period 2 in the four corresponding scenarios. We therefore assume that (A.5) holds. Using equations (A.1)–(A.5), we obtain  $\phi_i^+ < \phi_{ii}^+$ .

##### ■ A Wholesale Price Decrease

If the wholesale price decreases to  $w_1^- = w_0 - \alpha$  in period 1, the present values yielded by two price choices in period 2 are:

$$\Phi_i^- = \sum_{t=2}^T \pi_u^- \rho^{t-1} \quad \text{and} \quad \Phi_{ii}^- = \sum_{t=2}^T \pi_{op}^- \rho^{t-1} - S\rho,$$

where  $\pi_u^- = \pi_0 + \alpha Q_0$  and  $\pi_{op}^- = (P_{op}^- - w_0 + \alpha) Q_{op}^-$  with  $P_{op}^- = g(w_0 - \alpha)$  and  $Q_{op}^- = f(P_{op}^-)$ . We obtain

$$(A.6) \quad \Phi_{ii}^- > \Phi_i^- \Leftrightarrow J_i(\alpha) = (\pi_{op}^- - \pi_u^-) (1 - \rho^{T-1}) / (1 - \rho) - S > 0$$

and define  $\varphi_i^- = J_i^{-1}(0)$ , where  $J_i^{-1}(\bullet)$  is the inverse function of  $J_i(\alpha)$ . The present values of the expected total net profits of two price choices in period 1 are:

$$\Pi_{delay}^- = \begin{cases} \pi_u^- + \theta \sum_{t=2}^T \pi_0 \rho^{t-1} + (1 - \theta) \sum_{t=2}^T \pi_u^- \rho^{t-1} & \text{if } \alpha \in (0, \varphi_i^-] \\ \pi_u^- + \theta \sum_{t=2}^T \pi_0 \rho^{t-1} + (1 - \theta) \left[ \sum_{t=2}^T \pi_{op}^- \rho^{t-1} - S\rho \right] & \text{if } \alpha > \varphi_i^- \end{cases}$$

and

$$\Pi_{iii}^- = \pi_{op}^- - S + \theta \left[ \sum_{t=2}^T \pi_0 \rho^{t-1} - S\rho \right] + (1 - \theta) \sum_{t=2}^T \pi_{op}^- \rho^{t-1}.$$

We compare them to find:

$$(A.7) \quad \Pi_{iii}^- > \Pi_{delay}^- \Leftrightarrow J_{ii}(\alpha) = \pi_{op}^- - \pi_u^- - (1 - \rho + 2\rho\theta)S > 0 \quad \text{when } \Phi_{ii}^- > \Phi_i^-$$

and define  $\varphi_{ii}^- = J_{ii}^{-1}(0)$ , where  $J_{ii}^{-1}(\bullet)$  is the inverse function of  $J_{ii}(\alpha)$ .

Applying the envelope theorem yields

$$(A.8) \quad \partial J_i(\alpha) / \partial \alpha = (Q_{op}^- - Q_0) (1 - \rho^{T-1}) / (1 - \rho) > 0$$

and

$$(A.9) \quad \partial J_{ii}(\alpha) / \partial \alpha = Q_{op}^- - Q_0 > 0.$$

Based on equations (A.5)–(A.9), we obtain  $\varphi_i^- < \varphi_{ii}^-$ .

We now compare  $\varphi_i^+$  and  $\varphi_{ii}^+$  with  $\varphi_i^-$  and  $\varphi_{ii}^-$ . The retailer's per period profit is a function of the wholesale price, i.e.,  $\pi = (P - w)Q = [g(w) - w]f(g(w))$ . We use the second-order Taylor approximation to obtain:

$$(A.10) \quad \pi_{op}^+(w = w_0 + \alpha) \approx \pi_0(w = w_0) + \left. \frac{\partial \pi}{\partial w} \right|_{w=w_0} \times \alpha + \frac{1}{2} \left. \frac{\partial^2 \pi}{\partial w^2} \right|_{w=w_0} \times \alpha^2$$

and

$$(A.11) \quad \pi_{op}^-(w = w_0 - \alpha) \approx \pi_0(w = w_0) + \left. \frac{\partial \pi}{\partial w} \right|_{w=w_0} \times (-\alpha) + \frac{1}{2} \left. \frac{\partial^2 \pi}{\partial w^2} \right|_{w=w_0} \times (-\alpha)^2.$$

Using (A.10), (A.11), and the formulae for  $\pi_u^+$  and  $\pi_u^-$ , we find  $\pi_{op}^+ - \pi_u^+ \approx \pi_{op}^- - \pi_u^-$ . Based on this condition, (A.1), (A.2), (A.6), and (A.7), we obtain  $\varphi_i^+ \approx \varphi_i^-$  and  $\varphi_{ii}^+ \approx \varphi_{ii}^-$ . When the retailer's per period profit is a quadratic or linear function of the wholesale price, the second-order Taylor series are equal to the values of  $\pi_{op}^+(w = w_0 + \alpha)$  and  $\pi_{op}^-(w = w_0 - \alpha)$  so that we have  $\varphi_i^+ = \varphi_i^-$  and  $\varphi_{ii}^+ = \varphi_{ii}^-$ .

### The Market with Consumption Inertia

#### ■ A Wholesale Price Increase

Comparing the two present values,  $\Psi_i^+$  and  $\Psi_{ii}^+$ , yields:

$$(A.12) \quad \Psi_{ii}^+ > \Psi_i^+ \Leftrightarrow V_i(\alpha) = \pi_{ci}^+ - \pi_u^+ + (\pi_{op}^+ - \pi_u^+) (\rho - \rho^{T-1}) / (1 - \rho) - (1 + \rho)S > 0.$$

We define  $\eta_i^+ = V_i^{-1}(0)$ , where  $V_i^{-1}(\bullet)$  is the inverse function of  $V_i(\alpha)$ . We also obtain

$$(A.13) \quad \Omega_{iii}^+ > \Omega_{delay}^+ \Leftrightarrow V_{ii}(\alpha) = \pi_{ci}^+ - \pi_u^+ + (\pi_{op}^+ - \pi_u^+)(\rho - \rho\theta)/(1 - \rho + \rho\theta) - (1 + \rho)S > 0 \text{ when } \Psi_{ii}^+ > \Psi_i^+$$

and define  $\eta_{ii}^+ = V_{ii}^{-1}(0)$ , where  $V_{ii}^{-1}(\bullet)$  is the inverse function of  $V_{ii}(\alpha)$ . We find

$$(A.14) \quad \partial V_i(\alpha) / \partial \alpha = (Q_0 - Q_{ci}^+) + (Q_0 - Q_{op}^+)(\rho - \rho^{T-1}) / (1 - \rho) > 0$$

and

$$(A.15) \quad \partial V_{ii}(\alpha) / \partial \alpha = (Q_0 - Q_{ci}^+) + (Q_0 - Q_{op}^+)(\rho - \rho\theta) / (1 - \rho + \rho\theta) > 0$$

due to  $Q_{ci}^+ < Q_0$  and  $Q_{op}^+ < Q_0$ . Using equations (A.5) and (A.12)–(A.15), we obtain  $\eta_i^+ < \eta_{ii}^+$ .

The definition of consumption inertia requires  $\delta$  to be a relatively small number. Specifically, we set  $\delta < \text{Min}\{Q_0 - Q_{op}^+(\alpha = \varphi_i^+), Q_{op}^-(\alpha = \varphi_i^+) - Q_0\}$  to facilitate exposition. (Although some specific analytical solutions are different in the other case when  $\delta$  is small but  $\delta \geq \text{Min}\{Q_0 - Q_{op}^+(\alpha = \varphi_i^+), Q_{op}^-(\alpha = \varphi_i^+) - Q_0\}$ , the qualitative results about consumption inertia effects on APT remain the same.) If  $\alpha \leq g^{-1}[f^{-1}(Q_0 - \delta)] - w_0$ , the retailer can raise her price to the optimal level  $P_{op}^+$  without triggering a consumption inertia effect. So, the analysis returns to the benchmark case. Using  $\delta < \text{Min}\{Q_0 - Q_{op}^+(\alpha = \varphi_i^+), Q_{op}^-(\alpha = \varphi_i^+) - Q_0\}$ , we obtain  $g^{-1}[f^{-1}(Q_0 - \delta)] - w_0 < \varphi_i^+$ . Based on the benchmark case results, the retailer will not change her price in all periods when  $\alpha \leq g^{-1}[f^{-1}(Q_0 - \delta)] - w_0$ .

■ A Wholesale Price Decrease

If the wholesale price decreases to  $w_1^- = w_0 - \alpha$  in period 1, we find that retail price changes can trigger consumption inertia effects in  $\Gamma$  periods if  $\alpha > w_0 - g^{-1}[f^{-1}(Q_0 + \delta)]$ , where  $\Gamma$  is the largest integer that satisfies  $Q_{ci,\Gamma}^- < Q_{op}^-$  and the subscript  $ci, \tau$  denotes the  $\tau$ th period when a consumption inertia effect is triggered with  $\tau \in [1, \Gamma]$ . We set  $\Gamma \in [1, T - 2]$  to facilitate exposition. The results about consumption inertia effects do not change when  $\Gamma > T - 2$ . Then we find that  $P_{ci,1}^-$  is equal to the smaller one of two values:  $f^{-1}(Q_0 + \delta)$  and the solution of  $P$  for  $f(P) + (P - w_0 + \alpha)f' + (Q_0 + \delta)(1 - k) / k = 0$ , and  $Q_{ci,1}^- = kf(P_{ci,1}^-) + (1 - k)(Q_0 + \delta)$ . If  $2 \leq \tau \leq \Gamma$ ,  $P_{ci,\tau}^-$  is equal to the smaller one of two values:  $f^{-1}[f(P_{ci,\tau-1}^-) + \delta]$  and the solution of  $P$  for  $f(P) + (P - w_0 + \alpha)f' + [f(P_{ci,\tau-1}^-) + \delta](1 - k) / k = 0$ , and  $Q_{ci,\tau}^- = kf(P_{ci,\tau}^-) + (1 - k)[f(P_{ci,\tau-1}^-) + \delta]$ .

The present values of the total net profits for periods  $t \in [2, T]$  of two price choices in period 2 are:

$$\Psi_i^- = \sum_{t=2}^T \pi_u^- \rho^{t-1}$$

and

$$\Psi_{ii}^- = \sum_{\tau=1}^{\Gamma} \pi_{ci,\tau}^- \rho^\tau + \sum_{t=\Gamma+2}^T \pi_{op}^- \rho^{t-1} - S(\rho - \rho^{\Gamma+2}) / (1 - \rho),$$

where  $\pi_{ci,\tau}^- = (P_{ci,\tau}^- - w_0 + \alpha)Q_{ci,\tau}^-$ . We find

$$(A.16) \quad \Psi_{ii}^- > \Psi_i^- \Leftrightarrow Z_i(\alpha) = \sum_{\tau=1}^{\Gamma} (\pi_{ci,\tau}^- - \pi_u^-) \rho^{\tau-1} + \sum_{t=\Gamma+2}^T (\pi_{op}^- - \pi_u^-) \rho^{t-2} - S(1 - \rho^{\Gamma+1}) / (1 - \rho) > 0$$

and define  $\eta_i^- = Z_i^{-1}(0)$ , where  $Z_i^{-1}(\bullet)$  is the inverse function of  $Z_i(\alpha)$ . The present values of the expected total net profits of the two price choices in period 1 are:

$$\Omega_{delay}^- = \begin{cases} \pi_u^- + \theta \sum_{t=2}^T \pi_0 \rho^{t-1} + (1 - \theta) \sum_{t=2}^T \pi_u^- \rho^{t-1} & \text{if } \alpha \in (0, \eta_i^-] \\ \pi_u^- + \theta \sum_{t=2}^T \pi_0 \rho^{t-1} + (1 - \theta) \left[ \sum_{\tau=1}^{\Gamma} \pi_{ci,\tau}^- \rho^\tau + \sum_{t=\Gamma+2}^T \pi_{op}^- \rho^{t-1} - S(\rho - \rho^{\Gamma+2}) / (1 - \rho) \right] & \text{if } \alpha > \eta_i^- \end{cases}$$

and

$$\Omega_{iii}^- = \pi_{ci,1}^- - S + \theta \left[ \sum_{t=2}^T \pi_0 \rho^{t-1} - S\rho \right] + (1-\theta) \left[ \sum_{\tau=2}^{\Gamma} \pi_{ci,\tau}^- \rho^{\tau-1} + \sum_{t=\Gamma+1}^T \pi_{op}^- \rho^{t-1} - S(\rho - \rho^{\Gamma+1}) / (1-\rho) \right].$$

Based on these two present values, we find

$$(A.17) \quad \Omega_{iii}^- > \Omega_{delay}^- \\ \Leftrightarrow Z_{ii}(\alpha) = \pi_{ci,1}^- - \pi_u^- + \left[ \sum_{\tau=2}^{\Gamma} (\pi_{ci,\tau}^- - \pi_u^-) \rho^{\tau-1} (1-\rho) + (\pi_{op}^- - \pi_u^-) \rho^{\Gamma} \right] (1-\theta) / (1-\rho + \rho\theta) \\ - S(1 + \rho\theta - \rho^{\Gamma+1} + \rho^{\Gamma+1}\theta) / (1-\rho + \rho\theta) > 0 \quad \text{when } \Psi_{ii}^- > \Psi_i^-$$

and define  $\eta_{ii}^- = Z_{ii}^{-1}(0)$ , where  $Z_{ii}^{-1}(\bullet)$  is the inverse function of  $Z_{ii}(\alpha)$ . We also obtain

$$(A.18) \quad \partial Z_i(\alpha) / \partial \alpha > 0$$

and

$$(A.19) \quad \partial Z_{ii}(\alpha) / \partial \alpha > 0$$

due to  $Q_{ci,\tau}^- > Q_0$  and  $Q_{op}^- > Q_0$ . Using equations (A.5) and (A.16)–(A.19), we find  $\eta_i^- < \eta_{ii}^-$ .

If  $\alpha \leq w_0 - g^{-1}[f^{-1}(Q_0 + \delta)]$ , the retailer can lower her price to the optimal level  $P_{op}^-$  without triggering a consumption inertia effect. Thus, the analysis returns to the benchmark case. Using  $\delta < \text{Min}\{Q_0 - Q_{op}^+(\alpha = \varphi_i^+), Q_{op}^-(\alpha = \varphi_i^+) - Q_0\}$  and  $\varphi_i^+ \approx \varphi_i^-$ , we obtain  $w_0 - g^{-1}[f^{-1}(Q_0 + \delta)] < \varphi_i^-$ . So, the retailer will keep her price at  $P_0$  in all periods.

We now compare  $\eta_i^+$  and  $\eta_{ii}^+$  with  $\eta_i^-$  and  $\eta_{ii}^-$ . We use

$$\pi_{ci}^+ > \left[ kf(P_{op}^+) + (1-k)(Q_0 - \delta) \right] (P_{op}^+ - w_0 - \alpha) > f(P_{op}^+) (P_{op}^+ - w_0 - \alpha) = \pi_{op}^+, \\ \pi_{ci,1}^- = \left[ kf(P_{ci,1}^-) + (1-k)(Q_0 + \delta) \right] (P_{ci,1}^- - w_0 + \alpha) \leq f(P_{ci,1}^-) (P_{ci,1}^- - w_0 + \alpha) < \pi_{op}^-,$$

and

$$\pi_{ci,\tau}^- = \left\{ kf(P_{ci,\tau}^-) + (1-k) \left[ f(P_{ci,\tau-1}^-) + \delta \right] \right\} (P_{ci,\tau}^- - w_0 + \alpha) \leq f(P_{ci,\tau}^-) (P_{ci,\tau}^- - w_0 + \alpha) < \pi_{op}^-$$

for  $2 \leq \tau \leq \Gamma$  to obtain  $V_i(\alpha) > Z_i(\alpha) \Rightarrow \eta_i^+ < \eta_i^-$  and  $V_{ii}(\alpha) > Z_{ii}(\alpha) \Rightarrow \eta_{ii}^+ < \eta_{ii}^-$ .

## Appendix B: Proof of Proposition 2

Based on the definition of  $\eta_i^+$ , we have  $V_i(\eta_i^+) = 0$ . Using the implicit function theorem and the envelope theorem yields:

$$\partial \eta_i^+ / \partial k = - \left[ dV_i(\eta_i^+) / dk \right] / \left[ dV_i(\eta_i^+) / d\eta_i^+ \right] \\ = \left[ Q_0 - \delta - f(P_{ci}^+) \right] (P_{ci}^+ - w_0 - \alpha) \times \left[ dV_i(\eta_i^+) / d\eta_i^+ \right] > 0$$

and

$$\partial \eta_i^+ / \partial \delta = - \left[ dV_i(\eta_i^+) / d\delta \right] / \left[ dV_i(\eta_i^+) / d\eta_i^+ \right] \\ = (1-k) (P_{ci}^+ - w_0 - \alpha) / \left[ dV_i(\eta_i^+) / d\eta_i^+ \right] > 0.$$

Similarly, using the definitions of  $\eta_{ii}^+$ ,  $\eta_i^-$ , and  $\eta_{ii}^-$ , the implicit function theorem, and the envelope theorem, we obtain  $\partial \eta_i^- / \partial k \leq 0$ ,  $\partial \eta_i^- / \partial \delta < 0$ ,  $\partial \eta_{ii}^+ / \partial k > 0$ ,  $\partial \eta_{ii}^+ / \partial \delta > 0$ ,  $\partial \eta_{ii}^- / \partial k \leq 0$ , and  $\partial \eta_{ii}^- / \partial \delta < 0$ . Therefore, the range  $(\eta_i^+, \eta_i^-) \cup (\eta_{ii}^+, \eta_{ii}^-)$  is wider when  $k$  or  $\delta$  is smaller.  $\square$