Causes of Retail Price Fixity: An Empirical Analysis

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Abstract:

Existing empirical studies do not provide a unifying explanation for retail price fixity. However, economic hysteresis, or the persistence of an economic phenomenon after its initial cause has disappeared, offers a general explanation. Estimates of an empirical model of retail-price hysteresis using store-level scanner data support our hypothesis.

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Introduction

Aggregate price rigidity has long been an issue of concern to macroeconomists, primarily because of the role this phenomenon plays in theories of macroeconomic disequilibrium. Indeed, the search for a suitable explanation for fixed nominal prices has become a central part of micro-foundations, drawing research interest from both macro- and microeconomists alike (Stiglitz; Ball and Romer; Blinder et al.). Perhaps of greater concern to microeconomists in general, and others interested in marketing strategy and channel performance are the implications of fixed retail prices for pricing efficiency within vertical food marketing channels. Some argue that by setting retail prices at "price points" suggested by category management models, retailers may not allow market forces to increase product movement during times of oversupply.[1] If retail prices are not allowed to reflect the fundamentals of supply and demand, they maintain, both upward and downward wholesale price movements will be exacerbated. Further, consumers will not have access to produce at the lowest possible price, so they will consume less than they would otherwise. This argument, however, presumes that retail price fixity arises as a result of imperfectly competitive behavior on the part of food retailers.

Rather, if such retail price fixity results from optimal, competitive behavior on the part of retailers, then there is little argument against this practice on efficiency grounds. Indeed, fixed retail prices may result from retailers' rational response to high costs of price adjustment (menu costs) (Akerlof and Yellen; Mankiw; Shonkwiler and Taylor; Slade 1998, 1999; Powers; Levy *et al.*; Caplin and Spulber), their recognition of the high search costs incurred by consumers if retail prices adjust prices too frequently (Lal and Matutes; Warner and Barsky; Bliss; Bils), counter-cyclical price

[1] In general, category management refers to a set of retail practices designed to optimize sales revenue from a set of related products by efficiently allocating shelf space, setting relative price points, and offering periodic promotions on high-volume category components.

elasticities (Rotemberg and Saloner; Abreu, Pearce, and Stacchetti), the existence of nominal contracts between retailers and their customers to maintain stable prices (Okun), constant marginal costs (Blinder), or simply if prices are not a point of competition given intense non-price rivalry among firms. Indeed, even among the explanations that derive from theories of imperfect competition, there is some question as to whether fixed prices result from a failure of firms to coordinate (Ball and Romer), or from successful coordination (Stiglitz; Mischel). Given the myriad of potential and disparate explanations for fixed retail prices, there is clearly a need for one that subsumes as many of these as possible while lending itself to empirical tests within a specific industry or product category. Only by ruling out all other explanations will we be able to determine whether or not fixed prices do indeed arise from some form of tacit agreement among retail sellers.

Among existing research, Slade's (1998) approach of combining menu costs, strategic pricing behavior and goodwill erosion (or consumer costs) comes the closest to a comprehensive model. In fact, menu costs, competitive rivalry and consumer costs may be logically combined to represent a generalized measure of the costs of changing prices. Such fixed costs introduce a fundamental non-convexity to the price-change decision so that prices will not change smoothly in response to underlying changes in wholesale prices or marketing costs, but rather follow an (s_L, S, s_U) bounds rule (Sheshinski and Weiss; Caballero and Engel; Slade 1998, 1999). According to this rule, a desired, latent price varies around its target, *S*, but once it reaches either an upper or lower threshold is immediately changed to the target value. However, this is only part of the story. Indeed, if we combine these high fixed costs with the underlying volatility of supply typical of many food products, price changes will involve significant real option values (Dixit 1992). Thus, the underlying latent price change variable will vary widely between upper and lower threshold values before actual price changes occur. Consequently, observed prices exhibit significant rigidity that may be interpreted as an example of economic hysteresis, or the reluctance of an economic variable to revert to previous levels even though the original impetus for change no longer exists. As a rational, competitive response to volatility and sunk costs, hysteresis does not represent a market failure, but rather may be exacerbated by imperfectly competitive pricing behaviors that raise adjustment costs. Therefore, this study develops an economic model of retail price fixity that distinguishes between non-competitive sources of rigidity, namely tacit collusion, and hysteretic, or competitive sources. Unfortunately, there is little empirical evidence on a disaggregate level that distinguishes between these sources of price rigidity.

In a study of price-setting behavior by mail-order catalog retailers, Kashyap finds considerable support for explanations that rely on menu costs generating endogenous bands around existing nominal prices and for price-points being set simply for "convenience" or psychological purposes. Similarly, Cecchetti uses an econometric analysis to show how magazine sellers absorb significant fluctuations in margins by maintaining fixed cover prices for long periods of time while Carlton does the same for a sample of industrial products. Among studies of price fixity among food products, Slade (1998) uses a high frequency, store-level data set to show that menu costs dominate variable adjustment costs in explaining price fixity and, in another paper, finds that strategic pricing among manufacturers accentuates price thresholds that must be met before actual prices are changed (Slade 1999). On the other hand, citing problems with existing econometric approaches of testing explanations for price fixity, Blinder et al conduct a broad survey of managers in a variety of firms to determine their reasons for maintaining fixed selling prices. Failing to find a single, dominant explanation, their findings suggest a fundamental weakness of existing empirical work, namely that price fixity arises for a number of different reasons, each unique to the characteristics of the product or industry at hand.[2] Consequently, our approach focuses on a particular product category at one point in the marketing channel and shows

[2] Wolman provides a recent and comprehensive review of the extensive literature on price adjustment.

how each of several potential causes may be complementary to one another in causing what may otherwise be a minor factor to become a significant cause of price fixity. Our empirical application uses the econometric model suggested by this conceptual framework to test among several potential explanations for price fixity. In this way, we are able to distinguish among a variety of explanations and also make meaningful comment on the performance of a particular industry sector.

The paper begins by reviewing the conceptual arguments underlying each potential cause of price fixity. By forming a synthesis of existing explanations, we are able to venture a new one, namely economic hysteresis, that subsumes all of the others. Next, we present a formal economic model of fixed retail prices that admits each potential cause. Based on this theoretical framework, we then develop an empirical model of economic friction that is able to distinguish among a variety of hypotheses for fixed retail prices. A detailed description of an application of this econometric model to retail fresh apple pricing follows, including a discussion of our retail-scanner data set, results from testing a series of hypotheses regarding likely causes of price fixity, the parametric results, and their implications for both channel efficiency and management strategy. We conclude with a discussion of how these results are likely to apply to product categories and marketing levels that need only share a few commonalities with our example.

Alternative Explanations for Retail Price Fixity

Among the many potential explanations for price rigidity that Blinder et al explore, only a few are found to be relevant to firms engaged in retail trade. By far the most common response by firms of all types in Blinder et al's survey, and particularly those in retail trade, is that sticky prices are caused by a "failure to coordinate" in the words of Ball and Romer (1991). This explanation recognizes that if prices are strategic complements, then there may exist multiple equilibria in which firms raise prices to a given level, but then are reluctant to change them once they are stable (Cooper and John). However, the question posed to survey respondents reflects a concept more akin to Sweezy's or Okun's notions of a kinked demand curve in that firms merely expressed a reluctance to be the first to raise prices for fear of losing market share, or to lower prices for fear of instigating a price war. If they could coordinate their price changes, clearly it would be optimal for them all to move together to a new desired price level. Although considered distinct explanations, this notion is very similar to the idea that prices are fixed by "implicit contracts" between a firm and its customers -- maintaining relatively constant prices to loyal customers benefits firms through higher average prices that result from their inelastic demand, but also benefits customers by allowing them to save on search costs. Despite the empirical support for these explanations in Blinder's survey, Mischel develops a conceptual model to show that sticky prices can be the result of a coordination success in an infinite repeated-game context, rather than a coordination failure. Indeed, the notion that a failure to coordinate alone is responsible for price fixity is inconsistent with the price-reaction models of Liang, Gasmi, Laffont, and Vuong or Slade (1990) wherein a variety of firms are found to collude to some degree. Ball and Romer's explanation is also at odds with other empirical research -- based in econometric analysis of secondary price data rather than survey responses.

In particular, the notion of coordination failure is inconsistent with Stiglitz's argument, and runs contrary to much empirical evidence (Lee and Porter; Porter; Brander and Zhang ; Koontz, Garcia, and Hudson; Richards, Acharya, and Patterson). Green and Porter's argument is that fixed prices arise because oligopolistic firms enforce tacitly collusive price setting arrangements through punishment strategies based on the shared recognition of trigger prices. When firms have complete, yet imperfect information regarding their rivals' behavior, Green and Porter assume firms begin in a state of collusion, but punish rivals for a single-period defection by reverting to Nash behavior until a cooperative equilibrium is restored (Friedman). With complete and perfect information, and with sufficient patience, such a strategy can support a collusive outcome in a repeated game.[3] When information is less than perfect, however, a firm does not know whether a low price (in the case of output market rivalry) represents a defection by a rival, or simply results from adverse market conditions. Employing the punishment strategy described above results in a discontinuous pattern of behavior, varying between Cournot and somewhat less than a perfectly collusive outcome.[4] This explanation, while not originally intended as a rationale for fixed prices, has found empirical support in 19th century railroads (Porter, Lee and Porter, Haltiwanger and Harrison, Hajivassiliou), the airline industry (Brander and Zhang), beef packing (Koontz, Hudson, and Garcia) and processing potatoes (Richards, Patterson, and Acharya). If this explanation is correct, then fixed prices are a direct artifact of strategic behavior in imperfectly competitive industries. A trigger price explanation is not the only one based in a oligopolistic pricing that generates fixed prices, however. Indeed, Slade (1999) shows that price rivalry widens a firm's optimal (s_L, S, s_U) price-adjustment thresholds, thus creating a wider range of desired prices over which actual prices remain fixed. Still other explanations for fixity do not require an assumption of imperfect competition.

In fact, Rotemberg and Saloner develop a conceptual model of price wars that uses countercyclical price or markup behavior as another potential cause of apparently fixed prices. If prices fall or do not rise during periods of high demand as we would expect, then this would appear as

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[3] This is by no means the only effective punishment strategy. Abreu, Pearce and Stacchetti show that, in a more general model than Green and Porter, optimal punishments are less benign than a reversion to Nash strategies and can last for only a single period.

[4] Green and Porter develop their model assuming Cournot rivalry, while Porter (1985) considers the same example from a Bertrand perspective. As Porter notes, the models differ very little.

a form of price rigidity. In the Rotemberg and Saloner model, periods of high demand represent opportunities for profitable cheating on collusive pricing agreements, while the promise of future punishment is seen as less onerous because demand is expected to be lower. Thus, collusive agreements are particularly hard to maintain during periods of high demand, so cheating is more likely to occur. While the implications of a cyclical model may seem counterintuitive in many cases, Bresnahan shows that the tacitly collusive equilibrium among automobile manufacturers broke down in 1955 -- a period of unprecedented demand. This result, however, is in direct contrast to the nickel price war between Inco and Falconbridge which was instigated by a sharp reduction in demand (Slade 1990). Neither of these cases addresses the unique nature of pricing in a multi-product consumer retailing context, however.

Among microeconomic models of retail pricing, Warner and Barsky and Lal and Matutes also develop models wherein prices move in a counter-cyclical manner, but for different reasons than those advanced above. In Lal and Matutes' loss-leader model, firms must advertise prices if consumers have imperfect information. Because advertising is a fixed cost, firms have an incentive to advertise more intensively products that are in relatively high demand. Warner and Barsky, on the other hand, maintain that search represents a fixed cost to consumers. Consumers will search more intensively during periods of high demand because they intend to buy more products on each trip, and thus benefit from economies of scale in the search activity. This intensive search leads to more elastic demand for all products. Similarly, Bils argues that a repeat customer will have a higher willingness to pay compared to a new customer because they have resolved their uncertainty over untried products, thus giving the firm greater pricing power over this brand loyal segment. During periods of high demand, however, the firm benefits more from lowering prices and attracting new customers rather than exploiting existing ones. The empirical evidence on this point is also mixed.

In particular, Chevalier et al show using high frequency, product-level, retail price, wholesale price, promotion and sales data from one retail grocery chain that retailer margins are countercyclical, thus supporting the loss-leader model of Lal and Matutes rather than the collusive models (Rotemberg and Saloner, Haltiwanger and Harrington). Although each of these studies is able to explain why prices appear to adjust slowly, they do not explain the observation that prices often remain fixed in an absolute sense for long periods of time. Indeed, Carlton observes prices for intermediate industrial goods that often do not change for a year or more, while Kashyap reports similar behavior among retail mail-order catalog sellers. Although Carlton claims that counter-cyclical discounting behavior represents more variation than macroeconomists had come to expect, discrete changes from one level to the next commonly observed to result from period price cuts are not the same as the smooth and continuous variation in prices around an equilibrium level that we are conditioned to expect in a competitive environment. Rather, it is more likely that firms "...take no action until a threshold is crossed and then act for sure once the barrier is passed...." (Kashyap), but where the threshold varies over time with the economic environment similar to the (s_L, S, s_L) bands model of Caballero and Engel. Merging demand considerations with a cost-based approach moves closer to this more general explanation.

In fact, an important branch of micro-foundations research explores the possibility that price rigidity around a competitive equilibrium is based on considerations of cost rather than demand. Namely, non-convex adjustment costs cause discontinuous price paths that lead prices to be fixed for significant periods of time.[5] If price changes entail re-printing catalogs and labels, then such "menu

[5] While menu costs represent a fixed cost of adjusting prices, responses by rivals or breaking implicit contracts with customers are both likely to rise with the magnitude of the price change. The implications of this difference are important. Whereas convex adjustment costs, which are typically modeled as quadratic (Rotemberg; Roberts et al.) yield smooth AR(1) adjustment paths, non-convex adjustment costs mean that it will likely be optimal for the firm to do nothing until the underlying pressure to change prices exceeds a certain threshold, and then to adjust immediately to the desired price level (Bar Ilan and Blinder; Caballero and Engel 1993). Such (S, s) pricing thresholds (Sheshinkski and Weiss) may also be two-sided, or (s^L, S, s^U) if it is possible for the optimal price to

costs" are likely to cause considerable rigidity as the benefit from changing prices must exceed a relatively high hurdle before changes are viable (Akerlof and Yellen; Mankiw; Caplin and Spulber). In particular, Mankiw shows that very small menu costs may generate relatively long periods of prices that are apparently fixed. Moreover, Levy et al, find that menu costs may not be small, but may in fact represent a significant operational expense for firms that sell many different products simultaneously. While they do not explicitly test the significance of menu costs, Lach and Tsiddon cite the costly adjustment of prices as the only plausible explanation for their observation among multi-product retailers that price changes tend to be synchronized within stores, but staggered across stores selling similar products. Their conclusion supports the argument that price rigidity is a function of institutional processes -- minimizing the cost of changing several prices at once. Moreover, this is an important result as it generalizes the role of menu costs beyond the single-product retailer to the more realistic and relevant case where the decision maker must set several prices simultaneously.

If we expand the definition of menu costs to include both the direct economic cost of changing the price itself and the implicit cost in reducing goodwill among consumers, then the menu cost explanation becomes more plausible and, in fact, broaches many other arguments that attempt to synthesize the cost- and demand-side explanations. In particular, Slade (1998) develops a model wherein the cost of adjusting prices includes both menu costs and the erosion of goodwill and in which prices are regarded as strategic variables. As such, her model is able to address both menu-cost and consumer-cost arguments. Significantly, she shows that menu costs are sufficient to generate thresholds of demand that must be broached before price changes occur, and that these thresholds are wider for firms that behave strategically relative to those that behave in a myopic fashion. Although menu costs as traditionally measured may appear to be arguably too small to make a difference, Dixit (1989) shows

experience both positive and negative innovations (Slade 1999).

that under conditions of dynamic uncertainty, even small fixed costs can make a large difference in terms of the threshold desired price change required to induce a change in the posted price. In fact, the presence of some form of "real option" in the decision to change retail prices may mean that they are best held constant over a wide range of wholesale prices. Waiting for wholesale prices to exceed a threshold that includes a real option value, in turn, gives rise to a form of economic hysteresis.

Often mistaken for the apparent *persistence* of an economic effect after its cause has disappeared, hysteresis is better described as *remanence*, or the tendency for a shocked variable to exhibit no memory as to its former location (Piscitelli et al). Once a retail price is tagged with a new, higher price, it will tend to remain there until the incentive to move it again becomes overwhelming. In the model to follow, the underlying desire to change retail prices comes directly from changes in the wholesale price, but actual price changes do not follow a smooth, continuous path due to each of the factors discussed above, namely (1) menu costs, (2) costs imposed by strategic reactions from rival firms, (3) costs incurred by breaking implicit contracts with customers, (4) internalizing a share of consumer search costs, or (5) structural factors such as counter-cyclical price elasticities or constant marginal retailing costs. However, the degree of hysteresis in observed price changes also depends upon the volatility of underlying wholesale prices. Introducing volatility as a factor contributing to price fixity has counter-intuitive implications. If wholesale prices are changing frequently, one would think that retail prices would mimic their pattern. However, if the volatility is two-sided then retailers would likely find themselves changing prices only to change them back shortly thereafter, incurring costs, inciting rival reaction, and needlessly annoying customers. Consequently, the conceptual model below incorporates option values into the cost of making a decision to change prices while the econometric model incorporates all the likely causal factors, including volatility. In this way, we are able to test the hypothesis that price fixity derives in part from economic hysteresis.

Conceptual Model of Hysteresis and Price Fixity

Our conceptual model of price fixity rests upon the hysteresis hypothesis, but incorporates other explanations as potentially exacerbating or ameliorating factors. Before developing this model formally, however, we first evaluate the three necessary conditions for the existence of a real option value: (1) ongoing uncertainty, (2) fixed costs, and (3) a unique opportunity to profit from a decision (Dixit 1989). Assuming the wholesale price of a non-processed food product is volatile is not controversial. Whether from variations in supply from the farm, seasonal demand factors, prices of competing produce items, or from the level of imports, there are many factors that may potentially cause the optimal retail selling price to be uncertain. Second, Levy et al document the magnitude of adjustment costs in a retail grocery environment. While the cost of each individual price change is relatively small, these costs can be significant as retailers make pricing decisions for entire chains that can now consist of over 2000 stores. Third, grocery retailers possess some market power over their own shelf space. Whether through location, brand identification, loyalty, or advertising, large chains are able to differentiate themselves sufficiently so that their shelf space is a scarce commodity that they control -- witness the rise in slotting fees and other payments suppliers must pay for access to retail shelf space. In summary, we expect not only an option value to become embodied in the price change decision, but for this option value to be significant relative to the list price of the product.

For purposes of this study, grocery retailers are assumed to compete as rivals in local, differentiated product oligopolies. This assumption is justified due to the importance consumers place on location in choosing their grocery store and survey evidence that most produce managers set their prices based on local competition (Produce Marketing Association). Further, retailers must recognize the intertemporal impacts of their price-setting decisions due to the existence of fixed costs of price adjustment (Mankiw; Akerlof and Yellen; Levy et al.; Slade 1998), strategic responses by rivals (Stiglitz; Gasmi, Laffont, Vuong; and Liang; Slade 1999), higher search costs by price-sensitive consumers (Warner and Barsky; Lal and Matutes; Bils; Willis), or lost goodwill with consumers used to a particular level of prices (Rotemberg; Stiglitz; Okun). The conceptual model that follows incorporates each of these factors in a general model of retail price adjustment.

Specifically, we begin by defining a desired or "frictionless" price and then examine how managers change actual prices under general adjustment costs in order to maximize firm value. To anticipate results, we show that the firm will follow an (s^L, S, s^U) pricing policy wherein the desired price must either rise above an upper threshold or fall before a lower threshold before actual prices change. In a commodity-driven vertical marketing channel without storage or significant branding, the underlying pressure for changing retail prices emanates from the wholesale level. Therefore, the desired price change follows a path determined by independent shocks from the supply side, reflected in the wholesale price, p_t^w. In this framework, a firm will only increase prices when the desired price is sufficiently greater than the current price, p^o, such that the benefit from adjusting the price is greater than total cost of doing so. Therefore, as in Caballero and Engel (1999), define a firm's desired price change as $g\,(p_t^w) = p_t^*(p_t^w) - p_t^o$, with an optimal return point, c_t, and the observed price change as Δp_t^0. Further, assume g_t is governed by a stochastic process underlying the desired price. Fixed, or menu, costs are given by: $A_t = F_t I(\Delta p_t^0 \neq 0)$, where I is an indicator function that is equal to one when the argument is true and zero otherwise. Second, assume adjustment costs arising from lost consumer goodwill (k_t) are determined by previous own-price changes (Slade 1999): $C(k_t) = C(\Delta p_{t-1}^0) I(\Delta p_t^0 \neq 0)$. Third, assume prices are strategic complements. If this is the case, price reductions by a rival induce like responses, thus imposing a cost in the form of lower profits each period. Therefore, adjustment costs due to strategic reactions are: $R_t(p_t^R) = R_t(\Delta p_t^R) I(\Delta p_t^0 \neq 0)$, where p_t^R is an index of rival retail prices in each market.[6] Consequently, the value of a firm not currently selling at its desired price is the maximum of whether it adjusts or does not adjust (Caballero and Engel):

$$V^*(g_t, p_t^*, A_t, k_t, p_t^R) = \max\,[V^N(g_t, p_t^*),\ V^A(c_t, p_t^*) - (F_t + C_t + R_t) I(\Delta p_t^0 \neq 0)], \tag{1}$$

Solving this problem, therefore, requires finding the values of g that constitute optimal switching points between a firm that does not change prices and one that does and how these switching points, or thresholds, depend on each potential cost of adjusting prices.

Unlike other menu cost explanations, our explanation for price fixity holds that the difference between a firm's existing and ideal prices must be large enough to not only cover the direct costs of adjustment, but also the implicit option value of waiting to make the change. Indeed, even for small menu, goodwill, or strategic costs, we show that ongoing uncertainty in the supply price can cause a wide gap between the frictionless and current prices to arise. Waiting for the frictionless price to either rise or fall enough to induce a change in actual prices represents hysteresis, or the apparent reluctance of retail prices to change.

In contrast to Caballero and Engel and Slade (1999), who solve adjustment problems similar to (1) using stochastic dynamic programming, a contingent claims approach (Dixit 1989, 1992) provides an analytical solution that is more amenable to deriving explicit hypotheses as to the effect of each potential cause on the likely size of a price adjustment. Therefore, assuming the underlying desired price follows a geometric Brownian motion with drift, g follows a process written as follows:

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[6] Notice that this cost can be interpreted as the punishment inflicted upon firm *i* for attempting to cheat on a tacitly collusive oligopolistic agreement to maintain a given price level. This cost is assumed to be greater than the benefit attainable by cheating in order for the punishment to be a credible one (Green and Porter). We test the assumption of strategic complementarity in the empirical model below. Higher profits (negative costs) due to a rival's increase in price are not necessarily symmetric, but are allowed in this model.

$$dg = \mu g dt + \sigma g dz, \tag{2}$$

where : is the mean growth rate, F is the standard deviation of the process, and *dz* defines the Wiener increment with properties: E(*dz*) = 0 and E(dz^2) = *dt*. In order to derive the optimal price-change decision rule, compare the value of a firm that decides to change prices with one that does not using the value functions in (1). With adjustment costs, and uncertainty of the form shown in (2), the value of a firm that does not adjust consists of capitalized sub-optimal operating profits plus the value of the option to adjust prices, while the value of a firm that does adjust is the discounted value of optimal operating profit. Note that, although our initial solution concerns a firm that decides to increase prices, a directly analogous reasoning, with potentially different adjustment costs, yields a lower threshold for the decision to reduce prices. Given the process represented by (2), the fundamental differential equations, or asset equilibrium condition (Hull; Dixit 1989), for an firm that decides not to adjust is found by applying Ito's lemma to the value function in (1) and equating the instantaneous expected return to the required return on the firm's invested capital:

$$(1/2)\sigma^2 g^2 V^N_{gg} \sigma^2 g^2 + \mu g V^N_g - \rho V^N = p^{v} - p^{0}. \tag{3}$$

where D is the required rate of return and the other variables are as previously defined. The general solution to (3) is found by trying g^2 in the homogeneous part and solving the resultant quadratic equation:

$$\phi(\theta) = (1/2)\sigma^2 \theta (\theta - 1) + \mu \theta - \rho = 0, \tag{4}$$

which has two roots $\$_1 < 0$ and $\$_2 > 1$ such that:

$$\beta_1, \beta_2 = \left(\frac{(1 - 2\mu/\sigma^2) +/- [(1 - 2\mu/\sigma^2)^2 + 8\rho/\sigma^2]^{1/2}}{2} \right). \tag{5}$$

Further, because the wholesale price, and hence the ideal price, drifts at an average rate of : the particular solution for a firm that adjusts must reflect this fact so we can write:

$$V^N = A^N g^{\beta_1} + B^N g^{\beta_2} + p^0/\rho - p^w/(\rho - \mu), \tag{6}$$

for A_i and B_i to be determined, while the value of a firm that decides to adjust is:

$$V^A = (g + p^0 - p^w)/(\rho - \mu), \tag{7}$$

Solving for these constants is possible if we recognize that for small values of g the value of the option to wait will be very low, so $A^N = 0$. Further, at a sufficiently high level of g, call it the upper threshold, or g^+, a firm will immediately adjust its shelf price so the value of a non-adjusting firm must equal the value of a firm that does adjust less the fixed cost of adjustment:

$$\begin{aligned} V^N(g^+) &= B^N g^{+\beta_2} - w/(\rho - \mu) + p^0/\rho \\ &= (g^+ + p^0 - p^w)/(\rho - \mu) - F - C(k) - R(p^R) = V^A(g^+), \end{aligned} \tag{8}$$

because the value of a firm that adjusts is equal to the capitalized value of operating income at the desired price level. Next, the smooth pasting condition requires that the incremental value of waiting to adjust prices as g rises must be equal to the incremental value of a firm that has already adjusted, or:

$$V_g^N(g^+) = \beta_2 B^N g^{+\beta_2 - 1} = 1/(\rho - \mu) = V_g^A(g^+). \tag{9}$$

The smooth pasting and value matching conditions yield two equations and two unknowns. Solving these for g^+ gives a closed-form expression for the threshold desired price change as a function of the parameters of the model:

$$g^+ = \left(\frac{\beta_2}{\beta_2 - 1}\right)\left((F + C(k) + R(p^R))(\rho - \mu) - \rho/\mu\right). \qquad (10)$$

where $\$_2$ is, in turn, a function of both the drift rate and volatility of wholesale prices from (7) and is strictly greater than one in value. Using traditional economic investment rules, a retailer changes prices if the desired price change exceeds the annualized fixed cost of doing so: $g^+ > (F + C(k) + R\,(p^R))(D - :)$. However, because $\$_2$ is greater than one, the existence of a real option creates a wedge between the traditional and true thresholds that depends on the volatility of underlying prices and the magnitude of the all adjustment costs. Because a similar reasoning and calculation applies to the case when the ideal price is falling, the gap becomes even larger than that suggested by (10) and can, in fact, be asymmetric depending upon the value of the $\$_2$ parameter for falling prices. Either direction, waiting for the disequilibrium to exceed a more distant threshold appears as hysteresis, or what we interpret as retail price fixity.

Empirical estimation of the size of this gap is complicated by the fact that $\$_2$ is a highly non-linear function of the volatility and drift of desired prices. Willis; Slade (1999); Caballero and Engel; and Cecchetti, each estimate different types of “adjustment hazard function” in order determine the factors that influence the probability that a firm changes its list price. However, we are less interested here in the probability of a price change than the size of the thresholds that give rise to fixity. Consequently, the empirical model we describe here not only provides estimates of each threshold, but also a means of testing various theories of price fixity. We explain how in the next section.

Empirical Model of Price Fixity

Hysteresis has many implications for the process followed by high-frequency, product-specific retail price data. First, the observed retail price will not change despite considerable variation in a latent (unobservable) desired price. Second, the extent to which the desired price fluctuates before actual prices are changed (the threshold disequilibrium) will rise with the volatility of the desired price level. Third, the thresholds will rise with the magnitude of fixed (menu) costs of price adjustment as well as with the costs of any lost consumer goodwill or punishment from rival price reactions. Fourth, the price series will show significant irreversibility, meaning that when price changes do occur, they tend to persist even after their apparent cause has disappeared, and fifth, upward price changes need bear no quantitative relationship to the size of downward price changes so price adjustment may be asymmetric. We test each of these hypotheses by specifying an econometric model of economic “friction” (Rosett) wherein observed retail prices do not change until an underlying desired price either rises above, or falls below a certain threshold level. With this approach, we are able to test whether alternative explanations for price fixity remain valid once we account for hysteresis. Prior to developing the empirical friction model, we first describe how we account for each of these alternate explanations of price fixity.

In each case, we find that higher costs of adjustment, whether imposed by rivals, consumers, or menu costs, widen the hysteresis bounds and thus contribute to the fixity of retail prices. To measure the first effect, that emanating from rival price changes, we construct an index of rival prices in first-difference form. The index consists of a volume-share weighted average of each competitor’s apple price in each geographic market. We choose rival chain prices, rather than prices for potential substitute products within the same chain, for the same reasons that we use rival-chain quantities in the demand function above. Moreover, to account for irreversibilities that hysteresis may cause, we also include the cumulative change of rival prices. If prices are indeed strategic complements, we expect to see rival price responses widen a firm's own price thresholds as successive rounds of price cuts cause an industry-wide loss in profit. Next, we define goodwill in terms of a firm's reputation for maintaining stable price levels. Changes to this accepted price, both now and in the past, represent an erosion of goodwill that imposes a cost on the firm (Slade 1999). We measure goodwill in two ways. First, consumers' most recent memory is likely to be the most important, so we include a one-period lagged change in the retail price to capture the most recent experience. Second, reputation is an inherently dynamic concept, so we proxy a firm's reputation for price stability by including the sum of the absolute value of retail price changes since the beginning of the sample period. Taking these two factors together, therefore, the cost of lost goodwill can be approximated as a linear function of each such that: $C(k_t) = \alpha_1 \Delta p^0_{t-1} + \alpha_2 \sum_i \Delta p^0_{t-i}$. Again, including cumulative changes allows us to test whether this effect is irreversible. Other factors may arise not from consumer behavior toward the firm, but its own cost structure.

Therefore, we account for changes in fixed costs of price adjustment by including an index of retailing costs. Retail costs are, in turn, defined as an index of four cost components: labor in food stores, labor in the finance, insurance, and real estate (FIRE) sector, an index of transportation and utility costs and an energy cost index. The weight of each component in the overall index is taken from USDA sources (Elitzak). We include both the most recent change and cumulative change in retail costs and wholesale prices again to isolate short-run pressures to change price from any irreversibility endgendered by hysteresis. Besides the three theories of price fixity that we are able to test with the variables defined so far, there are others that derive from structural conditions in the industry.

In particular, the pressure to change prices may also arise from attributes of the particular product market, namely the structure of supply (cost) and demand. If marginal costs are constant over a wide range of output levels, then there is no competitive cost-pressure to change prices (Blinder, et al.). To test this hypothesis, we include a weekly measure of chain-level output to account for any size-related cost economies. Specifically, if there are any unexploited scale economies then we expect to witness narrower price-bounds. In addition, countercyclical variation in demand elasticities may also help explain retail price fixity. We account for this possibility by including a time-varying estimate of the inverse elasticity of demand, which we obtain by estimating an inverse-demand curve over the same data set, into the second-stage friction model. The demand curve estimated for this purpose is:

$$p_t^0 = \beta_0 + \beta_1 (q_t^0/y_t) + \beta_2 q_t^R + \beta_3 q_t^F + \beta_4 t + \sum_i \gamma_i M_i + \epsilon_t, \tag{11}$$

where q^0 is own quantity, q^R is rival quantity, q^F is the quantity of other fruit sold in the same store, y is regional per capita income, M is a store-based binary variable, t is a linear time trend and , is assumed to be an i.i.d. normal error term. With this function the time-varying inverse elasticity of demand is: $\hat{\eta}^{-1} = (\bar{q}/\bar{p})(\hat{\beta}_1/y_t)$, when evaluated at the mean of the data. By controlling for these structural factors, our tests of the remaining hypotheses are likely to be more credible.

As suggested above, testing the specific implications of hysteresis requires a specification that captures the effects of: (1) irreversibility, (2) volatility, and (3) asymmetry on the desired price change. We allow for the possibility that each of the factors underlying price fixity has an irreversible effect on actual price changes by segmenting each explanatory variable into two separate variables, one representing cumulative increases from the previous period to T periods in the past and the other representing cumulative reductions (Vande Kamp and Kaiser; Wolffram and Houck). Define $\mathbf{z}_t$ as a vector consisting of both changes in the underlying wholesale price as well as each of the "threshold factors" -- previous own-price changes, rival price changes and changes in retailing costs – we then write each variable as:

$$z_{it}^{+} = \sum_{\tau=0}^{T} \max[\Delta z_{it-\tau}, 0], \quad z_{it}^{-} = \sum_{\tau=0}^{T} \min[\Delta z_{it-\tau}, 0]. \tag{12}$$

To avoid the multicollinearity problems reported by Vande Kamp and Kaiser that result from including *each* of the J = 0, 1, 2, ... T segmented regressors in the same model, we restrict our analysis to one value of T, consisting of the entire sample period. This assumption is useful for two reasons. First, allowing for permanent effects of transient phenomena is consistent with the notion of hysteresis used here. Second, the relatively short sample period means that "permanent" effects persist for a length of time that is easily within a retailer's likely price-planning horizon. Segmenting each explanatory variable in this way also allows us to test for asymmetry in price response. Clearly, there is no *a priori* reason to expect the magnitude of upward price revisions to mirror downward revisions. Further, to allow for the possibility that price changes exhibit more normal *long term reversibility*, we also include lagged values of the change in each element of ***z***. In contrast to the short term irreversibility case, a positive response to) $z_{i,t-1}$ implies that desired price changes of sufficient size induce a price response that reverses itself when) $z_{i,t-1}$ returns to its prior value. Including each of these variables in a linearized version of (10) (Slade; Cabellero and Engel; Cecchetti) results in a model for the desired price change as a function of the wholesale price:

$$g_t^{k} = \alpha_{k0}\Delta p_t^{w} + \alpha_{k1}\sum_{i=1}^{T} \Delta^{+} p_{t-i}^{w} + \alpha_{k2}\sum_{i=1}^{T} \Delta^{-} p_{t-i}^{w} + u_{1t}, \tag{13}$$

and the option-values as a function of each of the other elements of $\boldsymbol{z}$:

$$O_t^k = \beta_{k1}\Delta p_{t-1}^0 + \beta_{k2}\sum_{i=1}^{T}\Delta^+ p_{t-i}^0 + \beta_{k3}\sum_{i=1}^{T}\Delta^- p_{t-i}^0 + \beta_{k4}\Delta p_{t-1}^R + \beta_{k5}\sum_{i=1}^{T}\Delta^+ p_{t-i}^R + \beta_{k6}\sum_{i=1}^{T}\Delta^- p_{t-i}^R + \beta_{k7}\Delta c_{t-1} + \beta_{k8}\sum_{i=1}^{T}\Delta^+ c_{t-i} + \beta_{k9}\sum_{i=1}^{T}\Delta^- c_t + \beta_{k10}\eta_t^{-1} + \beta_{k11} q_t^0 + \beta_{12}\sigma_t^2 + \beta_{13} + \sum_{j=1}^{S}\gamma_j M_j + u_{2t}, \tag{14}$$

where k = 1 represents the upper (+) threshold, k = 2 the lower (-), u_t is an i.i.d normal error term, ■ is a vector of parameters describing the effect of wholesale price variation on the desired price change, and $\$$ is a vector parameterizing option values. However, the distribution of retail price changes is not continuous as observed prices tend to remain fixed if the desired price change and option values are between the upper and lower thresholds. As is well known, application of ordinary least squares to (13) and (14) results in biased and inconsistent parameter estimates, so we require a framework that instead recognizes that the distribution of retail price changes is likely to be censored at the upper and lower thresholds.

To account for this fact, we divide the data into regimes of falling, rising, and stable prices and estimate the parameters of the combined equations (13) and (14) using Rosett's friction model. With this approach, we are able to estimate both the size of each threshold as well as test the effect of each explanatory variable on the extent of hysteresis likely to be present. Formally, separating the desired price change into traditional and option-value driven components, the observed price change becomes:

$$\Delta p_{it} = \begin{bmatrix} g_{it}^-(p_t^W) - O_{it}^-(z) - u_t; & g_{it}^-(p_t^W) - O_{it}^-(z) - u_t > 0; \\ 0; & g_{it}^+(p_t^W) - O_{it}^+(z) - u_t < 0 > g_{it}^-(p_t^W) - O_{it}^-(z) - u_t; \\ g_{it}^-(p_t^W) - O_{it}^-(z) - u_t; & g_{it}^-(p_t^W) - O_{it}^-(z) - u_t < 0 \end{bmatrix} O_{it}^+ > 0;\ O_{it}^- < 0. \tag{15}$$

Where g_t^+ is the desired price increase, and g_t^- is a desired price reduction. Assuming the error term u

is normally distributed, M is the unit-normal cumulative density function and N is the probability density function, the likelihood function for the above problem is written as:

$$L(g_t^h(p_t^w)) = \prod_{n_1}\left(\frac{1}{\sigma}\right)\phi\left(\frac{\Delta p_{n_1} - g_{n_1}^{+} + \alpha_{n_1}^{+}}{\sigma}\right)\prod_{n_3}\left[\Phi\left(\frac{\alpha_{n_3}^{-} - g_{n_3}^{-}}{\sigma}\right) - \Phi\left(\frac{\alpha_{n_3}^{+} - g_{n_3}^{+}}{\sigma}\right)\right] \prod_{n_2}\left(\frac{1}{\sigma}\right)\phi\left(\frac{\Delta p_{n_2} - g_{n_2}^{-} + \alpha_{n_2}^{-}}{\sigma}\right), \tag{16}$$

defined over regimes of n_1 observations where the price rises, n_2 observations where it falls, and n_3 observations with no change. With this model, we are able to estimate both the potentially persistent effects of each element of ***z*** on observed retail price changes as well as impact of drift and volatility in underlying prices. Moreover, with high-frequency, store-level data on a specific grocery product we are also able to test whether price fixity is an artifact of imperfectly competitive pricing, if price changes are inhibited by adjustment costs (or driven by changes in operating or acquisition cost), or if prices are fixed due to consumer habit formation, brand loyalty (store loyalty), or counter-cyclical elasticities.

Data Description

The price data for this study consist of two years of weekly observations of store-level retail scanner and wholesale (FOB) prices for Red Delicious apples. We select Red Delicious apples to test our hypotheses regarding price fixity for several reasons: (1) our objectives are to investigate why price fixity exists even in a product with volatile wholesale prices – typically not the case for consumer packaged goods, (2) apples are the third largest component of the fresh fruit category in aggregate behind only bananas and grapes, (3) Red Delicious apples are the only variety offered consistently in all sample stores in all markets, and (4) wholesale prices are readily available for fresh produce. Whereas fresh apples are available only on a seasonal basis, the widespread use of controlled atmosphere storage over the sample period means that there are 104 weeks of price data for each market. Retail price and movement data are from a commercial data vendor located in Chicago, Illinois that maintains a large-scale retail produce scanner database. Our sample consists of a total of 24 retail accounts (supermarkets) from six regional markets: Albany, NY, Chicago, IL, Dallas, TX, Atlanta, GA, Los Angeles, CA, and Miami, FL. These markets are selected based on the market coverage provided by the available database (an average of 70% ACV (all category volume)) as well as their geographic distribution throughout major population centers in the U.S. The scanner data provide price and movement data for all product codes within a given category, so we are able to construct a data series that is as consistent as possible among the sample stores. Wholesale prices are from the Washington Growers' Clearing House in Wenatchee, WA, while all retailer cost and regional income data are from the Bureau of Labor Statistics. Table one provides a summary of each variable used in the empirical model. This summary, however, does not reveal the pattern of primary interest to us here.

[Table 1 in here]

Most of the empirical analyses of price fixity in other industries devote a considerable amount of effort in verifying that prices did indeed appear to be fixed (Cecchetti; Lach and Tsiddon; Kashyap; Levy et al.). More recent studies, on the other hand, take such observations as stylized facts and rather seek to explain why they appear so. As the only research to focus on a product that is typically regarded as a commodity, however, it is particularly important for us to establish that price points do indeed exist at the store-level and that this price fixity is maintained in the face of considerable variation in wholesale prices. Figure 1 shows the pattern of wholesale (FOB) prices in Washington State, the primary source for most Red Delicious apples consumed in the U.S., and retail prices for representative stores in each of our six sample markets. Clearly, retailers absorb much of the variation in wholesale prices without passing changes immediately on to consumers. In fact, prices in stores 1 and 3 do not change over the entire sample period, while managers of store 4 appear to hold prices constant for long periods of time before making a significant change to a new level. Only in store 6 do retail prices change significantly from week to week and even then apparently not in response to changes in wholesale prices. While others attribute such imperfect pass-through directly to imperfect competition in the retail industry, our analysis suggests that there may indeed be other explanations that are entirely consistent with optimal firm behavior in a competitive industry. However, simple graphics such as figure 1 are insufficient to prove this point, so we must defer to our econometric estimates.

[Figure 1 in here]

Results and Discussion

Given the results of Blinder et al., it is important to control for structural reasons why retail prices may appear fixed in order to accurately estimate the independent effect of each potential “behavioral” cause. To account for the possibility that counter-cyclical demand elasticities explain price fixity, we first estimate a time-varying demand elasticity for Red Delicious apples so that we may include it as an explanatory variable in the full price adjustment model. The results obtained by estimating equation (11) are in table 2. Prior to interpreting these results, however, there are two features of this specification that require further explanation. First, we include rival store quantities for Red Delicious apples rather than quantities for other products in the same store because produce managers follow similar strategies for each category, thus creating multicollinearity problems if we were to use same-store quantities. Further, selling strategies are formed at a chain-level so comparing sales among different varieties in the same chain would be uninteresting. Moreover, it is not our objective to construct an exhaustive model of store-level apple demand, so we keep this specification as parsimonious as possible while ensuring that the elasticity estimates that result are consistent.

Second, there are plausible arguments for either price or quantity endogeneity in a retail produce environment. However, it is our thesis that managers adjust prices to clear markets when they are provided sufficient incentive to do so. Nonetheless, instead of assuming price endogeneity *a priori* we use a Hausman test to determine which specification is appropriate in these data. For both price- and quantity-dependent specifications, ordinary least squares is efficient under the null hypothesis of quantity- and price-exogeneity, respectively, while two-stage least squares is the only consistent estimator under the alternative. Applying this test to the apple data, we find a Chi-square statistic of 5.795 for the inverse (quantity exogenous null hypothesis) and 540.105 for the direct (price exogenous) demand model. With four degrees of freedom at a 5% level of significance the critical Chi-square value is 9.49, so we reject the null hypothesis of price exogeneity and fail to reject quantity exogeneity. Based on this result, we calculate the inverse price elasticity using an inverse demand model. By controlling for variations in the elasticity of demand in the price change model, and variations in marginal cost by including chain-level measures of sales quantity (and hence economies of scale), any remaining evidence of fixity is more likely due to the possible causes outlined above. Prior to testing the significance of each of these factors, however, we first establish the validity of the friction model.

[Table 2 in here]

At the core of the friction model is the assumed stochastic process underlying wholesale prices. To determine whether (1) is an appropriate specification for apple prices, we estimate the discrete version suggested by Dixit and Pindyck and test for the significance of the drift and volatility terms. At a 5% level, we fail to reject the null hypothesis that the drift in wholesale prices is zero, so we proceed with a simplified process for wholesale prices.

Next, we test the friction model itself by applying three tests based on the parameter estimates shown in table 3: (1) the significance of both cumulative increases and decreases of $\boldsymbol{z}_i$ in each regime, (2) a single regime versus three-regime model, and (3) zero threshold values. The first test is required to determine whether a more parsimonious representation of observed price change is preferred to the most general model presented in (16). This test yields a Chi-square statistic of 829.894, easily rejecting the simplified model at a 5% level of significance and eight degrees of freedom. Therefore, we conduct all subsequent tests using the general friction model. Second, we compare the three-regime friction model to one that consists of a single price-adjustment regime. In order to nest the single-regime special case within the general friction model, we restrict all parameters to be equal between upward and downward adjustments and apply a likelihood ratio test.[7] This test produces a Chi-square statistic of 523.771, again suggesting rejection of the null hypothesis in favor of the general model at a 5% level and 21 degrees of freedom. Third, we determine if the price-adjustment function exhibits (s_L, S, s_U) bounds similar to those found by Slade (1999) or Sheshinski and Weiss by testing whether the option value terms are equal to each other and jointly equal to zero (Shonkwiler and Taylor). This test provides a Chi-square value of 203.464, so we again reject the null hypothesis of equality at a 5% level and 13 degrees of freedom. However, the existence of non-zero thresholds is not the only implication of hysteresis.

[Table 3 in here]

As explained above, three further hypothesis tests evaluate whether or not a real option value and the attendant hysteretic effect represent plausible explanations for retail price fixity. In testing the validity of the friction model we establish the first of these, namely, that there is indeed a significant real option value embedded in both the decision to increase and to decrease prices. Therefore, any desired

[7] A single-regime OLS model is not nested within the general friction model. If we reject the more general two-regime alternative, however, single stage OLS will be more efficient than the likelihood estimation described in equation (17). Note that this is also a test of the symmetry of upward and downward price adjustments.

price change must be greater (in absolute value) than in a traditional menu cost model by the value of this option. Second, the remanence attribute of hysteresis suggests that if a threshold is exceeded, the effect will be irreversible. A test of this hypothesis involves establishing whether actual prices change in response to either current or cumulative changes in the desired price. If current (or most recent lagged) values are more important, then any impact on actual prices of a change in the desired price must be reversible, whereas the significance of accumulated changes in the desired price suggests irreversibility. Given that lagged changes in wholesale prices are insignificant for both price increases and decreases (see table 3), but their cumulative changes are significantly different from zero in both regimes, we can conclude that changes in the desired price do indeed have an irreversible impact on actual prices changes – as expected if they exceed either the upper or lower threshold. If each of the other factors have similar irreversible effects, then these results may add support to the hysteresis argument.

The results in table 3 show that this is indeed the case – that the single period lag value of each variable exerts an insignificant impact on the size of a price change, whereas cumulative changes are significant in both directions. Specifically, consumer goodwill, measured by recent and cumulative changes in the own price, has an irreversible effect both when prices are rising and falling. Similarly, changes in rival prices have an effect that persists beyond one period. This result supports Stiglitz's contention that price fixity may arise out of a dynamic process of tacit collusion because the objective of punishing a rival is to ensure that they don't change prices against the better, collusive interests of the industry group. Finally, changes in retailing costs, both in terms of wholesale prices and menu costs, have irreversible effects on own-price changes, but are not long-term reversible. Consequently, the weight of empirical evidence of irreversibility or remanence provides considerable support for the hysteresis hypothesis. Nonetheless, such persistence may still be due to other factors (institutional rigidity, or time lags in implementation) so still constitutes only partial proof. A third factor, volatility of the desired price, however, is unique to the hysteresis argument.

Measured as the three-week moving variance of wholesale prices to capture the underlying volatility of supply, the estimates in table 3 show that volatility is a key factor in determining real option values, and hence reducing the rate at which observed prices change. For price increases and decreases, the marginal impact of a one cent change in the variance of wholesale prices implied by the parameter estimates in table 3 are -2.9 and -4.9 cents, respectively, suggesting that this effect is not only statistically significant, but economically important as well. Therefore, these results show that real option values do exist with respect to both price increases and reductions and that they give rise to hysteresis, and hence fixity, in retail prices. This result supports a somewhat counter-intuitive prediction following from the conceptual model, namely that retail prices will be more rigid the more volatile are wholesale prices. Higher wholesale price volatility leads to a higher option values, which in turn, leads to a larger hysteresis effect. Intuitively, if a retailer does not know what his FOB price is going to be from one day to the next, he is better off to not even try to track the changes with retail prices, but rather hold his list prices at long term average values. This does not mean, however, that the other explanations are not valid, but rather hysteresis may instead exacerbate other causes of price fixity.

Specifically, our model allows for goodwill costs, strategic rivalry, menu costs, and the structure of both demand and supply as potential complementary explanations. Assuming goodwill falls if a firm changes an otherwise stable price, we expect own-price changes to widen the distance between upper and lower price change thresholds. Given that the estimates in table 3 imply that both cumulative upward and downward price changes cause observed price changes in the same direction to be smaller, this implies that price changes are attenuated by previous price changes. At least in these data, goodwill costs are a plausible cause of fixity. This effect is at least partially supported by strategic responses to others' price changes.

Indeed, changes in rival prices induce a similar effect to own-prices while prices are rising, but an opposite one when they are falling. Normally, an increase in a rival price would cause a positive own-price response if prices are strategic complements. However, if matching price increases impose a cost on the first firm that increases the option value inherent in its own price change, then the desired response is reduced through the hysteretic effect. On the other hand, when prices are falling the incentive for a firm to match its rival's price, whether positive or negative, is greater than the option value created so observed prices move in the same direction as rival prices. This is similar to the kinked demand curve argument of Okun or Sweezy where price increases are met with inherent forces to reverse themselves, but price reductions are not. More importantly, this result can be interpreted as support for Stiglitz' conjecture that price fixity results from dynamic processes of punishment and capitulation intended to sustain a collusive oligopoly. According to these results, price cuts by a rival induce larger price cuts by a firm intent on punishing a rival for doing so as they revert to Nash behavior. Similarly, price increases are met with "soft" responses as the firm falls in line to a new cooperative equilibrium. These results are particularly compelling given that we also control for changes in retailing costs.

In particular, changes in retailing costs tend to support price movements in the same direction. In the first column of table 3, higher direct costs cause retailers to raise prices despite the fact that the real option value imbedded in this decision is likely to rise as well. On the other hand, higher costs support lower price reductions, while lower costs allow retail prices to fall faster. Again, it is clear from this result that the direct effect outweighs the indirect effect in the opposite direction of wider price-change thresholds. It may also be the case, of course, that some of the effect of higher costs is reflected in the econometric results through the coefficients on own-price changes. Despite the importance of each of these factors, table 3 also shows that structural factors within the market are also likely to impact the decision to change prices.

In contrast to each of the price or cost variables, the elasticity of demand and level of output do not appear in cumulative-change form because the theory does not suggest that changes in either are likely to cause retail prices variation, but rather their values are thought to condition the way in which firms respond to other factors. In contrast to Rotemberg and Saloner, Warner and Barsky; or Lal and Matutes these results lend support to a notion of pro-cyclical rather than counter-cyclical demand elasticities. Because the variable O is an inverse-demand elasticity, higher values indicate a “steeper” demand curve, or a more inelastic demand curve as traditionally measured. Therefore, we expect retailers to be more willing to increase prices during a surge in demand, rather than less as the aforementioned authors suggest. Indeed, this result is opposite to the expected effect if counter-cyclical demand elasticities are truly a structural cause of price fixity. On the supply side, however, the apple price data show that attempts to either raise or lower prices are attenuated with greater sales levels. Smaller price changes with higher quantity tend to support the notion that prices will be fixed if marginal cost curves tend to flatten with scale. Because of the complexity of retailing costs and the imprecision with which they are typically measured, however, a more careful analysis of this issue would be required to arrive at a more definitive conclusion.

Conclusions and Implications

This study addresses the ongoing debate over the cause, or causes, of retail price fixity. While much of the historical concern over price fixity focuses on the role of fixed nominal prices in monetary non-neutrality, microeconomists are increasingly concerned with the efficiency implications of retail prices that do not change even though wholesale prices exhibit significant volatility. Indeed, suppliers claim that fixed retail prices harm the supply sector because the price mechanism is not being allowed to fulfill its essential role as an allocation mechanism. By insulating consumers from fluctuations in supply and demand, suppliers are forced to absorb more volatility than would otherwise be the case. Further, suppliers also believe that consumers do not buy as much as they would if retail prices followed wholesale fluctuations more closely. Considerable evidence exists in support of a wide variety of potential explanations for retail price fixity, including fixed or menu costs of adjustment to strategic pricing behavior, consumer dynamics or structural causes rooted in the shape of market demand or firm supply curves. However, this study maintains that the presence of even small adjustment costs, arising from any source, in an environment of ongoing uncertainty is likely to cause a significant real option value to arise in any price-change decision. Thus, wholesale price volatility is likely to explain a significant part of price fixity.

To test this hypothesis, we develop an empirical model of economic friction which posits upper and lower thresholds (option values) that must be exceeded before actual prices change. We estimate this model with two years of store-level retail price data on Red Delicious apples. Our results support our central hypothesis that real option values and, hence, hysteresis are important factors contributing to price fixity. Perhaps counter-intuitively, this finding implies that retail prices adjust more slowly the more volatile are underlying wholesale prices. Because option values, and hence hysteresis, rise with volatility, the optimality of doing nothing becomes more clear the more variable are wholesale prices. Instead of trying to track day to day FOB price variations, therefore, a retailer will be better off to leave prices fixed at some long term average value. However, we also show that other types of adjustment cost, namely lost goodwill, strategic punishment from rival retailers, or fixed menu costs tend to support the hysteretic effect of real options in reducing the rate of retail price changes. In fact, the empirical results show support for Stiglitz' notion that fixed retail prices may arise as a result of retailers tacitly following trigger-price strategies intended to sustain cooperative oligopoly solutions. If this is indeed the case, then there is a strong anti-competitive argument to the existence of fixed retail prices. Other causes, however, are entirely consistent with competitive behavior.

Indeed, our results support the contention that retail price fixity arises simply from relatively flat cost curves among retail outlets. On the other hand, we do not find support for a rather large part of the literature that argues for retail price fixity as an artifact of counter-cyclical price elasticities. In fact, we find the opposite is more likely to be true in our retail apple price data.

In order to arrive at more conclusive evidence as to the causes of price fixity, however, future research should seek to apply a similar, general framework to other retail price data – data for other products, temporal samples, or even levels of the vertical marketing channel. Further, deeper scrutiny of this issue would invite the analysis of the role of multiple products in retailers' product portfolio similar to Lach and Tsiddon or a more detailed analysis of the price change process along the lines of Zbaracki et al.

Figure 1. Store-Level Retail Prices in Six Markets and Wholesale Price: 1998 - 1999

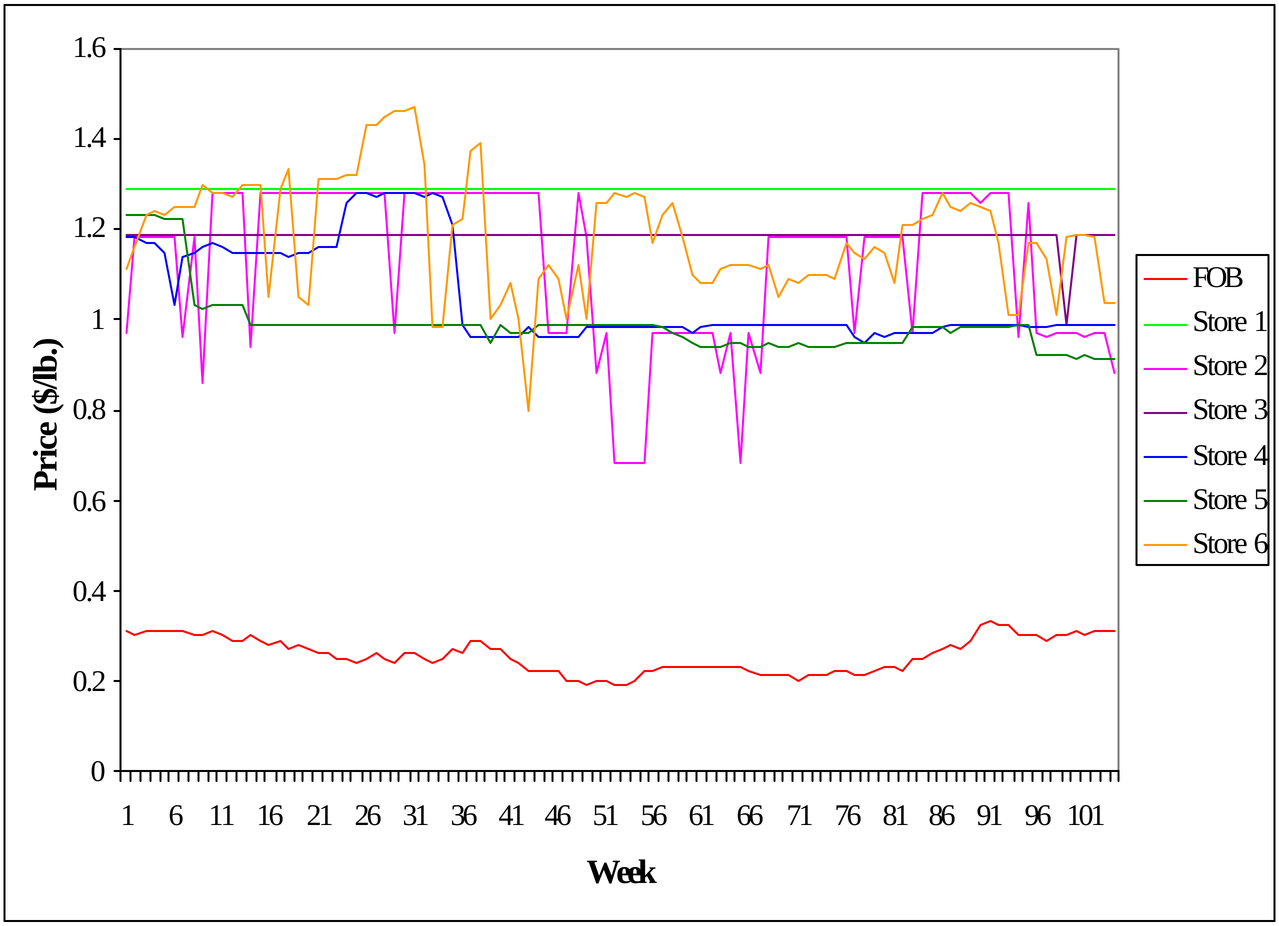

Table 1. Summary of Retail Apple Price Model Data: 1998 - 1999

Variable[1]	N	Mean	Std. Dev.	Variance	Minimum	Maximum
p^0	2080	1.034	0.306	0.093	0.200	1.580
q^0	2080	37.697	55.119	3038.200	0.022	768.440
p^R	2080	0.682	0.285	0.081	0.000	1.452
q^R	2080	35.951	49.741	2474.200	0.008	549.560
p^w	2080	0.257	0.039	0.002	0.190	0.330
σ^2_w	2080	0.224	0.209	0.044	0.003	0.884
C	2080	7.435	0.428	0.183	6.597	8.406
Δp^0	2080	0.002	0.085	0.007	-0.720	0.59

[1] In this table, the variables are defined as follows: p^0 = retailer's own price ($ per pound); q^0 = retailer's own weekly quantity movement ('000 pounds); p^R = index of rival prices for each store and market; q^R = weighted average of rival's shipments; p^w = wholesale or FOB price; σ^2_w = moving variance of wholesale price; C = input price index, and Δp^0 = weekly change in retail shelf price.

Table 2. Store-Level Retail Apple Demand

Variable	Estimate[1]	t-ratio
q^0 / y	-0.019*	-7.857
q^R	-0.001*	-3.143
q^F	0.005*	7.896
t	-0.001*	-10.2
Constant	0.554*	9.458
R^2	0.899	

[1] In this table, a single asterisk indicates significance at a 5% level. Store-level effects are not included in this table due to space constraints, but are available from the authors.

Table 3. Estimates of Retail Price Friction Model

Variable	Variable Definition	Price Increases		Price Decreases	
		Estimate	t-ratio	Estimate	t-ratio
Underlying Prices:					
Δp^{w}_{t-1}	Lagged change in wholesale price	-10.269	-0.313	-9.257	-0.346
$\Sigma^{-} \Delta p^{w}_{t-1}$	Cumulative decrease in wholesale	17.321*	2.213	15.349*	2.842
$\Sigma^{+} \Delta p^{w}_{t-1}$	Cumulative increase in wholesale	-33.680*	-3.541	-4.709*	-4.300
Structural Factors:					
0	Inverse elasticity of demand	0.002*	2.642	0.003*	2.233
q^{0}	Own quantity sales	-0.051*	-146.94	0.043*	3.658
Threshold Factors:					
Δp^{0}_{t-1}	Lagged change in own price	19.112	0.979	10.436	1.852
$\Sigma^{-} \Delta p^{0}_{t-k}$	Cumulative decrease in own price	-11.603*	-3.343	-20.569*	-6.483
$\Sigma^{+} \Delta p^{0}_{t-k}$	Cumulative increase in own price	-7.674*	-2.196	-23.719*	-7.515
Δp^{R}_{t-1}	Lagged change in rival price	5.760	1.682	3.341	0.787
$\Sigma^{-} \Delta p^{R}_{t-k}$	Cumulative decrease in rival price	-7.375*	-3.122	5.122*	2.469
$\Sigma^{+} \Delta p^{R}_{t-k}$	Cumulative increase in rival price	-5.584*	-2.187	3.133*	3.350
ΔC_{t-1}	Lagged change in cost	-6.24	-1.282	6.005	1.263
$\Sigma^{-} \Delta C_{t-k}$	Cumulative decrease in cost	1.167*	2.590	-1.486*	-2.806
$\Sigma^{+} \Delta C_{t-k}$	Cumulative increase in cost	-4.624*	-2.04	4.897*	2.285
Constant	Constant term	16.410*	10.182	-14.650*	-8.862
F^{2}	Wholesale price variance	-2.897*	-3.109	-4.900*	-3.872

[1] In this table, a single asterisk indicates significance at a 5% level. The variables and parameters are defined as follows: p^{0} = retailer's own price, p^{R} = index of rival prices in same market, p^{R} = wholesale (FOB) price, C = index of input prices, 0 = inverse price elasticity of demand, q^{0} = level of own output for each store, and F^{2} = variance of wholesale prices.

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