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# 17 Dynamic pricing

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## **Abstract**

This chapter reviews pricing issues that are relevant to oligopolistic firms competing in markets characterized by demand dynamics, i.e. state dependence and reference price effects. Normative models of dynamic pricing predict that (1) in inertial markets, competing firms have an incentive to compete fiercely using low prices in the early (growth) stages, but tacitly collude on high prices in the later (mature) stages, (2) variety-seeking markets always sustain higher prices for competing firms, and (3) markets with reference prices show cyclical pricing, which is more profitable for competing firms as long as enough consumers weigh price gains more heavily than price losses. Descriptive models of dynamic pricing show that (1) competing firms in inertial and variety-seeking markets indeed account for the future effects, in addition to current effects, of their current pricing decisions, and (2) such firms behave in a boundedly rational manner in the sense of looking into a few future periods only. Descriptive models of dynamic pricing in the presence of reference price effects need to be estimated in future research.

## **1. Introduction**

When pricing strategies of firms recognize the future (i.e. long-term) implications – for consumers and/or competitors – of their current prices, dynamic pricing is said to exist. Such dynamic pricing incentives arise, for example, for the following reasons: (1) consumers learn about a brand's attributes by repeatedly buying it over time, and eventually form stable preferences for the brand, which suggests that using low prices to encourage brand trial may speed up, for example, the brand's market penetration; (2) consumers provide word of mouth – positive or negative – for previously tried brands, which suggests that targeting low initial prices at 'opinion leaders' may pay off for brands in the long run; (3) declining prices erode brand equity, which suggests that high prices may be necessary for firms to positively cultivate their brand strength in the long term; (4) seasonality or excess production capacity leads firms to adopt clearance pricing strategies for their brands etc. All of these reasons typically apply to markets involving new brands. Interestingly, however, dynamic pricing incentives also arise for mature brands when conditions of 'demand dynamics' exist. This is the focus of this chapter, on which we now elaborate.

### *1.1 Demand dynamics*

In order to effectively price their brands in mature product categories, brand managers must understand how prices of competing brands influence consumers' brand choices within the product market. Some product markets are characterized by demand dynamics that arise due to the effects of state dependence or/and reference prices in consumers' brand choices. We explain these effects below.

*State dependence* The probability that a given consumer is likely to buy Coke or Pepsi on a visit to the store is partly a function of which cola brand the consumer bought on their previous visit. One consumer may buy Coke on consecutive purchase occasions 'out of habit' (even if Pepsi were on sale at the second purchase occasion), while another

consumer may switch from Coke to Pepsi (even if Coke were on sale at the second purchase occasion) just to try ‘something different’. The first consumer’s brand choices are said to exhibit positive state dependence or ‘inertia’, while the second consumer’s brand choices are said to exhibit negative state dependence or ‘variety-seeking’.

*Reference prices* The probability that a given consumer is likely to buy Coke or Pepsi on a visit to the store is a function of not only the current values of the two cola brands’ prices, but also their relative values when compared to the brands’ historical prices, as perceived by the consumer, referred to as ‘reference prices’. For example, a consumer may buy Coke even when it is higher priced than Pepsi because Coke’s price is lower than its reference price, while Pepsi’s price is higher than its reference price. Such reference prices for brands are generally formed on the basis of what the consumer has observed during previous shopping trips.

When state dependence or reference price effects, as explained above, are present, market shares of brands in the corresponding market will tend to be serially correlated over time. We refer to such serial correlations as demand dynamics. This chapter deals with pricing decisions of competing firms in markets characterized by such demand dynamics.

### 1.2 Pricing implications of demand dynamics

Under demand dynamics, a brand’s demand in a given period is not just a function of the brand’s price in that period, but also a function of the brand’s price or/and demand in previous periods. A pricing implication of demand dynamics that arises due to inertia is that reducing the price for one’s brand in the current period may increase the brand’s market share not only in the current period but also in the subsequent period when the price reduction on the brand has been retracted (assuming no competitive responses in prices). A pricing implication of demand dynamics that arises due to either variety-seeking or reference prices is that reducing the price for one’s brand in the current period may increase the brand’s market share in the current period, but may hurt in the subsequent period when the price reduction is retracted. For example, in the reference price case, the subsequent high price may be evaluated negatively when compared to the previous lower price. In the variety-seeking case, an increased market share in the current period may lead to decreased market share in the subsequent period when consumers switch away from the previously tried brand. In other words, for a given brand, price reductions may be more attractive in the presence of inertia, while price increases may be more attractive in the presence of reference prices or variety-seeking, when compared to markets where such demand dynamics are absent. A game-theoretic equilibrium analysis of oligopolistic prices under demand dynamics will shed light on this issue.

### 1.3 Econometric models of dynamic pricing

When setting prices for their brands in markets characterized by demand dynamics, brand managers must know both (1) the actual extent of demand dynamics in the market, and (2) the pricing techniques that are actually adopted by competing brand managers. Analyzing historical market-level data on market shares and prices of competing brands over time will enable brand managers to obtain an accurate understanding of (1) and (2). Brand managers can then set prices based on their understanding of these two elements.

The rest of this chapter is organized as follows. We briefly review empirical findings on demand dynamics in Section 2. In Section 3, we discuss theoretical results pertaining to the pricing implications of demand dynamics that have been derived using game-theoretic equilibrium analyses. Section 4 discusses empirical findings on firms' pricing strategies in the presence of demand dynamics, which have been obtained using econometric models of dynamic pricing. Section 5 concludes.

## **2. Demand dynamics**

Since the seminal empirical study of Guadagni and Little (1983), dynamic considerations have generally been shown to govern consumers' brand choices in packaged goods categories. These dynamics operate in the sense that a consumer's probability of buying a brand in the current period is a function of, among other things, whether or not the consumer has bought the same brand in previous periods, as well as the brand's previously observed prices. The first influence is that of state dependence effects, while the second is that of reference prices. We next discuss the existing empirical findings pertaining to these two effects.

### *2.1 State dependence*

A positive effect of past consumption of a brand on the consumer's current probability of buying the brand is referred to as 'inertia', while a negative effect is referred to as 'variety-seeking'. For example, to the extent that it is cognitively expensive for consumers to 'think' extensively about their brand choice decisions, they may routinize their brand purchases by buying the same brand repeatedly over time. This means that a previously chosen brand has a higher probability of being chosen in the current period than other brands, all else being equal. This is called inertia. In contrast, consumers may satiate themselves on attributes contained in previously chosen brands and, therefore, switch to new brands that contain new, untried attributes. In such a scenario, a previously chosen brand has a lower probability of being chosen in the current period than other brands, all else being equal. This is called variety-seeking.

The effects of inertia and variety-seeking on consumers' brand choices have been documented in numerous empirical studies over the years (Jeuland, 1979; McAlister, 1982; Givon, 1984; Kahn et al., 1986; Bawa, 1990; Fader and Lattin, 1993; Trivedi et al., 1994; Allenby and Lenk, 1995; Erdem, 1996). These effects have been shown to persist even after accounting for the effects of marketing variables and unobserved heterogeneity on brand choices in a flexible manner (Keane, 1997; Gupta et al., 1997; Seetharaman and Chintagunta, 1998; Seetharaman et al., 1999; Ailawadi et al., 1999; Abramson et al., 2000; Erdem and Sun, 2001; Moshkin and Shachar, 2002).

### *2.2 Reference prices*

Consumers often evaluate the price of a brand at the store with respect to some summary statistic representing the brand's historically observed prices from the past, which is referred to as the brand's reference price. When the brand's observed price is higher than its reference price, the brand is perceived by the consumer as less attractive than when the brand's observed price is lower than the reference price, all else being equal. This means that frequent price cuts may have a hurtful consequence to the brand in the long run since they are likely to reduce the brand's reference price and, therefore, consumers'

evaluations of future prices of the brand. In this sense, demand dynamics arise on account of the long-run effects of brands' pricing decisions.

The effects of reference prices on consumers' brand choices have been extensively documented since the late 1980s (Winer, 1986; Lattin and Bucklin, 1989; Rajendran and Tellis, 1994; Briesch et al., 1997; Chang et al., 1999). Reference price effects have been shown to be consistently larger for price losses than for price gains, i.e. the negative impact of a price increase (loss) is greater in magnitude than the positive impact of an equal-sized price decrease (gain), on a consumer's probability of buying the brand (Kalwani et al., 1990; Kalwani and Yim, 1992; Mayhew and Winer, 1992; Krishnamurthi et al., 1992; Hardie et al., 1993; Kalyanaram and Little, 1994; Mazumdar and Papatla, 1995, 2000; Bell and Lattin, 2000; Erdem et al., 2001; Han et al., 2001).

In the presence of demand dynamics – intertemporal linkages in demand for brands that arise due to the effects of inertia, variety-seeking and reference prices – a managerial question that arises pertains to the long-term effectiveness of pricing. Past empirical studies have quantified the magnitudes of long-term 'spillover' effects of price cuts in markets with inertia, variety-seeking or reference prices (Lattin and Bucklin, 1989; Roy et al., 1996; Seetharaman, 2003, 2004). For example, Seetharaman (2004) shows that ignoring inertia underestimates the total incremental impact of a price cut by as much as 35 percent. This suggests that the reduced profit margin for a brand during a period of a price cut may be offset by increases in brand volume not just during the period of promotion but also in future periods. But these findings are predicated on the assumption that competitive responses are absent. In reality, however, price changes on a brand would have not only direct effects on its sales, but also indirect effects through the changes triggered in competitive brands' prices. A game-theoretic analysis of price competition between brands in markets with demand dynamics will throw light on this issue. We discuss this in the next section.

### 3. Pricing implications of demand dynamics

Game-theoretic models are typically used to provide insights into the nature of price competition in oligopolistic markets. In the presence of demand dynamics, such as those discussed in Section 2, these game-theoretic models are rendered dynamic. Such dynamic pricing models are also called state-space pricing models, in which firms' pricing actions in one period shift their payoffs (profits) in subsequent periods. One of two common informational assumptions are typically invoked to solve for firms' optimal pricing strategies in such state-space pricing models: (1) open-loop, i.e. firms commit to their pricing actions in the initial period, (2) closed-loop, i.e. firms' pricing actions are functions of all payoff relevant information ('state'), which are typically the most recent period and market shares. An open-loop pricing equilibrium is a Nash equilibrium in open-loop strategies and is, therefore, static. A closed-loop equilibrium is a sub-game-perfect equilibrium and is, therefore, dynamic. Since closed-loop strategies are much more difficult to solve analytically than open-loop strategies (since each firm's pricing actions enters the opponent's pricing decision rules and affects their future choices), one analytical simplification that is typically made is to restrict attention to 'stationary strategies', i.e. pricing strategies that do not depend on time and only on brands' most recent market shares (see Slade, 1992 for insightful discussions of these issues). Many theoretical studies have employed one or more of these concepts

to solve state-space pricing models in the presence of demand dynamics. We discuss them below.

### *3.1 Pricing implications of state dependence*

Klemperer (1987a) derives the normative pricing implications of demand inertia in an undifferentiated duopoly using a two-period game-theoretic framework, and shows that the non-cooperative pricing equilibrium in the second period is the same as the collusive outcome in an otherwise identical market without inertia. In other words, two competing firms in a mature market characterized by inertia – each firm with an installed base of customers from the previous period – face demand functions that are relatively price inelastic compared to their counterparts in an identical mature market without inertia. This decreased price elasticity reduces the price rivalry among the firms, leading to higher prices for the brands of both firms. Klemperer (1987a) also shows that the pricing power that the two firms gain in the second period leads to vigorous price competition in the first period, which may more than dissipate the firms' extra monopolistic returns from the second period. In other words, in the early growth stages of a market characterized by inertia, competing firms would engage in fierce price competition to build market shares for their brands.

Klemperer (1987b) shows that the central implications of Klemperer (1987a), discussed above, also apply for a differentiated duopoly. Klemperer (1987b) also extends the modeling framework to allow for rational (i.e. 'forward-looking') consumers, and shows that first-period prices of the two firms become less competitive because consumers who realize that firms with higher market shares will charge higher prices in the future are less price elastic than naive consumers.

The two-period game-theoretic models of Klemperer (1987a, 1987b) do not tell us what to expect from price competition over many periods when old (locked-in) customers and new (uncommitted) customers are intermingled and firms cannot discriminate between these groups of customers. Will firms' temptation to exploit their current customer bases lead to higher prices, or will firms' desire to attract new customers lead to lower prices than in the case of no inertia? In order to answer this question, Beggs and Klemperer (1992) extend the duopoly pricing model of Klemperer (1987b) to the infinite-period case, where new consumers arrive and a fraction of old consumers leaves in each period. Beggs and Klemperer (1992) show, over a wide range of parametric assumptions, that firms obtain higher prices and profits compared to those in the absence of inertia. The authors find that prices rise as (1) firms discount the future more, (2) consumers discount the future less, (3) turnover of consumers decreases, and (4) the rate of growth of the market decreases.

In contrast to the discrete-time, game-theoretic framework adopted by Beggs and Klemperer (1992), Wernerfelt (1991) adopts a continuous-time, game-theoretic framework to study price competition between firms in inertial markets. Consistent with the findings in Beggs and Klemperer (1992), Wernerfelt (1991) also derives higher equilibrium prices for firms, as well as a positive effect of the extent of firms' future discounting behavior on equilibrium prices, in inertial markets. This shows that the equilibrium pricing results are robust to whether the game-theoretic pricing models are solved in discrete or continuous time.

As in Wernerfelt (1991), Chintagunta and Rao (1996) also study the normative pricing

implications of demand dynamics using a continuous-time, game-theoretic framework. The authors show that in the presence of demand inertia, the firm with the higher baseline preference level will charge the higher price in steady state. They also show that myopic pricing strategies of firms that fail to recognize the long-run impact of their current prices lead to prices that are 100–200 percent higher than those implied by dynamic pricing strategies.

Seetharaman and Che (forthcoming) extend the two-period game-theoretic frameworks of Klemperer (1987a, 1987b) to derive the normative pricing implications of variety-seeking in a duopoly. Unlike the inertia case of Klemperer (1987a, 1987b), where the positive effects of a tacitly collusive pricing equilibrium in the second period could effectively unravel on account of vigorous price competition in the first period, the variety-seeking case implies tacitly collusive prices among firms in both periods. This is because in the early growth stages of a market characterized by variety-seeking, competing firms have no incentive to build market shares for their brands since each firm recognizes that its customers have an incentive to defect to the competing firm in the future on account of variety-seeking. In later stages, firms exploit the fact that previous customers of competitors will buy their brands in a search for variety and, therefore, again end up charging high prices. Once the model allows for rational (i.e. ‘forward-looking’) consumers, first-period prices of the two firms become even less competitive.

### 3.2 Pricing implications of reference prices

Greenleaf (1995) derives the normative pricing implications of reference price effects for a retailer. He finds that a price promotion on a brand can increase retail profit if the retailer’s gain in the promotion period – from increased demand for the promoted brand at the lower price – outweighs the retailer’s loss in future periods – from a lowered reference price for the brand in the future. He derives conditions under which the optimal pricing policy for the retailer is cyclical, i.e. involves periodic price promotions.

Kopalle et al. (1996) derive the normative pricing implications of reference price effects in a duopoly involving two manufacturers. Assuming a linear demand function and allowing for two consumer segments – one that weighs price gains more heavily than losses, and another that does the opposite – in the analysis, the authors derive a Markov-perfect Nash equilibrium in prices. They derive the sufficient condition, i.e. the relative sizes of the two consumer segments, for cyclical pricing to be optimal for both manufacturers. They find that the existence of the first consumer segment (i.e. those who weigh gains more heavily than losses) is necessary for cyclical pricing to be an optimal policy.

While the models discussed in this section throw light on how prices in an oligopoly ought to be in the presence of demand dynamics, a pertinent question that arises next is how prices actually operate in real-world markets with demand dynamics. In other words, do real-world manufacturers and retailers indeed account for demand dynamics while setting prices for their brands? We cover this issue in the next section.

## 4. Econometric models of dynamic pricing

Econometric models of dynamic pricing – pricing models that are necessary in the presence of demand dynamics – require both (1) the solution of discrete-time, stochastic dynamic optimization problems for each firm, where a firm chooses from a continuum of possible prices, and the (2) the fixed point to the game-theoretic problem of multiple

firms employing their best pricing responses to each other's pricing choices. Recently proposed techniques in the econometric literature – Pakes and McGuire (1994); Berry and Pakes (2000); Pakes and McGuire (2001) – enable the estimation of such dynamic pricing models while successfully circumventing the challenges posed by the large dimensionality of each firm's pricing choices, as well as the possibility of the existence of multiple pricing equilibria.

Chan and Seetharaman (2004) investigate price competition between cola brands – Coke and Pepsi – using two years of IRI's scanner panel data (from June 1991 to June 1993) on household purchases in the cola category in a metropolitan market in a large US city. The authors first estimate the extent of demand dynamics in the product category using a stochastic brand choice model of state dependence. This model incorporates the effects of households' intrinsic brand preferences, as well as responsiveness to marketing variable – in addition to the effects of inertia and variety-seeking – and allows all parameters to be heterogeneous across households in a flexible manner. Using the estimated brand choice model, along with estimates of interpurchase times in the product category, the authors then construct a predictive model of brand sales. This brand sales model is assumed to serve as an input for the pricing decisions of firms. The authors develop a game-theoretic dynamic pricing model, which is based on the idea that firms compete on prices in an infinite-period, repeated game with discounting. This dynamic pricing game – which uses the predictive brand sales model as an input – is estimated using historical data on brands' prices in the market, adopting a recently proposed estimation technique (Berry and Pakes, 2000). The estimates of the dynamic pricing model are compared to those obtained using (1) a myopic pricing model that assumes that firms are not forward looking (even though firms recognize the existence of demand dynamics in the market), and (2) a static pricing model that assumes that firms ignore demand dynamics altogether when pricing their products. The authors show that the dynamic pricing model better fits and predicts the observed prices, and also yields more intuitively reasonable estimates of brand-specific marginal costs and, therefore, profit margins (about 20 percent for each brand), when compared to the myopic and static pricing models (which yield brand-specific average margins of about 100 percent and 70 percent, respectively).

Che et al. (2007) investigate price competition between breakfast cereals brands, as well as the nature of strategic pricing interactions between breakfast cereals manufacturers and the retailer, using two years of IRI's scanner panel data (from June 1991 to June 1993) on household purchases in the breakfast cereals category in a metropolitan market in a large US city. For this purpose, the authors extend the econometric methodology of Berry et al. (1995) to handle the dynamic aspects of the manufacturers' and the retailer's pricing problems. The authors study whether firms look ahead, as well as to what extent, while setting prices. The authors find that (1) omission of demand dynamics biases the econometrician's inference of manufacturer behavior, i.e. one erroneously infers tacit collusion among cereals manufacturers when firms are competitive, and (2) the observed retail prices are consistent with a pricing model in which both cereals manufacturers and the retailer are forward looking, but the firms' time horizon when setting prices is short term, i.e. firms look ahead by only one period, suggesting that firms are boundedly rational in their dynamic pricing behavior. The authors also find that 94 percent of the additional explanatory power of the dynamic pricing model over the static pricing model

(that ignores state dependence effects) arises from the firm's accounting for the effects of lagged demand on current demand, while only 6 percent arises from the firm's looking into the future when setting current prices.

While the above-mentioned studies estimate pricing decisions of oligopolistic firms in the presence of state dependence, no econometric study has looked at firms' pricing decisions in the presence of reference prices. This is a notable omission in the literature on dynamic pricing and merits further study.

## 5. Conclusions

This chapter discusses pricing models in the presence of demand dynamics that arise due to the effects of state dependence and reference prices in consumers' brand choices over time. One notable omission in the existing literature on these dynamic pricing models pertains to the estimation of pricing decisions of competitive firms in the presence of reference price effects. While normative models of what firms must do have been proposed by Kopalle et al. (1996), no descriptive model of what firms actually do in practice has been estimated so far. Addressing this is an important avenue for future research. Future econometric research on pricing should also systematically investigate how alternative sources of demand dynamics – such as consumer stockpiling, retailer forward buying, consumer learning, word of mouth, price expectations etc. – affect strategic pricing decisions of firms in practice. Future research should also focus on the implications of dynamic pricing for firms' distribution channel or contracting strategies.

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