

**Theoretical and Empirical Analysis
of Price Dispersion**

by

Zhen Liu

(2948190)

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Supervisor: Professor Gamal Atallah

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Abstract

This paper reviews the theoretical and empirical literature on price dispersion. I start with a discussion of theoretical models of price dispersion. Imperfect information and search costs are considered major sources of price dispersion. Furthermore, firms' cost heterogeneity, demand uncertainty, market concentration and product characteristics are predicted to have significant effects on price dispersion. Then I discuss some empirical models of price dispersion. Most of them are in line with the prediction that imperfect information and search costs are major sources of price dispersion. Moreover, empirical evidence suggest that demand uncertainty, cost heterogeneity and product characteristics affect price dispersion.

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1. Introduction

Casual observation of market prices of individual products reveals that the proverbial “law of one price” is never empirically valid. Homogeneous goods are often sold at widely different prices by competitors. Many studies have shown that an equilibrium with price dispersion for homogeneous products can exist under various conditions. Following Stigler (1961)’s seminal paper, economists have proposed many models explaining price dispersion. The earlier studies were theoretical; empirical papers started to appear in the late 1980’s. Based on these studies, we know that imperfect information is the major source of price dispersion, however, there are also empirical studies investigating the effects of firms’ heterogeneity, product characteristics, demand conditions and market structure on price dispersion.

The objective of this paper is to provide a survey of the theoretical and empirical analysis of price dispersion. The paper is organized as follows. Section two provides brief descriptions of the theoretical models. This section is divided into four subsections: 1) models under the assumptions of incomplete information and consumers’ search, 2) sequential-search based models, 3) models focusing on the nature of firms’ costs, and 4) models exploring the relationship between price dispersion and demand uncertainty. Section three reviews a section of the empirical literature. This section is composed of four subsections: 1) price dispersion in online markets, the airline industry, insurance markets, prescription drugs markets and retail markets; 2) advertising and price dispersion; 3) inflation and price dispersion; 4) product characteristics, demand conditions and market structure. Section four provides concluding remarks.

2. Theoretical models

Theoretical discussions on price dispersion date as far as Bertrand (1883). The Bertrand model of competition relies on the following four assumptions: i) consumers are perfectly informed about prices, ii) goods are homogeneous, iii) firms compete in prices, and iv) firms are able to supply the demanded quantity at constant marginal cost. Bertrand argued that consumer search in a posted offer market will enforce price to converge to the competitive level even when there are only two sellers. In such a market, if a firm charges a higher price than a competitor, it faces zero demand. The intuition is simply that undercutting is profitable at any higher price; at least one seller will have an incentive to significantly increase quantity and profit by slightly decreasing his price.

However, many subsequent models analyzing price dispersion deviate from Bertrand's conclusion that price will be forced down to the competitive level in equilibrium. These models introduce various factors keeping prices from converging to the competitive level, which can be loosely grouped into the following four categories¹: 1) imperfect information and search models, 2) sequential search models, 3) cost heterogeneity models, and 4) demand uncertainty models.

2.1 Imperfect information and search models

Imperfect information and search models assume that consumers differ in the costs of becoming perfectly informed and examine how individuals ought to behave in face of a

¹ Note that these groups are not mutually exclusive.

variety of unknown prices in the market. According to this group of models, search costs and incomplete information explain most of the observed price dispersion.

Stigler (1961)

Stigler (1961) studies consumer behavior in the market, given search costs as well as an exogenous and constant distribution of asking prices. In the market where price dispersion is ubiquitous even for homogeneous goods, consumers have to search to identify the most favorable price. If there are search costs, consumers will want to limit the search activity. They will search a fixed number of stores where the expected gain from searching once more is less than the search cost and buy at the lowest price they know of.

According to Stigler, price dispersion arises because knowledge becomes obsolete. The instability of supply and demand conditions and the changing identity of buyers and sellers cause the distribution of asking prices to change over time. Buyers and sellers can only ascertain the new average price in the market by searching, which comes at a cost. Therefore, the greater the instability, the greater price dispersion will be.

Stigler also studies the determinants of search and finds positive relationships between the following four pairs of factors: 1) the fraction of the buyers' expenditures on the commodity and the savings from search; 2) the fraction of repetitive buyers in the market and the effective amount of search; 3) the fraction of repetitive sellers and the amount of accumulated search; and 4) the cost of search and the geographical size of the market.

Furthermore, Stigler discusses the effect of advertising on price dispersion. Advertising is an immensely powerful instrument that potential buyers use to drastically reduce the cost of search. More specifically, price advertising has a decisive negative influence on the

dispersion of prices. Search becomes extremely economical with the help of price advertising. The effect of price advertising, then, is equivalent to that of introducing a very large amount of search by a large portion of the potential buyers. Since advertising of prices will be devoted to products for which the marginal value of search is high, it will tend to reduce price dispersion most in commodities with large aggregate expenditures.

Stigler also suggests that price dispersion will vary with the size of the market in terms of dollars and number of firms. Agents or brokers specializing in selling price information will appear in the market as the market grows. The provision of information market will eventually become monopolistic; therefore, there will be a "standard" source for trade information. But Stigler does not clarify the effect of market size on price dispersion.

Diamond (1971)

One of the criticisms of Stigler's theory is that it partially focuses on only one side of the market. Although it explains how consumers ought to behave facing price variety, it does not explain price setters' behavior. Diamond (1971) was the first to model simultaneously buyer search and seller price setting decision making. In Diamond's model, consumers are not rational and choose which stores to visit randomly. Firms do not behave as they would in the perfectly competitive market. Aware of consumers' difficulty of obtaining information, firms behave as rational profit maximizers with full information about the market. Diamond's model is constructed in discrete time. Consumers search and visit only one store each period. Diamond does not assume that consumers know the distribution of prices in the market. The representative consumer learns the price in a store only by entering it. He is aware that other stores may have different prices currently

and may have different prices in the next period when he could reach another store. When the representative consumer decides to buy, he buys according to the demand function:

$$x^*(p) = \begin{cases} x(p) & p \leq q \\ 0 & p > q \end{cases} \quad (1)$$

where x is the quantity, p is the price and q is the cutoff price such that the consumer purchases at any price less than or equal to q . The consumer's utility is a function of the price at which he purchases and the number of periods he searches before purchasing: $u(p, z)$, where z is the number of period the consumer has spent searching.

The aggregate demand function is as follows:

$$X_t(p) = x(p) \sum_{\tau} N_t^{\tau}(p) \quad (2)$$

where $N_t^{\tau}(p)$ is the number of consumers of generation τ who are willing to purchase in time t at price p . Then, the firm's maximization problem can be written as²:

$$\underset{p}{\text{Max}} \quad pX_t(p) = px(p) \sum_{\tau} N_t^{\tau}(p) \quad (3)$$

Firms are assumed to face the same demand function, solve the same maximization problem and all select the same price. Since $N_t^{\tau}(p)$ is continuous and nondecreasing, $px(p)$ is quasiconcave and continuous with a maximum at p^* , a finite price, this problem has a solution. The maximization of $px(p)$ at p^* will lead to a long-run equilibrium.

Diamond reaches a surprising conclusion which is known as Diamond paradox. Diamond concludes that if there is no search cost, all firms must charge the competitive price, otherwise, a monopoly price should be charged by all firms no matter how high that price is, how small the search cost is and how many firms there are. For any positive

² The firm has no costs by assumption.

search cost, in equilibrium, no consumer would search. In a steady state, consumers expect the next period price to equal the long-run value. They have a cutoff price this period slightly above the long-run price, since it is worth a small amount to make the purchase this period rather than next period. With constant shares of consumers each period, firms are interested only in short-run profits. Therefore, the equilibrium price does not seem to converge to the competitive price and all firms would charge prices at the monopoly level.

Diamond's result generates three uncomfortable implications. Firstly, he does not consider the size of the market or the actual search cost. As long as search costs are positive, all firms should charge the monopoly price, and even a reduction in search costs would not change the equilibrium price. Secondly, he suggests no role for search in equilibrium since neither equilibrium displays price dispersion, thus Stigler's hypothesis that the search process will sustain price dispersion appears invalid. Thirdly, the two equilibrium results are discontinuous, either the monopoly outcome with strictly positive search costs, or the competitive outcome without search costs.

The important message from Diamond's model is that for price dispersion to exist in equilibrium, there ought to be some buyers' and/or sellers' heterogeneity. Suppose there is consumer heterogeneity with respect to search costs, a group of "shoppers" with negligible search costs will eventually get informed about the stores charging the lowest price. It then pays to charge prices below the monopoly price because stores that deviate will get all of shoppers of this type. In equilibrium, the shoppers will pay a low price, while the remaining consumers shop randomly and will pay either the low or the high price.

Salop-Stiglitz (1977)

Maybe the most famous modern studies describing price dispersion in equilibrium are “Bargains and ripoffs” (Salop and Stiglitz, 1977) and “A model of sales” (Varian, 1980).

Salop and Stiglitz (1977) analyze the industry equilibrium in which consumers can only become fully informed at a cost. When the market price increases, there are two possibilities: the price will keep cycling, or the price will settle down at the monopoly price level. This assumption leads to a monopolistically competitive price equilibrium and to price dispersion.

In their model, Salop and Stiglitz present a market with two types of consumers. Informed consumers know the price distribution, while the uninformed do not. There are four possible Nash equilibrium configurations³ in the market where risk-neutral consumers have two decisions to make. First, they must decide whether to enter the market or not. Second, they must choose between searching and purchasing at a randomly selected store. The crucial assumption is that only complete information may be obtained. On the other hand, by assumption, firms know prices charged by other firms. Firms also know the distribution of consumers’ search costs so they know how many consumers will search. Consequently, firms face no uncertainty.

Salop and Stiglitz derive equilibrium prices in the market using the following methodology. They first propose a potential equilibrium in which the zero profit condition is satisfied. Then they examine whether a deviant firm’s⁴ profit maximization condition is satisfied at the proposed potential equilibrium. Only if the deviant firm prefers the equilibrium price is the potential equilibrium the actual one. Salop and Stiglitz

³ 1) Single price equilibrium at the competitive price p^* ; 2) single price equilibrium at the monopoly price level u ; 3) a two-price equilibrium in which the lower price p_l is the competitive price p^* , and the higher price p_h is no greater than the monopoly price; 4) non-existence of any Nash equilibrium.

⁴ Deviant firms are those who make more profits by charging different prices.

find that in equilibrium some percentage of stores sell at a competitive price while some charge a higher price. The stores charging a high price have lower sales volumes, whereas the sales volumes of those stores with low prices are large. Both types of firms, therefore, earn the same profits in equilibrium. As a result, informed consumers always use a low-priced store, while the uninformed buy at random.

Shilony (1977)

Shilony observes that in oligopolistic markets, price fluctuations and sale policies suggest some deliberate randomization. Motivated by this observation, Shilony uses a game-theoretic framework to explain the existence of price dispersion. His model considers both sides of the market: rational consumers and sellers engaged in a non-cooperative game and concerned with their competitors' actions. The model assumes that the market is segmented in terms of location, consumer loyalty, access to information and that it is costly for consumers to move across segments. In fact, consumers' being stuck in their segment of the market and incurring a cost in moving out generates the monopolistic power of firms. Shilony concludes that there is no Nash equilibrium in pure pricing strategies and he also constructs a mixed strategy equilibrium where firms randomize their pricing.

Varian (1980)

As indicated by Varian himself, his model can be regarded as a combination of the Salop-Stiglitz (1977) and Shilony (1977) models. As in Salop and Stiglitz (1977), he divides consumers into two groups, informed and uninformed. And as in Shilony (1977), he allows for the possibility of random pricing by firms. The market comprises exogenously

informed and uninformed consumers. The stores are identical and randomly choose a price according to a density function described below. Consumers are unable to learn by experience which stores have low prices, since stores use mixed-strategy pricing. Stores attempt to price discriminate between informed and uninformed consumers which leads to persistent price dispersion in equilibrium.

Varian presents a model analyzing a different type of price dispersion which he refers as "temporal price dispersion". He constructs the expected profit function of a representative store. Let n be the number of stores. When a store charges price p , two things could happen. With probability $(1 - F(p))^{n-1}$, P could be the lowest price in the market and this store will get all the consumers, informed and uninformed. On the other hand, there could be other stores charging prices lower than p ; the representative store only can get its share of the uninformed consumers. This event has probability $1 - (1 - F(p))^{n-1}$. Each week, each store chooses a random price according to its density function $f(p)$ indicating the probability with which it charges each price p . Stores have identical strictly decreasing average cost curves denoted as $C(q)$. The maximization problem of the representative firm is to choose the density function $f(p)$ to maximize expected profits. Varian derives the equilibrium density function. As an example, given $C(q)$ and assuming zero marginal costs, Varian transforms the equilibrium density function into a much simpler form $f(p) = 1/p(1-p/r)$ (where r is the consumers' reservation price) which is illustrated in figure 1.

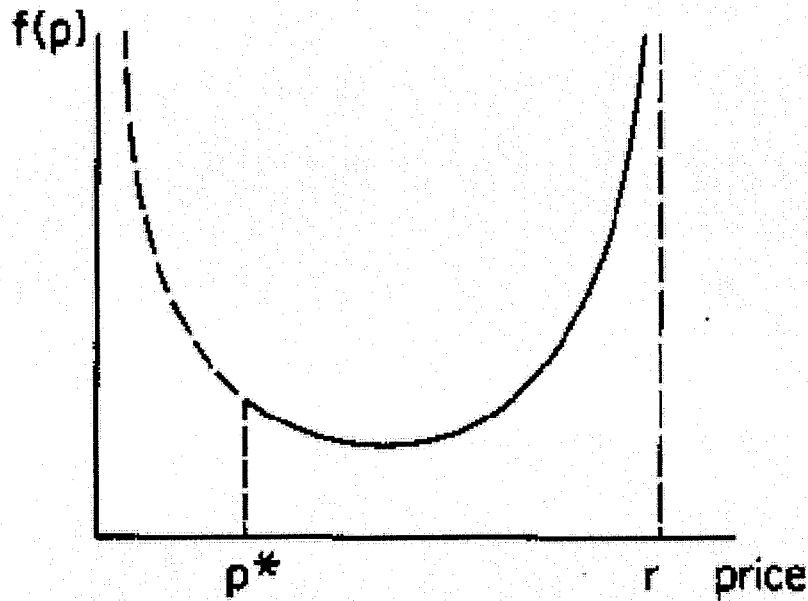


Figure 1: Graph of the density function

Source: Varian (1980)

Observing the U-shaped equilibrium density function, it seems that stores tend to charge extreme prices with higher probability than they charge intermediate prices. Intuitively, stores want to charge informed consumers the lowest price to keep their business but also want to charge uninformed consumers p^* to exploit profit. The relevant part of the density function is between p^* and r . If the fixed cost is small or the number of informed consumers is large, p^* will be small. Therefore, a lower price will be charged more often over time. In other words, the market will be more competitive. However, the influence of the uninformed should not be ignored: high prices will sometimes appear.

In addition, Varian also calculates the average prices paid by informed consumers and uninformed consumers. In his example, the informed consumers pay almost half the price that uninformed consumers pay. Moreover, Varian considers the situation that consumers can become fully informed about the market price by paying a fixed cost. Consumers'

decision of becoming informed or uninformed now depends on the “full price”, the original price plus the cost of information. He concludes that neither informed nor uninformed consumers will change their behavior in equilibrium.

Salop and Stiglitz (1982)

Salop and Stiglitz (1982) examine equilibrium in a competitive market coupled with incomplete information and search costs. Like Salop and Stiglitz (1977), Shilony (1977) and Varian (1983), this paper shows that when search costs are positive, the equilibrium involves price dispersion. But this paper differs mainly in assuming identical agents and the possibility of storage of products. In this two-period model, all firms have identical technologies. Some of them charge high prices while the others charge low prices. Meanwhile, firms are unable to perfectly differentiate among consumers. All consumers are assumed to be identical with respect to preference and income. They can, at any price no greater than the reservation price, purchase one unit in each period or buy two units in period 1 and save one unit for period 2. The storage cost is assumed not to be too great. Consumers have rational expectations of price distribution and randomly select stores. However, they don't know precisely which store charges what price. Some of them purchase at high-priced stores only for immediate needs and can enter the market again later. Those lucky consumers arriving at low-priced stores can buy more than present needs and store the excess for future consumption. In equilibrium, high-priced stores and low-priced stores earn the same profit. High-priced stores will earn more profit per sale but will have smaller sales volumes while low-priced stores will have higher sales volumes to compensate. As a result, price dispersion may exist in equilibrium.

A critical assumption of this paper is that consumers have rational expectations. However, there is no convincing evidence showing that consumers' expectations of

probability distribution of prices coincide with the actual probability distribution of prices in the market. This paper argues that price dispersion will emerge even if consumers do not have rational expectations.

Benabou (1988)

Until this paper, the literature had ignored price dynamics. Benabou (1988) introduces the effect of inflation on price dispersion by modeling a dynamic, imperfectly competitive market. Following Sheshinski and Weiss (1977), Benabou shows that a monopolist facing a fixed cost of changing his price during a period of inflation will choose (S, s) price policy⁵, in which the firm allows its relative price level to drift below the optimal price, to S, and then adjusts it above the optimal price, to s. This price policy is found optimal for a firm facing a constant, positive rate of inflation and a fixed cost of adjusting price. In the presence of costs of price adjustment, the effect of inflation is not neutral any more⁶. It generates price dispersion, which makes potential search profitable and thereby increases price competition, resulting in lower prices in the market. The author establishes a causal relationship between the aggregate rate of inflation and the amount of price dispersion, i.e. price uncertainty for buyers in the market. According to this paper, considerable evidence suggests that higher inflation rates are associated with greater price dispersion.

Another interesting point of this paper is that it explains Diamond's paradox as a limiting case where menu costs on the seller's side vanish: if price adjustment is free but

⁵ Sheshinski and Weiss (1977): (S, s) price policy is characterized by a sequence of finite intervals during which firms' nominal price is held constant, followed by discrete price adjustments. .

⁶ Sheshinski and Weiss (1977): An increase in the rate of inflation will increase the initial price, S and decrease the terminal price, s in each period, thereby increasing the magnitude of each price change.

consumers' search is costly, the market is biased against buyers and all purchases take place at the monopoly price.

2.2 Sequential search models

Some economists suggest that the decision rule suggested by Stigler (1961) is not optimal and that the best procedure is a sequential one. The optimal search rule of sequential search models is of this form: buy if the quoted price is less than the minimum price at which the expected decrease in the minimum price from another search equals the search cost, otherwise, keep on searching.

Salop (1977)

This paper provides the rationale for price dispersion such that a monopolist uses price dispersion as a sorting device to split consumers into submarkets. Consumers differ in their search techniques and their efficiency of gathering information varies too. On average, more efficient information-gatherers will obtain better deals. This gives the monopolist an incentive to price discriminate against those less efficient but more price-inelastic information-gatherers. Given the potential profits from price discrimination, monopolists first need to identify the less efficient consumers in the market. Since less efficient information-gatherers are assumed to search less and pay more on average than efficient information-gatherers, price dispersion can be used by monopolists as a device to split the market into two sub-markets in order to permit price discrimination.

Salop models consumers' decision process as a sequential search model. Consumers have rational but limited prior information. They know the actual probability density function of prices in the market but they don't know exactly which store charges which price.

Therefore, they have to gather specific price information by randomly sampling stores. Given the subjective distribution of price and cost-minimizing reservation price, consumers try to minimize the expected total cost of the commodity (original price plus search costs). Monopolists actually set their optimal distribution of prices by choosing the expected price, expected search and expected total search costs where these functions must satisfy consumers' maximization problems. Consumers differ in the effective search cost due to the heterogeneity in their ability in analyzing and processing gathered information. Given price structure and demand conditions, monopolists will maximize profits by exploiting price dispersion as a screening device.

Burdett and Judd (1983)

Burdett and Judd's (1983) show that an equilibrium with dispersed prices exists assuming both sides of the market are identical and rational. In contrast with Reinganum's model (discussed below in section 2.3) and Salop and Stiglitz's (1977) model, Burdett and Judd confine their attention to models where firms' costs are identical, consumers are identical and search only to lower the expected cost of acquiring desired goods. This paper considers two types of search methods: non-sequential search and noisy sequential search. With the non-sequential search method, a consumer will choose the number of prices to observe before receiving any offers. With noisy sequential search, one consumer pays to receive an unknown number of price quotations. The consumer can buy at the observed lowest price or search again. When one of the methods is specified, a market equilibrium can be defined where firms maximize their profits given correct knowledge of consumers' behavior and consumers minimize their costs of purchasing given correct

knowledge of distribution of prices in the market. The most important information for firms is the distribution of prices of other firms and consumers' search behavior.

The authors argue that in the case of non-sequential search, a monopoly market equilibrium will always exist and dispersed equilibrium can exist under certain conditions. Let q_n denote the probability that a randomly selected consumer observes n prices before comparing the lowest observed price with his reservation price. The authors characterize the conditions for equilibrium involving price dispersion using the following rationale. First, if there is a positive search cost, and there is a market equilibrium with non-sequential search, then it is either a monopoly price equilibrium or a dispersed price equilibrium. Second, suppose all consumers face the same positive search cost per price observation, then in this case there are one, two or three market equilibria with non-sequential search. In the case of noisy search, the authors argue, given fixed consumer search behaviour and positive search costs: a) the unique equilibrium is the monopoly price equilibrium if $q_1=1$; b) the unique equilibrium is the competitive price equilibrium if $q_1=0$; and c) the unique equilibrium is the dispersed price equilibrium if $0 < q_1 < 1$. The authors demonstrate the possibility of price dispersion in equilibrium with fully rational and identical buyers and sellers. This study provides proof that price dispersion may exist independently of heterogeneity and could be a long-run phenomenon.

Gatti (2000)

Gatti (2000) points out that Diamond (1971)'s result depends crucially on the assumption of single commodity search and does not hold when the model is generalized to allow for multi-commodity search. In Gatti's paper, a multi-commodity search model is developed where consumers search to minimize total expenditure on a specific bundle of

commodities, but firms do not sell all the commodities demanded, so consumers must search among different firms. Naturally, the model is a multi-commodity extension of the single commodity model analyzed by Diamond (1971); however, the results are quite different. It is shown that all equilibria in the model display price dispersion, with no two firms charging the same price with positive probability. Furthermore, as the cost of search falls to zero the equilibrium distribution of prices converges to the competitive price. In equilibrium, the consumers hold correct beliefs over the distribution of prices, and firms maximize expected revenues given correct beliefs over the search behavior of consumers. Furthermore, the author finds important differences in the effect on the equilibrium distribution of prices from changes in demand. An increase in demand generated by an increase in the number of consumers per store will increase revenue but will have no impact on the distribution of prices. In contrast, an increase in demand generated by an increase in the quantity desired by individual consumers will decrease the equilibrium distribution of prices. The result also confirms Stigler (1961)'s suggestion that it is the search behavior of consumers which is generating the equilibrium price distribution.

2.3 Cost heterogeneity models

Persistence and the degree of price dispersion in cost heterogeneity models depend crucially on the existence of different marginal costs among firms and on the nonzero elasticity of demand functions.

Reinganum (1979)

Instead of allowing for heterogeneity among consumers, Reinganum (1979) introduces firms' heterogeneity by assuming different unit costs and hence different monopoly prices. This model relaxes the assumption of unitary demand and assumes that identical consumers with elastic demand curves sample sequentially from a known price distribution, at a fixed cost per observation. On the one hand, each consumer possesses a strictly quasi-concave, twice continuously differentiable utility function $U(W, P_0, P)$ where W denotes wealth, P_0 is the vector of fixed prices for all other goods, and P is the price paid by the buyer for the "product". This utility function can be simplified as $V(P_0, P)$. Consumers are assumed to have perfect information in the markets for all commodities except one, referred to as the "product" market which is characterized by a distribution of prices. Each consumer, in attempting to maximize his expected utility, engages in search behavior in the product market, i.e., consumers attempt to identify a minimum price for the product.

Firms are not identical: each has a constant marginal cost, and each value of marginal cost occurs with some frequency among the firms in the industry. Firms are also assumed to be perfectly informed of consumers' reservation prices and demand functions and they exploit this information in their price-setting decisions. Firms act as monopolistic competitors pursuing profit maximization.

Given the distribution of marginal costs together with consumers' and firms' optimizing behavior, Reinganum presents the equilibrium distribution of prices and a range of prices offered by firms. Nevertheless, given the distribution and price range, consumer will still choose to buy at the reservation price. As a result, the distribution of prices, the price

range and consumers' reservation price jointly result in an equilibrium with price dispersion.

In this model, the explanation of price dispersion is that consumers do not purchase the same amount of the product for all prices at or below the reservation price. They adjust their demand rather than purchase the same quantity regardless of the price. In other words, due to search costs, the product price is not lowered down to the minimum price nor can it rise up to the reservation price because of the substitution effect.

Carlson and McAfee (1983)

In the model of Carlson and McAfee (1983) price dispersion is attributed to firms' heterogeneous marginal costs. In their paper, consumers are assumed to be using a sequential, reservation price search strategy and have knowledge of the price distribution. Responding to that, firms need to be heterogeneous in some respects in order to sustain price dispersion. Carlson and McAfee develop their model assuming firms have cost heterogeneity in supplying the product.

The basic model is as follows. Let q_j denote the expected quantity demanded for the firm at the price p_j ; n is the number of firms in the markets; x is search cost; T is the range of search cost and $1/s$ is the density for $0 \leq x \leq T$. Initially, a firm's demand depends on the difference between a firm's price and the average price of all firms:

$$q_j = \frac{1}{sn} \left(T - \frac{n-1}{n} p_j + \sum_{i \neq j} \frac{p_i}{n} \right) = \frac{1}{sn} [T - (p_j - \bar{p})] \quad (4)$$

where $\bar{p} = \sum_{j=1}^n (p_j / n)$.

The cost function is defined as

$$c_j(q_j) = \alpha_j q_j + \beta q_j^2 \quad \alpha_j, \beta > 0; \alpha_j \leq \alpha_{j+1}, j=1,2,\dots,n-1. \quad (5)$$

The firm's profits are

$$\pi_j = p_j q_j - \alpha_j q_j - \beta q_j^2 = (p_j - \alpha_j - \beta q_j) q_j \quad (6)$$

By solving the first order conditions, they find the equilibrium price

$$p_j = \alpha_j + \frac{(1 + \gamma)n}{n-1} \left[\gamma + \frac{n-1}{2n-1 + \gamma} (\bar{\alpha} - \alpha_j) \right] \quad (7)$$

where $\gamma \equiv 2\beta(n-1)/sn^2$ and $\bar{\alpha} = \sum_{i=1}^n \alpha_i / n$.

Equation (7) illustrates that a firm with a lower marginal cost will set a lower price. Cost differences among firms play a crucial role. Price dispersion occurs only if the variance of the cost function parameter α_j is not zero. Further study of how the changes of β, s, n will affect p_j and the variance of p shows that a higher β or a lower s will raise the price of every firm in the market but will have more effect on lower-cost firms, and as a result, price dispersion will fall. When β increases, all firms move up their marginal cost curves and firms with the lowest price experience the largest increase in marginal cost, and hence the largest price increase. Consequently, \bar{p} will increase and the variance of p will decrease.

Carlson and McAfee also examine the effect of market structure on price dispersion. The not surprising result is that the variance of prices grows as the number of firms increases.

2.4 Demand uncertainty models

Demand uncertainty models provide explanations for price dispersion in industries such as airlines, automobile rentals, hotels, restaurants, theatres and sporting events, where capacity is costly and prices are set in advance and firms face demand uncertainty.

According to demand uncertainty models, firms will sell at multiple prices and limit the availability of products at each price. This optimal pricing strategy exhibits price dispersion in equilibrium.

Dana (1999)

This paper models price dispersion in equilibrium in markets with capacity costs (perishable assets) and demand uncertainty. Dana shows that demand uncertainty and capacity costs are sufficient to explain price dispersion. In addition, the paper examines the effect of market structure on equilibrium price dispersion under demand uncertainty.

Dana points out that in order to manage capacity costs and to maximize profits, many industries such as airlines and hotels use sophisticated revenue management under demand uncertainty. For example, revenue management in the airlines industry implements peak-load pricing⁸, third-degree price discrimination⁹ and a seat inventory control system¹⁰ for coping with uncertain demand for a perishable asset. Formally, the airline industry revenue management involves a process of setting fares for each route and each set of fare restrictions and limiting the availability of seats at each fare. However, Dana's model differs from traditional revenue management models for it ignores market segmentation and fare restriction. Since peak-loading pricing and price discrimination are primarily pricing problems, Dana only addresses the role of seat-inventory control. He focuses on how firms can profit from setting multiple fares and limiting seat availability at low fares when market segmentation is not possible.

⁷ Changes in β imply differences in costs.

⁸ Peak-load pricing is used to smooth the utilization of very expensive capital equipment and reduce congestion at peak usage times.

⁹ A form of price discrimination in which a seller charges different prices to groups that are differentiated by an easily identifiable characteristic, such as location, age, sex, or ethnic group. This is the most common type of price discrimination.

The model assumes price rigidity such that firms must precommit to a menu of prices before demand is known. Firms do not timely update their prices in response to new and relevant demand information. This enforces a price system in which consumers who arrive early or arrive late when demand is low pay lower prices while consumers who arrive late when demand is high pay higher prices. Further, since prices are not adjusted to clear markets, goods will be rationed in equilibrium according to a proportional rationing rule which means that goods are allocated to each consumer in proportion to his demand.

This model demonstrates that firms facing capacity costs, price rigidity and uncertain demand will set multiple prices and limit the quantity available at each price. Moreover, price dispersion is shown to be positively related to market competition. Price dispersion increases when the market becomes more competitive.

Dana (2001)

In contrast with Dana (1999), Dana (2001) considers a more general demand system and shows that price dispersion can be explained by demand uncertainty alone. Monopolists choose dispersed prices because they don't know the distribution of demand in advance.

This model uses proportional rationing rules to decide on how to allocate available units to consumers. This rationing rule is consistent with the following queuing model. Goods are sold in order of price, with cheaper goods being sold first. Consumers arrive in random order, with consumers arriving first paying a lower price for the goods. This model also assumes high transaction costs of adjusting prices.

¹⁰ Seat inventory control means assigning limits on the availability of seats at each fare.

This paper starts with the derivation of the monopoly optimal pricing strategy responding to two demand states: high demand and low demand. Firms set at most two prices and limit the availability of their outputs at lower prices. Then the paper extends the pricing strategy to the more general case where firms can freely choose any price schedule. In fact, firms set at most as many prices as there are states of demand. Price dispersion arises because of the combination of demand uncertainty and the fact that firms are required to set their prices before the distribution of demand is known. By assumption, consumers are free to buy at the lowest price available and the monopolists can only implement price schedules in which the ex post monopoly price is positively correlated with the level of demand.

3. Empirical analysis of price dispersion

The empirical analysis of the price dispersion models discussed in the previous section is divided into four parts. First, the effect of search costs on price dispersion is tested in five markets including sophisticated and emerging ones. Surprisingly, evidence from the emerging online industry is not consistent with the search model's prediction that a reduction of search costs will reduce prices and price dispersion. Second, the effect of inflation on price dispersion is considered. Two papers (Van Hoomissen, 1988 and Parsley, 1996) provide empirical evidence supporting that inflation is positively related to price dispersion. However, Reinsdorf (1994) has opposite findings. Third, the effect of price advertising on price dispersion is examined. According to Milyo and Waldfogel (1999), the effect of alcohol price advertising on price dispersion is inconsistent with Stigler (1960)'s suggestion that price advertising will reduce price dispersion. Fourth, the effect of product characteristics, demand conditions and market structure on price dispersion is examined. Aalto-Setälä (2003) finds evidence that product characteristics and demand conditions can have some effect on price dispersion while the effect of market structure is insignificant.

3.1 Search costs and price dispersion

3.1.1 The online market

Clay, Krishnan and Wolff (2001)

Clay, Krishnan and Wolff (2001) examine pricing by 39 online bookstores.¹¹ It is predicted that shopping over the Internet can dramatically reduce consumers' search costs, and consequently, reduce prices and price dispersion. Surprisingly, the findings of this paper are inconsistent with this prediction. Prices and price dispersion are unchanged over the sample period. The authors explain that this discrepancy may be due to the fact that stores have succeeded in differentiating themselves even though books are almost perfectly homogeneous goods. It points to an important interaction between price dispersion, product differentiation and search costs: increased product differentiation may cancel the negative effect of a reduction in search costs on price dispersion.

Krishnan and Wolff find evidence supporting the prediction of search theories that the price of advertised items or repeatedly purchased items will be lower than for unadvertised or infrequently purchased items. As a fraction of the publisher's recommended prices, the average prices of New York bestsellers and former New York bestsellers are the lowest followed by those of computer bestsellers and former computer bestsellers, while random books have the highest average price.

¹¹ This paper uses data between 1999 and 2000 including New York Times bestsellers, computer bestsellers and randomly chosen books.

Baylis and Perloff (2002)

Baylis and Perloff (2002) investigate price dispersion in the online retail market of cameras and scanners.¹² Once again, the traditional wisdom that prices for homogeneous products will eventually converge to the competitive level appears invalid. The prices of cameras and scanners vary extensively. Over the sample period¹³, the price range of cameras is from \$673 to \$1015, which is 42 percent of the average price. At the same time, the price range of scanners is 29 percent of the average price. Even though the law of one price is violated, one might expect internet firms to compete to undercut each other, so that the price rankings of firms would vary over time. This hypothesis is rejected: firms with high prices remain high-priced and firms with low prices remain low-priced over time. Moreover, prices do not fluctuate over time in a manner suggestive of periodic sales by e-retailers.

To distinguish whether price dispersion is due to price-discrimination or to the service-premium¹⁴, the authors regress each firm's price on various firm characteristics, shipping and other fees, and time dummies. Under the service premium hypothesis, one would expect that firms with superior service, such as return guarantees, low shipping fees and so on, will charge a higher price while firms with poor service will charge a lower price. Interestingly, firms in the retail market of the specific cameras and scanners are divided into two groups: good firms offering superior service coupled with lower prices and bad firms offering poor service coupled with higher prices. This situation can be interpreted

¹² This paper collected price and relevant information on 41 firms that sold the Olympus C2000Z camera and 28 firms that sold the HP 6300 scanner in the U.S..

¹³ The collection period lasted 14 weeks (September 24th to December 19th, 1999) for the camera and 11 weeks (October 7th to December 19th, 1999) for the scanner.

¹⁴ Firms that provide services or have other attributes that build customer loyalty may charge premium prices.

partially in line with Salop and Stiglitz's (1977) model in the sense that if consumers have different costs of obtaining information, firms with these desirable attributes will charge lower prices primarily to efficiently informed consumers. In general, price dispersion in the e-commerce retail market is due to significant consumer search costs.

3.1.2 The airline market

Borentein and Rose (1994)

Borentein and Rose (1994) analyze price dispersion in the U.S. airline industry based on 10 percent of a random sample of U.S. eleven major airlines' tickets during the second quarter of 1986. They used the Gini coefficient of fares paid to measure the magnitude of price dispersion or inequality. Multiplying the Gini coefficient by two yields the expected absolute difference in price as a proportion of the mean price for two customers drawn at a random from a population. The authors find significant dispersion in the prices charged by individual firms within the largest direct service airline city-pair markets. The average Gini coefficient of their sample is .181. Corresponding to that, the expected difference paid by two passengers randomly selected on a route is about 36 percent of the airline's mean ticket price on the route.

To distinguish price dispersion due to discriminatory pricing from dispersion resulting from cost differences, Borentein and Rose examine the degree to which price dispersion is affected by factors that might indicate either price discrimination or cost variations. Consumers' population attributes, products and market structure are grouped as factors likely to influence the amount of discriminatory price dispersion in the airline market. Borentein and Rose pay attention to the effect of market structure and firms' relative

positions on price dispersion, an issue which is overlooked by many other empirical papers. They argue that price dispersion should increase with concentration if industry elasticities are the more prevalent basis for segmentation¹⁵, and should decrease with concentration if heterogeneities in cross-elasticities are the more common source of price discrimination.¹⁶ Under monopoly-type discrimination, monopoly markets display the most price dispersion, followed by duopoly, followed by competitive markets. The order is reversed under competitive-type discrimination. The data provide clear evidence that the level of a carrier's price dispersion within a market is related to the structure of the market. As the number of competitors in a market grows, with the total number of flights held constant, price dispersion increases.

Two sources of cost variations across passengers may generate significant price dispersion: systematic peak-load pricing and stochastic peak-load pricing. Systematic peak-load pricing means that airlines have good information on their own utilization rates and on expected airport congestion levels at the time they set their flight schedules. Schedules are rarely changed in response to demand patterns after a flight is opened for booking. Stochastic peak-load pricing, however, indicates airlines that have pricing flexibility and can adjust their prices as demand is revealed over time. Systematic peak-load pricing reflects variations in the expected shadow costs of capacity at the time a flight is scheduled. Price dispersion due to systematic peak-load pricing is captured by variability in the airline's fleet utilization rates and airports' operations rates. In the case of stochastic peak-load pricing, the optimal peak-load price will reflect marginal operating costs plus expected shadow costs of capacity. However, price dispersion due to stochastic peak-load pricing cannot be directly controlled. Regression results show strong

¹⁵ Referred to as monopoly-type discrimination.

support for the hypothesis that competitive price discrimination is one source of airline price dispersion. Cost variability is also proved to be an additional source of price dispersion.

Hayes and Ross (1997)

Inspired by Borenstein and Rose (1994), Hayes and Ross investigate the sources of price dispersion in the airline industry by distinguishing markets with market power from those where competitive shocks lead to fare wars. The following sources could drive price dispersion: peak load pricing, fare wars and price discrimination. Fare wars appear when carriers, mostly those with financial problems offer discounted prices to attract travelers. As an unplanned reaction to aggressive carriers, fare wars increase consumer surplus. On the other hand, customers may be charged differing prices when the seller has sufficient information regarding demand elasticities. This type of price dispersion, as a carefully planned scheme, reduces consumer surplus.

Hayes and Ross estimate their models using the Gini coefficient, the Atkinson inequality measure and the entropy measure of price dispersion.¹⁷ Firstly, they find that the relationship between price dispersion in the airline industry and peak load pricing and the fare wars of the early 1990s¹⁸ is more evident although price discrimination exists to a certain extent too. Carriers with excessive financial difficulties play a significant role in price dispersion. Carriers in bankruptcy are desperate to sell tickets and frequently offer fare discounts. Other viable competitors react by offering discounts too. The resulting

¹⁶ Referred to as competitive-type discrimination.

¹⁷ Hayes and Ross (1997): Three measure of price dispersion are chosen for the following reason: the Gini coefficient gives more weight to the middle portion of a distribution, the Atkinson inequality measure is particularly informative about dispersion above the average price and its relationship with market power and the entropy index is more sensitive to variation in prices at the lower end of the distribution.

fare wars create price dispersion. In short, financial difficulties, fare wars and the expansion of new airlines refrain the major national carriers' ability to exploit market power through price discrimination. Moreover, Hayes and Ross find that competition from new airlines in fact reduces price dispersion by moving airfares to a lower uniform level.

3.1.3 The retail market

Adams (1997)

Frank Adams (1997) compares the price dispersion of gasoline with that of in-store items.¹⁹ Since grades of gasoline are almost always displayed prominently on an outdoor sign easily visible from several hundred feet away, gasoline is referred to as a good associated with relatively low consumer search and information costs. On the contrary, consumers can obtain the prices of most in-store items only by entering the store. Consequently, the in-store items are associated with relatively high consumer search and information costs.

The analysis of the multiple price equilibrium for homogeneous convenience store items is based on a simple search model where a positive relationship between price dispersion and search costs is established. Following Stigler (1961)'s argument, consumers tend to search more for gasoline since consumers' expenditure on gasoline is large relative to that on most in-store items. In addition, gasoline sales comprise more than one half of the total sales of convenience stores that sell gasoline. In response to consumers' demand for gasoline price information, retailers practice outdoor advertising. The above

¹⁸ From 1990 to 1992, fare wars proliferated and the financial challenges of the passenger airlines industry increased in the U.S..

considerations suggest that the consumers' cost of search for the purchase of gasoline is less than is the cost of search for in-store items. Therefore, the author expects that the degree of price dispersion for gasoline would be less than the degree of price dispersion for in-store items.

The empirical results are very supportive of the above prediction. Two methods are used to calculate the sample variance. One is to calculate the standard variance of the sample and the other is to calculate the variance in terms of percentage variation around the respective means. With the first method, for the 20 in-store items whose variances are greater than gasoline's variance, all 20 F-statistics are statistically significant. With the second method, for the 21 in-store items whose variances are greater than gasoline's variance, 20 F-statistics are statistically significant. The results prove that heterogeneity in search and information costs for consumers is important in explaining the observed price dispersion that occurs for homogeneous items sold at convenience stores, which is consistent with Stigler's prediction.

Lach (2002)

Lach (2002) tests the results of Varian (1980) empirically using a unique data set on store-level monthly prices of four homogenous products²⁰ sold in Israel. Varian (1980) states that consumers cannot learn about stores which consistently post low prices since stores randomize their prices. Therefore, price dispersion will not disappear and may persist over time.

¹⁹ The data for this study were obtained by surveying 20 convenience stores in Auburn/Opelika (Finland) from November 13 through November 16, 1994.

²⁰ One durable good: refrigerator, and three frequently purchased food staples: chicken, coffee, and flour.

First, Lach finds that the “law of one price” does not hold. In fact, even controlling for permanent observed and unobserved differences across stores, prices still exhibit substantial price dispersion which cannot be attributed to store heterogeneity as measured here. Moreover, the cross-sectional price distributions are quite stable over time.

Second, price dispersion decreases with the mean price of the good. For instance, refrigerator is the product with the lowest price dispersion, while coffee exhibits the highest price dispersion. Given fixed search costs, search is more valuable for high-price goods. On the other hand, search costs relative to the price of low-price goods may be significant and these refrain consumers from identifying the lowest-priced store. Henceforth, price dispersion will persist over time, especially for inexpensive goods.

In addition, Lach studies the existence and nature of mobility within the cross-sectional distribution, or intra-distribution dynamics in the context of price dispersion. Indeed, there is considerable variation in the ranks assigned to a given store over time and a lot of “jumping” around the cross-sectional distribution, particularly for coffee and chicken. Cross-sectional mobility is significant: stores move up and down the cross-sectional price distribution.

To sum up, the stability of the cross-sectional price distribution over time disguises significant intra-distribution dynamics. Consumers cannot learn which store is charging what price. This “short memory” feature of the markets is consistent with Varian’s model of consumer search and stores’ use of mixed price strategies.

3.1.4 The insurance market

Dahlby and West (1986)

Dahlby and West (1986) examine price dispersion using data from the Alberta automobile insurance market to test whether price dispersion is due to costly consumer search. Their study adopts Carlson and McAfee (1983)'s model. Instead of testing the model directly, they derive three predictions. First, they test the correlation predictions including the correlation between firms' premiums in different driver classes in a given year and the correlation between firms' premiums in the same driver class in different time periods. Second, they test the prediction that the firm's market share will fall if the firm raises its price relative to other firms' prices. Third, they test the prediction that cost differences between firms play a crucial role in explaining the variance of premiums. To test these predications, they estimate the following equation using the pooled time-series and cross-section data:

$$\begin{aligned} \text{var}[p'_{ik}(t)] = & \delta_1 + \delta_2 \text{LOSSCOSTSQ}_{ik} + \delta_3 \text{NOFIRMS}(t) + \delta_4 \text{NOCARS}_k(t) \\ & + \delta_5 \text{AGENCIES}_k(t) + \delta_6 \text{DSEARCH}_i + \delta_7 \text{DWPC}(T) \end{aligned} \quad (8)$$

where $\text{var}[p'_{ik}]$ is the variance of premiums in driver class i , $i=1, 2, 3, \dots, 19$; territory k , $k=1, 2, 3$; and year t , $t=1974, 1975, \dots, 1980$; $\text{LOSSCOSTSQ}_{ik}(t)$ is the real loss cost per car insured squared; $\text{NOFIRMS}(t)$ is the number of firms with over \$1000 in premium written; $\text{NOCARS}_{ik}(t)$ is the number of cars insured; $\text{AGENCIES}_k(t)$ is the number of insurance agencies per square mile; DSEARCH_i is a dummy variable for driver classes and $\text{DWPC}(t)$ is a dummy variable for wage and price controls.

According to the findings of the regression, there appears to be a significant price fluctuations in the automobile insurance markets and price dispersion can be mainly explained by imperfect information, i.e. costly consumer search.

3.1.5 The prescription drugs market

Sorensen (2000)

Sorensen (2000) examines patterns in dispersion and margins in the retail prices of prescription drugs. The data were directly from the 20 pharmacies in Middletown and Newburgh, New York in March 1998. Following search cost based theories of price dispersion; Sorensen predicts that a high frequency of purchase of prescription drugs should reduce the prices of the prescriptions and the degree of price dispersion. Moreover, the price-cost margin and price dispersion should move together in the same direction. Sorensen regresses the price range on purchase frequency, drug's acquisition costs, dummies for two kinds of brand-name drugs, a dummy variable for Newburgh and variables indicating 20 categories of drug therapy. The regression results show that the estimated coefficient on the purchase frequency variable is negative and statistically significant. The prices of repeatedly purchased prescriptions exhibit significant reductions both in price dispersion and in price-cost margins. Regression on an alternative measure of absolute dispersion, standard deviation, confirms this conclusion. This matches his prediction that the consumers' increased propensity to search for frequently purchased drugs constrains pharmacy price dispersion and markups. Additionally, Sorensen points out the important implication for policies that affect the cost of acquiring information. He suggests that programs or policies that facilitate consumer's search for price information will lead to lower prices. For instance, legalizing

pharmaceutical price advertising can provide efficient access to price information for consumers.

Sorensen also examines the effects of pharmacy heterogeneity and cost heterogeneity on price dispersion. Although prescription drugs are almost perfectly homogeneous products, pharmacies can differentiate themselves with respect to the services provided. This pharmacy heterogeneity can have an effect on price dispersion. The empirical results illustrate that pharmacy-specific differences cannot entirely explain the observed price dispersion. Even after taking these pharmacy differences into account, frequency of purchase still has explanatory power. As to the effect of cost heterogeneity, it is difficult to ascertain its precise importance since the cost information of pharmacies is not available. However, the evidence suggests that the effect of different acquisition costs on the observed price dispersion is trivial.

3.2 Inflation and price dispersion

Van Hoomissen (1988)

Van Hoomissen (1988) focuses on the dispersion in monthly-observed prices for 13 strictly defined consumer goods in different outlets over a period of 12 years in Israel. The central hypothesis of the paper is that the extent of price dispersion is strongly influenced by inflation. During an inflationary period, firms don't adjust prices in lockstep, fully rational consumers who purchase one item repeatedly will find it optimal to be less informed since currently acquired information will have diminished future value. And firms will take this into consideration when choosing price strategies.

The central hypothesis is tested by regressing price dispersion on the market rate of inflation. In addition, she also tests whether different goods are differently affected by inflation. For instance, it is possible that relative expensiveness and frequency of purchase will affect the relationship between price dispersion and inflation. This hypothesis is tested by examining differences in regression results of different goods sorted by expensiveness and frequency of purchase.

The basic model is:

$$V_{it} \equiv \alpha_i + \beta_i(DP_{it}) + \Theta_i(DP_{it})^2 + \varepsilon_{it} \quad (9)$$

where $V_{it} \equiv \sqrt{\frac{1}{n_{it}} \sum_j (DP_{ijt} - DP_{ij})^2}$ measures the price variability, $DP_{ijt} \equiv \ln(P_{ijt} / P_{ijt-1})$ is the logarithmic first difference between the price charged by store j ($j=1,2,\dots,n_{it}$) in period t and $t-1$, $DP_{it} \equiv (1/n_{it}) \sum_j DP_{ijt}$ can be regarded as the appropriate rate of inflation in market i in period t and n is the number of stores sampled for good i in period t .

The author finds that inflation, as a proxy for changes of information, strongly influences the extent of price dispersion in all goods over most of the experienced inflation rates. The implication is that for repeatedly purchased goods, inflation-induced obsolescence decreases the optimal stock of information held by consumers, and price dispersion will therefore increase.

Generally speaking, the findings of this paper support price dispersion theories based on optimally imperfect decision making suggested by Stigler (1961).

Reinsdorf (1994)

Reinsdorf (1994) models price dispersion using price data from the U.S. Consumer Price Index (CPI) for nine cities covering 65 detailed classes of food from 1980 to 1982,

known as the Volcker disinflation period.²¹ In contrast with Van Hoomissen's paper, this paper shows that inflation and price dispersion may be negatively related although both papers are based on similar incomplete information theories. This paper is also different in its use of a broad panel of micro-level data on different sellers' prices for the same good instead of aggregate average prices. To test the theories of inflation and price dispersion, the author uses the coefficient of variation c_{it} to represent price dispersion:

$$c_{it} = \frac{1}{p_{it}} \sqrt{\sum (p_{ijt} - p_{it})^2 / (n_{it} - 1)} \quad (10)$$

where $p_{it} = 1 / (n_{it} \sum_{j=1}^{n_{it}} p_{ijt})$, p_{ijt} is price i charged by store j in month t and n_{it} is the number of sellers that provide observations of prices for good i in months t and $t-1$.

c_{it} summarizes contemporaneous price dispersion between different sellers for good i .

Following Van Hoomissen, the inflation rate here is defined as:

$$DP_{it} = \frac{1}{n_{it}} \sum_{j=1}^{n_{it}} DP_{ijt} \text{ where } DP_{ijt} = \log(p_{ijt} / p_{ijt-1}), \text{ the rate of change for prices } i \text{ for seller } j$$

between month t and $t-1$.

In the pooled sample, the lowest mean of the coefficient of variation occurs in the highly inflationary 1980 while price dispersion measured by c_{it} increases in the year of 1980.

The pattern of means for c_{it} is in line with the hypothesis that price dispersion is negatively related to inflation. Random coefficient regression results also support this hypothesis. The pooled-cities regression coefficient implies that a 10-percentage-point increase in inflation yields a 1.4-percentage-point decrease in c_{it} and it is statistically significant. Moreover, the rising unemployment rate causes consumers to search more, which reduces price dispersion as inflation falls.

²¹ There was a major break in the U.S. inflation trend during this period.

The difference between the findings of Reinsdorf and Van Hoomissen could be due to the fact that Reinsdorf's data may reflect the short-run effect of incomplete adjustment of expectations after unexpected changes in inflation, while Van Hoomissen's 13 years series reflect the long-run shift in Israel's inflation rate from 13 to 200-300%. Distinguishing short-run and long-run effects resolves the apparent contradiction between the theory that inflation reduces price dispersion by inducing more consumers' search, and the theory that inflation increases price dispersion by diminishing consumers' stock of information. The theory that inflation reduces price dispersion is based on lagged adjustment of expectations, so it describes a short-run effect; in contrast, the theory that inflation increases price dispersion indicates that rapid inflation must continue long enough to create an expectation that it will persist, so it describes a long-run effect.

To distinguish between the effects of unexpected and expected inflation, Reinsdorf partitions inflation into expected and unexpected components. He models prices by a random walk equation incorporating unobserved permanent and transitory error components. The regression results reveal that unexpected inflation seems to have a negative impact on price dispersion while expected inflation has a positive impact.

Parsley (1996)

Parsley (1996) argues that there are some obstacles in terms of interpreting the empirical results. First, aggregation tends to mask the degree of relative price variability in the data so that the linkages of relative inflation rates and price dispersion may in fact be stronger. As well, the observed variability may be due to products' changes within the price index so that the effect of inflation on price dispersion may in fact be smaller. Second,

aggregation increases the simultaneity bias²². Third, many existing results may be due to the particular econometric specification. Finally, some findings may be due to important variables being omitted from the econometric specification.

This study proposes four measurements of price dispersion: measurement of within-product relative price variability, within-city relative price variability, measurement of dispersion of inflation rates holding the product constant around the overall product inflation rate for the product, and measurement of dispersion of product-level inflation rates within a given city around the average for that city. This methodology seems to overcome the obstacles mentioned above and the author comes to a conclusion that higher inflation is associated with greater cross-sectional dispersion of relative prices and relative inflation rates, both across cities and products.

This study also tests an implication which is ignored by many empirical papers, namely that an increase in the ratio of aggregate inflation variability to cross-section inflation variability leads to lower relative price variability since firms react less to any given change in aggregate inflation rates. And he finds supportive results that as the ratio of aggregation to cross-sectional shock increases, the degree of the price dispersion-inflation rate linkage diminishes.

The second part of this study examines the persistence of the effect of inflation on price dispersion. The four time-series of dispersion measures and the measure of inflation used all display mean reversion, implying that the interactions between these variables are necessarily of a short-term nature. An examination of impulse response functions²³ of these four measures of price dispersion proves additionally that the effect is short-lived.

²² An unknown variable can cause both inflation and price variability.

²³ Impulse response functions show the dynamic paths of each endogenous variable in response to a one-standard-deviation shock to the inflation equation.

The intuition is that the welfare implication of the effect of inflation on relative price dispersion is not dramatic.

3.3. Price advertising and price dispersion

Milyo and Waldfogel (1999)

Using Massachusetts alcohol prices as controls (alcohol price advertising is legal in Massachusetts), Milyo and Waldfogel (1999) investigate the effect of alcohol price advertising on prices and price dispersion in Rhode Island where the ban on alcohol price advertising was just lifted.²⁴ Considering that advertising and non-advertising stores may behave differently, the authors decompose the overall effect of price advertising on price dispersion into three separate effects referred to as “non-advertising store effect”²⁵, “advertising store effect”²⁶ and “advertised product effect”²⁷. They find that Rhode Island liquor prices declined insignificantly after the ban on price advertising was lifted. Advertising stores substantially cut only prices of the products that they advertise. Prices of other products, at both advertising and non-advertising stores, did not change. Stores’ own advertising status plays an important role in stores’ responses to their rival’s advertising activities. Advertising stores cut their prices on products advertised by rivals, while non-advertising stores do not. If rivals are advertising the same item at the same time, the advertising store will reduce the price of the advertised item much more than if the store alone advertises the price of the item.

²⁴ Prior to May 13, 1996, Rhode Island retailers couldn’t advertise prices of alcoholic beverages in any way.

²⁵ Prices of products at stores that do not advertise in the newspaper.

²⁶ Not-currently advertised prices of products at stores that currently advertise other products.

²⁷ Currently advertised prices of products at stores that currently advertise them.

To examine the effect of price advertising on price dispersion, the authors measure inter-store price dispersion in two ways. First, they calculate the inter-store variation in store fixed effects. Second, they compare regression standard errors from regressions of price levels on product dummies and time dummies. Neither method provides evidence that price dispersion across stores decreases in the presence of price advertising.

The empirical results of this paper appear to be at odds with Stigler (1961)'s analysis. Stigler states that since price advertising reduces search costs, all stores will be forced to reduce their prices to remain competitive, resulting in lower mean and variance of prices. However, the authors argue that stores face customers with different price elasticities of demand; different stores may change their prices differently in the presence of rival price advertisements. In fact, if non-advertising stores charging higher prices do not reduce their prices while lower-price stores do reduce their prices, price dispersion will increase. As a matter of fact, these results support Salop and Stiglitz (1977)'s finding that firms will optimally charge different prices when facing different demand elasticities. Given consumers' heterogeneous ability to get information, consumers may still remain differentially informed in the post-advertising equilibrium although price advertising may reduce the cost of becoming informed. As a consequence, price advertising may affect firms' demand curves differently.

3.4 Product characteristics, demand conditions, market structure and price dispersion

Aalto-Setälä (2003)

Aalto-Setälä (2003) examines how price dispersion for an individual product is affected by product characteristics, demand conditions, and market structure. As expected, the

variables describing product-specific search costs – budget share, average price, and fresh-product indicator – have significant effects on price dispersion. A high budget share of a product reduces price dispersion. The estimated coefficient of the fresh product indicator is positive and very significant. The search cost of fresh products per purchased unit is higher than the search cost of other products, which increases the price dispersion. The average price of a product has a very significant impact on price dispersion. The interpretation is that nominal price dispersion for expensive products is wider than for low-price products. On the other hand, the relative price dispersion for low-price products is wider than for expensive products. As a measurement of store heterogeneity, store-level fixed effects explained only a small part of the price dispersion in the data. Imperfect information, nevertheless, is an important reason for the variation in prices. This study is of interest in that it examines not only the effect of product characteristics but also the effect of demand characteristics and market structure on consumers' search costs. The demand elasticity of households has a clear effect on price dispersion: the estimates of the variable *child* (families with children) are negative and significant, and those of *income* (household medium income level) are positive and significant.

According to Carlson and McAfee (1983), price dispersion should increase with the number of stores in a market area. Price dispersion should be low under perfect competition and monopoly, and high in between. In other words, the effect of concentration on price dispersion depends on the degree of concentration.

The Herfindahl index and number of stores in the market area describe market structure. The estimates of both are highly insignificant. Thus, concentration in the market area seems to have no effect on price dispersion in the data. The reason for this may be that there was not enough variation in the concentration in the market.

4. Conclusion

The early analysis of price dispersion was mostly theoretical. Earlier and more recent economists provided various models studying price dispersion. There are several major sources of price dispersion. First, price dispersion arises because of imperfect information and search costs. Second, price dispersion is due to heterogeneity among consumers and/or firms. Different models emphasize different sources of heterogeneity. For example, price dispersion may arise because of 1) differences in consumers' search costs (Salop and Stiglitz, 1977; Varian, 1980); 2) differences in sellers' production costs (Reinganum, 1979; Carlson and McAfee, 1983). Even when consumers and firms are identical ex-ante, a price dispersion equilibrium can arise as a result of ex-post heterogeneity in the price information (Burdett and Judd, 1983). Note that in all these models the heterogeneity pertains to the buyers and/or to the sellers. Third, price dispersion can emerge due to uncertain demand (Dana, 1999; Dana, 2001). Fourth, market structure, products' nature and demand conditions are predicted to affect price dispersion too.

The empirical analysis of price dispersion started in the 1980's. Many of the empirical papers followed Stigler (1961) and found strong inter-industry differences, supporting imperfect information and search based models. One exception is Milyo and Waldfogel (1999) who analyze the effect of price advertising on price dispersion. However, the authors still don't entirely reject Stigler's argument that price advertisement will reduce

search costs and hence the average price and price dispersion. Rather, they argue that the inconsistency could be caused by a data problem.

Almost all of the models in this review analyze price dispersion in equilibrium. More recently, disequilibrium models have been developed under the title of learning and evolution. While there are some disequilibrium models analyzing price dispersion (Samuelson and Zhang, 1992; Hopkins, 1995; Roth and Erev, 1995), these works have been mostly at an abstract level. Meanwhile, maybe due to the fact that it is difficult to apply those disequilibrium models to the real economic world, empirical papers about price dispersion using disequilibrium models as their theoretical framework are limited.

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