Information, Search, and Price Dispersion

Michael R. Baye
Kelley School of Business
Indiana University

John Morgan
Haas School of Business and Department of Economics
University of California, Berkeley

Patrick Scholten
Bentley College

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Abstract

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1 Introduction

Textbook models of competitive markets for homogeneous products suggest that all-out competition among firms will lead them all to charge the same price; that is, competition will lead to the so-called "law of one price." Yet, data from over one hundred years suggests that, to the contrary, price dispersion in homogeneous product markets is ubiquitous and persistent. This led Hal Varian to suggest that, in reality, "the 'law of one price' is no law at all" (Varian, 1980, p. 681). A simple explanation for the discrepancy between the textbook theory and the observed price dispersion is that, even in markets for seemingly homogeneous products, subtle differences among the products offered by competing firms lead them to be offered at different prices. Yet, as noted by Nobel Laureate George Stigler, "... a portion of the observed dispersion is presumably attributable to such difference [in products]. But it would be metaphysical, and fruitless, to assert that all dispersion is due to heterogeneity" (Stigler, 1961, p. 215). Indeed, the sustainability of price dispersion stemming from product heterogeneity is questionable. In markets with low barriers to entry or where differentiation strategies are easily imitated, prices in the long run would converge to competitive levels and the law of one price will be restored.

The purpose of this chapter is to provide a coherent treatment of a variety of economic models that have been developed to explain price dispersion, to highlight some of the predictions and testable implications of different models, and to survey some of the empirical literature that documents the ubiquitous price dispersion in both online and offline markets. A key motivation for this chapter is to dispel the erroneous view that the Internet—through its facilitation of the dramatic decline in information costs—would ultimately lead to textbook competition and restore the so-called "law one price."

Empirical research documenting and explaining price dispersion in seemingly homogeneous products has abounded since Stigler's seminal 1961 paper. Until about 1998, most of these studies focused on markets where consumers incurred "shoe leather" (or search) costs to obtain each price quote. In these market environments, search costs primarily consist of consumers' opportunity cost of time and transportation costs. Consumers in these markets balance search costs with the expected benefit from search activity. As we highlight in section 2.1, equilibrium price dispersion has been shown to arise in such environments under a variety of different market conditions including the presence of firm product cost heterogeneities, consumer search cost heterogeneities, different forms of consumer search (fixed sample versus sequential), and so on.

While explanations relying on positive marginal costs to search are useful in explaining price dispersion in many markets, including most offline markets, where such search costs are economically significant, in online markets such search frictions are dramatically lower. This led a number of pundits to speculate that in this "frictionless" world, conditions approximating the law of one price were likely to arise. For instance, *The Economist* offered the following assessment in 1999:

> "The explosive growth of the Internet promises a new age of perfectly competitive markets. With perfect information about prices and products at their fingertips, consumers can quickly and easily find the best deals. In this brave new world, retailers' profit margins will be competed away, as they are all forced to price at cost." *The Economist*, November 20, 1999, p. 112.

As we shall see, this is exactly the prediction of the search-theoretic models presented in Section 2.1 of the paper—as the marginal cost of search goes to zero, transaction prices move toward marginal cost.

The "frictionless" Internet environment led to renewed interested in empirically measuring the causes and nature of price dispersion. Internet technology has unquestionably made it easier for consumers to search for price and product information. For example, price comparison sites and shopbot technologies create environments where consumers can obtain price information for physically identical products with a few "mouse clicks." The popularity of such sites is growing. Finally, the Internet was touted as a way to create a world without borders, and one might think that this globalization of competition would erase price differences both within and across countries.

Despite all of these factors, the overwhelming empirical finding is that price dispersion online is persistent and ubiquitous—the law of one price is egregiously violated online as well as in traditional markets. Indeed, Table 1 catalogs the wide array of studies finding significant price dispersion in traditional and online markets.

While early views like the one in the quote above suggest that competition on the Internet would lead to Bertrand-style competition and zero economic profits. unsustainable profits. The empirical findings, however, illustrate firms' resilience in avoiding Bertrand competition. Some firms use obfuscation strategies to switch consumers from a low price product to an "upgrade" at a higher price. Other firms use rapid and unpredictable price changes to prevent the competitors from systematic undercutting. These rapid and unpredictable price changes also have the effect of preventing consumers from consistently learning about the identity of the low-price firm; thus making the price comparison site valuable to consumers.

In Section 2.2, we examine an alternative line of theoretical research where marginal costs of search are not the key driver for price dispersion. This literature stresses several possibilities: First, when markets consist of both searching consumers and "captive" consumers, then firms optimally price above marginal cost and in an unpredictable fashion; thus there is price dispersion in the market. This is true even when it is completely costless for the searching consumers to obtain a complete list of prices from a "clearinghouse" (i.e. a newspaper in traditional markets or price comparison site in online markets).

A complementary research line points out that the "gatekeeper" operating the clearinghouse is also a strategic player. A profit maximizing gatekeeper will set fees for firms to post prices at the clearinghouse so as to induce price dispersion. Why is this? Notice that the gatekeeper can only earn rents from the clearinghouse when it contains useful price information to consumers. Moreover, the price information at the clearinghouse is only valuable if prices are dispersed, otherwise, consumers have no need to use the clearinghouse in searching for the lowest price.

The remainder of the chapter proceeds as follows: In Section 2, we explore the theoretical underpinnings of information, search, and price dispersion. Section 3 then looks at the empirical findings related to these issues. Finally, section 4 concludes.

2 Theoretical Models of Price Dispersion

This section presents alternative models that have been used to rationalize the price dispersion observed in both traditional and online markets. One approach is to assume that it is costly for consumers to gather information about prices. In these "search theoretic" models, consumers searching for the best price incur a positive cost of obtaining each additional price quote. Representative examples include Stigler (1961), Rothschild (1973), Reinganum (1979), MacMinn (1980), Braverman (1980), Burdett and Judd (1983), Carlson and McAfee (1983), Rob (1985), Stahl (1989, 1996), Dana (1994), and McAfee (1995).

A second approach assumes that consumers "passively" obtain price information directly from firms (as in direct mail advertisements; see Butters (1977), Grossman and Shapiro (1984), Stegeman (1991), Robert and Stahl II (1993), McAfee (1994), and Stahl (1994)) or "actively" obtain price information from a central clearinghouse (i.e., the newspaper or a price comparison site on the Internet, as in Salop and Stiglitz (1977), Shilony (1977), Rosenthal (1980), Varian (1980), Narasimhan (1988), Spulber(1995), Baye and Morgan (2001), Baye, Morgan, and Scholten (2004)). The distinguishing feature of "clearinghouse models" is that a subset of consumers gain access to a list of prices charged by all firms and purchase at the lowest listed price. In the earliest of these models, equilibrium price dispersion stems from *ex ante* heterogeneities in consumers or firms. For example, in the Varian and Salop-Stiglitz models, some consumers choose to access the clearinghouse to obtain price information, while others do not. In Shilony, Rosenthal, and Narasimhan, some consumers are loyal to a particular firm (and thus will buy from it even if it does not charge the lowest price), while other consumers are "shoppers" and only purchase from the firm charging the lowest price. Spulber (1995) shows that equilibrium price dispersion arises even when all consumers can costlessly access the clearinghouse—provided firms are privately informed about their heterogeneous marginal costs. Baye and Morgan (2001) offer a clearinghouse model that endogenizes not only the decisions of firms and consumers to utilize the information clearinghouse (in the existing clearinghouse models, firms' listing decisions are exogenous), but also the fees charged by the owner of the clearinghouse (the "information gatekeeper") to consumers and firms who wish to access or transmit price information. They show that a dispersed price equilibrium exists even in the absence of any *ex ante* heterogeneities in consumers or firms.

In this section, we provide an overview of the key features and ideas underlying this literature.

2.1 Search-theoretic Models of Price Dispersion

We begin with an overview of search-theoretic approaches to equilibrium price dispersion. The early literature stresses the idea that, when consumers search for price information and search is costly, firms will charge different prices in the market. There are two basic sorts of models used: Models with fixed sample size search and models where search is sequential. We will discuss each of these in turn.

The search models considered in this subsection are all based on the following general environment. A continuum of price-setting firms (with unit measure) compete in a market selling an identical (homogeneous) product. Firms have unlimited capacity to supply this product at a constant marginal cost, m. A continuum of consumers is interested in purchasing the product. Let the mass of consumers in the market be μ, so that the number of customers per firm is μ. Each consumer has a quasi-linear utility function $U = u(q) + y$, where q is the quantity of the homogeneous product and y is the quantity of some numeraire good whose price is normalized to be unity. This implies that the indirect utility of a consumer who pays a price p for the product and who has an income of M is

$$V(p, M) = v(p) + M$$

where $v(\cdot)$ is nonincreasing in p. By Roy's identity, note that the demand for the product of relevance is $q(p) \equiv -v'(p)$.

To acquire the product, a consumer must first obtain a price quote from a store offering the product for sale. Suppose that there is a search cost, c, per price quote. If, after obtaining n price quotes, a consumer purchases the product from one of the firms at price p, the consumer's (indirect) utility is

$$V = v(p) + M - cn$$

The analysis that follows focuses on posted price markets where consumers know the distribution of prices but do not know the prices charged by particular stores. Given a distribution of prices set by firms, consumers engage in search and decide whether or not to purchase the product and at what price. Following this, payoffs are realized.

2.1.1 The Stigler Model

Stigler (1961) considers the special case of this environment where:

1. Each consumer wishes to purchase $K \geq 1$ units of the product; that is, $q(p) = -v'(p) = K$;

2. The consumer's search process is fixed sample search—prior to searching consumers determine a fixed sample, n, of firms from whom to obtain price quotes and then buy from the firm offering the lowest price; and

3. The distribution of firms' prices is given by an *exogenous* non-degenerate cdf $F(p)$ on $\left[\underline{p}, \overline{p}\right]$.

In light of the fact that $v'(p) = K$ maximizing expected utility is equivalent to minimizing the expected cost of purchasing K units of the product:

$$\min_n E[C] = KE\left[p_{\min}^{(n)}\right] + cn$$

where $E\left[p_{\min}^{(n)}\right] = E[\min\{p_1, p_2, ..., p_n\}]$; that is, the expected lowest price quote obtained from n draws from the cdf. F. Since this distribution is given by $F_{\min}^{(n)}(p) = 1 - [1 - F(p)]^n$, the consumer's problem is to choose a fixed sample size n to minimize her expected total costs (expected purchase cost plus search cost):

$$\begin{aligned} E[C] &= K \int_{\underline{p}}^{\overline{p}} p dF_{\min}^{(n)}(p) + cn \\ &= K\left[\underline{p} + \int_{\underline{p}}^{\overline{p}} [1 - F(p)]^n dp\right] + cn \end{aligned}$$

Notice that the term in square brackets reflects the expected purchase price, which is a decreasing function of the sample size, n. However, since each additional price observation costs $c > 0$ to obtain, an optimizing consumer will choose to search a finite number of times, n^*, and thus stop short of obtaining the best price $\left(\underline{p}\right)$ in the market.

The distribution of transaction prices is the distribution of the lowest of n^* draws from F; that is,

$$F_{\min}^{(n^*)}(p) = 1 - (1 - F(p))^{n^*}$$

From this, Stigler concludes that dispersion in both posted prices and transactions prices arises as a consequence of costly search.

How do transactions prices and search intensity relate to the quantity of the item being purchased (or equivalently on the frequency of purchases)? Table 2 presents levels of price dispersion that tend to differ depending on the frequency with which products are purchased. Stigler's model offers sharp predictions in this dimension. To see this, note that the expected benefit (the expected reduction in purchase costs) to a consumer who increases her sample size from $n - 1$ to n is

$$E\left[B^{(n)}\right] = \left(E\left[p_{\min}^{(n-1)}\right] - E\left[p_{\min}^{(n)}\right]\right) \times K \tag{1}$$

Notice that this expression is increasing in K ; thus the expected benefits from search are greater for products bought in greater quantities. Since the cost of the nth search is independent of K while the expected benefit is increasing in K, it then immediately follows that the equilibrium search intensity, n^*, is increasing in K. That is, consumers obtain more price quotes for products they buy in greater quantities.

Despite the fact that the Stigler model assumes each individual inelastically purchases K units of the product, a version of the "law of demand" holds: Each firm's expected demand is a nonincreasing function of its price. To see this, note that each firm is visited by μn^* consumers and offers the lowest price with probability $(1 - F(p))^{n^*-1}$. Thus, a representative firm's expected demand when it charges a price of p is

$$Q(p) = \mu n^* K (1 - F(p))^{n^*-1} \tag{2}$$

which is decreasing in p.

Perhaps somewhat counterintuitively, the Stigler model implies that consumers expected total costs are lower when prices are more dispersed. To see this, compare the expected costs to a consumer under price distribution F to her expected costs when posted prices occur on some distribution G that is a mean-preserving spread of F. Letting C_G (C_F) denote the expected surplus under the G (F) distribution of posted prices and letting n^* be the optimal number of searches under F, then

$$\begin{aligned} E[C_G] &\leq K\left[\underline{p} + \int_{\underline{p}}^{\overline{p}} [1 - G(p)]^{n^*} dp\right] + cn^* \\ &< K\left[\underline{p} + \int_{\underline{p}}^{\overline{p}} [1 - F(p)]^{n^*} dp\right] + cn^* \\ &= E[C_F] \end{aligned}$$

where the first inequality follows from the fact that n^* is not necessarily the optimal sample size under G and the second (strict) inequality follows from the fact the G is a mean-preserving spread of F.

2.1.2 The Rothschild Critique and Diamond's Paradox

While Stigler offered the first search-theoretic rationale for price dispersion, the model has been criticized for two reasons. First, as pointed out in Rothschild (1973), the search procedure consumers are assumed to use in Stigler's model may not be optimal. In fixed sample search, consumers commit to a fixed number, n, stores to search and then buy at the lowest price at the conclusion of that search. A clear drawback to such a strategy is that it fails to incorporate new information arising as the search is ongoing, such as an exceptionally low price from an early search. Indeed, once the best price quote obtained is sufficiently low, the benefit in the form of price improvement drops below the marginal cost of the additional search. As we will see below, sequential search results in an optimal stopping rule such that a consumer searches until she locates a price below some threshold, called the *reservation price*. Secondly, the distribution of prices, F, is exogenously specified and is not based on optimizing firm behavior. In fact, in light of equation (2), a representative firm with constant marginal cost of m enjoys expected profits of

$$\pi(p) = (p - m) Q(p).$$

That is, absent any cost heterogeneities, each firm faces exactly the *same* expected profit function. Why then, would firms not choose the same profit-maximizing price or, more generally, how could the distribution of prices generated by profit-maximizing firms be consistent with the price distribution over which consumers were searching? In short, Rothschild pointed out that it is far from clear that information costs give rise to an equilibrium of price dispersion with optimizing consumers and firm; in Stigler's model, only one side of the market, the consumers, are acting in a fashion consistent with equilibrium. For this reason, Rothschild (1973) criticized the early literature for its "partial-partial equilibrium" approach – looking at one side of one market.

Diamond (1971) advanced this argument even further—he identified conditions under costly search where the unique subgame perfect equilibrium involves all firms charging the same price—the monopoly price. Diamond's result may be readily seen in the following special case of our environment where:

1. Consumers have identical downward sloping demand, i.e. $-v''(p) = q'(p) < 0$;

2. Consumers engage in optimal *sequential* search;

3. A firm acting as a monopoly has a strictly concave profit function and would optimally charge all consumers a finite monopoly price, p^*, and earn finite monopoly profits and;

4. A consumer who is charged the monopoly price earns surplus sufficient to cover the cost of obtaining single price quote; that is $v(p^*) > c$.

In this environment, there is a unique equilibrium with optimizing firms and consumers: All firms post the monopoly price and consumers visit only one store, purchase at the posted price p^*, and obtain surplus $v(p^*) - c > 0$. Given the stopping rule of consumers, each firm's best response is to charge the monopoly price; given that all firms charge p^* it is optimal for each consumer to search only once. To see that the equilibrium is unique, suppose to the contrary that there was an equilibrium in which some firm posted a price below the monopoly price (clearly, there are no equilibria in which firms price above the monopoly price). Let p' be the lowest such posted price. A firm posting the lowest price could profitably deviate by raising its price to the lower of p^* or $p' + c$. Any consumer visiting that firm would still rationally buy from it since the marginal benefit of an additional search is smaller than c—the marginal cost of an additional search. Thus, such a firm will not lose any customers by this strategy and will raise its earnings on each of these customers.

The Diamond paradox is striking: even though there is a continuum of identical firms competing in the model—the textbook condition for perfect competition—in the presence of any search frictions whatsoever the monopoly price is the unique equilibrium. Rothschild's criticism of the Stigler model, along with the Diamond paradox, spawned several decades of research into whether search costs could possibly generate equilibrium price dispersion — a situation where consumers are optimally gathering information given a distribution of prices, and where the distribution of prices consumers are searching over is generated by optimal (profit-maximizing) decisions of firms.

2.1.3 The Reinganum Model and Optimal Sequential Search

Reinganum (1979) was among the first to show that equilibrium price dispersion can arise in a sequential search setting with optimizing consumers and firms. Reinganum's result may be seen in the following special case of our environment where:

1. Consumers have identical demands given by $-v'(p) = q(p) = Kp^{\varepsilon}$, where $\varepsilon < -1$ and $K \geq 1$;
2. Consumers engage in optimal *sequential* search;
3. Firms have heterogeneous marginal costs described by the atomless and non-degenerate distribution $G(m)$ on $[\underline{m}, \overline{m}]$;
4. A consumer who is charged the monopoly price by a firm with the highest marginal cost, $\overline{m}$, earns surplus sufficient to cover the cost of obtaining single price quote; that is $v\left(\frac{\varepsilon}{1+\varepsilon}\overline{m}\right) > c$.

Reinganum shows that under these assumptions, there exists a dispersed price equilibrium in which firms optimally set prices and each consumer optimally engage in optimal sequential search. To establish this, we first show how one derives the optimal reservation price in a sequential search setting. Suppose consumers are confronted with a nondegenerate distribution of prices $F(p)$ with density $f(p)$ and support $\left[\underline{p}, \overline{p}\right]$, and engage in optimal sequential search with free recall. If, following the nth search, a consumer has already found a best price $z \equiv \min(p_1, p_2, ..., p_n)$, then, by making an additional search, such a consumer expects to gain benefits of

$$B(z) = \int_{\underline{p}}^{z} (v(p) - v(z)) f(p) \, dp \tag{3}$$

Using Leibnitz' rule, we have

$$\begin{aligned} B'(z) &= -v'(z) F(z) \\ &= K z^{\varepsilon} F(z) > 0 \end{aligned} \tag{4}$$

Thus, the expected benefits from an additional search are lower when the consumer has already identified a relatively low price. Notice from equation (4) that $B'(z)$ is an increasing function of K, z, and ε. Since search is costly ($c > 0$), consumers must weigh the expected benefits against the cost of an additional search. The expected net benefits of an additional search are

$$h(z) \equiv B(z) - c$$

If the expected benefits gained from an additional search exceed additional cost, $h(z) > 0$, it is optimal for the consumer to obtain an additional price quote. If $h(z) < 0$, the consumer is better off purchasing at the price z than obtaining an additional price quote.

A consumer's optimal sequential search strategy may thus be summarized as follows:

Case 1. $h(\overline{p}) < 0$ and $\int_{\underline{p}}^{\overline{p}} v(p) f(p)\, dp < c$. Then the consumer's optimal strategy is to not search.

Case 2. $h(\overline{p}) < 0$ and $\int_{\underline{p}}^{\overline{p}} v(p) f(p)\, dp \geq c$. Then the consumer's optimal strategy is to search (once) to obtain a price at or below the reservation price, $r = \overline{p}$:

Case 3. $h(\overline{p}) \geq 0$. Then the consumer's optimal strategy is to search until she obtains a price quote at or below the the reservation price, r, where r solves

$$h(r) = \int_{\underline{p}}^{r} (v(p) - v(r)) f(p)\, dp - c = 0 \tag{5}$$

Equation (5) represents a price at which a consumer is exactly indifferent between buying and making an additional search. To see that such a price is uniquely defined by this equation, notice that $h\left(\underline{p}\right) = -c < 0$ and $h'(z) = B'(z) > 0$. A consumer who observes a price that exceeds r will optimally "reject" that price in favor of continued search, while a consumer who observes a price below r will optimally "accept" that price and stop searching.

Case 1 is clearly not economically interesting as it leads to the absence of any market for the product in the first place. Case 2 arises when there is little or no dispersion in posted prices relative to the cost of search. Most of the existing search literature, including Reinganum, restricts attention to Case 3.

The reservation price obtained in equation (5) has several interesting comparative static properties. One feature of particular economic interest is the relationship between the reservation price and the cost of search. Totally differentiating equation (5) with respect to r and c, and using equation (4) reveals that

$$\frac{dr}{dc} = \frac{1}{q(r)F(r)} = \frac{1}{Kr^{\varepsilon}F(r)} > 0$$

Thus, an increase in search costs leads to a higher reservation price: Other things equal, the range of "acceptable" prices is greater for products with higher search costs. Note that, for the special case when $q(r) = 1$, $dr/dc = 1/F(r) > 1$. In this case, a one dollar increase in search costs increases the range of acceptable prices by more than one dollar—that is, there is a "magnification effect" of increases in search costs.[1]

Reinganum avoids Rothschild's criticism and the "Diamond paradox" by introducing firm cost heterogeneities. Notice that since each firm j differs in its marginal costs, m_j, then even if all firms price as monopolists, price dispersion will still arise.

Suppose that a fraction $1 > \lambda \geq 0$ of firms price above r and recall that the number of consumers per firm is μ, then a representative firm's profits when it prices at p_j are:

$$E\pi_j = \begin{array}{cl} (p_j - m_j)\,q(p_j)\left(\frac{\mu}{1-\lambda}\right) & \text{if} \quad p_j \leq r \\ 0 & \text{if} \quad p_j > r \end{array}$$

Ignoring for a moment the fact that a firm's demand is zero if it prices above r, note that profit-maximization implies the first-order condition

$$\frac{d}{dp_j}(p_j - m_j)\,q(p_j)\left(\frac{\mu}{1-\lambda}\right) = 0.$$

Recall that $\partial \ln q(p)/\partial \ln p = \varepsilon < -1$. Hence, standard manipulation of the first-order condition for profit-maximization then implies that firm j's (unconstrained) profit-maximizing price is a constant markup over its cost:

$$p_j = \left(\frac{\varepsilon}{1+\varepsilon}\right) m_j.$$

Notice that if each firm priced according to this formula, the resulting distribution of prices would follow a distribution induced by the distribution of costs, namely $F(p) = G(p(1+\varepsilon)/\varepsilon)$ on the interval $[\underline{m}\varepsilon/(1+\varepsilon), \overline{m}\varepsilon/(1+\varepsilon)]$. But as we saw above, given this distribution of prices consumers would set a reservation price r, and firms charging prices in the interval $(r, \overline{m}\varepsilon/(1+\varepsilon)]$ would enjoy no sales. Since the elasticity of demand is constant, firms that would maximize profits by pricing above r in the absence of consumer search find it optimal to set their prices at r when consumers search.[2] Taking this into account, it follows that given a reservation price

[1] Note, however, that this magnification effect is specific to the unit demand case; in general, there may be either a magnification or attenuation effect of a one dollar increase in the cost of search.

[2] Reinganum assumes that $\overline{m} < \underline{m}\varepsilon/(1+\varepsilon)$, which guarantees that firms who would otherwise price above r find it profitable to price at r.

of r, optimizing behavior on the part of firms implies the following distribution of prices:

$$F_r(p) = \begin{cases} G(p(1+\varepsilon)/\varepsilon) & \text{if} \quad p < r \\ 1 & \text{if} \quad p = r \end{cases}$$

To establish that this is, in fact, an equilibrium distribution of prices one must verify that consumers facing this "truncated" distribution of prices have no incentive to change their reservation price; that is, $h(r) = 0$. Given this truncated distribution of prices, the net expected benefits to search is

$$\begin{aligned} h(r) &= \int_{\underline{p}}^{r} (v(p) - v(r))\, dF_r(p) - c \\ &= \int_{\underline{p}}^{r} (v(p) - v(r))\, dF(p) + [1 - F(r)][v(r) - v(r)] - c \\ &= \int_{\underline{p}}^{r} (v(p) - v(r))\, dF(p) - c = 0 \end{aligned}$$

Thus, r is an optimal reservation price given the distribution of prices F_r, and F_r is the distribution of prices that results from firm optimization given the reserve price, r. In short, Reinganum's assumptions of downward sloping demand and cost heterogeneity give rise to an equilibrium of price dispersion with optimizing consumers and firms.

It is instructive to examine how the variance in the distribution of posted (and transactions) prices varies with search costs. Note that, in equilibrium, the variance in prices is given by

$$\begin{aligned} \sigma^2 &= E\left[p^2\right] - (E[p])^2 \\ &= \int_{\underline{p}}^{r} p^2 dF_r(p) - \left(\int_{\underline{p}}^{r} p dF_r(p)\right)^2 \\ &= \int_{\underline{p}}^{r} p^2 f(p)\, dp + (1 - F(r))\, r^2 - \left(\int_{\underline{p}}^{r} p f(p)\, dp + (1 - F(r))\, r\right)^2 \end{aligned}$$

Hence,

$$\begin{aligned} \frac{d\sigma^2}{dr} &= 2r(1 - F(r)) - 2\left(\int_{\underline{p}}^{r} p f(p)\, dp + (1 - F(r))\, r\right)(1 - F(r)) \\ &= 2[1 - F(r)](r - E[p]) > 0 \end{aligned}$$

Thus, we have:

Remark 1 *In the Reinganum model, an increase in search costs increases the optimal reservation price and increases the variance of equilibrium prices.*

As we will see below, however, this is not a general property of search-theoretic models of price dispersion.

We conclude by noting that downward sloping demand and cost heterogeneities both play a critical role in generating equilibrium price dispersion in this environment. To see that both assumptions are required, suppose first that costs are heterogeneous but that each consumer wished to purchase one unit of the product, valued at v. In this case, given a reservation price of $r \leq v$, all firms would find it optimal to price at r, in which case the distribution of prices would be degenerate. Of course, a reservation price $r < v$ is inconsistent with optimizing behavior on the part of consumers. To see this, suppose that a consumer was unexpectedly presented with a price $p' = r + \delta$ for a small enough $\delta > 0$. According to the search strategy, such a consumer is supposed to reject this price and continue searching; however, the benefit from this additional search is δ (small) while the cost of the search is $c > \delta$; thus, a consumer should optimally accept a price p' rather than continuing to search. The upshot of this is that the only equilibrium reservation price is $r = v$. However, these are precisely the conditions given in Case 1; hence the only equilibrium is where no consumers shop at all. We note, however, that if one introduces heterogeneities in consumer search costs (as in Carlson and McAfee, 1983, for instance) a dispersed price equilibrium may exist even when individual consumers have zero-one demands.

If demand was downward sloping but firms had identical marginal costs of m, each firm would have an incentive to set the same price, $p^* = \min\{r, m\varepsilon/(1+\varepsilon)\}$, given the reservation price. This leads back to Case 2 and one obtains the Diamond paradox: All firms charge the monopoly price, $p^* = m\varepsilon/(1+\varepsilon)$. Indeed, in the environment above, a limiting case where the distribution of marginal costs converges to a point is exactly the Diamond model presented above.

2.1.4 Remarks on Fixed versus Sequential Search

At this point is useful to highlight some key differences between sequential and fixed sample sized search. With sequential search, the number of searches is a random variable and the expected number of searches, given a distribution of prices $F(p)$ and reservation price r, is

$$E[n] = \frac{1}{F(r)}$$

In contrast, with fixed sample sized search consumers commit up front to n searches. Both types of search have advantages and disadvantages, and indeed Morgan and Manning (1985) have shown that both types of search can be optimal in different circumstances. The key advantage of sequential search is that it allows a searcher to economize on information costs – the decision-maker weights the expected benefits and costs of gathering additional price information after each new price observation is obtained. If an acceptable price is obtained early on, the expected gains from additional searches are small and there is no need to pay the cost of additional searches. The primary advantage of fixed-sample sized search is that it allows one to gather information quickly. Consider, for instance, a firm that requires raw materials by the end of the week. If it takes a week for a raw material's vendor to provide a price quote, sequential search would permit the firm to obtain only a price quote from a single vendor. In this case, fixed sample sized search would be optimal – the firm commits to obtain quotes from n vendors, where n is chosen by the firm to minimize expected costs as outlined above in our discussion of the Stigler model.

2.1.5 The MacMinn Model

In light of the fact that there are instances in which fixed sample sized search is optimal, one may wonder whether an equilibrium of price dispersion can arise in such a setting. MacMinn (1980) provides an affirmative answer to this question. MacMinn's result may be seen in the following special case of our environment where:

1. Consumers have unit demand with valuation v;
2. Consumers engage in optimal *fixed sample* search and;[3]
3. Firms have heterogeneous marginal costs described by the atomless and non-degenerate distribution $G(m)$ on $[\underline{m}, \overline{m}]$ where $\overline{m} < v$.

At the time, MacMinn derived equilibrium pricing by solving a set of differential equations under the special case where G is uniformly distributed. However, subsequent to his paper, the key finding of auction theory, the *Revenue Equivalence Theorem* (Myerson, 1981) was developed. Using the revenue equivalence theorem, we can generalize MacMinn's results to a more general set of cost distributions.

To see this, notice that when consumers optimally engage in a fixed sample search consisting of n^* firms, each firm effectively competes with $n^* - 1$ other firms to sell one unit of the product. Of these n^* firms, the firm posting the lowest price wins the "auction".

Using the revenue equivalence theorem, one can show that the expected revenues to a firm with marginal cost m in any "auction" where the firm charging the lowest price always wins and the firm with the highest marginal cost earns zero surplus is

$$R(m) = m(1 - G(m))^{n^*-1} + \int_m^{\overline{m}} (1 - G(t))^{n^*-1} \, dt \tag{6}$$

In the MacMinn model, expected revenues are simply a firm's posted price, $p(m)$, multiplied by the probability it charges the lowest price, which, in equilibrium, is

[3] MacMinn also provides a version of the model that is valid for optimal sequential search.

$(1 - G(m))^{n^*-1}$. Thus, from equation (6), one obtains the following equilibrium pricing strategy of a firm with marginal cost m when consumers sample n^* firms:

$$\begin{aligned} p(m) &= \frac{R(m)}{(1 - G(m))^{n^*-1}} \\ &= m + \int_m^{\overline{m}} \left(\frac{1 - G(t)}{1 - G(m)} \right)^{n-1} dt \end{aligned} \tag{7}$$

Notice that, after integration by parts, we can rewrite equation (7) to obtain the familiar formula for equilibrium bidding in reverse first-price auctions

$$p(m) = E\left[m_{\min}^{(n^*-1)} | m_{\min}^{(n^*-1)} \geq m \right] \tag{8}$$

where $m_{\min}^{(n-1)}$ is the lowest of $n^* - 1$ draws from the distribution G.

For the special case where G is uniformly distributed, the equilibrium pricing strategy simplifies to

$$p(m) = \frac{n^* - 1}{n^*} m + \frac{1}{n^*} \overline{m}. \tag{9}$$

Notice that the equilibrium pricing strategy gives rise to a distribution of posted prices, $F(p)$ induced by the distribution of costs; that is

$$F(p) = G(p(m))$$

Given this distribution, it must be optimal for consumers to sample n^* firms. That is,

$$E\left[B^{(n^*+1)}\right] < c \leq E\left[B^{(n^*)}\right]$$

where the expression $E\left[B^{(n)}\right]$, as previously defined in equation (1) when $K = 1$, is the expected benefit from increasing the number of price quotes obtained from $n - 1$ to n.

Thus, MacMinn shows that, provided search costs are low enough, a dispersed price equilibrium exists. The intuition is that, when search costs are sufficiently low, consumers will sample more than one firm. This not only leads to ex post differences in consumers' information sets (different consumers sample different firms and so observe different prices), but induces a degree of competition among firms (since they are competing against at least one other firm, whose cost they do not know). As in the Reinganum model, the level of price dispersion depends on the dispersion in stores' costs. For the special case where costs are uniformly distributed, in equilibrium, the variance in prices (σ_P^2) is given by

$$\sigma_p^2 = \left(\frac{n^* - 1}{n^*} \right)^2 \sigma_m^2 \tag{10}$$

where n^* is the optimal number of searches by consumers and σ_m^2 is the variance in firm's costs. For sufficiently small search costs, consumers sample multiple stores ($n^* \geq 2$) and there is a nondegenerate distribution of prices.

Two interesting results emerge from the model. First, the variance in prices increases as the variance in firms' marginal costs increase. This result is intuitive. Somewhat counterintuitively, note that as the sample size increases, the variance in prices increases. This implies that – taking into account the interaction between consumers and firms in this fixed-sample sized search model:

Remark 2 *In the MacMinn model, an increase in search costs reduces the optimal sample size and decreases the variance of equilibrium prices.*

This result is in contrast to Remark 1, where precisely the opposite implication is obtained in the Reinganum sequential search model. This highlights an important feature of search-theoretic models of price dispersion: Depending on the model, increases in search costs may be associated with higher or lower levels of price dispersion.

2.1.6 The Burdett and Judd Model

Burdett and Judd (1983) are the first to show that equilibrium price dispersion can arise in a model with ex ante identical consumers and firms. Burdett and Judd's main result may be seen in the following special case of our environment where:

1. Consumers have unit demand with valuation v;
2. Consumers engage in optimal *fixed sample* search;[4]
3. A firm acting as a monopoly has a strictly concave profit function and would optimally charge all consumers a finite monopoly price, p^*, and earn finite monopoly profits, and;
4. A consumer who is charged the monopoly price earns surplus sufficient to cover the cost of obtaining single price quote; that is $v(p^*) > c$.

In the Burdett and Judd model, an equilibrium consists of a price distribution $F(p)$ (based on optimal pricing decisions by firms) and an optimal search distribution $< \theta_n >_{n=1}^{\infty}$where $< \theta_n >_{n=1}^{\infty}$is the distribution of the number of times a consumer's search in the population. Thus, θ_i is the probability that a consumer (or alternatively, the fraction of consumers) that search exactly i firms. Note that if $\theta_1 = 1$, then consumers search only one firm. If $\theta_1 = 0$, then all consumers search at least two

[4] Burdett and Judd also provide a version of the model that is valid under optimal sequential search.

firms, and so on. Consumers purchase from the firm offering the lowest price quote provided that it does not exceed v.

We begin by studying optimal search on the part of consumers given a price distribution $F(p)$. Recall that the expected benefit to a consumer who increases her sample size from $n-1$ to n is

$$E\left[B^{(n)}\right] = \left(E\left[p_{\min}^{(n-1)}\right] - E\left[p_{\min}^{(n)}\right]\right)$$

as in the Stigler model. Moreover, the expected benefit schedule is strictly decreasing in n. Thus, an optimal number of price quotes, n, satisfies

$$E\left[B^{(n+1)}\right] < c \leq E\left[B^{(n)}\right]$$

An interesting case arises when $E\left[B^{(n)}\right] = c$. In that case, a consumer is indifferent between obtaining n and $n-1$ price quotes and prefers these to all other numbers of price quotes.

Using this observation, first consider the case where all consumers obtain two or more price quotes; that is, where $\theta_1 = 0$. In this case, the optimal pricing strategy on the part of firms is to price at marginal cost (the Bertrand paradox) since each firm is facing pure price competition with at least one other firm and all firms are identical. Of course, if all firms are pricing at marginal cost, then it would be optimal for a consumer to sample only *one* firm, which contradicts the hypothesis that $\theta_1 = 0$. Thus, we may conclude that, in any dispersed price equilibrium, $\theta_1 > 0$.

Next, consider the case where consumers all obtain exactly one price quote. In that case, optimal firm pricing would be to charge the monopoly price, v. Facing this price distribution, consumers would be better off not searching at all. Hence, $\theta_1 \neq 1$.

From these two arguments it follows that $\theta_1 \in (0,1)$. In light of the fact that consumers' expected benefits from search are decreasing in the sample size, it follows that a consumer must be indifferent between obtaining one price quote and obtaining two price quotes. That is, in any dispersed price equilibrium

$$E\left[B^{(1)}\right] > E\left[B^{(2)}\right] = c > E\left[B^{(3)}\right] > ... > E\left[B^{(n)}\right].$$

Thus, in any dispersed price equilibrium, $\theta_1, \theta_2 > 0$ while $\theta_i = 0$ for all $i > 2$. Let $\theta_1 = \theta$ and $\theta_2 = 1 - \theta$.

We are now in a position to characterize a dispersed priced equilibrium..

First, note that since $\theta \in (0,1)$, there is a positive probability that a firm faces no competition when it sets its price. Thus, if firm i charges the monopoly price, it earns expected profits of

$$E\left[\pi_i | p_i = v\right] = (v - m) \times \mu\theta$$

In contrast, a firm choosing some lower price "wins" when its price is below that of the other firm a consumer has sampled. Thus, if firm i charges a price $p_i \leq v$, it earns expected profits of

$$E\left[\pi_i | p_i = v\right] = (p_i - m) \times \mu\left(\theta + (1-\theta)\left(1 - F(p_i)\right)\right)$$

Thus, for a given distribution of searches, equilibrium price dispersion requires that the distribution of firm prices, $F(\cdot)$, satisfies

$$\theta + (1-\theta)(1-F(p)) = \frac{(v-m)}{(p-m)}\theta$$

or

$$F(p) = 1 - \frac{(v-p)}{(p-m)}\frac{\theta}{1-\theta} \tag{11}$$

which is a well-behaved atomless cumulative distribution having support $[m+\theta(v-m), v]$.

Finally, it remains to determine an equilibrium value of θ. Since a consumer must be indifferent between searching one or two stores, this requires that

$$E\left[B^{(2)}\right] = c$$

Notice that, when $\theta = 0$ or $\theta = 1$, $E\left[B^{(2)}\right] = 0$ while $E\left[B^{(2)}\right] > 0$ for all $\theta \in (0,1)$. Burdett and Judd show that $E\left[B^{(2)}\right]$ is quasi-concave; thus, when c is sufficiently low, there are generically two dispersed price equilibria—one involving a relatively high fraction of consumers making two searches, the other with a relatively low fraction of consumers.[5]

To summarize, Burdett and Judd show that equilibrium price dispersion can arise even when all firms and consumers are ex ante identical. In the equilibrium price distribution, all firms charge positive markups. A fraction θ of consumers do not comparison shop—they simply search at one store and purchase. The remaining fraction of consumers are "shoppers"—these consumers search at two stores and buy from whichever offers the lower price.

2.2 Models with an "Information Clearinghouse"

In search-theoretic models, consumers pay an incremental cost for each additional price quote they obtain. These models are relevant, for example, when consumers must visit, or phone traditional sellers in order to gather information about prices. They are also relevant in online environments where consumers must search the websites of individual retailers to gather information about the prices they charge.

An alternative class of models is relevant when a third party — an information clearinghouse – provides a subset of consumers with a list of prices charged by different firms in the market. Examples of this environment includes newspapers which display prices different stores charge for the same product or service and online price comparison sites.

In this section we provide a general treatment of clearinghouse models, and show that these models are surprisingly similar to those that arise under fixed sample sized

[5] In addition, there is an economically uninteresting equilibrium where firms all charge the monopoly price and no consumers participate in the market.

search. One of the key modeling differences is that clearinghouse models tend to oligopoly models; thus, there is not a continuum of firms in such settings.

Where possible, we shall use the same notation as in the previous section; however, for reasons that will be come clear when we compare clearinghouse models with the search models presented above, we now let n denote the number of firms in the market. The general treatment that follows relies heavily on Baye and Morgan (2001) and Baye, Morgan and Scholten (2004).

Consider the following general environment (which we will specialize to cover a variety of different models). There is a finite number, $n > 1$, of price-setting firms competing in a market selling an identical (homogeneous) product. Firms have unlimited capacity to supply this product at a constant marginal cost, m. A continuum of consumers is interested in purchasing the product. This market is served by a price information clearinghouse. Firms must decide what price to charge for the product and whether to list this price at the clearinghouse. Let p_i denote the price charged by firm i. It costs a firm an amount $\phi \geq 0$ if it chooses to list its price. All consumers have unit demand with a maximal willingness to pay of $v > m$.[6] Of these, a mass, $S > 0$, of the consumers are price-sensitive "shoppers." These consumers first consult the clearinghouse and buy at the lowest price listed there provided this price does not exceed v. If no prices are advertised at the clearinghouse or all listed prices exceed v, then a "shopper" visits one of the firms at random and purchases if its price does not exceed v. A mass $L \geq 0$ of consumers per firm purchase from that firm if its price does not exceed v. Otherwise, they do not buy the product at all.

Theorem 1 establishes that if it is not too costly for firms to list prices at the clearinghouse, price dispersion *always* arises in the general clearinghouse model:

Theorem 1 *Let* $0 \leq \phi < \frac{n-1}{n}(v-m)S$. *Then, a symmetric equilibrium of the general clearinghouse model exists when:*

1. *Each firm lists its price at the clearinghouse with probability*

$$\alpha = 1 - \left(\frac{\frac{n}{n-1}\phi}{(v-m)S} \right)^{\frac{1}{n-1}}.$$

2. *A firm lists its price at the clearinghouse it charges a price drawn from the distribution*

$$F(p) = \frac{1}{\alpha}\left(1 - \left(\frac{\frac{n}{n-1}\phi + (v-p)L}{(p-m)S}\right)^{\frac{1}{n-1}}\right) \quad on \ [p_0, v],$$

where

$$p_0 = \frac{\frac{n}{n-1}\phi + Lv + Sm}{L+S}.$$

[6] Baye and Morgan (2001) consider an environment with downward sloping demand.

3. *A firm does not list its price at the clearinghouse, it charges a price equal to v.*

4. *Each firm earns equilibrium expected profits equal to*

$$E\pi = (v-m)\,L + \frac{1}{n-1}\phi$$

Proof. First, observe that if a firm does not list its price at the clearinghouse, it is a dominant strategy to charge a price of v.

Next, notice that $\alpha \in (0,1]$ whenever

$$\frac{n\phi}{(n-1)\,(v-m)\,S} < 1.$$

This condition holds, since $\phi < \frac{n-1}{n}\,(v-m)\,S$.

We next show that F is a well-defined cdf with $m < p_0 < v$. First,

$$\begin{aligned} p_0 &= \frac{\frac{n}{n-1}\phi + (Lv+Sm)}{(L+S)} \\ &< \frac{(v-m)\,S + (Lv+Sm)}{(L+S)} \\ &= v, \end{aligned}$$

where the inequality follows from the fact that $\phi < \frac{n}{n-1}\,(v-m)\,S$. Furthermore,

$$\begin{aligned} p_0 &= \frac{\frac{n}{n-1}\phi + (Lv+Sm)}{(L+S)} \\ &\geq \frac{(Lv+Sm)}{(L+S)} \\ &> \frac{(L+S)\,m}{(L+S)} \\ &= m, \end{aligned}$$

where the weak inequality follows from the fact that $\phi \geq 0$ and the strict inequality follows since $v > m$.

By construction, $F\,(p_0) = 0$. To see that $F\,(v) = 1$, we compute

$$\begin{aligned} F\,(v) &= \frac{1}{\alpha}\left(1 - \left(\frac{\frac{n}{(n-1)}\phi}{(v-m)\,S}\right)^{\frac{1}{n-1}}\right) \\ &= \frac{1}{\alpha}\alpha. \end{aligned}$$

It remains to show that F is strictly increasing in p:

$$\begin{aligned} \frac{\partial F\,(p)}{\partial p} &= \frac{Z^{\frac{1}{n-1}-1}}{(n-1)\,\alpha}\frac{(v-m)\,L + \left(\frac{n}{n-1}\phi\right)}{(p-m)^2\,S} \\ &> 0, \end{aligned}$$

where

$$Z = \frac{\frac{n}{n-1}\phi + (v-p)\, L}{(p-m)\, S} > 0.$$

Next, we show that, conditional on listing a price, a firm can do no better than pricing according to F. It is obvious that choosing a price above or below the support of F is dominated by choosing a price in the support of F. A firm choosing a price p in the support of F earns expected profits of

$$E\pi\,(p) = (p-m)\left(L + \left(\sum_{i=0}^{n-1}\binom{n-1}{i}\alpha^i\,(1-\alpha)^{n-1-i}\,(1-F\,(p))^i\right) S\right) - \phi.$$

Using the binomial theorem, we can rewrite this as:

$$\begin{aligned} E\pi\,(p) &= (p-m)\left(L + \left((1-\alpha F\,(p))^{n-1}\right) S\right) - \phi \\ &= (p-m)\left(L + \left(\frac{\frac{n}{n-1}\phi + (v-p)\, L}{(p-m)\, S}\right) S\right) - \phi \\ &= (v-m)\, L + \frac{\phi}{n-1}. \end{aligned}$$

Since this is independent of p, it follows that F is a best response to the other $n-1$ firms pricing based on F.

When $\phi = 0$, it is a weakly dominant strategy to list. It remains to show that when $\phi > 0$ and $\alpha \in (0,1)$, a firm earns the same expected profits regardless of whether it lists its price. But a firm that does not list earns expected profits of

$$\begin{aligned} E\pi &= (v-m)\left(L + \frac{S}{n}\,(1-\alpha)^{n-1}\right) \\ &= (v-m)\, L + \frac{\phi}{n-1}, \end{aligned}$$

which equals the expected profits earned by listing any price $p \in [p_0, v]$. ■

We are now in a position to examine the many well-known clearinghouse models that emerge as special cases of this general environment.

2.2.1 The Rosenthal Model

Rosenthal (1980) was among the first to show that equilibrium price dispersion can arise in a clearinghouse environment when some consumers have a preference for a particular firm. Under his interpretation, each firm enjoys a mass L of "loyal" consumers. Rosenthal's main results may be seen in the following special case of the general clearinghouse model:

1. It is costless for firms to list prices on the clearinghouse: $\phi = 0$ and;

2. Each firm has a positive mass of loyal consumers: $L > 0$.

Notice that since $\phi = 0$, all of the n firms advertise their prices with probability one; hence, $\alpha = 1$. Using this fact in Theorem 1, the equilibrium distribution of prices is

$$F(p) = 1 - \left(\frac{(v-p)}{(p-m)} \frac{L}{S} \right)^{\frac{1}{n-1}} \quad \text{on } [p_0, v] \tag{12}$$

where

$$p_0 = m + (v-m) \frac{L}{L+S}$$

The price dispersion arising in the Rosenthal model stems from exogenous differences in the preferences of consumers. While shoppers view all products as identical and purchase at the lowest listed price, each firm is endowed with a stock of L loyals. The equilibrium price dispersion arises out of the tension created by these two types of consumers: Firms wish to charge v to extract maximal profits from the loyal segment, but if all firms did so a firm could slightly undercut this price and gain all of the shoppers. One might imagine that this "undercutting" argument would lead to the Bertrand outcome. However, once prices get sufficiently low, a firm is better off simply charging v and giving up on attracting shoppers. Thus, the only equilibrium is in mixed strategies—firms randomize their prices sometimes pricing relatively low to attract shoppers and other times pricing fairly high to maintain margins on loyals.

It is interesting to examine the equilibrium transactions prices in the market. Loyal customers pay the average price charged by firms:

$$E[p] = \int_{p_0}^{v} p dF(p)$$

while shoppers pay the lowest of n draws from $F(p)$; that is, the expected transaction price paid by shoppers is

$$E\left[p_{\min}^{(n)}\right] = \int_{p_0}^{v} p dF_{\min}^{(n)}(p)$$

where $F_{\min}^{(n)}(p)$ is the cdf associated with the lowest of n draws from F.

How do transactions prices vary with the number of competing firms? Rosenthal's striking result is that, as the number of competing firms increases, the expected transactions prices paid by *all consumers* goes up. As we shall see below, the result hinges on the fact that entry brings an increasing number of loyals to the market. Indeed, the fraction of shoppers in the market is S/nL and it may readily be seen that as n becomes large, shoppers account for an increasingly small fraction of the consumer base of firms. As a consequence, the incentives to compete for these customers is attenuated and prices rise as a result. They key is to recognize that increases in n change the distribution of prices, and this effect as well as any order statistic effect associated with an increase in n must be taken into account.

Formally, notice that the equilibrium distribution of prices, F, is stochastically ordered in n. That is, the distribution of prices when there are $n+1$ firms competing first-order stochastically dominates the distribution of prices where there are n firms competing. This immediately implies that the transactions prices paid by loyals increases in n. To show that the transactions prices paid by shoppers also increase requires a bit more work; however, one can show that the same stochastic ordering obtains for the cdf, $F_{\min}^{(n)}(p)$.

Finally, it is useful to note the similarity between the Rosenthal version of the clearinghouse model and the search-theoretic model of Burdett and Judd. In Burdett and Judd, even though there is a continuum of firms, each consumer only samples a finite number of firms (one or two). Further, in Burdett and Judd, a fixed fraction of consumers per firm, $\mu\theta$, sample only a single firm. In effect, these consumers are "loyal" to the single firm sampled while those sampling two firms are "shoppers"— they choose the lower of the two prices. It is therefore not surprising that when $n = 2$ in the Rosenthal model, the equilibrium price distribution given in equation (12) is *identical* to equation (11) modulo relabeling the variables for loyals and shoppers.

2.2.2 The Varian Model

Varian (1980) was among the first to show that equilibrium price dispersion can arise in a clearinghouse environment when consumers have different ex ante information sets. Varian interprets the S consumers as "informed consumers" and the L consumers as "uninformed" consumers. Thus a mass, S, of consumers choose to access the clearinghouse while others, the mass L per firm, do not. Varian's main result may be seen in the following special case of the general clearinghouse model:

1. It is costless for firms to list prices on the clearinghouse: $\phi = 0$,and;
2. The total measure of consumers lacking access to the clearinghouse is $Y > 0$; hence, each firm is visited by $L = \frac{Y}{n}$ of these consumers.

Again, since $\phi = 0$, it follows that $\alpha = 1$ and hence all n firms advertise their prices at the clearinghouse. Using this fact and setting $L = Y/n$ in Theorem 1, the equilibrium distribution of prices is

$$F(p) = 1 - \left(\frac{(v-p)}{(p-m)} \frac{\frac{Y}{n}}{S} \right)^{\frac{1}{n-1}} \quad \text{on } [p_0, v]$$

where

$$p_0 = m + (v-m) \frac{\frac{Y}{n}}{\frac{Y}{n} + S}$$

The fact that this non-degenerate distribution of prices exists whenever there is an exogenous fraction of consumers who do not utilize the clearinghouse raises the obvious question: Can this equilibrium persist when consumers are making optimal decisions? Varian shows that the answer this question is yes — provided different consumers have different costs of accessing the clearinghouse. The easiest way to see this is to note that the value of information provided by the clearinghouse is the difference in the expected price paid by those accessing the clearinghouse, $E\left[p_{\min}^{(n)}\right]$ and those not $E[p]$; that is;

$$VOI^{(n)} = E[p] - E\left[p_{\min}^{(n)}\right] \tag{13}$$

where VOI denotes the "value of information" of price information contained at the clearinghouse. Suppose consumers face a cost of accessing the information provided by the clearinghouse. Note that this cost is essentially a fixed cost of gaining access to the entire list of prices, not a per price cost as in the search-theoretic models considered above. Varian assumes that the cost to type S and L consumers of accessing the clearinghouse is κ_S and κ_L , with $\kappa_S < \kappa_L$. Then provided $\kappa_S \leq VOI^{(n)} < \kappa_L$ type S consumers will optimally utilize the clearinghouse while the type L consumers will not. In short, different consumers have different costs of accessing the clearinghouse, there exists an equilibrium of price dispersion with optimizing consumers and firms. In such an equilibrium, note that informed consumers pay lower average prices than uninformed consumers.

How does competition, in the form of the number of competing firms, affect transaction prices? In the Rosenthal model, we saw that increased "competition" in this form led to higher expected transactions prices for all consumers. In the Varian model, in contrast, the effect of competition on consumer welfare depends on whether or not the consumer chooses to access the clearinghouse. Morgan, Orzen, and Sefton (forthcoming) show that as n increases, the competitive effect predictably leads to lower average transaction prices being paid by informed consumers. However, the opposite is true for uninformed consumers—as the number of competing firms increases, firms face reduced incentives to cut prices in hopes of attracting the "shoppers" and, as a consequence, the average price charged by a firm, which is also the average price paid by an uninformed consumer, increases. If one views the clearinghouse as representing access to price information on the Internet, then one can interpret the price effect as one consequence of the so-called "digital divide". Consumers with Internet access are made better off by sharper online competition while those without such access are made worse off.

2.2.3 The Baye-Morgan Model

All of the above models assume that it is costless for firms to advertise their prices at the clearinghouse. Baye and Morgan (2001) point out that in practice, it is generally costly for firms to advertise their prices and for consumers to gain access to the list of prices posted at the clearinghouse. For example, newspapers charge firms fees to advertise their prices and may choose to charge consumers subscription fees to access any posted information. The same is true of many online environments. Moreover, the clearinghouse is itself an economic agent, and presumably has an incentive to endogenously choose advertising and subscription fees to maximize its own expected profits. Thus, Baye-Morgan examine the existence of dispersed price equilibria in an environment with optimizing consumers, firms, and a monopoly "gatekeeper" who controls access to the clearinghouse.

More specifically, Baye-Morgan consider a homogeneous product environment where n geographically distinct markets are each served by a local firm. Distance or other transaction costs create barriers sufficient to preclude consumers in one market from buying this product in another market; thus each firm in a local market is a monopolist. Now imagine that an entrepreneur creates a clearinghouse to serve all markets. In the Internet age, one can view the clearinghouse as a virtual marketplace – through its creation, the gatekeeper expands both consumers' and firms' opportunities for commerce. Each local firm now has the option to pay the gatekeeper an amount ϕ to post a price on the clearinghouse in order to gain access to geographically disparate consumers. Each consumer now has the option to pay the gatekeeper an amount κ to shop at the clearinghouse and thereby purchase from firms outside the local market.

The monopoly gatekeeper first sets κ and ϕ to maximize its own expected profits. Given these fees, profit maximizing firms make pricing decisions and determine whether or not to advertise them at the clearinghouse. Similarly, consumers optimally decide whether to pay κ to access the clearinghouse. Following this, a consumer can simply click her mouse to research prices at the clearinghouse (if she is a subscriber), visit the local firm, or both. With this information in hand, a consumer decides whether and from whom to purchase the good.

Baye and Morgan show that the gatekeeper maximizes its expected profits by setting κ sufficiently low that all consumers subscribe, and charging firms strictly positive fees to advertise their prices. Thus, Baye and Morgan's main result may be seen in the following special case of the general clearinghouse model:

1. The gatekeeper optimally sets positive advertising fees: $\phi > 0$ and;

2. The gatekeeper optimally sets subscription fees sufficiently low such that all consumers access the clearinghouse; that is, $L = 0$.

Under these conditions, using Theorem 1, we obtain the following characterization of equilibrium firm pricing and listing decisions: Each firm lists its price at the clearinghouse with probability

$$\alpha = 1 - \left(\frac{\frac{n}{n-1}\phi}{(v-m)\,S} \right)^{\frac{1}{n-1}}.$$

When a firm lists its price at the clearinghouse it charges a price drawn from the distribution

$$F(p) = \frac{1}{\alpha}\left(1 - \left(\frac{\frac{n}{n-1}\phi}{(p-m)\,S}\right)^{\frac{1}{n-1}}\right) \text{ on } [p_0, v]\,,$$

where

$$p_0 = m + \frac{\frac{n}{n-1}\phi}{S}.$$

When a firm does not list its price, it charges a price equal to v, and each firm earns equilibrium expected profits equal to

$$E\pi = \frac{1}{n-1}\phi$$

Notice that $n\alpha$ represents the aggregated demand by firms for advertising, and is a decreasing function of the fee charged by the gatekeeper. Prices advertised at the clearinghouse are dispersed, and strictly lower than unadvertised prices (v).

Several features of this equilibrium are worth noting. First, equilibrium price dispersion arises with fully optimizing consumers, firms, and endogenous fee-setting decisions on the part of the clearinghouse – despite the fact that there are no consumer or firm heterogeneities and all consumers are "fully informed" in the sense that, in equilibrium, they always purchase from a firm charging the lowest price in the *global* market. Second, while equilibrium price dispersion in the Varian model is driven by the fact that different consumers have different costs of accessing the clearinghouse, Baye-Morgan show that an optimizing clearinghouse will set its fees sufficiently low that all consumers will rationally access the clearinghouse. Equilibrium price dispersion arises because of the gatekeeper's incentives to set strictly positive advertising fees. Strikingly, despite the fact that all consumers are buying at the lowest global price, firms still earn positive profits in equilibrium. In expectation, these profits are proportional to the cost, ϕ, of accessing the clearinghouse.

Why does the gatekeeper find it optimal to set low (possibly zero) fees for consumer access and higher fees to firms? Baye and Morgan point out that this result stems from a "free rider" problem on the consumer side of the market that is not present on the firm side. Recall that the gatekeeper can only extract rents equal to the value of the outside option of firms and consumers. For each side of the market, the outside option consists of the surplus obtainable by not utilizing the clearinghouse. As more consumers access the site, the number of consumers still shopping locally dwindles and the outside option for firms is eroded. In contrast, as more firms utilize the clearinghouse, vigorous price competition among these firms reduces prices charged by all firms and leads to a more valuable outside option to consumers not using the clearinghouse. Thus, to maximize profits, the gatekeeper optimally subsidizes consumers to overcome this "free rider problem" while capturing rents from the firm side of the market. No analogous "free rider problem" arises on the firm side; indeed greater consumer participation at the clearinghouse increases the frequency with which firms participate (α goes up) and hence permits *greater* rent extraction from firms.

2.2.4 Models with Asymmetric Consumers

In general, little is known about clearinghouse models with asymmetric consumers. However, for the special case of two firms, results are available. Here we show how one can adapt the general clearinghouse model to account for asymmetries in duopoly markets.

Suppose there are two identical firms ($i = 1, 2$) competing in the market. A mass L_1 of customers are loyal to firm 1 while L_2 customers are loyal to firm 2 where $L_1 \geq L_2$.

Proposition 1 *Let $0 \leq \phi < \frac{1}{2}(v-m)S$. Then, a symmetric equilibrium of the general clearinghouse model exists when:*

1. *Each firm lists its price at the clearinghouse with probability*

$$\alpha^* = 1 - \frac{2\phi}{S(v-m)}.$$

2. *A firm lists its price at the clearinghouse it charges a price drawn from the distribution*

$$F(p) = \frac{1}{\alpha^*}\left[1 - \left(\frac{L_j}{S}\frac{v-p}{p-m} + \frac{2\phi}{S(p-m)}\right)\right] \text{ on } [p_{0,1}, v],$$

where

$$p_{0,1} = m + \frac{L_1(v-m) + 2\phi}{L_1 + S}.$$

3. *A firm does not list its price at the clearinghouse, it charges a price equal to v.*

4. *Firm i earns equilibrium expected profits equal to*

$$E\pi_i = (v-m)L_i + \phi$$

Proof. Let $A_i \in \{0, 1\}$ denote an indicator variable for whether firm i advertises its price at the clearinghouse. Let α_i denote the probability that $A_i = 1$.Thus, firm i's expected profits from each of the two listing decisions given the strategy (α_j, F_j) of its rival are

$$E[\pi_i(p|A_i = 0)] = (L_i + (1-\alpha_j)\frac{S}{2})(p-m)$$

and

$$E[\pi_i(p|A_i = 1)] = (L_i + S(1 - \alpha_j F_j(p))(p-m) - \phi$$

From the first equation, it is obvious that the dominant strategy of a firm not listing its price is to charge the monopoly price, v. For firm i to mix between listing and not then requires that

$$(L_i + (1-\alpha_j)\frac{S}{2})(v-m) = (L_i + S(1-\alpha_j F_j(p))(p-m) - \phi$$

Suppose that the monopoly price, v, is the upper support of prices, in that case, the above equality reduces to:

$$(L_i + (1-\alpha_j)\frac{S}{2})(v-m) = (L_i + S(1-\alpha_j))(v-m) - \phi$$

from which we can deduce that the equilibrium listing frequency is:

$$\alpha_j^* = \alpha^* = 1 - \frac{2\phi}{S(v-m)}$$

What is the lowest price, $p_{0,i}$, that firm i will charge? This solves

$$(L_i + (1-\alpha^*)\frac{S}{2})(v-m) = (L_i + S)\left(p_{0,i} - m\right) - \phi$$

which we may simplify to

$$L_i(v-m) + \phi = (L_i + S)\left(p_{0,i} - m\right) - \phi$$

Hence

$$p_{0,i} = m + \frac{L_i(v-m) + 2\phi}{L_i + S}$$

and notice that $p_{0,1} > p_{0,2}$; that is, the lowest "sale" price offered to attract shoppers is higher for the large firm than for the small firm. Since equilibrium price distributions must have identical supports, we then know that $F_i(p)$ has support $[p_{0,1}, v]$ for all i. Finally, we solve for F_i to obtain

$$F_i^*(p) = \frac{1}{\alpha^*}\left[1 - \left(\frac{L_j}{S}\frac{v-p}{p-m} + \frac{2\phi}{S(p-m)}\right)\right]$$

which is a well-defined cdf. on $[p_{0,1}, v]$. This completes the proof.■

There are several noteworthy features of the equilibrium pricing and advertising strategies given in Proposition 1. First, notice that when $\phi = 0$, both firms advertise prices on the clearinghouse with probability one. Narasimhan (1988) analyzes duopoly competition where firms have an asymmetric number of loyal customers under the assumption that both firms list prices at the clearinghouse with certainty. The model presented above thus takes the main part of Narasimhan's analysis as a special case.

When $\phi > 0$, it is interesting to note that the propensity to advertise is less than one and, more surprisingly, it is exactly the *same* for both firms. Thus, asymmetries in the customer base of firms need not lead to asymmetries in firm advertising strategies. In contrast, the firms distributions of advertised prices do depend on their customer bases. Comparing the distributions of prices for the two firms, one finds that:

$$F_1(p) - F_2(p) = \frac{1}{\alpha^*}\frac{1}{S}\frac{v-p}{p-m}\left[L_1 - L_2\right] > 0$$

That is, the firm with fewer loyals is actually less aggressive in its pricing strategy than the firm with more loyals. Indeed, the larger the asymmetry of loyals, the larger the difference in the average prices charged by the two firms—but in an unexpected direction. Indeed, the firm with more loyals (firm 1) offers the lowest price, $p_{0,1}$ in the market with strictly positive probability.[7]

As in Baye and Morgan (2001), one may endogenize the advertising fee by allowing a profit-maximizing gatekeeper to determine the level of ϕ that maximizes its expected profits[8]. Since the profits of the clearinghouse are

$$\begin{aligned} E\left[\Pi\right] &= 2\alpha^*\phi \\ &= 2\left(1 - \frac{2\phi}{S(v-m)}\right)\phi \end{aligned}$$

it follows that the optimal advertising fee is

$$\phi^* = \frac{S(v-m)}{4} \tag{15}$$

Equation (15) shows that the gatekeeper optimally charges a price proportional to the consumer traffic (S) on its site. This price induces equilibrium price dispersion; indeed, as first noted by Baye and Morgan, price dispersion is necessary in order for the gatekeeper to profitable maintain a clearinghouse.

2.2.5 Cost Heterogeneities

Spulber (1995) considers a situation where consumers have access to the complete list of prices and buy from the firm offering the lowest price. Of course, in such a setting, if firms were identical one would immediately obtain the Bertrand outcome. To generate price dispersion, Spulber examines the situation where firms have heterogeneous costs and downward sloping demand. However, the main economic intuition underlying the model may be seen as the following adaptation of our general clearinghouse framework for the unit demand case:

[7] However, since firm 2's distrubution is atomless, a tie at price $p_{0,1}$ is a zero probability event.

[8] For simplicity, we assume the clearinghouse must set the fee charged to consumers for access at $\kappa = 0$ to induce them to all participate. This is typically the case, for example, at online price comparison sites.

1. All consumers are shoppers: $S > 0$ and $L = 0$;
2. There is no cost to advertise prices on the clearinghouse: $\phi = 0$ and;
3. Firms have heterogeneous marginal costs described by the atomless and non-degenerate distribution $G(m)$ on $[\underline{m}, \overline{m}]$.

Since there are no costs to advertise prices, all firms list prices on the clearinghouse. Each firm faces competition from $n-1$ other firms with random marginal costs. Since the firm charging the lowest price wins the entire market, firms are effectively competing in an auction in which their own costs are private information. For the special case of unit demand, the equilibrium price for a firm is again the familiar expression from a first price auction:

$$p(m) = E\left[m_{\min}^{(n-1)} | m_{\min}^{(n-1)} \geq m\right] \tag{16}$$

where $m_{\min}^{(n-1)}$ is the lowest of $n-1$ draws from the distribution G.

There are several noteworthy features of this equilibrium. First, equilibrium firm pricing entails positive markups despite the fact that all consumers are "shoppers" and have a complete list of prices. Intuitively, there is a trade-off between lowering one's price to attract shoppers and the profitability of this price. In equilibrium, this results in a markup which depends on the number of competing firms. As the number of firms grows large, the equilibrium markup becomes small. Second, notice that cost heterogeneity leads to equilibrium price dispersion despite the fact consumers are identical and all consumers are purchasing at the lowest price.

It is interesting to compare the Spulber model, which occurs in the clearinghouse framework, with the search-theoretic framework of MacMinn. Notice that, when the number of competing firms in Spulber, n, is equal to the optimal fixed sample size for consumers in the MacMinn model, n^*, the the equilibrium distribution of prices, equations (16) and (8) are exactly the same in the two models. That is, cost heterogeneities are sufficient to generate price dispersion in oligopoly models where all consumers obtain complete price information as well as in models where a continuum of firms compete but each consumer only obtains price quotes from a finite number n of these firms.

2.3 Other Approaches to Equilibrium Price Dispersion

Several recent papers have emphasized that bounded rationality can also lead to price dispersion. The idea is to relax the Nash equilibrium assumption – which requires that each decision maker in the market is choosing an action (be it a price or a search strategy) that is a best response to given actions of other market participants. Two equilibrium concepts – quantal response equilibrium and epsilon equilibrium – are particularly useful because they nest the standard Nash equilibrium concept as a special case.

In a quantal response equilibrium (QRE), the likelihood that a particular firm sets a specific price depends on the expected profits arising from that price. A firm's price is determined by a decision rule is stochastic, but has the property that prices leading to higher expected profits are more likely to be charge. Of course, each firm's expected profits from different pricing decisions depends on the probability distributions of other players' prices. For a given stochastic pricing decision, a QRE requires that all firms hold correct beliefs about the probability distributions of other players' actions. The nondegenerate distributions of prices resulting in a quantal response equilibrium may be viewed as shocks to firms' profit functions. Alternatively, nondegenerate price distributions might stem from decision errors by firms. Such errors may stem from limitations in managers' cognitive processing or "bugs" in dynamic pricing algorithms used by Internet retailers.

In an ε-equilibrium, the prices charged by each firm are such that no firm can gain more than ε in additional profits by changing its price. Such an equilibrium may arise because of cognitive or motivational constraints on the part of firms. For example, if it is costly to reprogram dynamic pricing algorithms, managers may not be willing to incur these economic or psychic costs when the resulting gain is small (less than ε).

Recently, Baye and Morgan (2004) applied QRE and ε-equilibrium concepts to pricing games, and showed that only a little bounded rationality is needed to generate the sorts of price dispersion documented in laboratory experiments as well as observed on Internet price comparison sites.

2.4 Summary

Despite the slow start, there are now a variety of models that can be used to rationalize equilibrium price dispersion in online and offline markets. We conclude with the following general observations:

1. There is not a "one-size fits all" model of equilibrium price dispersion. Instead a one should take a "horses for courses" modeling approach; that is, different models are appropriate for analyzing different market environments. For instance, search-theoretic models are most appropriate for analyzing environments where consumers must visit different stores or individual firms' websites to gather price information. Clearinghouse models are appropriate when consumers are able to access list of prices (for example, in a newspaper or at a price comparison site).

2. The distribution of prices is determined by the interaction of all market participants – firms, consumers and (in the case of clearinghouse models), information gatekeepers. As a consequence, the level of price dispersion depends on the

structure of the market – the number of sellers, the distribution of costs, consumers' elasticities of demand, and so on.

3. Reductions in search costs may lead to either more or less price dispersion, depending on the market environment. The elimination of consumer search costs need not eliminate price dispersion.

4. Depending on the market environment, heightened competition (increases in the number of firms) can increase or decrease the level of dispersion. Moreover, in some models, heightened competition of this form lead to higher transactions prices paid by all consumers. In other models, the welfare effect of increased competition depends on which side of the "digital divide" a consumer resides.

5. Price dispersion is not purely an artifact of *ex ante* heterogeneities in firms or consumers. While differences in firms' costs or base of loyal consumers (stemming from firms' branding efforts, differential service qualities or reputations) can contribute to equilibrium price dispersion, such differences are not necessary for equilibrium price dispersion.

6. Thanks to the Internet, information gatekeepers are playing an increasingly important role in the economy. In their attempt to maximize profits and enhance the value of information provided by their sites, information gatekeepers have an incentive to charge fees for their services that induce equilibrium price dispersion.

7. A little bounded rationality goes a long way in explaining price dispersion.

3 Empirical Analysis of Price Dispersion

In this section, we survey the empirical literature on price dispersion and highlight the "dialog" between theoretical and empirical findings. We begin, in section 3.1, by highlighting the strengths and weaknesses of several main measures of price dispersion used in the literature. The remaining sections then highlight the main empirical findings on price dispersion both online and offline.

3.1 Measuring Price Dispersion

The equilibrium models of price dispersion presented above each imply non-degenerate distributions of prices, $F(p)$ on some non-degenerate interval $\left[\underline{p}, \overline{p}\right]$. Given such a distribution, a standard measure of dispersion is the variance in prices:

$$\sigma^2 = \int_{\underline{p}}^{\overline{p}} (z - E[p])^2 \, dF(z)$$

Given a particular model of equilibrium price dispersion, this measure can be directly computed. For instance, in the MacMinn model where firms have uniformly distributed marginal costs, the predicted variance in prices is given in equation (10). Since the distribution of marginal costs is uniformly distributed on $[\underline{m}, \overline{m}]$, we have

$$\sigma^2 = \left(\frac{n^* - 1}{n^*}\right)^2 \frac{(\overline{m} - \underline{m})^2}{12}$$

Notice that one is then in a position to test comparative static predictions of the model (such as the fact that variance increases with n^*) using this measure. In a similar manner, expressions for the variance in prices may be derived from the other models presented previously.

The obvious advantage of using the (sample) variance to empirically measure price dispersion is that it uses all available data. For this reason, a number of authors use this measure (e.g., Pratt, Wise and Zeckhauser (1979); Bynjolfsson and Smith 2000; Pan, Ratchford, and Shankar 2003; and Ancarani and Shankar 2004). The drawback is when there is variation (either cross sectionally or over time) in the predicted price distribution. For instance, suppose that, during an inflationary period, the marginal costs of all firms in the MacMinn model increased by a factor $\gamma > 1$. In that case, the new variance would simply scale up the original variance by a factor γ^2. Thus, this measure of price dispersion would change even though the underlying real economics of the situation are the same after the inflationary period.

For this reason, if one wishes to compare levels of price dispersion either across different products or across time, one must standardize the data in some fashion. An alternative is to use the coefficient of variation,

$$CV = \frac{\sigma}{\mu}$$

which is homogenous of degree zero in the the level of prices. This makes it an ideal measure when comparing levels of price dispersion over over long periods of time (as in Scholten and Smith (2000)). An added advantage is that, unlike some methods of standardization, the coefficient of variation often nicely preserves the comparative static predictions of the model of interest. For instance, in the MacMinn model, equation (9) implies that the expected price is $E[p] = \frac{n^*-1}{n^*}\left(\frac{\overline{m}+\underline{m}}{2}\right) + \frac{\overline{m}}{n^*}$, and thus the coefficient of variation is

$$CV = \frac{1}{\sqrt{3}} \frac{(n^* - 1)(\overline{m} - \underline{m})}{(n^* - 1)(\overline{m} + \underline{m}) + 2\overline{m}}$$

One may verify that this statistic is, like the variance, increasing in n^*, but does not change with a multiplicative shift it firms' costs. We note, however, in other models the coefficient of variation may have comparative static properties that differ from that of the variance. Even in these cases, however, the models will yield testable predictions about how changes in parameter values influence this measure of price dispersion. For these reasons, it is not surprising that the CV has been widely reported in the studies of price dispersion involving cross-sectional data (see, for instance, Carlson and Pescatrice (1980); Sorenson (2000); Baye, Morgan and Scholten (2004)).

One of the more widely used measures of price dispersion is the range (see, for instance, Pratt, Wise and Zeckhauser (1979); Brynjolfsson and Smith (2002); Sorensen (2000); list the remaining studies here). Letting $p_{\min}^{(n)}$ and $p_{\max}^{(n)}$ denote, respectively, the lowest and highest of n observed prices drawn from some pricing distribution F, then the range is

$$R^{(n)} = p_{\max}^{(n)} - p_{\min}^{(n)}$$

Using the predicted equilibrium price distribution, $F(p)$, comparative static predictions about changes in the range are possible based on the behavior of the highest and lowest order statistics. That is, one can perform comparative static analysis on the expected range:

$$E\left[R^{(n)}\right] = E\left[p_{\max}^{(n)}\right] - E\left[p_{\min}^{(n)}\right]$$

For reasons analogous to the normalization of variance in the form of coefficient of variation, some researcher (see, Baye, Morgan, and Scholten (2004)) normalize the range by dividing by $p_{\min}^{(n)}$. This version of the range is then the difference between the lowest and highest sampled prices as a percentage of the lowest price.

All of the above measures of price dispersion suffer from a theoretical defect. Suppose that, $n > 2$ firms are competing in a classical homogeneous product Bertrand setting. Under standard conditions there will exist a unique symmetric equilibrium where all firms price at marginal cost. But in addition, there are asymmetric equilibria where two firms price at marginal cost and the remaining $n-2$ firms price strictly above marginal cost. Thus, price dispersion can arise in a classical Bertrand environment. But in this case, the apparent price dispersion is not economically relevant; the unique transactions price is marginal cost.

To overcome this deficiency, Baye, Morgan and Scholten (2004) propose a measure called the gap which they define to be the difference between the two lowest prices in the market: Letting $p_2^{(n)}$ denote the second lowest price realization from n draws from some distribution $F(p)$, then the gap is defined as

$$G^{(n)} = p_2^{(n)} - p_{\min}^{(n)}$$

As with the range measure, one can perform comparative static analyses for any of the theoretical models using the expected gap,

$$E\left[G^{(n)}\right] = E\left[p_2^{(n)}\right] - E\left[p_{\min}^{(n)}\right]$$

Finally, it is sometimes useful to normalize the gap by dividing by the realized lowest price. In this formulation, the gap represents the difference between the two lowest prices expressed as a percentage of the lowest price realization.

The classical Bertrand model implies that the gap between the two lowest prices is zero in any equilibrium (symmetric or otherwise). This measure also has the empirically desirable property that it gives greater weight to low prices, which in the absence of quantity data one might reasonably assume lead to more sales than higher prices. The key disadvantage, which is shared by both the gap and range measures, is that, since they use only a subset of (extreme values) of the data, they are more sensitive to outliers and other forms of "noise" than are measures that use the all available data, such as the variance and the coefficient of variation.

Finally, one economically useful measure of price dispersion is the value of information, first introduced in equation (13). This is simply the difference between the average observed price and the lowest observed price. The value of information is the amount of money a consumer might be expected to save by buying from the lowest price firm compared to choosing a firm at random.

3.2 Price Dispersion in the Field

3.2.1 Price Dispersion is Ubiquitous

Price dispersion has been ubiquitous for over one hundred years. In 1901 the U.S. Industrial Commission (USIC) conducted an investigation into predatory pricing allegations between local or regional geographic markets. The investigation consisted of a national survey on prices of six products: illuminating oil (kerosene), granulated sugar, three grades of salt, and a particular brand of baking powder – Royal Baking Powder. The survey was sent to over 5000 retail dealers, of whom 1578 replied.

Table 2 reveals that at the nationwide level for this set of products information was a valuable commodity in 1901. On average, consumers in 1901 would have spend 41 percent (of the minimum price) less purchasing from the low-price firm than from a randomly selected firm. Other measures of price dispersion were also substantial. The average difference between the high and low price (as a percent of the minimum price) was almost 145 percent. Similarly, the average coefficient of variation in 1901 amounted to about 17 percent. Since one of the primary issues was to explain price dispersion in a given local market the city-level measures of dispersion were also reported. At the city level, these measure of dispersion were somewhat lower. The weighted average coefficient of variation is 5.8 percent across all products and the average unweighted coefficient of variation was 5.4 percent.[9]

Eckard (2004) compares price dispersion in the 1901 data for cities with populations greater than 100,000 to observed dispersion in Denver, CO during 2001 (which has a population over 100,00). Eckard finds that despite significant cost-reducing technology in both transportation and communication, price dispersion measured by the coefficient of variation is actually lower in 1901 than in 2001. Table 3 presents these findings. The average coefficient of variation in 1901 for cities with populations

[9] Weighted by the number of firms per city.

over 100,000 amounted to 5.05 percent. In contrast, the unweighted coefficient of variation in 2001 was 5.34 percent while the brand-weighted coefficient of variation was 8.0 percent.[10]

The period between 1901 and 2001 marked significant changes in the U.S. This period was marked by the end of industrialism, wars and the Great Depression. The post-war era also brought along significant change and technological advancement, including the Internet. Yet, despite all these changes, price dispersion remains relatively constant.

The ubiquitous nature of price dispersion certainly inspired Stigler in motivating his seminal 1961 paper. Stigler collected asking prices for anthracite-grade coal and an identical model of an automobile. The market for anthracite coal exhibited significant price dispersion. The average bid price for federal government coal purchases amounted to \$16.90 per ton. Prices ranged from \$15.46 to \$18.92. These statistics suggest that the federal government would have saved 9.3 percent by purchasing from the low-price seller than from a randomly selected firm. Information about low-prices is indeed valuable. The standard deviation in coal prices amounted to \$1.15, which indicates a coefficient of variation of 14.7 percent. The average price for the automobile with an average amount of "higgling" was \$2,436 (in 1961 dollars), ranging from \$2,350 to \$2,515. The coefficient of variation in the prices of automobiles was about 1.7 percent. While the dollar magnitude of savings to consumers is relatively are large by 1961 standards, as we will see, the level of price dispersion comparatively small. Based on the coefficient of variation, prices are about four times more dispersed in the market for coal than for automobiles. Nonetheless, each market exhibits significant price dispersion and the value of low-price information to a consumer is economically meaningful.

An early study by Pratt, Wise and Zeckhauser (1979) again demonstrates the ubiquitousness of the price dispersion phenomenon—in products ranging from rebuilt alternators to the cost of boarding a poodle, they find significant price dispersion. Specifically, they find significant price dispersion in the Boston area for 39 homogenous products in different categories. Based on the statistics reported in Pratt et al. we construct three measures of price dispersion and report these results in Table 4. This table reinforces the notion that information about the low price in a market is a valuable commodity. Knowledge of the identity of the firm selling at the lowest price can save a typical consumer about 53.2 percent of the low-price. This savings ranges from about 6 percent to 200 percent. The other measures of price dispersion reported in table 4 – the coefficient of variation and range (as a percent of the low price) – reveal that price dispersion is a pervasive phenomenon in the Boston area. Across all 39 products the average coefficient of variation is 21.6 percent and average percentage range is 120.8 percent – significantly higher than those reported by Stigler.

[10]The original brand of baking powder and sugar were unavailable in 2001. As a result, Eckard (2004) collects a sample of three brands of baking powder, three brands of granulated sugar, and a store-brand of granulated sugar. Thus, Eckard includes a brand-weighted coefficient of variation.

The above results are not unique. Scholten and Smith (2002) compare the price dispersion in 2000 to 1976. Scholten and Smith find that price dispersion in 1976 is roughly the same as it is in 2000, whether traditional or Internet retail markets are compared. Nor is price dispersion merely a US phenomenon: Significant price dispersion has also been documented across within and between seven European countries. Gatti and Kattuman (2003) find that compared to relatively cheap products, price dispersion is relatively low for high value products.

Using a more conservative measure of price dispersion the "gap" – the difference between the two lowest prices in the market – Baye et al. (2004) find considerable persistence in dispersion over the most turbulent 8 month (short) history of the Internet. The average percentage gap from August 2, 2000 to March 31, 2001 was about five percent. Moreover, 90 percent of the products in that sample were found to have percentage gaps greater than zero; between 50-60 percent of the products experienced percentage gaps greater than one percent.

Price dispersion persists across a wide range of environments where firms' production costs are heterogeneous and search costs to consumers differ widely. Table 5 reports the average coefficient of variation for the 13 products examined in Roberts and Supina (2000) over the period 1963-1987. As the table illustrate, there is considerable variability in dispersion across these markets: The average coefficient of variation is between 6.35 percent and about 78 percent. Within each product, however, Roberts and Supina find considerable persistence in the price dispersion over time. They attribute the persistence in dispersion to underlying producer heterogeneity in demand elasticities and product costs. Given the wide variety of products examined Roberts and Supina, it is unlikely that any one model exactly captures these underlying markets.

Having shown that price dispersion is ubiquitous, we now turn to key factors suggested by the theory models in the previous section that are predicted to affect price levels and price dispersion.

3.2.2 Purchase Frequency

Carlson and Pescatrice (1980) obtain price data from the downtown central business district of New Orleans for 34 products differentiated only by the location where they are purchased. Price dispersion is somewhat less in Carlson and Pescatrice. Table 6 illustrates that the average coefficient of variation in their sample is 13.13 percent and ranges from 3.3 percent to 41.4 percent. Beyond the obvious difference of different geographic locations and product composition, there are more subtle difference between the Carlson and Pescatrice (1980) and Pratt et al. (1979) studies. Specifically, Pratt et al. (1979) use a random selection process whereas Carlson and Pescatrice used somewhat less scientific method by selecting products for which they prior notions.

Carlson and Pescatrice are particularly interested in the relationship between purchase frequency and price dispersion. They find that infrequently purchased products tend to exhibit higher dispersion than more frequently purchased products. Indeed, from Table 6, the median coefficient of variation for frequently purchased products is 7.3% compared to a median of 12.5% for infrequently purchased products. For instance, the coefficient of variation for a wrench, mattress, model chair, toaster, thermometer and batteries each exceed 12 percent. In contrast, commonly purchased products like hair spray, antacid, hair tonic, aspirin, deodorant, baby oil, contact lens solution and razor blades exhibit substantially less dispersion; each is less than 7.5 percent. While the relationship between frequency and dispersion holds in many cases, there are some notable exceptions: Perishable products like potatoes, lettuce, celery and lemons are frequently purchased items and tend to exhibit considerable price dispersion. The coefficient of variation for these perishable products ranges between 14.5 percent to 24 percent.

More recently, Sorensen (2000) examines how repeated purchases in the market for prescription drugs impact price dispersion. Sorensen finds that the average coefficient of variation across the 152 prescription-drug sample is 22 percent. He again finds that prescriptions that are purchased with greater frequency tend to exhibit less price dispersion and have lower markups.

3.2.3 Search Costs

Johnson (2002) provides empirical evidence that differences in search costs may lead to sticky prices and asymmetric price adjustments in response to changes in wholesale price in 15 U.S. markets gasoline and diesel. Prices adjust much more rapidly in the diesel market where search costs are conjectured to be much lower than for regular gasoline, where search costs are thought to be higher.

Along these same lines, Carlson and Pescatrice conjecture that batteries, flash bulbs and thermometers are as likely to be purchased from consumers with urgent needs (high search costs) and those who foresee needs (lower search costs). Table 6 illustrates that the coefficient of variation for these—batteries, flash bulbs and especially contraceptives— is high, 26.2 percent, 17.3 percent and 41.4 percent, respectively. These are significantly above the median coefficient of variation in their study.

The maturity of Internet and growth of e-commerce has led many to question the importance of search as a source of price dispersion. Bakos (1997) argues that one consequence of Internet technology is a reduction in consumers' search cost. As seen above, lower search costs may increase or decrease the level of price dispersion in Internet markets. Recently, the role that intermediaries play in traditional markets has decreased. The definition of an intermediary, however, has somewhat changed. Indeed, information systems that serve as intermediaries between buyers and sellers are gaining prominence in electronic marketplaces. As a result, intermediaries are playing an increasingly important role in many electronic marketplaces.

Brown and Goolsbee (2002) find that comparison shopping has lowered search costs and has made purchasing life insurance easier. The average price of policies has dramatically fallen. Using the residuals from a price regression that controls for observable characteristics of people and policy types, Brown and Goolsbee compute the standard deviation in residuals within the age-state group for each year. This measure is about 26 percent for the median age-state-year group. Using this measure of price dispersion, evidence is found indicating that dispersion within groups is rising when the share of individuals searching online for insurance is low. When this share exceed a threshold of about 5 percent, dispersion is actually falling. While this seems counterintuitive, Brown and Goolsbee point out that it is consistent with the literature.

3.2.4 Number of Competing Firms

Many models of price dispersion predict a relationship between the distribution of equilibrium prices and the number of competing firms. Borenstein and Rose (1994) investigate this relationship in the airline industry. They find considerable price dispersion in the prices airlines charge passengers on the same route. The difference two passengers traveling on the same route can expected to pay is about 36 percent of the airline's average ticket price. Cost differences explain some of the price dispersion, but other structural characteristics of the market play an important factor. In particular, Borenstein and Rose find that price dispersion *increases* as the number of competitors in a market grows, holding the total number of flights constant.

Barron, Beck and Umbeck (2004) empirically study the structural determinants of price dispersion in the retail gasoline industry in four geographic locations. Contrary to Borenstein and Rose, they find considerable evidence that, controlling for station-level characteristics, an increase in station density *decreases* both price levels and price dispersion.

Baye, Morgan and Scholten (2004) explore this question in online markets by examining nearly 4 million price quotes for over 1,000 electronics product sold at the price comparison site, Shopper.com. Using the gap measure of price dispersion, they find a systematic relationship between the percentage gap and the number of firms listing price information. In markets where only two firms list prices, the average percentage gap was over 22 percent. This average (almost) monotonically falls to 3.5 percent in markets where 17 firms list prices. This relationship is consistent with predictions in a number of clearinghouse models.

3.2.5 Mixed Strategies in Clearinghouse Models

One of the earliest papers to explore the "mixed strategy" justification for price dispersion is Villas-Boas (1996). He examines grocery markets for coffee and saltine crackers to determine whether the sample of prices are consistent with the theoretical density function of Varian (1980). Villas-Boas finds that some markets are consistent with the marginal distributions of the Varian model. More recently, using monthly store-level price data from Israel, Lach (2002) finds evidence of persistent price dispersion over a 48-month period. Lach finds considerable intra-distribution mobility among the firms. After controlling for observed and unobserved product heterogeneities, there is considerable evidence of firms moving up and down the price distribution over the 48-month period. Taken together, Lach concludes that the nature of price dispersion and firms' behaviors is consistent with that predicted in Varian (1980).

Further support for clearinghouse models is found in Baye, Morgan and Scholten (forthcoming). After an 18-month period spanning November 1999 to May 2001, there is no empirical evidence that prices for 36 products are converging to the "law of one price." This finding is robust to controls for shipping cost changes and product availability. After controlling for firm cost heterogeneities, branding, reputation, trust, shipping costs, 28 percent of price variability for homogeneous products remains unexplained. In a different study using the same data set, Baye, Morgan and Scholten (2004) find significant turnover in the identity of the low-price firm and the level of low prices. Again, this provides further support that firms use mixed strategies (short-term price promotions) to avoid Bertrand competition.

There are many other empirical results confirming that firms listing prices at comparison sites use mixed strategies to avoid the deleterious outcome associated with homogenous product price competition. Iyer and Pazgal (forthcoming) collect price data on music CDs, movie videos and books from five price comparison sites: mySimon, BottonDollar, EvenBetter, Bsilly and Pricescan. Consistent with their equilibrium mixed strategy model, they find empirical results suggesting that no single firm consistently charges the low price. Over a six-month period, the average number of low-price firms is 4.7 for books, 3.2 for music CDs and 4.0 for movie videos.

Since this measure simply captures the number of low-price retailers, Iyer and Pazgal also construct two other indices that capture the idea of the share of times a firm is the low-price firm and the frequency with which the identity of the low-price firms changes. The firm-share index is a measure similar to the Herfindahl-Hirshman index measure of concentration, which measure industry market concentration. This concentration measure, however, measures the fraction of days a firm was the low-price firm. The inverse of this concentration index could be viewed as the "effective" number of stores with the low price. Iyer and Pazgal's data suggests the effective number of low-price firms is about two over the six month period for each product category. The "switching" index measures the period-to-period change in the identity of the low-price firm relative to the maximum number of possible changes. A value of this index approaching unity suggests high variability in the identity of the low-price retailer across periods. The switching index for books is 0.73, 0.60 for music CDs and 0.68 for movie videos. Each of these values and measures of turnover in the identity of the low-price firm is consistent with the notion that there is turnover in the identity of the low-price firm and equilibrium mixed strategies.

Iyer and Pazgal's model predicting equilibrium in mixed strategies also predicts that the average price will increase in the number of participating retailers and the minimum price will decrease in the number of participating retailers. In each case, they find statistical support from the data consistent with each of these hypotheses.

3.2.6 How Price Sensitive are Online Shoppers?

Mixed strategies are not the only way that firms avoid Bertrand competition at price comparison sites. Some take issue with the argument that the Internet reduces search cost. While in many instances the Internet has lowered the cost of searching for price information and created greater price-sensitive consumers. Ellison and Ellison (2004) find that for some products, however, retailers have responded to the possibility of Bertand competition by resorting to obfuscation strategies. Such strategies may take different forms and will play an increasingly important role in retailers' profitability as price comparison sites gain popularity. The Internet is amenable to obfuscation strategies since it is relative easy and cheap to create sales pitches that use legal "bait-and-switch" techniques or offer personalized prices. Moreover, some products on the Internet are sold in bundles (the product and shipping, for instance), which permits retailers to offer many different prices. Obfuscation strategies include 1) making product description complicated; 2) creating multiple versions of products so consumer must make attribute and price trade-offs for many different products; and 3) employ a loss-leader strategy where firms offer product of low quality at very low prices to attract consumers and then offering a high-quality product at a higher price. Ellison and Ellison (2004) find evidence confirming the notion that price search on the Internet reduces frictions and extremely elastic demand: the price elasticity of demand for low-quality memory modules is between -25 and -40. In addition, charging a low price for low-quality memory increases the retailer's sales of medium- and high-quality memory modules. Ellison and Ellison (2004) also examine how obfuscation impacts profitability. They find that obfuscation strategies creates less informed consumers in the search context, which tends to raise firm profitability. In addition, obfuscation creates also an adverse selection problem in the competitive price discrimination model making price-cutting a less attractive way to induce consumers to purchase its products.

It is a widely held belief that the Internet will reduce search costs and induce more consumer search. There is little empirical evidence, however, to support this conjecture. In fact, according Adamic and Huberman (2001) the top 1 percent of sites on the Internet account for 50 percent of web visits, which is consistent with the notion that consumer search is limited. While there is little doubt that search costs have decreased, Johnson, Moe, Fader, Bellman, and Lohse (2004) find little direct evidence that consumer are searching more. Johnson et al. find that loyal runs deep: in their sample approximately 70 percent of CD shoppers, 70 percent of book shoppers and 42 percent of travel shoppers are loyal to one particular site. While one might conjecture that the pervasiveness of not searching is a function of experience, Johnson et al. find no evidence that consumers increase search as experience increases. It is important to note that the time period during which Johnson et al. study was in the infancy of the Internet – July 1997 to June 1998. Thus, their study captures a snapshot of early online shopping behavior. The authors caution that these results may be reversed as shopping agents or price comparison sites gain in popularity.

The authors offer three explanations why search on the Internet is so limited. First, the markets under study – books, CDs and travel – are efficient. Research examining efficiency in online markets, however, provides evidence to the contrary (cf. Bailey (1998); Brynjolfsson and Smith (2000); Clay et al. (2001); and Clemons et al. (2002)). Second, search models are incomplete. Johnson et al. suggest that the standard framework of the search models of the trade-off between the cost (measured by time) and benefit of search does not capture all aspects of search environments. They argue that other benefits of time such as the effects of context and mental accounts are important. Finally, the authors raise the possibility that search costs are dynamic and change as consumers gain experience with a particular online retailer. That is, consumers experience lock-in at a particular retail since they are familiar with a site, customization or offer recommendations.

Arnold & Saliba (2002) examine the market for college textbooks and find evidence that price dispersion stems from consumer ignorance about non-price parameters valued by consumers. They find support for the hypothesis that unobserved availability is sufficient to generate equilibrium price dispersion even when prices are common knowledge to consumers. In particular, tests conducted by Arnold and Saliba (2002) reveal that Amazon.com and BN.com tend to charge higher than average prices, but also have higher availability than the average firm. Other firms in their sample tend to charge lower than average prices, but have below average availability. Thus, non-price parameters also impact price dispersion in markets (cf. Smith, Bailey and Brynjolfsson (1999); Clay, Krishnan and Wolff (2001); Smith and Brynjolfsson (2001); Chen and Hitt (2002); Baye and Morgan (2003); Baye and Morgan (2004); Brynjolfsson and Smith (2004); Brynjolfsson, Dick and Smith (2004)).

The tension between the large number of shoppers observed in Ellison and Ellison and the large fraction of loyals in other work is addressed in Baye, Gatti, Kattuman and Morgan (2005).

3.2.7 Is Online Really More Competitive than Offline?

Three types of retailers have emerged since the Internet has arisen as a substantial distribution channel. The first is the pure-play Internet retailer. This type of firm specializes in distributing retail products via the Internet and online markets. It is assumed that these are low-cost retailer since they maintain no physical facilities and are likely have lower inventory carrying costs. The geographic reach of the pure-play retailer is worldwide; limited only by the number of individuals with computer and Internet access. The second retailer type is the traditional, brick-and-mortar or offline retailer. These retailers maintain physical locations consumers must usually visit to purchase a product. They maintain one or more physical locations, which are typically costly to establish and maintain a staff to assist individuals. Often times the geographical reach of these firms is somewhat limited to the areas surrounding the physical locations. The third firm type is called bricks-and-clicks, online and offline retailers or multichannel retailers. This third retailer type has both a traditional offline retail locations and an online presence in Internet markets. According to Zettelmeyer (2000), these three retailer types coexist in many product categories.

Chevalier and Goolsbee (2003) measure the degree of competition between pure-play Amazon.com and multichannel BN.com in the market for books by examining the period-by-period difference in prices. Despite that during their sample period both firms publicly announced pricing structure changes, competition appears to have decreased. On April 2001 they estimate the amount of dispersion between Amazon.com and BN.com to be about 8.1 percent. The level of dispersion steadily increases to 9.5 percent on June 23, 2001 and to 12.3 percent on August 3, 2001. Since price dispersion is a measure of market power and is increasing, these data suggest that competition has decreases over time. During this same time, Chevalier and Goolsbee find no evidence that consumer price sensitivity has fallen over time.

Goolsbee (2001) uses micro data on computer purchases to obtain estimates of direct competition between online and traditional retailers. The results suggest that there is substantial cross-channel competition. Conditional on purchasing a computer, the cross-price elasticity of demand between channels is greater than unity suggesting that online and offline sales are the same markets. Carlton and Chevalier (2001) also find evidence of substantial channel conflict. These research papers raise substantial questions about the nature of competition across channels. Will firms specialize in distributing products through any one channel or will multichannel distributors emerge and prevail? Will prices be lower on the Internet? Will lower search costs and greater information lead to lower price dispersion? A vast literature has emerged that attempts to address these and other questions. Unfortunately, however, there is no consistent answer to these questions.

Brynjolfsson and Smith (2000) argue that search costs, while lower for consumers on the Internet, are still not trivial. Consumers, they argue, may only be aware of a couple of Internet retailers for any given product and may have no knowledge of intermediaries that compare prices. Brynjolfsson and Smith (2000) examine prices and price dispersion for a set of books and CDs. The authors collect data from two types of distribution channels; among them are traditional retailers and Internet retailers. They find evidence that the mean price on the Internet is statistically less than the mean price in conventional retail markets. The mean price for books in conventional markets is $13.90 and only $11.74 in Internet markets. Similarly, the mean price for CDs in conventional markets is $16.07 and $13.49 on the Internet. These figures are weighted by Internet traffic, which is measured by "screen share."

The unweighted mean price remains lower, but the dollar magnitude is smaller. They were somewhat surprised to observe that dispersion in quoted prices was usually larger on the Internet. Giving equal weight to each title within a given time period the average price range for books amounted to 33 percent and 15 percent for CD titles. Their statistical analysis suggests that average price range among firms competing in Internet markets is slightly lower than the range in conventional markets. However, neither channel displays more dispersion than the other. Indeed, there is statistical evidence found supporting the claim that one channel displays more dispersion, as measured by the range, than its competing channel. The results are starkly different when the dispersion measures are share-weighted. Brynjolfsson and Smith de-meaned share-weighted kernel density plots suggest there is less dispersion on the Internet than in conventional channels for both books and CDs. This result is offered with a word of caution: Amazom.com has over 80 percent of the Internet market. In contrast, however, Barnes and Noble controls only 25.4 percent of the conventional market for books and CDs. To the extent that the market leader – Amazon.com – experiences lower average costs resulting from their relatively high market share, these observations would be consistent with Reinganum (1979). The author's, however, argue their results are inconsistent with the search cost story of Bakos (1997) since price dispersion for several of their measures is not lower on the Internet than in conventional markets. Instead, they suggest that unobserved retailer characteristics account for most of the observed dispersion in prices for books and CDs. The nature of this unobserved heterogeneity is, largely, left unexplored. But, they suggest that consumer awareness, brand heterogeneity and trust are likely important components contributed to price dispersion.

Acarani and Shankar (2004) address several important research questions regarding the pricing strategies related to the three retailer types. First, to what extent does there exist a difference in the price level across the three retailer types? Second, how much price dispersion exists within each retailer type? Finally, are different levels of price dispersion observed across the three retailer types? These are important questions since price levels are likely to indicate the level of competition across different channels. In contrast, price dispersion measures the level of competition within each channel.

In addition to Brynjolfsson and Smith (2000), a number of other studies examine price levels differences and differences in price dispersion in online and offline retail markets and partially address the questions posed by Acarani and Shankar. For instance, Morton, Zettelmeyer and Risso (2001) find that prices are lower in online markets for automobiles. Consumers who purchase a car through the Internet referral service Autobytel.com reduces the purchase price by approximately 2.2 percent; even lower than the 1 percent lower prices that online consumers pay compared to offline for the same automobile. Interestingly, Morton et al. (2001) results suggest that the consumers who purchase automobiles online are not typically those who negotiate well in the traditional channel. In their language, it is the "cowards" not the "cowboys" who are disproportionately more likely to use the Internet to purchase automobiles. A number of studies have found that multichannel retailers to have higher posted prices than pure-play retailers (cf. Pan, Rachford and Shankar (2002); Pan, Shankar and Ratchford (2002) and; Tang and Xing (2001)). For instance, Tang and Xing find that in the DVD market pure-play Internet retailers' prices are significantly lower than prices posted by multi-channel retailers by an average of \$3.27, or 14 percent of the price. Friberg, Ganslandt and Sandström (2001) find that prices are 15 percent less on the Internet, but that including transportation cost make prices in an Internet market roughly equivalent to a traditional market. There are a number of other studies, however, that find equal or higher prices online (cf. Clemons, Hann and Hitt (2002); Bailey (1998); Clay, Krishnan, Wolf and Fernandes (2002); Erevelles, Rolland and Srinivasan (2001)). While Pan, Shankar and Ratchford (2002) find that prices are lower for pure-play retailers than multi-channel retailers for CDs, DVDs, desktop computers, laptop computers, PDAs and electronics. Prices for pure-play retailers are, however, higher in the book and software markets.

Ancarani and Shankar (2004) examine price dispersion across all three retailer types in the Italian market for books and CDs. Based on the statistics reported in Ancarani and Shankar (2004), Table 7 computes the coefficient of variation and price range as a percentage of the list or posted prices including and excluding shipping costs. Ignoring shipping costs, pure-play Internet retailers books and CDs have the lowest price variability measured by the coefficient of variation despite having the highest price range. Multi-channel retailers of books have the next highest coefficient of variation and price range. Traditional retailers in the Italian market for books and CDs have the lowest coefficient of variation and price range. Comparing price levels across all three channels, Acarani and Shankar (2004) find that posted prices are highest among traditional retailers. Multi-channel retailers had the second highest posted prices, while pure-play Internet retailers posted the lowest prices. Including shipping costs changes the price-level ordering to multi-channel retailers have the highest prices followed by pure-play Internet retailers and then traditional retailers. These is obviously no consensus whether consumers will pay higher or lower prices in online or offline markets.

While comparing prices between online and offline retailers has produced mixed results, it is clear that price dispersion in both online and offline markets is significant. It appears that in many cases, retailers need to be concerned about cross-channel cannibalization and managing channels will become increasingly important as the Internet continues to gain popularity by consumers as a distribution channel.

The seemingly ambiguous results presented in the literature that compares price distribution among distribution channels in some light may not be as surprising as thought at first blush. The results reported in this empirical literature represent markets where costly consumer search is the dominate mode for collecting price information. While search costs have likely decreased, the industry cost structure has also experienced a dramatic shift. Indeed, pure-play Internet retailers likely experience lower costs than the traditional retailers or multi-channel retailers. As a result, this distribution of costs among retailers has widen. In this market environment decreased search costs and larger cost distributions have competing effects; a result consistent with Reinganum (1979). Whether price dispersion increases or decreases in these markets is a function of the relative magnitudes of change in search costs to the change in the production cost distribution.

Internet technologies have greatly impacted the ways in which retailers compete. While the Internet has created another distribution channel for retailers, the much touted increased competition has not yet come to fruition. Instead, the empirical evidence suggests that firms utilize strategies that soft price competition. These strategies range from using mixed strategies to create value at price comparison sites to obfuscation strategies to tend to increases consumers' search costs. A common theme that pervades the literature on price dispersion is that market structure plays an important role in determining the level of dispersion in a given market.

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Table 1: Empirical Price Dispersion Literature

Traditional-Offline Markets

Study	**Product Type**	**Region**	**Data Source**
Aalto-Setala (2003)	Groceries	Finland	Grocery Stores
Carlson and Pescatrice (1980)	Varied	New Orleans	Individual Stores
Eckard (2004)	Varied	Denver, CO/All of US	Survey
Johnson (2002)	Regular and Diesel Gasoline	US	ComScore Networks
Lach (2002)	Refrigerator, Chicken, Coffee and Flour	Israel	Central Buruea of Statistics
Pratt, Wise and Zeckhauser (1979)	Varied	Boston	Individual Stores
Roberts and Supina (2000)	Manufactured Goods	US	U.S. Census of Manufactures
Scholten and Smith (2002)	Varied	Indiana	Individual Stores
Sorensen (2000)	Prescription drugs	Upstate New York	Individual Stores
Stigler (1961)	Automobiles	Chicago	Individual Dealers
	Coal	Washington DC	Bids for govt. purchases
Villas-Boas (1995)	Saltine Crackers	US	Grocery Stores
	Coffee	US	Grocery Stores

Online Markets

Study	**Product Type**	**Region**	**Data Source**
Acarani and Shankar (2004)	Books and CDs	Italy	YellowPages and Virgilio.it
Arbatskaya and Baye (2004)	Mortgage Rates	US	Microsurf.com
Arnold and Saliba (2002)	College Textbooks	US	Various Search Engines to Identify Top-Selling Textbook Retailers
Baye, Gatti, Kattuman, and Morgan (2004a, b)	Consumer Electronics and Music CDs	7 European Countries	Kelkoo.com
Baye, Morgan and Scholten (2003)	Computer and Consumer Electronics	US	Cnet's Shopper.com
Baye, Morgan and Scholten (2004)	Computer and Consumer Electronics	US	Cnet's Shopper.com
Baye,Morgan & Scholten (2002)	Electronics	US	Cnet's Shopper.com
Brown and Goolsbee (2002)	Life Insurance	US	LIMRA Internation Annual Survey
Brynjolfsson & Smith (2000)	Books & CDs	US	8 online stores
Chen and Hitt (2002)	Brokerage Industry	US	Media Matrix Clickstream Data
Chevalier and Goolsbee (2003)	Books	US	Amazon.com and BN.com
Clay and Tay (2001)	Books	US, Canada, UK and Germany	9 online bookstores
Clay, Krishnan & Wolff (2001)	Books	US	32 online bookstores
Clemon, Hann & Hitt (2000)	Airline Tickets	US	Online Travel Agents
Ellison & Ellison (2001)	Computer Memory	US	Pricewatch.com
Friberg, Ganslandt and Sandstrom (2001)	Books and CDs	Sweden	YellowPages and 8 Swedish Book and CD E-retailers
Goolsbee (2001)	Computers	US	Forester Research Technographics 99 Survey
Iyer and Pazgal (2001)	Books, CDs and Videos	US	mySimon.com, BottomDollar, EvenBetter, Bsilly and PriceScan
Kattuman and Gatti (2004)	Consumer Electronics	7 European Countries	Kelkoo.com
Morton, Zettelmeyer and Siliva-Risso (2001)	Autos	US	MRI and Autobytel.com
Scholten & Smith (2002)	Varied	US	mySimon.com

Table 2: Price Dispersion in 1901

	Percentage Value of Information (%)	Percentage Range (%)	Coefficient of Variation (%)
Nationwide Level			
Baking Powder	15.0	35.0	6.5
Farm Salt	64.9	251.4	26.2
Granulated Sugar	13.1	38.1	6.4
Illuminating Oil (per gal.)	72.7	254.5	29.6
Average	41.4	144.8	17.2

	Weighted Average Coefficient of Variation (%)	Unweighted Average Coefficient of Variation (%)
City Level		
Baking Powder	3.3	3.1
Farm Salt	10.1	9.2
Granulated Sugar	3.4	3.3
Illuminating Oil (per gal.)	6.6	6.0
Average	5.8	5.4

Source: Eckard (2004)

Table 3: Comparison of Price Dispersion in 1901and 2001 for "Large Cities"

	1901 Coefficient of Variation* (%)	**2001 Coefficient of Variation (equal weights)** (%)	**2001 Coefficient of Variation (brand weights)** (%)
Baking Powder	3.65	4.72	5.97
Granulated Sugar	3.63	5.94	5.94
Illuminating Oil (Kerosene)	7.88	5.37	12.10
Average	5.05	5.34	8.00

* For cities with population size greater than 100,000.
Souce: Eckard (2004)

Table 4: Price Dispersion For 39 Products in Boston

Product	Coefficient of Variation (%)	Value of Information (%)	Range (%)	Number of Firms
Raleigh Grand Prix 10-Speed	4.4	7.2	11.0	7
3000 lbs of Concrete (price/cubic yard)	5.2	54.0	26.0	15
Amana Microwave Oven	5.8	6.2	16.0	12
10 Reams of Southworth 33C Stationery	6.1	11.2	25.0	15
Benjamin Moore Flat Latex Regal Wall Satin Super White	7.1	14.5	39.0	14
Rebuilt Alternator for 67' Camaro	7.8	8.8	29.0	15
Black Panther Ice Skates	8.2	19.0	39.0	8
HON #214 Black 4-Drawer File Cabinet	8.3	23.0	35.0	11
Case of Budweiser Beer	8.7	14.9	23.0	15
Konica Autoreflex T(3) f1.7 Lens	9.0	26.6	42.0	22
Plywood Fir AC (1/2" x 48" x 96")	9.5	14.8	37.0	7
Dektol Developer	9.7	20.0	33.0	19
Texas Instruments SR50 Calculator	9.9	21.0	42.0	7
Lube Job, Grease, Oil, and Filter Change	10.7	24.5	48.0	4
French Cut and Shampoo for Standard Poodle	12.8	30.3	50.0	12
Flying Instructions	14.0	48.4	70.0	13
Dry Clean 2-Piece Suit	16.8	76.3	112.0	14
Boarding a Poodle (price/day)	17.0	33.3	83.0	14
Single Exhaust Muffler for '67 Camaro	17.4	24.5	57.0	14
Johnson 9.9 HP Outboard Motor w/ 15" Shaft Manual Start	17.4	41.9	97.0	12
BSR 2310X Turntable	18.0	18.2	30.0	8
Auto Tune-Up for '67 Camaro	18.4	97.9	83.0	15
20 Gal. Fish Tank	21.1	34.2	116.0	12
Dental Office Visit for Teeth Cleaning	22.3	40.4	108.0	15
2000 #10 Printers Envelopes	23.1	64.8	150.0	20
Air Conditioner Repair	25.3	67.4	150.0	9
Towing Services -- 5 Miles Round Trip	25.4	75.5	150.0	12
Apraisal for 3 One-Karat Diamond Rings (price/item)	26.1	54.2	100.0	9
500 Gallons of Fuel Oil (price/gallon)	28.9	5.6	11.0	15
Electrodes	31.1	56.7	186.0	10
Repair Clarinet	31.1	47.6	133.0	8
100 lbs of Peanuts in Hull (price per pound)	32.1	23.3	109.0	5
Vocal Music Instruction	35.0	47.9	165.0	14
Watch Cleaning -- Clinton 25-Jewel Self Winding	37.9	97.3	250.0	15
200 Loose White Carnations -- undelivered	42.4	65.0	150.0	15
15% Strength Chlorine	44.1	198.3	400.0	12
Dennman Styling Brush	46.4	188.7	567.0	13
Horoscope -- Basic Charting and One-Hour Consultation	56.1	200.0	400.0	11
Canvas Cover for Pick Up Truck	71.4	171.7	538.0	12
Average	21.6	53.2	120.8	12.3

Source: Pratt, Wise and Zeckhauser (1979) and authors' calculations.

Table 5: Price Dispersion for 13 Products, 1963-1987

Product	Average Coefficient of Variation (%) (Standard Deviation)	Time Period
Hardwood Plywood	77.70 (8.58)	1963, 1967, 1972, 1977, 1982, 1987
Cotton Sheeting & Allied Fabrics	56.01 (13.22)	1963, 1967, 1972, 1977, 1982
100% Spun Polyester Blend with Cotton	53.87 (7.10)	1967, 1972, 1977, 1982
Hardwood Oak Flooring	34.50 (33.45)	1963, 1967, 1972, 1977
Finished Wool Apparel Fabrics	32.40 (6.83)	1963, 1967, 1972, 1977, 1982, 1987
Interior Softwood Plywood	32.33 (28.84)	1963, 1967, 1972, 1977
White Pan Bread	31.87 (9.15)	1963, 1967, 1972, 1977, 1982, 1987
Corrugated Shipping Containers	31.19 (7.67)	1963, 1967, 1972, 1977, 1982, 1987
Tinplate Steel Cans	27.38 (3.18)	1963, 1967, 1972
Ready-Mixed Concrete	19.49 (9.06)	1963, 1967, 1972, 1977, 1982, 1987
Roasted Coffee	17.41 (3.93)	1963, 1967, 1972, 1977, 1982, 1987
Motor Gasoline	9.27 (2.67)	1963, 1967, 1972, 1977, 1982, 1987
Newsprint	6.35 (1.72)	1963, 1967, 1972, 1977

Source: Roberts and Supina (2000)

Table 6: Price Dispersion and Purchase Frequency in New Orleans, 1976

Products	Coefficient of Variation	Number of Firms	Frequency of Purchase
Hair Spray	4.5	9	Frequent
Antacids	5.6	7	Frequent
Handcream	5.6	8	Frequent
Hair Tonic	5.8	8	Frequent
Asprin	5.8	9	Frequent
Deodorant	7.0	9	Frequent
Baby Oil	7.2	7	Frequent
Contact Lens Solution	7.3	8	Frequent
Razor Blades	7.4	8	Frequent
Insulin	11.3	9	Frequent
lb. Potatoes	14.9	9	Frequent
Lettuce	18.2	9	Frequent
Stalk Celery	18.4	8	Frequent
Dozen Lemons	21.1	7	Frequent
Dandelion Tea	24.0	10	Frequent
Contraceptives	41.4	7	Frequent
Expensive Camera	3.3	7	Infrequent
Drill	4.6	9	Infrequent
Gallon Paint	5.2	10	Infrequent
Film	5.9	9	Infrequent
Dozen Roses	6.4	11	Infrequent
Inexpensive Camera	7.5	10	Infrequent
Black & White TV	7.5	14	Infrequent
Washing Machine	8.4	6	Infrequent
Mattress	12.1	13	Infrequent
Wrench	12.8	10	Infrequent
Auto Polish	13.3	11	Infrequent
Charcoal Fluid	13.9	10	Infrequent
Molded Chair	15.8	11	Infrequent
Flash Bulbs	17.3	9	Infrequent
Thermometer	21.2	9	Infrequent
Toaster	25.4	7	Infrequent
Batteries	26.2	8	Infrequent
Carob Powder	34.5	14	Infrequent
Average	13.14	9.12	

Source: Carlson and Pescatrice (1980) and authors' calculations.

Table 7: Prices and Price Dispersion across Firm Type

Italian Book Market

Price levels	***Online and Offline -- Multichannel Retailer***	***Online Only -- Pure Play Internet Retailer***	***Offline -- Traditional Retailer***
List price levels	15.40	14.43	15.67
List price levels including shipping costs	17.68	17.17	15.67
Price dispersion	(%)	(%)	(%)
Coefficient of variation excluding shipping costs	31.4	29.5	30.2
Coefficient of variation including shipping costs	27.4	27.5	30.2
Range of list prices excluding shipping costs	129.9	144.8	127.6
Range of list prices including shipping costs	115.6	133.3	127.6

Italian CD Market

Price levels	***Online Only -- Pure Play Internet Retailer***	***Offline -- Traditional Retailer***
Posted price levels excluding shipping costs	18.89	19.64
Poste price levels including shipping costs	22.43	19.64
Price dispersion	(%)	(%)
Coefficient of variation excluding shipping costs	13.7	13.6
Coefficient of variation including shipping costs	12.4	13.6
Range of price levels excluding shipping costs	78.1	60.2
Range of price levels including shipping costs	65.8	60.2

Souce: Ancarni and Shankar (2004)