

E-commerce and the Market Structure of Retail
Industries¹

SHORT FORM: 'E-commerce and Market Structure'

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Abstract

This paper examines the effect of the advent and diffusion of e-commerce on supply-side industry structure. We specify a general industry model involving consumers with differing search costs buying products from heterogeneous producers. We interpret e-commerce as a reduction in consumers' search costs. We show how it reallocates market shares from high-cost to low-cost producers. We test the model using US data for three industries: travel agencies, bookstores, and new auto dealers. Each industry exhibits the market share shifts predicted by the model, but the mechanisms vary, ranging from aggregate factors in the travel industry to local-market factors in the other two industries.

This paper explores how the advent and diffusion of e-commerce impacts the structure of retail and similar industries. While there is a burgeoning literature studying how e-commerce has affected prices and price dispersion (Brynjolfsson and Smith, 2000; Clay *et al.*, 2001; Scott Morton *et al.*, 2001; Brown and Goolsbee, 2002; Baye *et al.*, 2004), much less work has looked at how the diffusion of the Internet has influenced the number or type of producers that operate in an industry. That is, questions of which businesses most benefit and most suffer (perhaps to the point of having to cease operations) from the new consumer-matching and distribution systems that e-commerce brings have received little attention. Conventional wisdom suggests that such effects can be large and diverse in impact; the rapid growth of Orbitz, Travelocity, and Expedia at the expense of local travel agencies is one oft-cited example. Yet we do not yet know quantitatively just how large this particular effect has been or whether similar mechanisms operate across different industries. This paper seeks to begin to address these issues.

It is almost certain that more than just equilibrium prices are affected when e-commerce spreads in an industry. Market shares are very likely to change; given the reduction in consumer search costs that e-commerce can bring, any firm's price advantage will be multiplied in terms of market-share gains. Higher cross-price elasticities imply differential impacts on industry firms depending on whether they have a cost advantage or disadvantage relative to their competitors. It is also quite likely that these market share changes can be drastic enough to lead some firms to exit from the market entirely. On the other hand, lower search costs could also induce new entry into the industry. Presumably, though, these entrants may differ on average from industry incumbents because e-commerce has raised the return to being efficient (or, alternatively, to being able to produce high-quality goods). In such ways, e-commerce can have important entry and exit consequences as well.

Our investigative approach combines theoretical and empirical analyses. We first model equilibrium in an industry comprised of heterogeneous firms selling to a set of consumers who differ in their search costs. Heterogeneity across firms arises from differences in underlying

abilities like production costs or output quality. We embody them as differing marginal costs for the sake of concreteness, though it is easy to modify the model to allow variation in product quality levels instead. Industry consumers search sequentially when deciding from whom to buy. Firms set prices given consumers' optimal search behaviour as well as their own and their rivals' production costs. Firms that cannot cover their fixed costs exit the industry. Initial entry into the industry is governed by an entry cost.

We interpret the advent and diffusion of e-commerce as a leftward shift in the consumer search cost distribution. We use our model to show how e-commerce activity impacts equilibrium market structure. The model offers predictions about not just equilibrium prices, but also market shares, the number of producers, and the producer type (marginal cost) distribution.

Consistently with previous literature, the model predicts a decline in equilibrium average price levels and price dispersion. The more novel implications of our work, however, regard what happens to the equilibrium distribution of firm types. Here the model predicts that the introduction of e-commerce into an industry should result in the shrinking and sometimes exit of low-type (i.e., high-cost) firms, a shift in market share to high-type (low-cost) firms, and with some additional assumptions about the firm type and consumer search cost distributions, a drop in the number of producers as well.

We test the model using US County Business Patterns (CBP) data from 1994-2003. CBP data contain, at the detailed industry level, the total number of establishments (stores) as well as their size distribution. While we cannot measure producer types directly, we can use size as a proxy; hence shifts in the size distribution are informative about heterogeneous effects of e-commerce within an industry. The panel nature of the data allows us to focus on changes in the distribution over time within local markets, removing possibly confounding differences in technology or demand across markets. We identify local differences in the impact of e-commerce (i.e., the size of the shift in the local search cost distribution) using consumer-level survey data to measure the fraction of the local population who report buying

goods and services online.

We focus the empirical tests on three industries perceived to have been considerably impacted by e-commerce: travel agencies, bookstores, and new auto dealers. We find support for the predictions of the theoretical model. Growth in consumers' use of the Internet for purchases is linked to declines in the number of small (and presumably low-type) establishments, but has either no significant impact or even positive impact on growth in the industries' numbers of large establishments. Interestingly, while the industries experience similar patterns in market share shifts, the specific mechanisms linking declining search costs to the shifts differed across the industries. The shifts in the travel agency industry reflected aggregate changes driven largely by airlines cutting agent commissions as consumers increasingly shifted to online ticket sources. In bookstores and new car dealers, on the other hand, the evidence suggests that the decline in small retail outlets reflect market-specific impacts of Internet diffusion.

We present the general industry model in the next section and explore its predictions for how shifts in search costs impact equilibrium in an industry with heterogeneous producers. The third section discusses the data used in the empirical analysis. This is followed by a presentation and discussion of the empirical results. A short discussion concludes.

1. Model

Our model combines elements of two distinct theoretical literatures. One is the set of search models with consumers that have heterogeneous search costs. Examples include Carlson and McAfee (1983), Rob (1985), Benabou (1993), and Hortaçsu and Syverson (2004). Our conceptual approach of treating the diffusion of e-commerce technologies as shifting consumers' search costs (perhaps disparately for different consumers) is the obvious motivation for drawing on this previous work. The second literature involves industry equilibrium models that feature heterogeneous producers and endogenous selection into production, like Hopenhayn (1992), Melitz (2003), Syverson (2004), and Asplund and Nocke (2006). Endogenising the

set of equilibrium producers is important to meet our goal of assessing how e-commerce might differentially impact industry producers by type, including determining which types enter and exit when search costs change.

1.1. *Set-up*

There is a continuum of firms selling a homogeneous good for consumption by a continuum of consumers. All consumers have perfectly inelastic unit demand for the good being sold, but are heterogeneous in their search costs $s \in \mathbb{R}_+$. The total mass of consumers is fixed and normalised to one. The probability distribution of consumer search costs is given by cdf Q having a continuously differentiable pdf q . It is assumed that 0 is the greatest lower bound of the support of q and that $Q(0) = q(0) = 0$. Like in Benabou (1993), firms are also heterogeneous, differing in their marginal costs of production $c \in \mathbb{R}_+$, which are their private information. The total mass of all operating firms is L . Unlike Benabou, we let the mass of firms be determined endogenously, through a zero-profit condition (see Section 1.4).

The timing of decisions by firms and consumers is as follows. At the beginning of the period, potential firms consider entering the industry. If a firm decides to enter, it pays the sunk cost of entry, κ and learns its own marginal cost c , which is drawn i.i.d. from a publicly known probability distribution with cdf Γ and pdf γ , whose support lies in $[0, 1]$. Next, firms decide whether to stay in the industry or not. Those that choose to stay then decide how much to charge and produce. Production requires a fixed cost of operation ν , which is identical in all firms. This cost can be avoided if the firm chooses to stay out of the market.¹

¹We could have eliminated the fixed cost of operation from the model, but in that case, those firms that otherwise exit the market would stay in the market by charging prices equal to their marginal costs. Thus having a fixed cost in the model leads to the sensible implication that only firms that make positive profits stay in the market.

1.2. Consumers' Problem

We make the standard assumption that consumers know the price distribution, F (with density f), but must engage in costly search to learn the price charged by any particular firm. Consumers' search is undirected and sequential; they visit stores one-by-one to learn their price and after every visit compare the benefit and cost of continued search. If the expected price reduction from visiting another store is greater than the marginal (search) cost s , the consumer continues to search; otherwise, she buys the product at the lowest price in hand. Thus, as in McCall (1970), the optimal stopping rule is characterised by a reservation price where a consumer continues to search as long as she finds a price greater than some reservation price $\rho(s)$, where $\rho(s)$ is given by:

$$s = \int_0^{\rho(s)} [\rho(s) - p]f(p) dp. \quad (1)$$

As seen in the equation, the reservation price is such that, if the price in hand is $\rho(s)$, the marginal cost of search s equals the expected benefit from continuing search. (The integral on the right-hand side is the expected reduction in price from another search, accounting for the option value of discarding higher price draws.) It also implies that a consumer with zero search cost always buys from the firm with the lowest price. We convert this optimality condition into an equivalent but slightly less intuitive form (albeit easier to work with analytically) by integrating (1) by parts. This yields:

$$s = \int_0^{\rho(s)} F(p) dp. \quad (2)$$

Differentiating this with respect to s yields $1 = F(\rho(s))\rho'(s)$, which shows that $\rho(s)$ is strictly increasing in s , and hence invertible on its range. The inverse is given by

$$\rho^{-1}(r) = \int_0^r F(p) dp.$$

1.3. Sellers' Problem

We assume that firms do not know the marginal costs and hence the prices set by their rivals, but instead know the marginal-cost distribution Γ . Further, firms do not know the search cost of any individual consumer, but they do know the distribution Q of search costs. Taking as given the distributions of search costs and marginal costs, each firm determines its optimal price based on the demand it faces, characterised by the reservation price rule $\rho(s)$ implied by (1).

Let us now consider the optimisation program of a firm with marginal cost draw c that chooses to stay in the industry. We first determine market share as a function of the price p charged by the firm: $x(p)$.² The optimal search rule implies that only consumers with reservation prices $\rho(s)$ above p will buy from the firm. Take one such consumer with reservation price r . Recalling that the price distribution in the market is given by the cdf F and that the total mass of operating firms is L , the mass of firms charging a price less than r is $LF(r)$. The assumption of undirected search implies that this particular consumer is equally likely to buy from any one of these firms. That is, the probability that she will buy from a particular firm charging price p is $1/(LF(r))$. Integrating over all such potential customers of this firm yields an expression for market share:

$$x(p) = \int_p^\infty \frac{g(r)}{LF(r)} dr, \quad (3)$$

where $g(r)$ is the pdf of the reservation price. We can use (2) to write the corresponding cdf as

$$G(r) = Q[\rho^{-1}(r)] = Q \left[\int_0^r F(p) dp \right]. \quad (4)$$

²We use the market share interchangeably with the quantity because there is no outside good, each consumer demands one unit of the good, and the total mass of consumers equals one.

Taking the derivative of $G(r)$ with respect to r , we find $g(r)$ as

$$g(r) = q [\rho^{-1}(r)] F(r). \quad (5)$$

We use the reservation price distribution to simplify the integral for market share. Inserting (5) into (3) gives

$$x(p) = \frac{1}{L} \int_p^\infty q [\rho^{-1}(r)] dr. \quad (6)$$

This equation is a standard (residual) demand curve: a firm faces demand determined by its own price as well as its competitors' prices. Here, these prices are embodied in the distribution $F(p)$. Note that demand is downward sloping, since

$$x'(p) = -\frac{1}{L} q [\rho^{-1}(p)] < 0.$$

The profit function of a firm with marginal cost c choosing to stay in the industry can be expressed as the solution to the firm's optimisation program:

$$\pi(c) = \max_p (p - c)x(p) - \nu. \quad (7)$$

The values of p that maximise this equation for given values of c will define the equilibrium pricing function $p(c)$. The first-order condition for an optimum requires that, for all c ,

$$[p(c) - c]x'[p(c)] + x[p(c)] = 0, \quad (8)$$

while the second-order condition for a maximum at this point stipulates that

$$[p(c) - c]x''[p(c)] + 2x'[p(c)] < 0. \quad (9)$$

1.4. Industry Equilibrium

Let $p(\cdot)$ and $x(\cdot)$ be, respectively, the pricing and residual demand functions in equilibrium. Note that this implies that $p(\cdot)$ is optimal for each firm, given $x(\cdot)$, and therefore the first and second order conditions for individual optimality, (8) and (9), must hold at each point. The downward-sloping demand then yields three important properties of the industry equilibrium.

PROPERTY 1. *The equilibrium pricing function $p(c)$ is increasing with marginal cost: $p'(c) > 0$ ($\forall c$).*

Proof. Applying the Implicit Function Theorem to the first-order condition (8) yields

$$p'(c) = \frac{x'(p)}{[p(c) - c]x''[p(c)] + 2x'[p(c)]} > 0,$$

since demand slopes downward and the denominator is negative by the second-order condition.

PROPERTY 2. *The demand function $x(p(c))$ is decreasing with marginal cost: $\frac{dx}{dc}p(c) < 0$ ($\forall c$).*

Proof.

$$\frac{dx}{dc}p(c) = x'[p(c)]p'(c) < 0$$

by downward-sloping demand and Property 1.

PROPERTY 3. *The profit function is decreasing with marginal cost: $\pi'(c) < 0$ ($\forall c$).*

Proof. Applying the Envelope Theorem to (7) yields $\pi'(c) = -x[p(c)] < 0$.

Note that Property 3 implies that the firms' decision rule for staying in the industry or leaving is characterised by a cut-off value: there exists a threshold $\bar{c} > 0$ such that firms stay in the industry if and only if their marginal cost is $c \leq \bar{c}$ (we assume here that the exit

decision is non-trivial, that is, some firms do exit and some produce). The threshold value is given by

$$0 = \pi(\bar{c}) = [p(\bar{c}) - \bar{c}]x[p(\bar{c})] - \nu. \quad (10)$$

The initial stage involves ex-ante identical potential entrants deciding whether or not to commence operations. We assume that there is unlimited entry into the industry: firms keep entering until the expected value of post-entry profits equals the sunk entry cost. That is,

$$\kappa = \int_0^{\bar{c}} \pi(c)\gamma(c) dc = \int_0^{\bar{c}} [p(c) - c]x[p(c)]\gamma(c) dc - \Gamma(\bar{c})\nu. \quad (11)$$

Note that this entry condition implies ex-ante zero profits and ex-post positive profits.

Finally, note that Property 1 implies that prices will be distributed with support $[\underline{p}, \bar{p}]$, where $\underline{p} = p(0)$ and $\bar{p} = p(\bar{c})$, with the cdf (for $q \in [\underline{p}, \bar{p}]$) given by

$$F(q) = \Pr\{p(c) \leq q \mid \pi(c) \geq 0\} = \frac{\Pr\{c \leq p^{-1}(q) \ \& \ c \leq \bar{c}\}}{\Pr\{c \leq \bar{c}\}} = \frac{\Gamma[p^{-1}(q)]}{\Gamma(\bar{c})}. \quad (12)$$

Note that $F(q) = 0$ for $q < \underline{p}$ and $F(q) = 1$ for $q > \bar{p}$. We are now ready to define the equilibrium in this industry.

DEFINITION 1. *A search equilibrium is a set $\{\rho : \mathbb{R}_+ \rightarrow \mathbb{R}_+, p : \mathbb{R}_+ \rightarrow \mathbb{R}_+, x : \mathbb{R}_+ \rightarrow \mathbb{R}_+, F : \mathbb{R}_+ \rightarrow [0, 1], \bar{c} > 0\}$ satisfying equations (2), (6), (8), (10), (11), and (12), along with inequality (9).*

2. Comparative Statics

Our goal is to determine the effect of a decrease in search costs on the search equilibrium. In particular, we are interested in how shifts in search costs affect the equilibrium price distribution F , the operating cut-off cost \bar{c} and the total mass of firms L . To this end, consider a family of search cost distributions $Q(\cdot \mid t)$, where higher t corresponds to higher

search costs in the sense of the monotone likelihood ratio property (MLRP).³

First, let us consider the function $p(c, F, t)$, which gives the best-response price for a firm with marginal cost c when the price distribution of all operating firms is F and the search costs are $Q(\cdot | t)$. Examining the firm's first-order condition and applying the MLRP condition, we obtain our first comparative statics result.

PROPOSITION 1. *The best-response pricing function $p(c, F, t)$ is increasing in t .*

Proof. See Appendix B.

Thus, the optimal price charged by each firm is increasing in the search costs, *holding fixed other firms' pricing and entry/exit decisions* (which affect F). However, this by itself does not guarantee that the *equilibrium* prices will increase with search costs. Therefore, we must look for conditions on the search cost distribution that will guarantee that the equilibria will move in the same direction as the individual response functions. To this end, we must first make precise the notion of increasing price distributions. Following Rauh (forthcoming), we adopt the following partial order \geq on the set of distribution functions with support in $(0, \infty)$: $F \geq F'$ iff F first-order stochastically dominates F' (i.e., $F(p) \leq F'(p)$ for all $p > 0$). We now ask for conditions on q that will ensure that the equilibrium distribution F will be increasing in t (with respect to the partial order \geq).

As explained in Appendix A, a natural sufficient condition for the equilibrium distribution to be increasing in search costs is that the market be supermodular in the sense of Rauh (forthcoming). Verifying this condition is not trivial in our model, however, since our setting differs substantially from Rauh's model due to the endogenous entry/exit decisions of firms. Therefore, for the rest of our analysis, we will restrict our attention to the case when the search cost distribution is uniform, where we can characterise equilibria explicitly. Although we are able to obtain exact results only in the uniform search cost case, numerical simulations show that the comparative statics under other search cost distributions (such as

³That is, for each $s_1 > s_0$, the ratio $q(s_1 | t)/q(s_0 | t)$ is increasing in t .

the exponential distribution) tend to be very similar to those obtained under the uniform distribution (see Appendix C).

2.1. Uniform Search Costs

Following the discussion in Appendix A, we focus on uniform search cost distributions:

ASSUMPTION 1. *The search cost distribution is uniform on $[0, a]$ for $a > 0$.*

With this formulation, a decrease in search costs can be identified with a decrease in the parameter a . The marginal cost distribution, on the other hand, is allowed to take a very general form, subject only to the weak condition of log-concave cdf, which is satisfied by most commonly used distributions (such as uniform, normal, log-normal, gamma, exponential, Pareto, and others; see Bagnoli and Bergstrom (2005)):

ASSUMPTION 2. *The cdf of the marginal cost distribution is log-concave, i.e., $\gamma(c)/\Gamma(c)$ is decreasing in c for all c .*

Given Assumption 1, the demand function (6) for any $p \geq \underline{p}$ simplifies to

$$x(p) = \frac{1}{L} \int_p^\infty \frac{1}{a} \mathbb{I}_{\{\rho^{-1}(r) \in [0, a]\}} dr = \frac{1}{aL} \int_p^\infty \mathbb{I}_{\{r \in [\rho(0), \rho(a)]\}} dr = \frac{1}{aL} [\rho(a) - p]. \quad (13)$$

The second equality follows because ρ is increasing. The final equality holds because it is not optimal for any firm to charge less than $\rho(0)$, so that $\underline{p} \geq \rho(0)$. Note that $x'(p) = -1/(aL) < 0$ and $x''(p) = 0$, so that the second-order condition (9) holds. Plugging (13) into (8), the first-order condition becomes

$$p(c) = \frac{1}{2}[\rho(a) + c], \quad (14)$$

so that the demand and profit functions reduce to

$$x(c) = \frac{1}{2aL}[\rho(a) - c] \text{ and} \quad (15)$$

$$\pi(c) = \frac{1}{4aL}[\rho(a) - c]^2, \quad (16)$$

and the operating threshold equation (10) yields

$$\bar{c} = \rho(a) - 2\sqrt{aL\nu}. \quad (17)$$

The upper and lower limits of the support of the equilibrium price distribution are therefore $\underline{p} = p(0) = \rho(a)/2$ and $\bar{p} = p(\bar{c}) = \rho - \sqrt{aL\nu}$.

We now see that a search equilibrium is fully determined by two parameters, $\bar{\rho} \equiv \rho(a) > 0$ and L , satisfying equations (2) (for $s = a$), (11), (12), and (14) through (17). Plugging (14) and (12) into (2) for $s = a$ yields

$$\begin{aligned} a &= \frac{1}{\Gamma(\bar{\rho} - 2\sqrt{aL\nu})} \int_{\bar{\rho}/2}^{\bar{\rho} - \sqrt{aL\nu}} \Gamma(2p - \bar{\rho}) dp + \int_{\bar{\rho} - \sqrt{aL\nu}}^{\bar{\rho}} 1 dp \\ &= \frac{1}{2\Gamma(\bar{\rho} - 2\sqrt{aL\nu})} \int_0^{\bar{\rho} - 2\sqrt{aL\nu}} \Gamma(c) dc + \sqrt{aL\nu}. \end{aligned}$$

Finally, we insert equations (14) through (17) into the entry condition (11), reducing the conditions for a search equilibrium to the following system of two equations in $\bar{\rho}$ and L :

$$\Psi(\bar{\rho}, L; a) \equiv \frac{1}{2\Gamma(\bar{\rho} - 2\sqrt{aL\nu})} \int_0^{\bar{\rho} - 2\sqrt{aL\nu}} \Gamma(c) dc + \sqrt{aL\nu} - a = 0; \quad (18)$$

$$\Phi(\bar{\rho}, L; a) \equiv \frac{1}{4aL} \int_0^{\bar{\rho} - 2\sqrt{aL\nu}} (\bar{\rho} - c)^2 \gamma(c) dc - \Gamma(\bar{\rho} - 2\sqrt{aL\nu})\nu = \kappa. \quad (19)$$

Manipulating the first equation (details in Appendix B) shows that either the mass of firms or the reservation threshold of the consumer with the highest search costs (or both) must increase as the search cost distribution shifts right.

LEMMA 1. *At least one of the quantities $\bar{\rho}$ and L must be increasing in a :*

$$\frac{\partial L}{\partial a} \leq 0 \Rightarrow \frac{\partial \bar{\rho}}{\partial a} > 0.$$

The proof, which is provided in Appendix B, amounts to showing that if both L and $\bar{\rho}$

were non-increasing in a , the left-hand side of (18) would be decreasing in a , which would violate the identity. The logic of this result is straightforward: a decrease in search costs (a lower a), if not accompanied by a decrease in search opportunities (a lower L), will result in increased marginal benefit of continued search, which will cause searchers to become more selective, thus decreasing $\bar{\rho}$.

In a similar manner, equation (19) implies that if the mass of firms decreases as the search cost distribution shifts left, the reservation threshold of the consumer with the highest search costs must also decrease.

LEMMA 2. *If L is increasing in a , so is $\bar{\rho}$:*

$$\frac{\partial L}{\partial a} > 0 \Rightarrow \frac{\partial \bar{\rho}}{\partial a} > 0.$$

The proof, shown in Appendix B, consists of demonstrating that the contrary statement would cause the left-hand side of (19) to be decreasing in a , violating that identity. Whereas Lemma 1 relied on the consumer side, Lemma 2 relies on the producer side: the intuition is that an increase in competition (higher L) must be accompanied by a compensating increase in searchers' reservation prices (thus increasing firms' expected profits per transaction) in order for average profits to stay constant.

The results of Lemma 1 and 2 imply that $\bar{\rho}$ must be strictly increasing in a :

$$\frac{\partial \bar{\rho}}{\partial a} > 0.$$

Together with the pricing equation (14), this gives us our first key result:

PROPOSITION 2. *When search costs decrease, the price $p(c)$ charged by a firm with marginal cost c decreases for any operating firm.*

Our next objective is to determine the effect of a change in a on the operating cut-off value \bar{c} and on the level of concentration in the market. It will be convenient to first define

the quantity

$$\delta(a) \equiv \frac{1}{aL(a)},$$

where we write $L(a)$ to emphasise its dependence on a . Note that this can be interpreted as the per-firm density of consumers with a given level of search costs, since the total number of firms is $L(a)$ and the density of consumers with any level of search cost s is simply $1/a$. It is easy to see that $\delta(a)$ is decreasing in a :

LEMMA 3. *The per-firm density of consumers with any given level of search costs is decreasing in a : $\delta'(a) < 0$.*

The proof of this result is straightforward (see Appendix B): since $\bar{\rho}$ is increasing with a , δ needs to decrease with a in order to preserve equality in (19).

The profit function of a firm with marginal cost c now becomes:

$$\pi(c; a) = \frac{1}{4aL(a)}[\bar{\rho}(a) - c]^2 = \frac{1}{4}\delta(a)[\bar{\rho}(a) - c]^2, \quad (20)$$

where we have written $L(a)$ and $\bar{\rho}(a)$ to emphasise the dependence of these parameters on a . Taking the derivative of this expression with respect to a and applying Lemma 3 (details in Appendix B), we can now easily make our next observation: if an increase of search costs hurts any currently operating firm, it must also hurt all firms with lower search costs:

LEMMA 4. *If there exists $c_0 \leq \bar{c}(a)$ such that $\pi_a(c_0; a) \leq 0$, then $\pi_a(c; a) < 0$ for all $c < c_0$.*

The intuition for this result is again quite simple. The only negative effect on a firm of increasing a and thus increasing $\bar{\rho}(a)$ is that the firm now has to share its current customer base with more higher-cost firms. This effect becomes larger and larger, as the marginal cost of the firm decreases. (Note, for example, that the firm with marginal cost $\bar{c}(a)$ was already sharing all of its consumers with all operating firms, so that the only additional sharing

comes from the additional firms that were not operating before, whereas the zero-cost firm now needs to share each of its customers with more of the firms that were operating before.)

It now becomes clear that the profit of the firm at the current marginal cost cut-off level $\bar{c}(a)$ must decrease as search costs decrease. If this were not the case, the profits of all currently operating firms would increase, which would result in an overall increase of ex-ante expected profits. This would violate the entry condition (19), which states that the ex-ante expected profits must remain constant at κ . Since the profit function (for each a) is strictly decreasing in c , the fact that the profit of the current cut-off-level firm falls below the operating threshold ν implies that the new cut-off level will be lower than the current level. Formalising these arguments (Appendix B), we obtain our second key result:

PROPOSITION 3. *When search costs decrease, so does the cut-off marginal cost, \bar{c} .*

Proposition 3 has the immediate empirically testable implication that some of the firms with the highest marginal costs of production will exit the industry in response to a decrease in consumers' search costs.

Propositions 2 and 3 together yield two more testable implications: both the prices charged in equilibrium and the marginal costs of operating firms will decrease, as search costs decrease (formal details in Appendix B):

COROLLARY 1. *When search costs decrease, the distributions of equilibrium prices and marginal costs of operating firms shift to the left in the sense of first-order stochastic dominance.*

Thus, search cost decreases lead to increased efficiency of operating firms and to lower prices for consumers. As Proposition 3 shows, this increased efficiency is due to the fact that the lowering of consumer search costs diminishes the profits of inefficient (high-marginal cost) firms, causing some of these firms to exit the industry. It is easy to see, however, that the more efficient firms will actually benefit from a search cost reduction. If a decrease in \bar{c} (and thus a reduced likelihood of staying in the market) were accompanied by decreased

profits of all operating firms, the ex-ante expected profits would decrease, violating the entry condition that says that those are constant and equal to the cost of entry.

COROLLARY 2. A decrease in search costs causes the profits of firms with sufficiently low marginal costs to increase: for each a , there exists $\hat{c}(a) < \bar{c}(a)$ such that $\pi_a(c; a) < 0$ for all $c < \hat{c}(a)$.

Similar reasoning leads to the conclusion that the total market share of low-cost firms should increase in response to decreasing consumer search costs, as the share of high-cost firms decreases. To state this formally, let us denote the total market share of all firms with marginal cost in $(c, c + dc)$ (for infinitesimal dc) by $X(c; a) dc$. Then, for each c ,

$$X(c, a) dc = Lx(c; a)\gamma(c) dc.$$

Applying similar arguments to those we used for determining the change in profits, we can readily obtain the following result (see Appendix B for details):

COROLLARY 3. A decrease in search costs causes the total market share of all firms with sufficiently low marginal costs to increase: for each a , there exists $\hat{c}(a) < \bar{c}(a)$ such that $X_a(c; a) < 0$ for all $c < \hat{c}(a)$.

The results of Proposition 3 and Corollaries 2 and 3 establish the main empirical hypothesis of our model: search cost declines driven by the advent and diffusion of e-commerce have differing effects across businesses in an industry. Low-type (high-cost) sellers are hurt, sometimes to the point of being forced to exit. Higher types (low-cost sellers), however, actually gain from the shift: the market share of low-cost firms grows, resulting in increasing concentration of the market. Finally, it appears to be impossible to sign the change in the total mass of firms analytically, but numerical simulations with a variety of marginal cost distributions suggest that the mass of firms may decrease when search costs decrease (Appendix C).

3. Data

Our empirical analysis uses data from two primary sources: industry employment and establishment counts from the US Census Bureau’s County Business Patterns (CBP), and US consumers’ online purchasing behaviour from Forrester Research Technographics surveys. We briefly describe these data sets here, as well as discuss our market definition.

3.1. *County Business Patterns*

Annual County Business Patterns data contain, by detailed industry, the number of establishments in each US county. Establishments are unique geographic locations where economic activity takes place (i.e., offices in the travel agency industry, storefronts in the bookstore industry, and car lots in the auto dealerships industry). A firm can own one or more establishments.⁴ Both the total number of establishments and establishment counts by employment range are included in the data.⁵ In cases where disclosure of confidential information is not an issue, total industry employment and payroll in the county are also reported. However, these are often missing in the industries we study, particularly in smaller counties served by only a handful of firms. We can, however, impute total employment by multiplying the establishment counts in an employment range category by an estimate of the average number of employees per establishment in the category. We use the simple average of the categories’ endpoints for this estimate. While imputations invariably introduce measurement error, we are reassured by the fact that the correlation between imputed and actual reported employment for those counties where the latter is available is quite high.

⁴While it would be very interesting to study the issues at hand in the context of within- and across-firm shifts, there is unfortunately no way to identify firms in the CBP data. ‘Firms’ in the model above can be interpreted here as distinct operations (offices, storefronts, or lots) in an industry. While it is possible that common ownership may affect individual establishments’ reactions to the shift to e-commerce, we think that the model’s basic implications about the relative impacts on low- versus high-type producers continue to hold to a large extent even within multiple-establishment firms. For example, all else equal, a firm seeking to reduce its size will tend to close its low-type operations first.

⁵The reported ranges are: 1–4 employees, 5–9, 10–19, 20–49, 50–99, 100–249, 250–499, 500–999, and over 1000 employees. Since very large establishments are relatively uncommon in the industries we study here, we aggregate the largest categories into a single category.

Further, most of the empirical work below focuses on establishment counts, which we never have to impute.

We use data spanning 1994 to 2003, which surrounds the period when the advent of browser software began the Internet’s diffusion into the broader population. It is also the time span for which CBP data are available with the level of industry detail necessary for our purposes here. We focus on three industries: travel agencies (SIC 4724/NAICS 561510), bookstores (SIC 5942, NAICS 451211), and new auto dealers (SIC 5510/NAICS 441110). While a major change in the industry classification scheme occurred in 1997 (from the SIC system to the NAICS taxonomy), these industries’ boundaries remained unaffected, so values before and after the change are comparable.

3.2. *Household Internet Use*

The data on households’ e-commerce activity comes from Forrester Research, a market research company with a program focusing on consumers’ technology use. Its annual Technographics survey is designed to be nationally representative and includes the responses of roughly 55,000 people living in the continental US.⁶

We have access to the 2003 and 2004 surveys. Survey responses reflect behaviour in the year previous to the title year, because the survey is typically administered from prior-year December through title-year January. For example, when the 2004 survey asks respondents about their behaviour over the past year, the answers reflect actions taken in 2003.

While the survey is primarily cross-sectional, conveniently for us there is a retrospective question asking when the respondent ‘start[ed] purchasing products or services online.’ The respondent can choose one of several time ranges: ‘less than 1 year ago’, ‘1 year to less than 2 years ago’, and so on up to ‘8 years ago or more’. We construct from these responses the fraction of market consumers that had started purchasing products or services online for each year from 1994 through 2003.⁷

⁶See Goolsbee (2000) for additional details about the survey.

⁷We used the 2003 survey to compute the fraction of online shoppers in 1994 and 1995, and the 2004

3.3. *Market Definition*

We define markets using the US Bureau of Economic Analysis' Component Economic Areas (CEAs). CEAs are collections of counties usually, but not always, centred on Metropolitan Statistical Areas (MSAs). Counties are selected for inclusion in a given CEA based upon their MSA status, commuting flows, and newspaper circulation patterns, subject to the condition that each CEA's counties are contiguous. CEA boundaries need not coincide with state boundaries. The selection criteria ensure that counties in a given CEA are economically intertwined. The roughly 3200 US counties are grouped this way into 348 markets that are mutually exclusive and exhaustive of the land mass of the United States. Since our Internet use data excludes Alaska and Hawaii, our empirical analysis uses data for the 345 CEAs in the continental US.⁸

Using CEAs offers a compromise between conflicting requirements of the analysis. The most constraining observation is that, with an Internet use sample of 55,000, using smaller market areas (like counties) would result in many markets having very thin samples. We use the county indicator in the Technographics survey to aggregate the respondents to the CEA level. This reduces the sampling error involved, though of course with the trade-off of losing some variation in market structures. Further, counties may in some cases be too small to accurately capture market areas in the industries we investigate. This is especially true in more rural areas, where cross-county commerce in travel agency, book sales, and auto purchases is likely to be commonplace. CEAs should be large enough to envelop businesses'

survey to compute the fractions from 1996 to 2003. The use of two surveys was necessary because the '8 years ago or more' responses in the 2004 survey correspond to any purchases occurring before 1996, not necessarily those in 1995 exclusively. We do see 1995 purchase patterns, however, in the 2003 survey (through the '7 years to less than 8 years ago' responses). We are still left with online activity in 1994 being measured with '8 years ago or more' responses from the earlier survey. However, given the small fractions of respondents reporting buying products online in 1995 (see below), as well as the fact that the Internet's commercial structure at that time was quite embryonic, it is unlikely that many of the purchases attributed to 1994 actually occurred before that year. The use of two separate surveys over the observation period does not seem to have created spurious increases in reported online purchases. There is no discernible trend break between 1995 and 1996, the surveys' point of contact.

⁸See US Bureau of Economic Analysis (1995) for more detailed information about creation of CEAs and the super-regions that they comprise, Economic Areas.

horizontal product differentiation. We do not model this above, but it almost surely exists to some extent in each industry we study. Horizontal product differentiation may dampen the quantitative impact of the substitutability-enhancing (via reduced search cost) features of e-commerce. (Researchers have noted efforts along these lines among booksellers; see Clay *et al.* (2002), for example.) To the extent that any changes did occur, our estimates offer guidance as to the magnitude of e-commerce's impact net of product differentiation shifts.

Another potential point of departure between our model and our analysis is that in two of the industries, travel agencies and bookstores, the diffusion of the Internet has allowed the entry of online-only retailers. As in Latcovich and Smith (2001), these businesses have different cost structures than traditional 'brick-and-mortar' retailers, in that they may have higher fixed costs, but lower marginal costs. Moreover, such Internet-only retailers arguably provide a different bundle of goods and services, in that customers cannot inspect the good first-hand and must wait for it to be shipped. By assuming uniform fixed costs and homogeneous products, our model does not explicitly account for the creation of Internet-only retailers, focusing rather on how brick-and-mortar retailer demand might change in response to a reduction in consumer search costs brought about by the Internet. An advantage of investigating new car dealers, however, is that regulations prevent similar 'online-only' entrants in this industry, making it a close match to our theoretical model.

Yet another dimension we do not model is the endogeneity of certain fixed costs, such as advertising, which can lead to industry dominance patterns, as in Sutton (1991). Latcovich and Smith (2001) document high level of advertising expenditure among online booksellers. If consumers are not fully informed about the quality of their retail service, and if advertising can signal vertical characteristics such as reliability, security, and ease of use, firms advertise heavily to increase consumers' willingness to pay. Just as with search costs, horizontal or vertical differentiation decreases consumers' abilities to substitute across industry producers.

numbers of industry employees and establishments in the market. The estimated impact of consumers' e-commerce activity is quite substantial for the smallest establishments. For example, a 15 percentage point increase in the fraction of consumers making purchases online – a one standard deviation change – corresponds to a 13% (21%) drop in establishments with 1–4 employees (5–9 employees). Notice, however, that this negative impact lessens as one works up the establishment size distribution. Indeed, it eventually becomes insignificant with positive point estimates for establishments with 50–99 employees and those with 100 employees or more.¹²

Greater e-commerce activity among consumers is therefore associated with losses among the smallest industry producers, but a positive influence on the largest producers. Despite the inclusion of market fixed effects, however, the test above does not answer the question of whether the market structure impact of the shift to e-commerce acts locally or instead more broadly. It could be that the many within-market changes reflect aggregate shifts, and while the overall increase in Internet purchasing behaviour shifts industry market shares in the direction predicted by the model, there is no sense in which this impact is noticeably stronger in markets that saw larger increases in consumers' Internet use than in those that experienced smaller gains. To answer the question of the geographic scope of e-commerce's impact in the industry, we add a set of year dummies to the regression. This removes the impact of aggregate shifts in Internet use, leaving only the idiosyncratic within-market

¹²The different sample sizes across establishment size categories reflect the fact that not all market-year observations have a positive number of establishments in a particular category. The small number of large establishments in the industry makes the sample for the largest size categories particularly small and may in part explain the imprecise results in these cases. To explore this issue further, we estimated an alternative specification for the 50–99 and 100+ employee size categories where, rather than using the logged number of establishments as the dependent variable, we used a dummy equal to one if there was at least one establishment in the size category in a market-year and zero otherwise. (The numbers in Table 1 indicate most of the observations where this dummy equalled one correspond to the presence of only one establishment.) In this case, all market-year observations can be included in the sample. This alternative specification also indicated a positive correlation between consumers using online commerce channels and growth among large establishments, but in this case the relationship was statistically stronger (significant at the 10% level for establishments with 50–99 employees and at the 5% level for those with more than 100.) The results in the first numerical column indicate that any employment gains in the larger size classes are swamped by employment losses due to the exit of smaller operations. Overall market employment, not shown here, enters positively and significantly in most of the specifications, as one might expect.

variation in the growth of online purchasing patterns and establishment counts to identify the coefficient. In essence, this regression tests if markets that had unusually high increases in Internet use also saw larger-than-average declines in small-establishment counts.¹³

The regression results (with year dummy coefficients not reported for parsimony) are in Table 2, Panel C. In this case all coefficients on the measure of consumers' e-commerce activity are statistically insignificant. There is no measurable market-specific influence of online purchases on local travel agencies. This indicates, very interestingly, that the shifts in industry market structure seen above, while coincident with consumers' increasing use of online sites to conduct their travel purchases, did not arise from a set of coordinated market structure shifts in specific markets that produced the observed patterns once aggregated up. Instead, the influence of Internet use on market structure in the industry is a completely aggregate phenomenon.

A consideration of the specific way e-commerce impacted this industry offers a likely explanation for this result. As Internet purchases of airline tickets became more common over our observation period, airlines incrementally decreased the commissions they paid to travel agents. The first, modest commission cut (imposing a \$50 cap per domestic ticket, which given the standard 10% rate at the time meant it was only binding for tickets above \$500) occurred in 1995.¹⁴ This ended up being only the first cut of a series, however. By 2002, major carriers had ceased paying commissions altogether. Since airline tickets accounted for an estimated 58% of travel agencies' revenues in 1996, these commission declines resulted in a serious income loss for the industry (some lost commissions were replaced by fees charged

¹³Specifically, the coefficient on the fraction of consumers in the market shopping online is identified from the correlation between two values: a market's growth rate in the number of industry establishments relative to the average across all markets in that year, and that same market's change in the fraction of consumers reporting shopping online relative to the across-market average. That is, the coefficient is negative if markets with larger-than-average declines in establishment counts saw higher-than average growth in Internet purchases.

¹⁴The facts on travel agent commissions discussed in this paragraph are from a 2002 report by the National Commission to Ensure Consumer Information and Choice in the Airline Industry (NCECICAI). The creation of the NCECICAI was a provision of the Aviation Investment and Reform Act for the 21st Century. The commission's congressionally mandated mission was to study the travel agent industry and, more generally, the airline services information available to consumers.

directly to the consumer, though these did not cover the losses). Small operations, having high fixed costs relative to their sales volume, found profitability increasingly difficult to obtain and began to exit, as seen in the data. Importantly, however, airlines cut commissions across-the-board nationwide – presumably in response to perceived changes in consumers’ aggregate ticket purchasing patterns – rather than market-by-market. We are aware of no instances where airlines selectively reduced commissions more in those particular markets where online purchases were growing fastest. This would explain why the connection between Internet use and market structure changes is starkly evident in aggregate changes over time but not so across markets within a period. It is also consistent with the fact that any growth among the largest establishments was uncorrelated with local Internet use, because many of these establishments plausibly tapped into the new (and national) Internet market, and drew their business growth largely from customers outside their local area.

One potential concern in the regressions with year fixed effects is that the results might be driven by changes in markets’ socio-economic composition over time, rather than by a change of online shopping habits. Unfortunately, it is not possible to fully control for market demographics, because detailed demographic information is not available on a yearly basis. However, we were able to control for one key demographic: age. We found that the age variable did on occasion enter the regressions significantly, but that there was little noticeable change in the key coefficient estimates on the fraction of online purchasers in a market, confirming that the observed correlation between establishment size distribution and the market’s fraction of online consumers cannot be explained away by a shift of consumer age distribution.

4.2. *Bookstores*

Another line of business that has by many accounts in the popular press been affected by the diffusion of Internet commerce is the retail bookstore industry. Several booksellers have blamed their demise in large part on the competitive demands of e-commerce (Herman, 2001;

Weisman, 2004; Melo, 2005). The process through which this competitive effect would take place is again that which is highlighted in our model: e-commerce induced reductions in consumers' search costs shift market share across the industry type distribution.

We investigate this possibility by repeating the empirical analyses above, this time using CBP data for the bookstores (SIC 5942/NAICS 451211) industry. We begin with the industry-wide establishment counts shown in Panel A of Table 3. They reflect similar patterns to those seen with the travel agency aggregates: declines in establishments in the smaller employment size categories with coincident expansion in the larger categories. For instance, while the number of bookstores with fewer than 20 employees fell by over one-fourth during the sample, those with more than 20 employees more than doubled. This growth was particularly pronounced among the 50–99 employee size category. So we again see the pattern of market share shifts from small (low-type) operations to large (high-type) ones.

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TABLE 3 ABOUT HERE

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Again the question arises of whether these effects reflect aggregate impacts or instead coincide with local Internet commerce patterns. No obvious analogy exists in the bookstores industry to the airlines' commission reductions and their impact on travel agencies. Therefore one might expect the impact of the Internet here to be more concentrated within particular markets. If this is the case, the overall shift from smaller to larger bookstores noted above reflects aggregated changes that occurred market-by-market.

We investigate this issue by estimating the above specification that includes year fixed effects, this time using bookstores CBP data. The results are reported in Panel B of Table 3. Again we have suppressed the estimated year effects and the coefficients on overall market employment.

In contrast to the market structure shifts in the travel agency industry, there is more

evidence that local market effects matter in bookstores. Markets seeing faster growth in local consumers making online purchases had greater declines in bookstore employment and the total number of bookstores, with establishment exit being driven by losses among operations having fewer than 20 employees. This increased exit was statistically significant, except for establishments with fewer than five employees.

There is weaker evidence, on the other hand, that local online purchasing behaviour impacted the growth seen among larger booksellers. None of the e-commerce activity ('fraction online') coefficients for the three largest size categories, while reflecting the positive co-movement between online shopping and the numbers of larger bookstores, are statistically significant. This is likely due to the fact that the industry classification system includes an industry separate from bookstores, 'Electronic Shopping and Mail-Order Houses' (NAICS 45411), into which the largest online booksellers are classified.¹⁵ The expansion seen in large bookstores may instead reflect the ascendance of the new-format large-store chains like Barnes and Noble and Borders. Their growth is not strongly correlated with local online shopping habits because, while these sellers have extensive online operations (Barnes and Noble has its own website and Borders has teamed with Amazon), their online operations have industrial classifications that are separate in the CBP data from their brick-and-mortar locations.

4.3. *New Auto Dealers*

The last industry in which we investigate the impact of e-commerce on different producer types is new auto dealers. The new auto dealers industry has special appeal as a forum for testing our model. Specifically, franchise law restrictions make it extremely difficult to

¹⁵Note that online airline ticket sales operations are not included in this industry. According to the US Census Bureau, businesses in NAICS 45411 sold \$4.16 billion of books and magazines in 2003, \$2.14 billion of which was exchanged via 'e-commerce' channels (these are defined as transactions over open networks like the Internet or proprietary networks running systems like Electronic Data Interchange). These book and magazine sales accounted for 3.2% and 5.3% of the industry's total and e-commerce product sales, respectively. See US Census Bureau (2005) for details.

operate Internet-only sales channels.¹⁶

This means that e-commerce in this industry functions in a way that almost exactly matches how we embody it in the model; that is, it is purely a demand-side device that lowers consumers' costs of gathering product information. The essential technology of production and delivery in the industry is unchanged, even among any new producers that might enter the market after the change in search costs. There are no issues of retailers selling the industry's product but not being counted in the industry's CBP data (as with Amazon or WalMart with regard to the bookstores industry, for instance), and consumers cannot use e-commerce channels to bypass retailers altogether and buy from manufacturers directly (as is the case for many airline ticket purchases). Thus new car dealers allow us to see quite directly how reductions in search costs impact an essentially isolated set of retailers whose basic distribution technology is not impacted by e-commerce. The only change they face is in how easy it is for consumers to find out about their products or to be matched to low-price dealerships.

There is anecdotal evidence that e-commerce channels have increased the number of dealers from whom they obtain quotes before purchasing (Gartner, 2004). Furthermore, Scott Morton, Zettelmeyer, and Silva-Risso examine in a set of papers the relationship between buyers' use of e-commerce channels and the (lower) final prices they pay for their cars.¹⁷ However, we are unaware of any attempt to formally analyse what this reduction in search costs leads to in terms of the market structure of auto dealerships. The model offers guidance as to the likely mechanism and its impact; namely, that declining search costs led to shrinking and exit among the low-type dealers and shifted market share to the highest-type operations.

¹⁶See, for example, Katz and Payne (2000) and Scott Morton *et al.* (2001). Auto manufacturers are prohibited from selling their cars directly. Even online buying services like autobytel.com and carsdirect.com do not sell their own inventories of cars to their customers. Instead, they act as referral services, matching customers to their affiliated physical dealers.

¹⁷Scott Morton, Zettelmeyer, and Silva-Risso (2001) show that car shoppers using Autobytel.com to get free quotes from dealers in their market end up paying lower prices. Zettelmeyer, Morton, and Silva-Risso (2005) provide evidence that the lower prices obtained by consumers utilising online resources is not solely due to a selection bias in which hard-bargaining or low-search-cost customers choose to use the Internet.

establishment count. At the same time, increasing e-commerce activity drives growth in the number of local dealerships with 50 or more employees. The result is not significant for the largest establishment size category (though the coefficient is large and positive), likely due to the small number of market-years in our sample with very large dealerships. If we estimate as above an alternative specification using an indicator for market-years where at least one such establishment exists, however, we do find a significant positive impact of e-commerce on the presence of very large auto dealers.

Interestingly, the first two columns of Panel B suggest that e-commerce has had an expansionary effect on the industry overall. Markets where Internet purchasing grew more than average saw higher increases in auto dealer establishment counts and employment (recall that this is controlling for overall employment changes in the market). This is of course opposite to what is seen in the travel agency and bookstores industries. This likely reflects the fact discussed above that e-commerce did not facilitate growth in new auto sales through channels external to the industry, unlike what happened for travel agents and booksellers. Thus here, industry producers overall were able to benefit from market expansions driven by reductions in consumers' search costs, rather than losing part or all of the expanded market to sellers outside the industry.

5. Conclusions

This paper has investigated the equilibrium market structure changes spurred by the introduction of e-commerce tools that reduce consumers' search costs. We specified a general industry model involving consumers with differing search costs buying products from heterogeneous-type producers. Solving for the equilibrium in the general case, we showed how shifts in the consumer search cost distribution impact equilibrium prices and market shares. Specifically, downward shifts in search costs lead to lower prices and shift market share from low-type producers to the industry's high-type businesses.

While there is an empirical literature investigating the advent and diffusion of e-commerce

on prices, little has been done regarding the market structure impacts – specifically, the shifts in market share from low- to high-type businesses that our model predicts. We test these predictions in three industries for which the introduction of e-commerce has arguably decreased consumers’ search costs considerably: travel agencies, bookstores, and new auto dealers.

We found evidence of the market share shifts predicted by the model. As consumers’ use of the Internet to make purchases rose, smaller establishments (where size reflects firm ‘type’) declined in number and larger establishments became more dominant.

Interestingly, while the nature of the market share reallocations were similar in the industries, the specific mechanisms through which the declining search costs created them were different. For travel agencies, the shifts reflected aggregate changes, common across markets, driven in large part by airlines’ reductions in agent commissions in response to consumers’ increasing use of online sources to buy tickets. This is evidenced by the fact that once these aggregate changes in Internet purchasing patterns were controlled for, there was no indication that the magnitude of the market share changes were any larger (smaller) in markets experiencing idiosyncratically high (low) growth in consumers’ online purchases. For bookstores and auto dealers, on the other hand, there was evidence that more exit occurred among smaller stores in those markets where Internet use grew fastest. This suggests that the industry-wide declines in small bookstores and auto dealers reflect market-specific impacts.

Appendix A: Rationale for Uniform Search Costs

Since we know (from Proposition 1) that the best-response price function $p(c, F, t)$ is increasing in t for all F and c , a natural sufficient condition for the equilibrium price function p^* and equilibrium distribution F^* to be increasing in t is that the market be supermodular in the sense of Rauh (forthcoming). That is, we look for conditions under which each firm’s profit function has increasing differences in own price p and market price distribution F . If

this is the case, the best-response function $p(c, F, t)$ is increasing in F . Since $p(c, F, t)$ is also increasing in t , this implies that the equilibrium price function $p^*(c, t)$ is increasing in t for all c . Intuitively, the increase of t has two effects on the price function of a given firm: first, the direct effect, holding the price distribution constant (which is positive by Proposition 1) and, second, the indirect effect due to the increase in the prices of other firms (which is positive by supermodularity). While the condition of supermodularity is not strictly necessary for the equilibrium price function to be increasing in t , intuition suggests that an unambiguous general comparative statics result for p^* with respect to t is unlikely to obtain when the effect of the market price on the best-response individual pricing function is ambiguous, which will typically be the case when the market exhibits no complementarities.

We now turn to Rauh (forthcoming) for a general insight into the class of search cost distributions that result in a supermodular search market. Before we do so, we must note, however, that the class of models considered in Rauh (forthcoming) differs from ours in two fundamental ways: first, our model contains an endogenous probability of firms quitting the market after realising that their marginal cost exceeds the threshold \bar{c} , which is absent from Rauh's model, and, second, the total mass of firms L is endogenously determined in our model, but is fixed at an exogenous level in Rauh's. These additional features make our model more complicated than Rauh's, yet the same basic forces are at play in determining the interaction between own price p and market price F . In particular, the nature of the added complexity suggests that the cases for which supermodularity can be guaranteed in our model is a subset of those that yield supermodularity in Rauh's model.

Unfortunately, it turns out that this observation forces us to restrict our attention to the uniform distribution of search costs. The reason for this conclusion is as follows. First, note that if the search cost density is *increasing* sharply over its range, a rightward shift of the distribution (i.e., an increase of search costs) decreases the advantage of low-cost firms, because they now need to share more of their customer base with more high-cost firms. Thus, in his Proposition 3, Rauh shows that the search cost density must not be increasing

too sharply, lest an increase in the search costs should actually decrease the demand faced by low-cost firms. Second, note that if the search cost density is *decreasing* sharply over its range, an increase in search costs increases the mass of marginal consumers (i.e., consumers indifferent between buying and not buying) at a range of prices, consequently decreasing incentives to raise prices. This observation is at the heart of Rauh’s Proposition 5, which gives an upper bound on the rate of decrease in the search cost density. Propositions 3 and 5 together show that supermodularity cannot be guaranteed unless the search cost is neither increasing nor decreasing too sharply. To quote Rauh (p. 15): ‘The uniform distribution therefore represents the canonical example of complementarities.’ Furthermore, the bounds that Rauh’s Propositions 3 and 5 place on the absolute value of the slope of the search cost density reduce to zero when there is no set price cap, beyond which consumers always have zero demand. Thus, with infinitely inelastic unit demand, as in our model, complementarity in the baseline model of Rauh (forthcoming) can be ensured only if the search cost distribution is uniform. This leads us to restrict our attention to the uniform distribution.

Appendix B: Proofs

Proof of Proposition 1

Denoting $p^* \equiv p(c, F, t)$ and rewriting the FOC for the best-response price (8), we obtain

$$0 = \psi(p^*, F, t) \equiv (p^* - c) + \frac{x(p^*, F, t)}{x_p(p^*, F, t)}.$$

Differentiating with respect to p^* yields (omitting the arguments for visual clarity):

$$\psi_p = 1 + \frac{(x_p)^2 - xx_{pp}}{(x_p)^2} = \frac{1}{x_p} \left(2x_p - \frac{x}{x_p} x_{pp} \right) \stackrel{(8)}{=} \underbrace{\frac{1}{x_p}}_{<0} \underbrace{[2x_p + (p^* - c)x_{pp}]}_{<0 \text{ by (9)}} > 0,$$

By the Implicit Function Theorem,

$$\frac{\partial p^*}{\partial t} = -\frac{\psi_t}{\psi_p},$$

which implies that $\frac{\partial p^*}{\partial t} > 0$ iff $\psi_t < 0$.

Now, we can write

$$\frac{x(p^*, F, t)}{x_p(p^*, F, t)} = \frac{\int_{p^*}^{\infty} q \left[\int_0^r F(u) du \mid t \right] dr}{-q \left[\int_0^{p^*} F(u) du \mid t \right]} = - \int_{p^*}^{\infty} \frac{q \left[\int_0^r F(u) du \mid t \right]}{q \left[\int_0^{p^*} F(u) du \mid t \right]} dr.$$

Since $\int_0^r F(u) du > \int_0^{p^*} F(u) du$ for all $r > p^*$, the MLRP implies that the integrand is increasing in t for each r . Consequently, the entire expression is decreasing in t , and thus also $\psi_t < 0$. But this implies $\frac{\partial p^*}{\partial t} > 0$, as noted above.

Proof of Lemma 1

Implicitly differentiating the two identities that define a search equilibrium, (18) and (19), yields a system of equations for $\frac{\partial \bar{\rho}}{\partial a}$ and $\frac{\partial L}{\partial a}$:

$$\Psi_a + \Psi_{\bar{\rho}} \frac{\partial \bar{\rho}}{\partial a} + \Psi_L \frac{\partial L}{\partial a} = 0; \quad (21)$$

$$\Phi_a + \Phi_{\bar{\rho}} \frac{\partial \bar{\rho}}{\partial a} + \Phi_L \frac{\partial L}{\partial a} = 0, \quad (22)$$

where the subscripts indicate partial derivatives. Denoting

$$I \equiv \frac{\gamma(\bar{\rho} - 2\sqrt{aL\nu}) \int_0^{\bar{\rho} - 2\sqrt{aL\nu}} \Gamma(c) dc}{2\Gamma(\bar{\rho} - 2\sqrt{aL\nu})^2} = \frac{\gamma(\bar{c}) \int_0^{\bar{c}} \Gamma(c) dc}{2\Gamma(\bar{c})^2}, \quad (23)$$

the derivatives of the reservation price condition (18) are

$$\Psi_a = \sqrt{\frac{L\nu}{a}} I - 1; \quad \Psi_{\bar{\rho}} = \frac{1}{2} - I; \quad \Psi_L = \sqrt{\frac{a\nu}{L}} I > 0. \quad (24)$$

Now, by Assumption 2, $\gamma(c)/\Gamma(c) > \gamma(\bar{c})/\Gamma(\bar{c})$ for all $c < \bar{c}$, so that

$$\int_0^{\bar{c}} \Gamma(c) dc < \int_0^{\bar{c}} \gamma(c) \frac{\Gamma(\bar{c})}{\gamma(\bar{c})} dc = \frac{\Gamma(\bar{c})^2}{\gamma(\bar{c})}.$$

Plugging this into (23) yields $I < 1/2$, which immediately implies that $\Psi_{\bar{\rho}} > 0$. Notice also that, since the integral in (18) is positive, (18) implies that $\sqrt{aL\nu} < a$, from which it follows that $\sqrt{\frac{L\nu}{a}} < 1$ and therefore that $\Psi_a < I - 1 < 0$. Consequently, equation (21) implies that at least one of $\bar{\rho}$ and L must be increasing in a :

$$\frac{\partial L}{\partial a} \leq 0 \Rightarrow \frac{\partial \bar{\rho}}{\partial a} > 0. \quad (25)$$

If both L and $\bar{\rho}$ were non-increasing in a , the left-hand side of (21) would be negative, which would contradict (21).

Proof of Lemma 2

The derivatives in (22) are

$$\Phi_a = -\frac{1}{4a^2L} \int_0^{\bar{\rho}-2\sqrt{aL\nu}} (\bar{\rho}-c)^2 \gamma(c) dc < 0; \quad (26)$$

$$\Phi_{\bar{\rho}} = \frac{1}{2aL} \int_0^{\bar{\rho}-2\sqrt{aL\nu}} (\bar{\rho}-c) \gamma(c) dc > 0; \quad (27)$$

$$\Phi_L = -\frac{1}{4aL^2} \int_0^{\bar{\rho}-2\sqrt{aL\nu}} (\bar{\rho}-c)^2 \gamma(c) dc = \frac{a}{L} \Phi_a < 0. \quad (28)$$

Thus, (22) implies that if L is increasing in a , then $\bar{\rho}$ must also be strictly increasing in a :

$$\frac{\partial L}{\partial a} > 0 \Rightarrow \frac{\partial \bar{\rho}}{\partial a} > 0. \quad (29)$$

If this were not true, the left-hand side of (22) would be negative, which would contradict (22).

Proof of Lemma 3

From (22) and (28),

$$\frac{\partial \bar{\rho}}{\partial a} = -\frac{1}{\Phi_{\bar{\rho}}} \left(\Phi_a + \Phi_L \frac{\partial L}{\partial a} \right) = -\frac{\Phi_a}{\Phi_{\bar{\rho}}} \left(1 + \frac{a}{L} \frac{\partial L}{\partial a} \right). \quad (30)$$

Since the $\frac{\partial \bar{\rho}}{\partial a} > 0$, $\Phi_a < 0$, and $\Phi_{\bar{\rho}} > 0$, this implies that

$$\frac{\partial L}{\partial a} > -\frac{L}{a}, \quad (31)$$

that is, aL is increasing in a , and thus $\delta = 1/(aL)$ is decreasing in a .

Proof of Lemma 4

Taking the derivative of the profit function with respect to a , we obtain

$$\begin{aligned} \pi_a(\bar{c}(a), a) &= \frac{1}{4}[\bar{\rho}(a) - c]^2 \delta'(a) + \frac{1}{2}\delta(a)[\bar{\rho}(a) - c] \frac{\partial \bar{\rho}}{\partial a}(a) \\ &= \frac{1}{4}[\bar{\rho}(a) - c] \left[-\delta'(a)c + \bar{\rho}(a)\delta'(a) + 2\delta(a)\frac{\partial \bar{\rho}}{\partial a}(a) \right]. \end{aligned}$$

Thus, for any $c \leq \bar{c} < \bar{\rho}(a)$, the sign of $\pi_a(\bar{c}(a), a)$ equals the sign of the rightmost term above. Since $\delta'(a) < 0$ by Lemma 3, this term is increasing in c . It follows that if the term is negative for c_0 , it is, *a fortiori*, negative for all $c < c_0$.

Proof of Proposition 3

We begin by showing that the profit of the firm at the current marginal cost cut-off level $\bar{c}(a)$ must decrease as search costs decrease. First, rewrite the entry condition (19) as

$$\int_0^{\bar{c}(a)} \pi(c; a) \gamma(c) dc - \Gamma[\bar{c}(a)] \nu = a.$$

Fully differentiating this with respect to a and noting that $\pi(\bar{c}(a); a) = \nu$, yields

$$\int_0^{\bar{c}(a)} \pi_a(c; a) \gamma(c) dc = 0. \quad (32)$$

Together with Lemma 4, this implies that $\pi_a(\bar{c}(a); a) > 0$: otherwise, the integrand in (32) would be everywhere negative (by Lemma 4), which would contradict (32).

It is now obvious that the marginal cost threshold $\bar{c}(a)$ decreases as a decreases. Let a change from a_1 to $a_2 < a_1$. Then

$$\pi[\bar{c}(a_2), a_2] = \nu = \pi[\bar{c}(a_1), a_1] > \pi[\bar{c}(a_1), a_2],$$

where both equalities follow from the definition of $\bar{c}(a)$, and the inequality follows from $\pi_a(\bar{c}(a); a) > 0$. Since $\pi_c(c, a) < 0$ for all a and c by Property 3, this implies that $\bar{c}(a_1) > \bar{c}(a_2)$, as desired.

Proof of Corollary 1

Let a change from a_0 to $a_1 < a_0$. Let us index all corresponding quantities and functions by 0 and 1, respectively. By Proposition 3, $\bar{c}_1 < \bar{c}_0$. The cdf of the marginal-cost distribution of operating firms is given by $\tilde{\Gamma}(c) = \Gamma(c)/\Gamma(\bar{c})$. Since $c_1 < c_0$, it immediately follows that $\tilde{\Gamma}_1(c) > \tilde{\Gamma}_0(c)$ for all c .

Next, observe that $p_1(0) < p_0(0)$ (by Proposition 2) and that $p_1(\bar{c}_1) < p_1(\bar{c}_0) < p_0(\bar{c}_0)$ (the first inequality by Property 2 and $\bar{c}_1 < \bar{c}_0$; the second by Proposition 2). Thus, the support of the equilibrium price distribution shifts down, $\underline{p}_1 < \underline{p}_0$ and $\bar{p}_1 < \bar{p}_0$. Consequently, $F_1(p) \geq F_0(p)$ on the complement of $[\underline{p}_0, \bar{p}_1]$, since $F_0(p) = 0$ for $p < \underline{p}_0$ and $F_1(p) = 1$ for $p > \bar{p}_1$.

Finally, by Proposition 2, $p_1(c) < p_0(c)$ for all $c \in [0, c_1]$, so that $p_1^{-1}(r) > p_0^{-1}(r)$ for all $r \in [\underline{p}_0, \bar{p}_1]$. Since $\bar{c}_1 < \bar{c}_0$, it follows from the definition of F ((12)) that $F_1(p) > F_0(p)$ for all $p \in [\underline{p}_0, \underline{p}_1]$.

Proof of Corollary 2

Recall the equation from the proof of Proposition 3:

$$\int_0^{\bar{c}(a)} \pi_a(c; a) \gamma(c) dc = 0.$$

This would be violated if $\pi_a(c; a) > 0$ for all $c < \bar{c}$. Thus, there exists $\hat{c} < \bar{c}$ such that $\pi_a(\hat{c}; a) \leq 0$. But then, by Lemma 4, $\pi_a(c; a) < 0$ for all $c < \hat{c}$.

Proof of Corollary 3

The total market share of all operating firms equals one: $1 = \int_0^{\bar{c}(a)} X(c, a) dc$. Differentiating this with respect to a yields

$$0 = \bar{c}'(a)X[\bar{c}(a), a] + \int_0^{\bar{c}(a)} X_a(c, a) dc.$$

Since $\bar{c}'(a) > 0$ by Proposition 3, this implies that $\int_0^{\bar{c}(a)} X_a(c, a) < 0$. In particular, there exists $\hat{c} < \bar{c}$ such that $X_a(\hat{c}, a) < 0$.

By definition,

$$X(c, a) = Lx(c; a)\gamma(c) = \frac{1}{2a}[\bar{\rho}(a) - c]\gamma(c).$$

Thus,

$$X_a(c, a) = \left\{ -\frac{1}{2a^2}[\bar{\rho}(a) - c] + \frac{1}{2a}\bar{\rho}'(a) \right\} \gamma(c).$$

The sign of this expression equals the sign of the expression in parentheses, which is clearly increasing in c . Thus, $X_a(\hat{c}; a) < 0$ implies that $X_a(c; a) < 0$ for all $c < \hat{c}$.

Appendix C: Numerical Simulations

Closed-form solutions for equilibrium components such as the price distribution, the marginal cost cut-off, and the mass of firms do not exist even in the case when the search cost distribution is uniform. When search costs are not uniformly distributed, algebraic means are even less successful: not only are there no closed form solutions, but also, as explained in Appendix A, it is in general very hard even to derive comparative statics results. We therefore turn to numerical simulations in this section. The goal is twofold: first, to illustrate the known comparative statics results for the uniform distribution, and, second, to determine whether similar results can be obtained for another class of distributions. These latter

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Fig. 1: Fraction of Consumers Purchasing Online and Total Number of Travel Agencies: 1994–2003

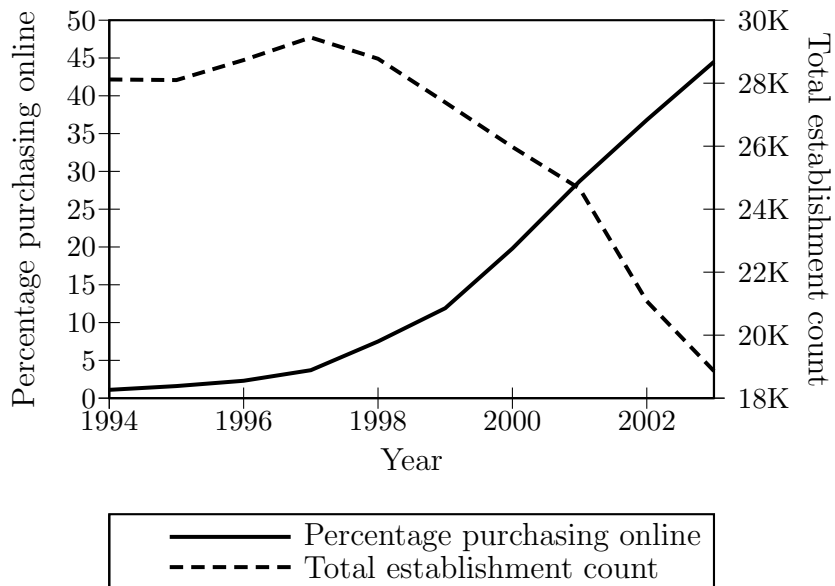


Fig. 2: Comparative Statics with Respect to Search Cost Changes When Search Costs Are Uniform

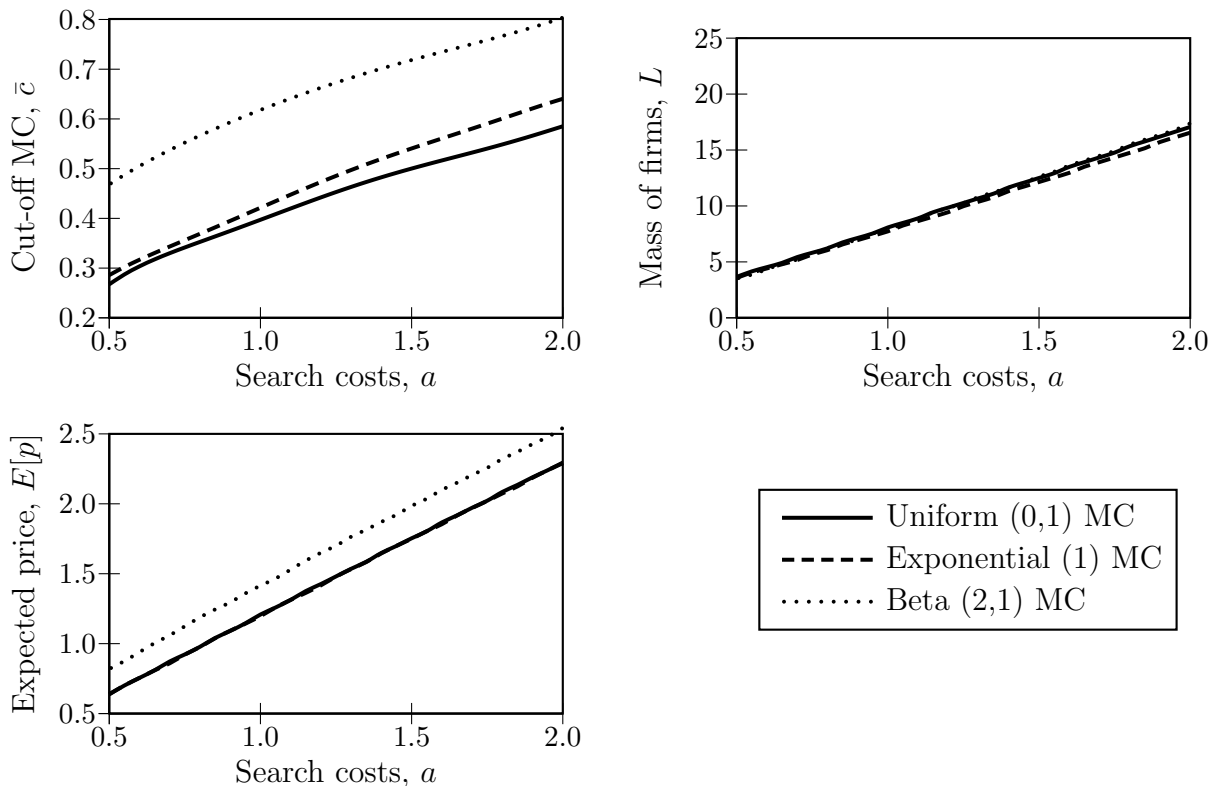


Fig. 3: Equilibrium Price Distributions for Three Levels of Uniform Search Costs under Three Types of Marginal Cost Distribution

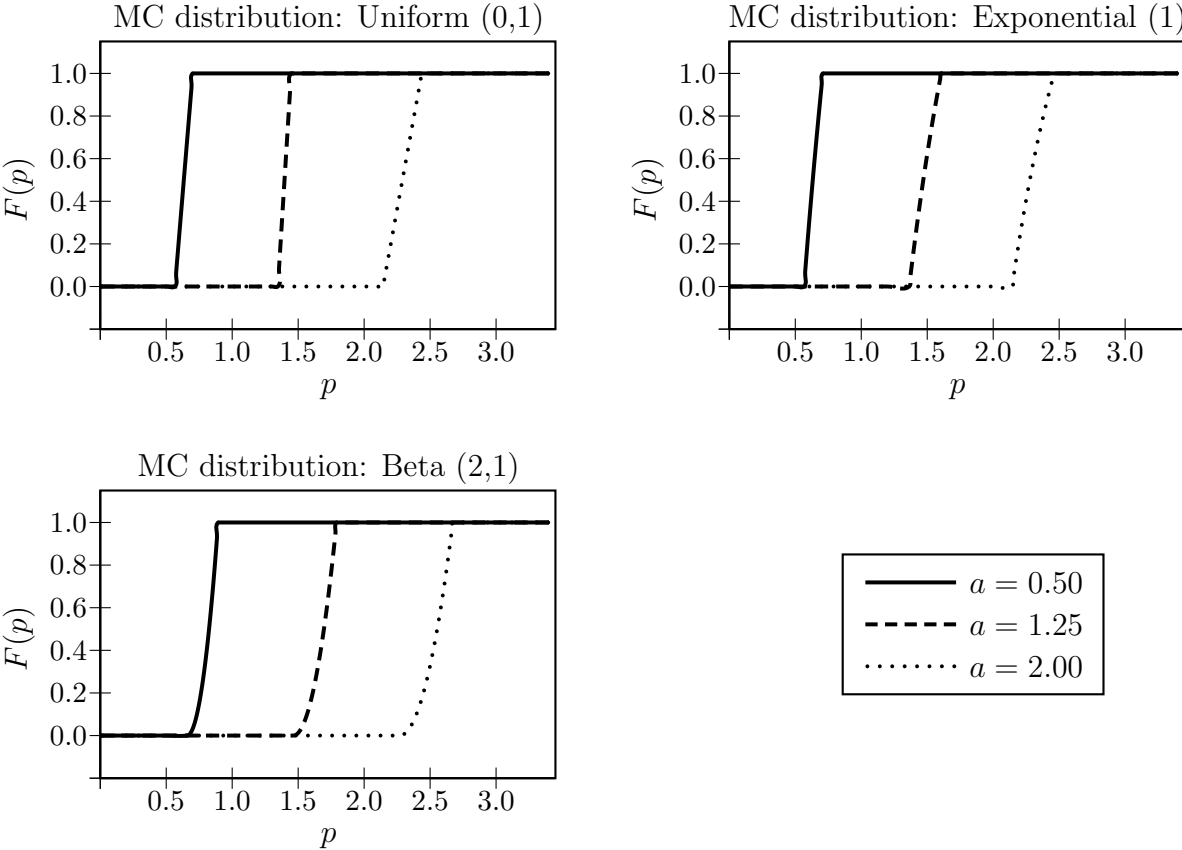


Fig. 4: Comparative Statics with Respect to Search Cost Changes When Search Costs are Exponential

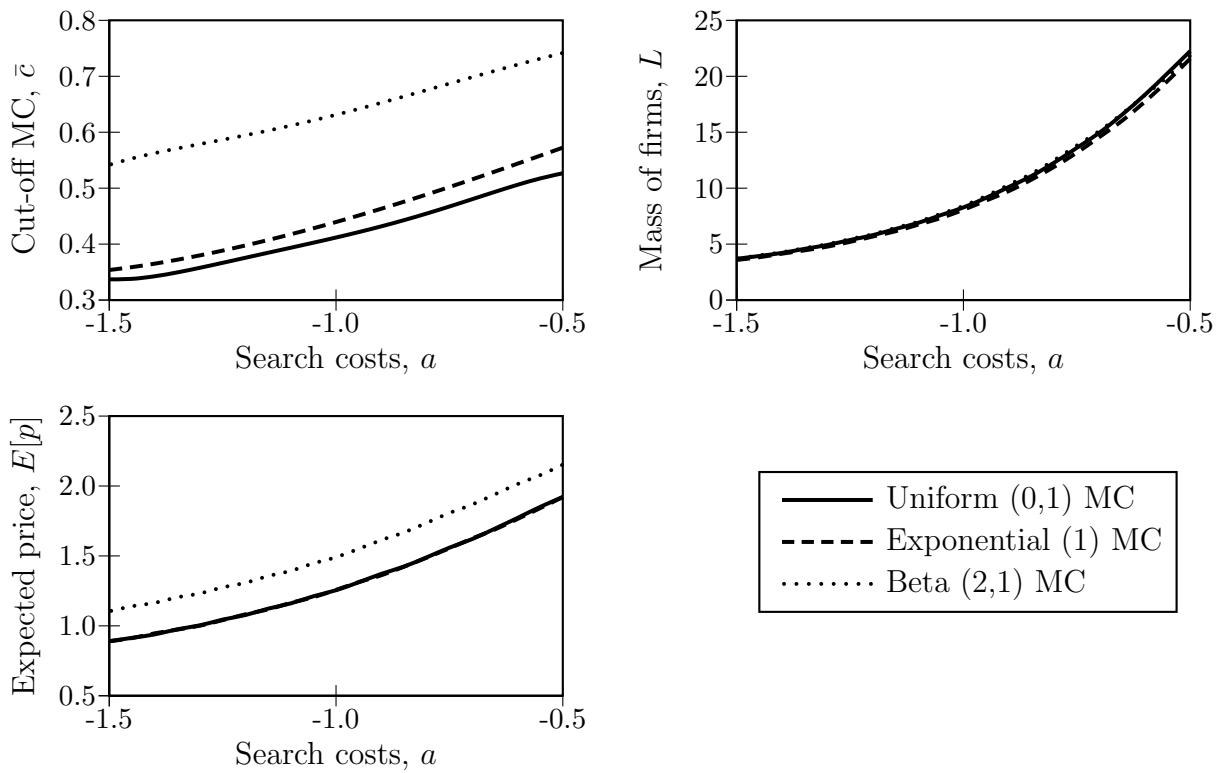


Fig. 5: Equilibrium Price Distributions for Three Levels of Exponential Search Costs under Three Types of Marginal Cost Distribution

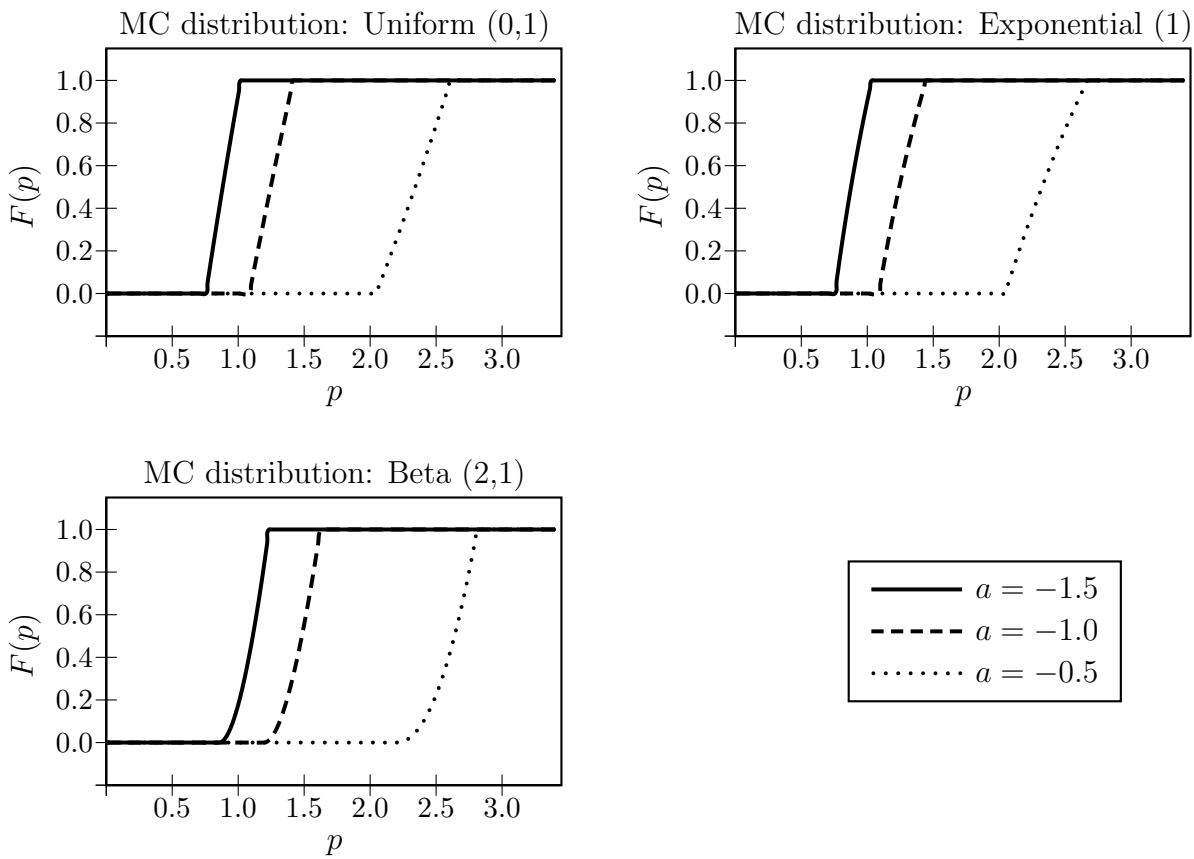


Table 1: Cross-Sectional Comparison of CEA Markets: Average Establishment Counts

A. *Travel Agencies*

	Mean	25%ile	Median	75%ile
Total establishments	74.3	10.8	22.4	58.3
Estabs. with 1–4 employees	48.4	6.6	13.6	35.7
Estabs. with 5–9 employees	16.8	3.0	6.0	13.7
Estabs. with 10–19 employees	5.9	0.7	1.9	4.5
Estabs. with 20–49 employees	2.3	0.0	0.6	1.8
Estabs. with 50–99 employees	0.6	0.0	0.0	0.4
Estabs. with over 100 employees	0.4	0.0	0.0	0.1

B. *Bookstores*

	Mean	25%ile	Median	75%ile
Total establishments	35.4	9.8	17.8	36.6
Estabs. with 1–4 employees	15.3	4.3	8.3	17.8
Estabs. with 5–9 employees	9.9	2.8	5.0	10.5
Estabs. with 10–19 employees	6.0	1.4	2.8	6.2
Estabs. with 20–49 employees	3.1	0.6	1.4	3.5
Estabs. with 50–99 employees	1.0	0.0	0.3	1.1
Estabs. with over 100 employees	0.2	0.0	0.0	0.1

C. *Auto Dealers*

	Mean	25%ile	Median	75%ile
Total establishments	73.5	24.8	41.7	82.0
Estabs. with 1–4 employees	11.3	3.2	5.8	12.1
Estabs. with 5–9 employees	5.2	1.7	3.3	6.7
Estabs. with 10–19 employees	10.5	3.6	7.2	13.5
Estabs. with 20–49 employees	24.8	9.0	15.5	28.3
Estabs. with 50–99 employees	15.4	3.9	7.4	16.3
Estabs. with 100–249 employees	6.0	0.4	1.9	5.6
Estabs. with over 250 employees	0.4	0.0	0.0	0.2

Table 2: Market Structure Patterns: Travel Agencies

A. *Establishment Counts: US Aggregates*

Year	Total	Employment Category					
		1-4	5-9	10-19	20-49	50-99	100+
1994	28,118	18,186	6,774	2,121	759	169	109
1995	28,099	18,089	6,710	2,212	802	176	110
1996	28,735	18,654	6,724	2,181	859	200	117
1997	29,452	19,183	6,758	2,332	834	206	139
1998	28,776	18,460	6,755	2,325	861	212	163
1999	27,390	17,611	6,281	2,276	821	225	176
2000	25,975	16,783	5,836	2,091	845	234	186
2001	24,654	16,050	5,306	2,000	853	243	202
2002	21,079	14,281	4,151	1,581	681	201	184
2003	18,860	12,865	3,556	1,430	653	182	174

B. *Local Market Structure and Fraction Purchasing Online*

	ln(total emp.)	ln(total estabs.)	ln(establishments) by employment category					
			1-4	5-9	10-19	20-49	50-99	100+
<i>N</i>	3449	3449	3426	3306	2548	1740	783	538
<i>R</i> ²	0.96	0.98	0.97	0.94	0.91	0.89	0.83	0.84
Fraction Online	-0.932*	-1.117*	-0.906*	-1.538*	-0.870*	-0.357*	0.072	0.161
	(0.047)	(0.026)	(0.036)	(0.047)	(0.065)	(0.070)	(0.106)	(0.137)

C. *Local Market Structure and Fraction Purchasing Online, with Year Fixed Effects*

	ln(total emp.)	ln(total estabs.)	ln(establishments) by employment category					
			1-4	5-9	10-19	20-49	50-99	100+
<i>N</i>	3449	3449	3426	3306	2548	1740	783	538
<i>R</i> ²	0.96	0.99	0.97	0.94	0.91	0.89	0.84	0.84
Fraction Online	0.278	0.033	0.029	-0.075	-0.178	0.180	-0.218	-0.195
	(0.165)	(0.084)	(0.138)	(0.161)	(0.226)	(0.251)	(0.509)	(0.592)

Notes: All regression specifications include CEA market fixed effects and control for (logged) overall employment in the market-year. Robust standard errors in parentheses. An asterisk denotes significance at the five percent level.

Table 3: Market Structure Patterns: Bookstores

A. *Establishment Counts: US Aggregates*

Year	Total	Employment Category					
		1–4	5–9	10–19	20–49	50–99	100+
1994	13,520	6,625	3,840	2,198	708	102	47
1995	13,403	6,234	3,985	2,165	806	154	59
1996	13,134	5,916	4,039	1,940	966	211	62
1997	12,301	5,254	3,753	2,021	933	286	54
1998	12,151	5,031	3,588	2,025	1,088	357	62
1999	11,957	4,878	3,467	2,063	1,076	410	63
2000	11,662	4,641	2,953	2,349	1,163	485	71
2001	11,559	4,678	3,100	2,023	1,276	411	71
2002	12,178	5,494	2,777	2,089	1,275	475	68
2003	11,036	4,493	2,900	1,909	1,237	428	69

B. *Local Market Structure and Fraction Purchasing Online, with Year Fixed Effects*

	ln(total emp.)	ln(total estabs.)	ln(establishments) by employment category					
			1–4	5–9	10–19	20–49	50–99	100+
N	3448	3448	3386	3338	3031	2400	1275	423
R^2	0.94	0.96	0.91	0.89	0.86	0.86	0.81	0.74
Fraction Online	-0.307* (0.148)	-0.316* (0.115)	-0.161 (0.172)	-0.398* (0.187)	-0.817* (0.210)	0.220 (0.208)	0.485 (0.357)	0.003 (0.377)

Notes: All regression specifications include CEA market fixed effects and control for (logged) overall employment in the market-year. Robust standard errors in parentheses. An asterisk denotes significance at the five percent level.

Table 4: Market Structure Patterns: New Auto Dealers

A. *Establishment Counts: US Aggregates*

Year	Total	Employment Category						
		1–4	5–9	10–19	20–49	50–99	100–249	250+
1994	24,130	2,715	1,724	4,142	9,017	4,853	1,601	78
1995	24,230	2,850	1,653	3,882	8,927	5,063	1,755	100
1996	24,639	3,320	1,691	3,735	8,757	5,155	1,866	115
1997	26,208	3,848	1,941	3,825	9,065	5,376	2,022	131
1998	26,216	4,117	1,971	3,777	8,873	5,421	1,931	126
1999	26,117	4,287	1,948	3,611	8,616	5,437	2,083	135
2000	26,225	4,440	1,841	3,505	8,380	5,592	2,303	164
2001	26,444	4,759	1,863	3,462	8,373	5,493	2,332	162
2002	25,625	4,176	1,723	3,282	8,202	5,600	2,451	191
2003	26,707	4,654	1,891	3,394	8,237	5,768	2,532	231

B. *Local Market Structure and Fraction Purchasing Online, with Year Fixed Effects*

	ln(total	ln(total	ln(establishments) by employment category						
	emp.)	estabs.)	1–4	5–9	10–19	20–49	50–99	100–249	250+
<i>N</i>	3423	3425	3300	3021	3311	3423	3363	2455	643
<i>R</i> ²	0.99	0.99	0.88	0.82	0.91	0.95	0.95	0.94	0.80
Fraction	0.155*	0.130*	0.200	-0.081	-0.063	-0.231*	0.230*	0.595*	0.530
Online	(0.054)	(0.042)	(0.187)	(0.215)	(0.146)	(0.091)	(0.117)	(0.175)	(0.602)

Notes: All regression specifications include CEA market fixed effects and control for (logged) overall employment in the market-year. Robust standard errors in parentheses. An asterisk denotes significance at the five percent level.