

# Match Quality, Search, and the Internet Market for Used Books\*

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October 2013  
PRELIMINARY

*The Internet is a nearly perfect market because information is instantaneous and buyers can compare the offerings of sellers worldwide. The result is fierce price competition, dwindling product differentiation, and vanishing brand loyalty.* Robert Kuttner, *Business Week*, May 11, 1998.

*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

## 1 Introduction

The empirical literature on Internet pricing has found from the beginning that online prices did not have the dramatic price-lowering and law-of-one-price-reinforcing effects that some had forecast. Brynjolfsson and Smith (2000), for example, found that online book and CD prices were just 9-16% lower than offline prices (and price dispersion was actually greater online), and Baye, Morgan and Sholten (2004) found an average range of over \$100 for consumer electronics products and noted that the more refined law-of-one-price prediction that at least the two lowest prices in a market should be identical fails spectacularly in their

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dataset.<sup>1</sup> We note here that the used book market appears to be an extreme example on this dimension – online prices are in fact typically higher than offline prices.<sup>2</sup> The failure of the Internet to bring about low and homogeneous prices has often been seen (including in Ellison and Ellison (2009)) as an indication that Internet retail markets are not working as well as one might have expected. The absence of a price decline, however, can also have a much more agreeable cause: if the Internet allows consumers to find goods that are better matched to their tastes, then there is effectively an increase in demand, which would lead to higher prices in many monopolistic and competitive models. In this paper, we explore this improvement-in-match-quality idea in the context of the Internet market for used books. We develop some simple models of how reduced search costs would affect price distributions in a model with competition and match-quality effects, note that several predictions of the model seem to be borne out in our data, discuss how a version of the model can be structurally estimated, and present estimates suggesting that Internet sales of used books may be providing substantial profit and welfare benefits.

It seems natural that many used book dealers were early adopters of Internet sales in the early to mid 1990's: many potential purchasers of out-of-print books were presumably lost due to time cost of finding books in physical bookstores, and books are both easily describable and easy to ship. In the second half of the 1990's, web sites such as Bibliofind, AbeBooks, Bookfinder, and Alibris developed web sites that aggregated listings from multiple bookstores helping savvy consumers find the books they wanted and compare prices. AbeBooks, which initially just aggregated listings of physical stores in Victoria B.C., grew to be the largest aggregator (in part by acquiring Bookfinder) with 20 million listings by 2000 and 100 million by 2007. Alibris is of comparable size. In the late 2000's there was a second substantial change after Amazon acquired AbeBooks. The 2008 acquisition had little immediate impact – Amazon initially left AbeBooks to operate as it had. But in 2010 they launched a program to allow used book dealers to have their AbeBooks listings also appear on Amazon. The addition of “buy used” links on Amazon could potentially have had a large effect on the number of consumers who viewed aggregated used book listings.

To help understand how the shift to online sales might affect price distributions and sales patterns in a market like that for used books, Section 2 presents some simple models which cast the selling of unique items as a waiting-time problem: the firm sets a price  $p$  for its item and consumers with valuations drawn from a distribution  $F$  arrive at a known Poisson rate

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<sup>1</sup>We borrowed the quotes at the start of our paper from these two papers.

<sup>2</sup>The first online vs. offline comparison paper we have found, Bailey (1998), reported that online prices for CDs were higher than offline prices, but have not seen such a finding in any later papers.

$\gamma$ . In a monopoly model we note that prices increase when the arrival rate is higher and when the distribution has a thicker upper tail. In a complete-information oligopoly model we note that a second important force, price competition, pulls prices down especially in the lower tail. And then we discuss a hybrid model along the lines of Baye and Morgan (2001) in which the some “shoppers” see all prices and some nonshoppers only visit a single firm. We note that there can be a pure-strategy dispersed-price equilibrium if firms have heterogeneous nonshopper arrival rates and discuss the form of the first-order condition. We note that a shift to online sales may have different effects at different parts of the price distribution – competition can pull down prices at the bottom end of the distribution even as match quality effects increase prices at the high end. The model also suggests a number of additional patterns that would be expected when comparing price distributions for different types of books and as the use of price comparison services grew.

Section 3 discusses the dataset. The data include information on 335 titles which we first found at physical used book stores in 2009. The set of titles was chosen to allow us to separately analyze three distinct types of books. In addition to the “standard” set of mostly out-of-print titles that fill most of the shelves at the stores we visited, we oversampled books that are of “local interest” to the area where the store is located, and we label a number of books found at a large number of Internet retailers as “popular.” We collected offline prices and conditions for these books in 2009. And we collected prices and conditions for copies of the same books listed online via Abebooks.com in 2009, 2012, and 2013. The 2009 online data collection lets us compare contemporaneous online and offline prices. The 2012 data collection lets us examine how prices compare before and after Amazon’s incorporation of the AbeBooks listings increased the size of the searcher population. The 2013 data collection provides something akin to demand data (which we infer by looking at whether copies listed in November 2012 are no longer listed for sale two months later.)

Section 4 presents descriptive evidence on online and offline prices. Our most basic observation is that online prices are typically higher than offline prices. Indeed this holds in a very strong sense: for more than half of our “standard” titles the one offline price that we found was below the single lowest online price even when one does not count the true cost of shipping in the online price. We then present a number of more detailed findings examining additional predictions of the theory and find a number of striking facts that support the model’s applicability. Among these are that the online price distribution for standard titles has a much thicker upper tail than the offline version, that offline and online prices are more similar “local interest” titles (as if the Internet is making the market for all

titles look more like the market for local interest titles), and that between 2009 and 2012 there has been growth in the number of sellers listing very low prices with strikingly little change in the upper tail. We note also that demand appears to be low and fairly price sensitive: the single lowest-priced listing has a substantial chance of being sold in less than two months, but the average title will not sell for years.

Observed price differences between offline and online books can be thought of as reflecting the net of two effects: a match-quality effect increases the effective demand for books and a competition effect pulls prices down. Estimating profit and/or social welfare effects requires separately estimating of the magnitudes of the two gross effects. In section 5 we develop a structural approach to provide such estimates. We begin by describing an econometric model along the lines of the theoretical model of section 2: shoppers and nonshoppers arrive at a poisson rates, firms are heterogeneous in the arrival processes they face, and products are sufficiently differentiated so that pure strategy equilibria exist. In a parsimonious model we note that there is a one-to-one correspondence between prices and arrival rates. This makes it possible to back out firm-specific arrival rates from observed prices, which makes the model relatively easy to estimate via simulated maximum likelihood and lets us avoid some difficulties associated with endogeneity while using our demand data. The structural estimates indicate that arrival rates are substantially higher at online stores than offline stores (although arrival rates are still very low for some titles), that demand includes a very price-sensitive “shopper” segment, and that firms also receive a (very small) inflow of much less price sensitive nonshoppers. Our profit and welfare calculations indicate that both book dealers and consumers are benefitting from the shift to online sales: profits and consumer surplus are estimated to be substantially higher in the online environment than in the 2009 offline world. Per-listing profit levels do, however, appear to have declined by about 25% between 2009 and 2012, perhaps due to the increased use of price comparison tools.

Our paper is related to a number of other literatures, both theoretical and empirical. One related empirical literature explores facts similar to those that motivate our analysis – comparing online and offline prices for various products and/or documenting the degree of online price dispersion. One early study, Bailey (1998), collected prices from samples of online and offline retailers in 1997 and reported that online prices for software, books and CDs were 3% to 13% higher on average than offline prices, but later studies like Brynjolfsson and Smith (2000), Clay, Krishnan, and Wolff (2001), Baye, Morgan, and Scholten (2004), and Ellison and Ellison (2009) report that online prices are lower than offline prices. All

of these studies note that there is substantial dispersion in online prices. Another (much smaller) related literature is that providing reduced-form evidence that price distributions appear consistent with models of heterogeneous search. Two noteworthy papers here are Baye, Morgan, and Scholten (2004), which discusses the implications of several theoretical models and notes that empirically dispersion is smaller when the number of firms is larger and Tang, Smith, and Montgomery (2010), which documents that prices and dispersion are lower for more frequently searched books. A number of other papers explore other issues in the book market including Chevalier and Goolsbee (2003), Brynjolfsson, Hu, and Smith (2003), Ghose, Smith, and Telang (2006), and Chevalier and Goolsbee (2009). The focus of Brynjolfsson, Hu, and Smith (2003) is most similar in that it also estimates welfare gains from Internet book sales, in its case estimating the consumer surplus improvement that results from Amazon’s making available to consumers books that they would have been unable to purchase at traditional brick and mortar stores.

On the theory side, although related stopping time problems can be found going back at least to McCall (1970), and there are substantial literatures covering more complex dynamic monopoly problems with inventory costs, finite time horizons, learning about demand, etc., we do not know of a reference for our simple initial analysis of monopoly pricing with Poisson arrivals. Our subsequent consideration of oligopoly pricing is influenced by the literature on pricing and price dispersion with consumer search including Salop and Stiglitz (1977), Reinganum (1979), Varian (1980), Burdett and Judd (1983), Stahl (1989), and Baye and Morgan (2001).<sup>3</sup> Relative to many of these papers, we simplify our model by focusing exclusively on the firm pricing problem without rationalizing the consumer search. Our approach of focusing on pure-strategy equilibria with heterogeneous firms harkens back to Reinganum (1979), although the structure of the population is more similar to that of Baye and Morgan (2001).

Another active recent literature demonstrates how one can back out estimates of search costs from data on price distributions under rational search models. Sorensen (2001) did this in the context of prescription drug prices. Hortacsu and Syverson (2004) examine index mutual funds. Hong and Shum (2006) discuss both a nonparametric methodology and an application involving used book prices. Subsequent papers extending the methodology and examining other applications include Moraga Gonzalez and Wildenbeest (2008), Kim, Albuquerque, and Bronnenberg (2010), Brynjolfsson, Dick, and Smith (2010), De los Santos, Hortacsu, and Wildenbeest (2012) (which also studies consumers shopping for books),

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<sup>3</sup>See Baye, Morgan, and Scholten (2006) for a survey that brings together many of these models.

Moraga Gonzalez, Sandor, and Wildenbeest (2013), and Koulayev (2013) Relative to this literature, we will not try to estimate search costs to rationalize demand – instead we focus just on estimating a consumer arrival process from price distributions (and some quantity data) in a model that allows for substantial firm-level heterogeneity (where much of this literature assumes firms are identically situated.)

## 2 A Model

In this section we'll discuss simple monopoly and duopoly models that can be used to think about the problems faced by traditional and online used book dealers. The models provide some predictions about offline and online prices that will be tested in section 4 and motivate the structural model that we'll estimate in section 5.

### 2.1 A monopoly model

We begin with a simple dynamic monopoly model. One can think of the model as a model of a brick-and-mortar bookstore or an internet store serving customers who are browsing at a particular store. It will also serve as a starting point for our subsequent analysis of an oligopoly model in which some consumers also search across stores.

Suppose that a monopolist has a single unit of a good to sell. Consumers randomly arrive at the monopolists' store according to a Poisson process with rate  $\gamma$ . The value  $v$  of the each arriving consumer is an independent draw from a distribution with CDF  $F(v)$ . Consumers buy if and only if their value exceeds the firm's price so the probability that the consumer will buy is  $D(p) = 1 - F(p)$ . We assume that  $\lim_{p \rightarrow \infty} pD(p) = 0$  to ensure that optimal prices will be finite.

One can think about the dynamic optimal monopoly price in two different ways. One is simply to compute the discounted expected profit  $\pi(p)$  obtained from any fixed price  $p$ . Intuitively, expected profit is simply  $E(pe^{-r\tilde{t}})$  where  $\tilde{t}$  is the random variable giving the time at which the good is sold. Consumers willing to pay at least  $p$  arrive at Poisson rate  $\gamma D(p)$ , so the density of the first arrival time is  $f(t|p) = \gamma D(p)e^{-\gamma D(p)t}$  and the expected profit is

$$\begin{aligned} \pi(p) &= \int_0^\infty pe^{-rt} f(t|p) dt \\ &= \int_0^\infty pe^{-rt} \gamma D(p) e^{-\gamma D(p)t} dt \\ &= \frac{\gamma p D(p)}{r + \gamma D(p)} \end{aligned}$$

Hence, one way to think of the dynamic optimal monopoly price  $p^m$  is as the maximizer of this expression:

$$p^m = \operatorname{argmax}_p \pi(p) = \operatorname{argmax}_p \frac{\gamma p D(p)}{r + \gamma D(p)}.$$

Note that expected profits are zero in both the  $p \rightarrow 0$  and  $p \rightarrow \infty$  limits so an interior optimum exists if  $D(p)$  is continuous. The monopoly price will satisfy the first-order condition obtained from differentiating the above expression if  $D(p)$  is differentiable. Note also that  $\pi(p)$  only depends on  $\gamma$  and  $r$  through the ratio  $\gamma/r$ . This is natural because the scaling of time is only meaningful relative to these parameters.

An alternate way to think about the dynamic profit maximization problem is as a dynamic programming problem. Let  $\pi^*$  (which depends on  $\gamma$ ,  $r$ , and  $D(\cdot)$ ) be the maximized value of  $\pi(p)$ . This is the opportunity cost that a monopolist incurs if it sells the good to a consumer who has arrived at its shop. Hence, the dynamic optimal monopoly price is also the solution to

$$p^m = \operatorname{argmax}_p (p - \pi^*) D(p).$$

Looking at the problem from these two perspectives gives two expressions relating the dynamic monopoly price to the elasticity of demand:

**Proposition 1** *Suppose  $D(p)$  is differentiable. The dynamic monopoly price  $p^m$  and the elasticity of demand  $\epsilon$  at this price are related by*

$$\frac{p - \pi^*}{p} = -\frac{1}{\epsilon},$$

and

$$\epsilon = -\left(1 + \frac{\gamma}{r} D(p^m)\right).$$

### Proof

The first expression is the standard Lerner index formula for the optimal monopoly markup. The second can be derived from the first by substituting  $\frac{\gamma p^m D(p^m)}{r + \gamma D(p^m)}$  for  $\pi^*$  and solving for  $\epsilon$ . It also follows directly from the first order condition for maximizing  $\pi(p)$ :

$$r p^m D'(p^m) + r D(p^m) + \gamma D(p^m)^2 = 0.$$

QED

Remarks:

1. In contrast to the static monopoly pricing problem with zero costs where a monopolist chooses  $p$  so that  $\epsilon = -1$ , the monopolist in this problem prices on the elastic portion of the demand curve to reflect the opportunity cost of selling the good.
2. The expressions in Proposition 1 are first-order conditions that one can be solved to obtain expressions for the monopoly price given a particular  $D(p)$ . For example, if values are uniform on  $[0, 1]$  so  $D(p) = 1 - p$  they can be solved to find  $p^m = \frac{\sqrt{1+(\gamma/r)}}{1+\sqrt{1+(\gamma/r)}}$ . Another fairly tractable example is a truncated CES demand curve:  $D(p) = \min\{1, hp^{-\eta}\}$ . Here the monopoly price is

$$p^m = \begin{cases} \left(\frac{h}{\eta-1}\right)^{1/\eta} \left(\frac{\gamma}{r}\right)^{1/\eta} & \text{if } \frac{\gamma}{r} > \eta - 1 \\ h^{1/\eta} & \text{otherwise} \end{cases}$$

One difference between traditional and online used book dealers is that more consumers may visit online stores. A relevant comparative statics result on the dynamic monopoly price is:

**Proposition 2** *The monopoly price  $p^m$  is weakly increasing in  $\frac{\gamma}{r}$ .*

Proof

As noted above the monopoly price can be defined by

$$p^m = \underset{p}{\operatorname{argmax}}(p - \pi^*(\gamma/r))D(p).$$

The function  $\pi^*(\gamma/r)$  is increasing because  $\pi(p, \gamma/r)$  is increasing in  $\gamma/r$  for all  $p$ . Hence, the function  $(p - \pi^*(\gamma/r))D(p)$  has increasing differences in  $\gamma/r$  and  $p$  and the largest maximizer is increasing in  $\gamma/r$ . QED

Remarks:

1. When the arrival rate  $\gamma$  is small the monopolist's problem is approximately that of a standard monopolist with zero costs so the monopoly price approaches the maximizer of  $pD(p)$ .
2. The behavior of the monopoly price in the  $\gamma/r \rightarrow \infty$  limit depends on the support of consumer value distribution. When the value distribution has an upper bound the monopoly price will approach the upper bound. When there is no upper bound on consumer valuations the monopoly price will go to infinity as  $\gamma/r \rightarrow \infty$ . To see this note that for any fixed  $p$  and  $\epsilon$ ,  $\pi(p + \epsilon, \gamma/r) = \frac{p+\epsilon}{1+r/(\gamma D(p+\epsilon))} \rightarrow p + \epsilon$  as  $\gamma/r \rightarrow \infty$ . Hence, the monopoly price must be larger than  $p$  for  $\gamma/r$  sufficiently large.



3. The rate at which  $p^m$  increases in  $\gamma/r$  depends on the thickness of the upper tail of the distribution of consumer valuations. In the uniform example, the monopoly price increases rapidly when  $\gamma/r$  is small, but the effect diminishes rapidly:  $p^m$  remains bounded above by one as  $\gamma/r \rightarrow \infty$  and converges to this upper bound at just a  $1/\sqrt{\gamma/r}$  rate. In the truncated CES example the monopoly price is proportional to  $(\gamma/r)^{1/\eta}$ . In the extremely thick-tailed version of this distribution with  $\eta$  slightly larger than one the monopoly price is almost to proportional to the arrival rate. But when the tail is thinner, i.e. when  $\eta$  larger, the monopoly price increases more slowly. When demand is exponential,  $D(p) = e^{-\gamma p}$ , the monopoly price is bounded above by a constant times  $\log(\gamma/r)$ .

Traditional and online used book dealers may also differ in the distribution of consumer values. For example, the probability that a consumer searches for a particular book online may be increasing in the consumer's valuation for the book, whereas consumers who are browsing in a physical bookstore will be equally likely to come across titles for which they have relatively low and high valuations. One way to capture such an effect would be to assume that offline searchers' valuation are random draws from the full population  $f(v)$  whereas the likelihood that a consumer with value  $v$  searches online for a title is an increasing function  $q(v)$  of his or her valuation for that title. The density of valuations in the online searcher population will then be  $g(v) = af(v)q(v)$  for some constant  $a$ . Note that  $g$  is higher than  $f$  both in the sense of first-order stochastic dominance and in having a thicker upper tail:  $\frac{1-G(x)}{1-F(x)}$  is increasing in  $x$ . The following proposition shows that shifts in the distribution satisfying the latter condition increase the monopoly price holding the arrival rate constant.

**Proposition 3** *Let  $p^m(\gamma/r, F)$  be the monopoly price when the distribution of valuations is  $F(x)$ . Let  $G(x)$  be a distribution with  $\frac{1-G(x)}{1-F(x)}$  is increasing in  $x$ . Then  $p^m(\gamma/r, G) \geq p^m(\gamma/r, F)$ .*

Proof

Let  $k = \frac{1-F(p^m(\gamma/r, F))}{1-G(p^m(\gamma/r, F))}$  be the ratio of demands under the two distributions when the firm charges  $p^m(\gamma/r, F)$ . The desired result follows from a simple two-step argument:

$$p^m(\gamma/r, G) \geq p^m(k\gamma/r, G) \geq p^m(\gamma/r, F).$$

The first inequality follows from Proposition 2 because  $k \leq 1$ . (This follows because  $k \leq \frac{1-F(0)}{1-G(0)} = 1$ .) The second holds because  $\pi(p; k\gamma/r, G)$  and  $\pi(p; \gamma/r, F)$  are identical

at  $p^m(\gamma/r, F)$  and their ratio is increasing in  $p$ . Hence for any  $p < p^m(\gamma/r, F)$  we have  $\pi(p; k\gamma/r, G) \leq \pi(p; \gamma/r, F) \leq \pi(p^m(\gamma/r, F); \gamma/r, F) \leq \pi(p^m(\gamma/r, F); k\gamma/r, G)$ . QED

## 2.2 An oligopoly model

We now discuss related oligopoly models. We begin with a simple symmetric full-information model which serves as a building block. And we then discuss an asymmetric oligopoly model in which firms serve both comparison shoppers and a local market.

Suppose that there are  $N$  firms in the market. Suppose there is a flow rate of arrival  $\gamma_0$  of shoppers who visit all  $N$  firms. Assume that shoppers buy from firm  $i$  with probability  $D(p_i, p_{-i})$  and that this demand function is symmetric, twice-differentiable, weakly decreasing in  $p_i$ , and weakly increasing in  $p_{-i}$ . Assume also that the set of feasible prices is a compact interval so  $\operatorname{argmax}_p pD(p, p_{-i})$  always exists. As in the monopoly model we are interested in modeling a firm endowed with a single unit of the good to sell that faces a dynamic waiting-time problem. In the oligopoly case it is natural that the dynamic problem would have a time-varying component: a firm should anticipate that competition could suddenly become more or less severe as additional sellers enter and/or current sellers sell their goods. Optimal pricing in such a setting could be an interesting topic to explore, but in this paper we will explore a simpler stationary model: we assume that whenever one of a firm's rivals makes a sale, that the rival is instantaneously replaced by an identical entrant. Profits in the dynamic model then relate to those of the static model as in monopoly case:

$$\pi(p_i, p_{-i}) = \frac{\gamma_0 p_i D(p_i, p_{-i})}{r + \gamma_0 D(p_i, p_{-i})}.$$

In the static version of this model with a nonzero marginal cost  $c$  it is common to assume that demand is such that  $\pi^s(p) = (p_i - c)D(p_i, p_{-i})$  has increasing differences in  $p_i$  and  $p_{-i}$ . The game is then one with strategic complements: best response correspondences  $BR_i(p_{-i})$  are increasing and results on supermodular games imply that a symmetric pure strategy Nash equilibrium always exists (Milgrom and Roberts, 1990). These results would carry over to our dynamic model.

**Proposition 4** *Suppose  $\pi^s(p) = (p_i - c)D(p_i, p_{-i})$  has increasing differences in  $p_i$  and  $p_{-i}$  when  $p_i > c$ . Then, best response correspondences in the the dynamic oligopoly model are weakly increasing and a symmetric pure strategy Nash equilibrium exists.*

Proof

Let  $\bar{V}(p_{-i}) \equiv \max_p \pi(p_i, p_{-i})$  be firm  $i$ 's profit when it plays a best response to  $p_{-i}$ . The best response correspondences satisfy

$$BR_i(p_{-i}) = \operatorname{argmax}_{p_i} (p_i - \bar{V}(p_{-i}))D(p_i, p_{-i}).$$

This will be monotone increasing if the function on the RHS has increasing differences in  $p_i$  and  $p_{-i}$ . Writing  $\tilde{\pi}(p_i, p_{-i})$  for the function and differentiating twice we see

$$\frac{\partial^2}{\partial p_i \partial p_{-i}} \tilde{\pi}(p_i, p_{-i}) = \frac{\partial^2}{\partial p_i \partial p_{-i}} ((p_i - c)D(p_i, p_{-i}))|_{c=\bar{V}(p_{-i})} - \frac{\partial \bar{V}}{\partial p_{-i}} \frac{\partial D}{\partial p_i}.$$

The first term on the right is nonnegative by the assumption about the static profit function because we only need to consider prices above  $\bar{V}(p_{-i})$  (because demand is a probability and hence less than one). The second is positive because firm  $i$ 's demand is decreasing in  $p_i$  and the value function are increasing in  $p_{-i}$ . As in Milgrom and Roberts (1990), this also suffices to guarantee equilibrium existence. QED

Remarks:

1. The first-order condition for the equilibrium in the full information oligopoly model is similar to that for the monopoly price in the monopoly model:

$$rp^* \frac{\partial D_i}{\partial p_i}(p^*, p^*) + rD_i(p^*, p^*) + \gamma_0 D_i(p^*, p^*)^2 = 0.$$

2. As in the monopoly model, equilibrium prices in the full information oligopoly model are increasing in the arrival rate  $\gamma_0$ . Each individual best response is increasing in  $\gamma_0$  by the same argument as in the monopoly case. And then the comparison of equilibria follows as in Milgrom and Roberts (1990). The static oligopoly model corresponds to  $\gamma_0 = 0$ , so this implies that prices in dynamic oligopoly model are higher than those in the static model.
3. A more precise statement of the previous remark on comparative statics is that the set of Nash equilibrium prices increases in  $\gamma_0$  in the strong set order. This is relevant because the dynamic oligopoly model may have multiple equilibrium even when the static model has a unique Nash equilibrium. For example, in a duopoly model with  $D_i(p_1, p_2) = \frac{1}{9}(1 - p_i + \frac{3}{2}p_{-i})$  the static ( $\gamma_0 = 0$ ) model has  $p^* = 2$  as its unique symmetric PSNE, whereas the dynamic model with  $\gamma_0/r = 1$  has both  $p^* = 4$  and  $p^* = 10$  as symmetric PSNE. Intuitively, the dynamic effect creates an additional complementarity between the firms' prices: when firm 2's price increases, firm 1's opportunity cost of selling the good increases, which provides an additional motivation for increasing  $p_1$ .

4. Although it is common to assume that demand is such that  $(p - c)D(p_i, p_{-i})$  has increasing differences, it is implausible that the assumption would hold at all price levels. For example, the assumption is globally satisfied in the linear demand case  $D_i(p_i, p_{-i}) = 1 - p_i + ap_{-i}$ , but assuming that this formula holds everywhere involves assuming that demand is negative for some prices.<sup>4</sup> In such static models it is common to modify the demand function in some cases, e.g. assuming demand is zero whenever the formula gives a negative answer. The modifications only affect cases that are unimportant so the equilibrium set is unchanged and best responses remain upward sloping. Similar modifications should also typically produce a more plausible dynamic oligopoly model without affecting the equilibrium or the best response functions. But it should be noted that the modified models will not globally have the increasing differences property.

In practice, we know that there is a great deal of price dispersion in online used book prices. The most common approach to explain such dispersion in the IO theory literature is to assume that some consumers are not fully informed about prices.<sup>5</sup> A simple way to incorporate a similar mechanism in the above framework is to consider a hybrid of the monopoly and full-information oligopoly models above along the lines of the gatekeeper model of Baye and Morgan (2001). Assume that there are  $N + 1$  populations of consumers. Assume there is a flow rate of arrival  $\gamma_0$  of shoppers who visit all  $N$  firms. And for each  $i \in \{1, 2, \dots, N\}$  assume there is a flow rate of arrival  $\gamma_i$  of nonshoppers who visit only firm  $i$ . Assume that nonshoppers again buy from firm  $i$  with probability  $D^m(p_i) \equiv 1 - F(p_i)$  as in the monopoly model. Assume that shoppers buy from firm  $i$  with probability  $D(p_i, p_{-i})$  as in the full information oligopoly model.

Again, we assume each firm that makes a sale is immediately replaced by an identical entrant. Expected firm profits can then be calculated just as in the monopoly model:

$$\pi_i(p_i, p_{-i}) = \frac{p_i(\gamma_i D^m(p_i) + \gamma_0 D(p_i, p_{-i}))}{r + \gamma_i D^m(p_i) + \gamma_0 D(p_i, p_{-i})}$$

For the reason noted in the final remark after Proposition 4 this objective function would not be expected to satisfy increasing differences at all prices. And here the departures are consequential: the model will not have a pure strategy Nash equilibrium for some

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<sup>4</sup>Prices for which demand is greater than one are also inconvenient for our interpretation of demand as a probability of purchase, but this can often be dealt with by scaling demand down by a constant and increasing all arrival rates by the same constant.

<sup>5</sup>Among the classic papers in this literature are Salop and Stiglitz (1977), Reinganum (1979), Varian (1980), Burdett and Judd (1983), Stahl (1989).

parameter values. Intuitively, if the oligopoly demand function is very price sensitive and two firms have nearly identical  $\gamma_i$ , then there cannot be an equilibrium where both firms set nearly identical high prices because each would then like to undercut the other, and there also cannot be an equilibrium with nearly identical low prices because the firms would then gain from jumping up to the monopoly price for their nonshopper customers. For other parameters, however, there will be a pure strategy equilibrium in which firms with more nonshoppers set a higher price. This will occur when the oligopoly demand is less price sensitive, the shopper population is relatively small, and/or when arrival rates  $\gamma_i$  of nonshoppers are farther apart.

When a pure strategy Nash equilibrium exists the equilibrium prices  $p_i^*$  will satisfy the first-order conditions which can be written as:

$$\begin{aligned}
0 = & \quad rp_i^* \gamma_i D^{m'}(p_i^*) + r \gamma_i D^m(p_i^*) + \gamma_i^2 D^m(p_i^*)^2 \\
& + rp_i^* \gamma_0 \frac{\partial D}{\partial p_i}(p_i^*, p_{-i}^*) + r \gamma_0 D(p_i^*, p_{-i}^*) + \gamma_0^2 D(p_i^*, p_{-i}^*)^2 \\
& + 2\gamma_0 \gamma_i D^m(p_i^*) D(p_i^*, p_{-i}^*).
\end{aligned}$$

Note that the first line of this expression is  $\gamma_i$  times the expression from the monopoly first-order condition. If the monopoly demand function is single peaked, it is positive for  $p < p^m$  and negative for  $p > p^m$ . The second line of the FOC is  $\gamma_0$  times the first-order condition from the oligopoly model in which all consumers are shoppers. When the shoppers-only oligopoly game has single-peaked profit functions and increasing best responses, this term will be positive for the player  $i$  setting the lowest price  $p_i$  if  $p_i$  is less than the lowest equilibrium price of the full-information oligopoly game. The third term is everywhere positive. Hence, when the monopoly price  $p^m$  is above the equilibrium price in the shoppers-only oligopoly model, all solutions to this  $N + 1$  population model will have firms setting prices above the shoppers-only oligopoly level.

Roughly, one can think of the solution as being that firms with  $\gamma_i$  large relative to  $\gamma_0$  will set prices close to  $p^m(\gamma_i)$ .<sup>6</sup> Meanwhile, firms with  $\gamma_i$  small will set prices somewhat above shoppers-only oligopoly level both because of the third term in the FOC and because some of their rivals are mostly ignoring the shopper population and pricing close to  $p^m(\gamma_{-i})$ .

Note that the mechanism behind the price dispersion is somewhat different from that of Baye and Morgan's (2001) clearinghouse model. In Baye and Morgan's model price dispersion is a mixed strategy outcome made possible by the fact that there is a positive

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<sup>6</sup>Prices may be lower than  $p^m(\gamma_i)$  because of the oligopoly demand, but may also be higher because the shoppers also constitute an increase in the arrival rate.

probability that no other firms will be listed with the clearinghouse. We have modified the model in two ways to get dispersion as a pure strategy phenomenon: we add product differentiation in the shopper segment to eliminate the discontinuity in demand; and we add exogenous firm heterogeneity (in the consumer arrival rates) to make asymmetric pricing natural. Given that arrival rates can be thought of as creating different opportunity costs of selling the good, the model can be thought of as more akin to that of Reinganum (1979) which first generated dispersed price equilibria via heterogeneous costs.

Figure 1 illustrates how one might think of the difference between offline and online prices in light of this model. We think of prices as differing because of two effects. First, differences in the searcher population would be expected to make online *monopoly* prices higher than offline monopoly prices. (Selection into searching may result in the distribution of searchers' values being higher and the customer arrival rate may be greater.) Second, online prices will be reduced below the monopoly level as firms (especially those with low arrival rates of nonshoppers) compete to attract customers from the shopper population.

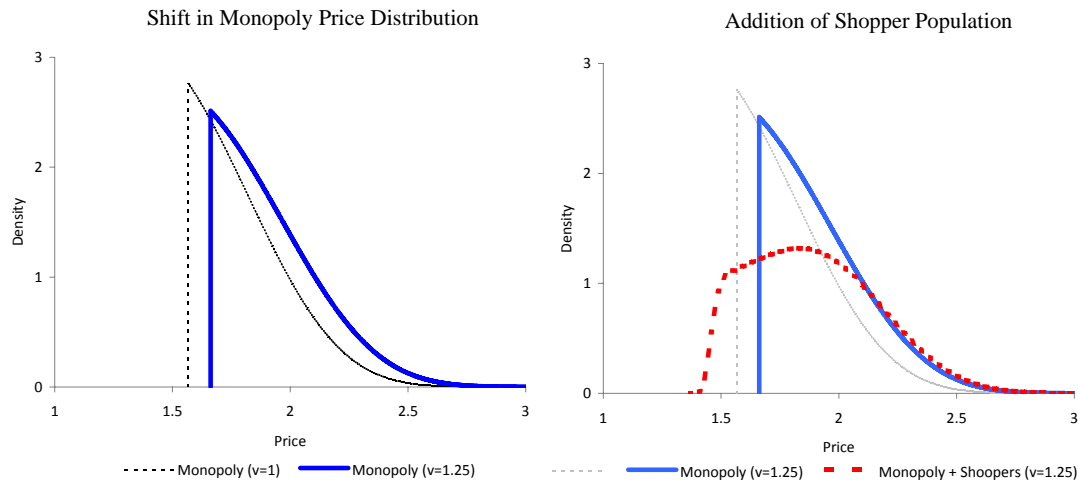


Figure 1: Numerical example: Effects of increasing valuations and adding shoppers

The left panel of Figure 1 illustrates the first effect. The thinner dashed line graphs the distribution of “offline” monopoly prices for one specification of the demand/arrival process. Each consumer  $j$  arriving at firm  $i$  is assumed to get utility  $1 - p_i + \epsilon_{ij}$  if he purchases from firm  $i$  and  $\epsilon_{0j}$  if he does not purchase, where the  $\epsilon_{kj}$  are independent type 1 extreme value random variables. The heterogeneous arrival rates  $\gamma_i$ , which lead firms to set different prices, are assumed to be exponentially distributed with mean 1. The thicker solid line line is the distribution of monopoly prices that results if we shift the distribution

of consumer valuations upward: we assume the utility of purchasing is now  $1.25 - p_i + \epsilon_{ij}$ . We think of this as the “online” monopoly price distribution. The gap between the two distribution illustrates how the higher valuations in the online population would lead to higher prices if retailers retained their monopoly power.

The right panel illustrates the competitive effect. The thick solid line is the online-monopoly distribution from the left panel. The thick dashed line is the distribution of equilibrium prices in a nine-firm oligopoly model. Each firm in this model faces a nonshopper arrival process identical to the online-monopoly process. But in addition there is also a population of shoppers who arrive at Poisson rate  $\gamma_0 = 2$ , see the prices of all firms, and buy from the firm that provides the highest utility if this is greater than the utility of the outside good (with random utilities as in the online monopoly model.) Note that the oligopoly model ends up displaying more dispersion than the monopoly models. At the high end of the distribution we see that the firms with high nonsearcher arrival rates essentially ignore the shopper population. Indeed their prices are slightly higher than they would set in the online-monopoly model due to the extra shopper demand. At the opposite end of the distribution, prices are substantially below the online-monopoly level as firms with low nonshopper arrival rates compete more aggressively for shoppers. Here the competition effect is sufficiently powerful so that the “online” oligopoly distribution has more low prices than even the “offline” monopoly distribution (the light gray line), but this lower tail comparison is parameter dependent: when the competitive effects dominate the online price distribution will feature more low prices; and when searcher population effect dominates there will be more low prices offline.

### 3 Data

Our dataset construction began with a sample of books found at physical used book stores in the spring and summer of 2009. One of the authors and a research assistant visited several physical used book stores in the Boston area, one store in Atlanta, and one store in Lebanon, Indiana, and recorded information on a quasi-randomly selected set of titles. The information recorded was title, author, condition, type of binding, and the presence of any special attribute, such as author’s signature.

We then collected online prices and shipping charges for the same set of titles from [www.AbeBooks.com](http://www.AbeBooks.com) at three points in time: first in the fall of 2009, then in November of 2012, and again in January of 2013.<sup>7</sup> Abebooks’ default sort in on the shipping-inclusive

<sup>7</sup>The latter two data collections were primarily conducted on November 3, 2012 and January 5, 2013,

price, but there is heterogeneity in how sellers use shipping charges – some sellers offer free shipping, others have shipping fees in line with costs, and others have very high shipping fees – so in most of our analyses we will use a price variable defined as listed price plus shipping charges minus two dollars designed to reflect the money received by the seller from the sale (with shipping minus \$2 being a rough estimate of the excess of the shipping fees over actual shipping costs). The online collection was restricted to books with the same type of binding, but includes books in a variety of conditions. We collected information on the condition of each online copy and control for condition differences in some analyses. For most of the titles the online data include the complete set of listings on [www.AbeBooks.com](http://www.AbeBooks.com).<sup>8</sup> But for some titles with a large number of listings we only collected a subset of the listings. In the 2009 data collection we collected every  $n$ th listing if a title had more than 100 listings, with  $n$  chosen so that the number of listings collected would be at least 50. In the 2012 and 2013 collections we collected all listings if a title had at most 300 listings, but otherwise just collected the 50 listings with the lowest shipping-inclusive prices plus every 5th or 10th listing.

Most of our analyses will be run on the set of 335 titles that satisfy three conditions: the copy found in a physical bookstore was not a signed copy, at least one online listing was found in 2009, and at least one online listing was found in November of 2012.

The quasi-random set of books selected was influenced by a desire to have enough books of different types to make it feasible to explore how online and offline prices varied with the type of book. First, we intentionally oversampled books of “local interest.” We defined this category to include histories of a local area, novels set in the local area, and books by authors with local reputations. For example, this category included Celestine Sibley’s short story collection *Christmas in Georgia*, the guidebook *Mountain Flowers of New England*, and Indiana native Booth Tarkington’s novel *The Turmoil*. Most local interest books were selected by oversampling from shelves in the bookstores labeled as having books of local interest and hence are of interest to the bookstore’s location, but that it not always the case: some are what we call displaced local interest books which were randomly swept up in our general collection but are of local interest to some other location. Prices for these displaced books are potentially informative, so for all local interest books we constructed a measure of distance between the locus of interest and the particular bookstore. For example, if a history of the State of Maine were being sold in a Cambridge, Massachusetts bookstore, respectively.

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<sup>8</sup>In 2012 new copies of some formerly out-of-print books have again become available via print-on-demand technologies. We remove any listings for new print-on-demand copies from our 2012 and 2013 data.



the distance measure would take on the value of the number of miles between Cambridge and Maine’s most populous city, Portland.

Second, we collected data on a number of “popular” books. We define this subsample formally in terms of the number of copies of the book we found in our 2009 online search: we classify a book as popular if we found more than 50 copies online in 2009. Some examples of popular books in our sample are Jeff Smith’s cookbook *The Frugal Gourmet*, Ron Chernow’s 2004 best-selling biography *Alexander Hamilton*, and Michael Dibdin’s detective novel *Dead Lagoon*. Informally, we think of the popular subsample as a set of common books for which there is unlikely to be much of an upper tail of the consumer valuation distribution for two reasons: many can be purchased new in paperback on Amazon, which puts an upper bound on valuations<sup>9</sup>; and many potential consumers may be happy to substitute to some other popular book in the same category.

Table 1 reports summary statistics for title-level variables. The average offline price (in 2009) for the books in our sample is \$11.29. One half of the titles were deemed to be of local interest to some location. The mean of the *Close* variable indicates that in a little more than three quarters the cases the location of interest is within 100 miles of the bookstore location. About 23% of titles are classified as *Popular*.

The table also provide some summary statistics on the online price distributions. In the contemporaneous 2009 data the median online price for a title is on average is well above the offline price we had found: the average across titles of the median online price is \$17.80 or a little more than 50% above the average offline price. But there is also a great deal of within-title price dispersion. The average minimum online price is just \$9.27 and range between the maximum and minimum online price averages almost \$100. To give more of a sense of how online and offline prices compare the *PlaceinDist* variables report where in the empirical CDF of online prices the offline price would lie. The average of 0.26 says that on average it would be in the 26th percentile of the online distribution. Median online prices have changed much between 2009 and 2012. There is, however, a moderate but noticeable decline in the lowest available online price and a substantial increase in the online price range.

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<sup>9</sup>Of the books mentioned above, Chernow and Dibdin’s books are in print in paperback, whereas *The Frugal Gourmet* is not.

Variable	Mean	St Dev	Min	Max
<i>OfflinePrice09</i>	11.29	21.11	1.00	250.00
<i>LocalInterest</i>	0.50	0.50	0	1
<i>Close</i>	0.74	0.44	0	1
<i>Popular</i>	0.23	0.41	0	1
<i>MinOnlinePrice09</i>	9.27	22.84	1.89	351.50
<i>MedOnlinePrice09</i>	17.80	23.87	2.95	351.50
<i>MaxOnlinePrice09</i>	108.16	488.38	5.00	8252
<i>PlaceinDist09</i>	0.26	0.28	0	1
<i>NumList09(Max50)</i>	23.55	17.72	1	50
<i>MinOnlinePrice12</i>	8.63	21.34	1.01	302.00
<i>MedOnlinePrice12</i>	17.67	25.46	1.95	302.00
<i>MaxOnlinePrice12</i>	184.23	1059.92	2.05	17,498
<i>NumList12(Max50)</i>	23.53	18.31	1	50

Note: Most variables each have 335 observations. *Close* is defined only for the 168 local interest titles.

Table 1: Summary statistics

## 4 Used Book Prices

In this section we present evidence on online and offline used book prices. The first three subsections compare offline and online prices from 2009. Our most basic finding is that online prices are on average higher than offline prices. The shapes of the distributions are consistent with our model’s prediction that “increased search” and “competition” effects will have different impacts at the high and low ends of the price distribution. We then examine how online prices have changed between 2009 and 2013 as Amazon has (presumably) come to play a much more important role. Finally, we use our data on listing withdrawals to present some evidence on demand.

### 4.1 Offline and online prices in 2009: standard titles

As we noted in the introduction one of the most basic facts about online and offline used book prices is that online prices are on average higher. In this section we note that this fact is particularly striking for “standard” titles, which we define to be titles that have no particular local interest and are not offered by sufficiently many merchants to meet our threshold for being deemed “popular.”

We have 100 standard titles in our sample. Most are out of print. The mean number of 2009 online listings for these books was 15.3. One very simple way to illustrate the difference between offline and online prices is to compare average prices. The average offline price for the standard titles in our sample is \$4.27. The average across titles of the average online

price is \$17.74.

Figure 2 provides a more detailed look at online vs. offline prices. The left panel contains the distribution of prices at which we found these titles at offline bookstores. Twenty of the books sell for less than \$2.50. Another 74 are between \$2.50 and \$7.50. There is essentially no upper tail: only 6 of the 100 books are priced at \$7.50 or more with the highest being just \$20.

The right panel presents a comparable histogram of online prices.<sup>10</sup> The upper tail of the online distribution appears is dramatically thicker: on average 27% of the listings are priced at \$20 or higher including 6% at \$50 or more.<sup>11</sup>

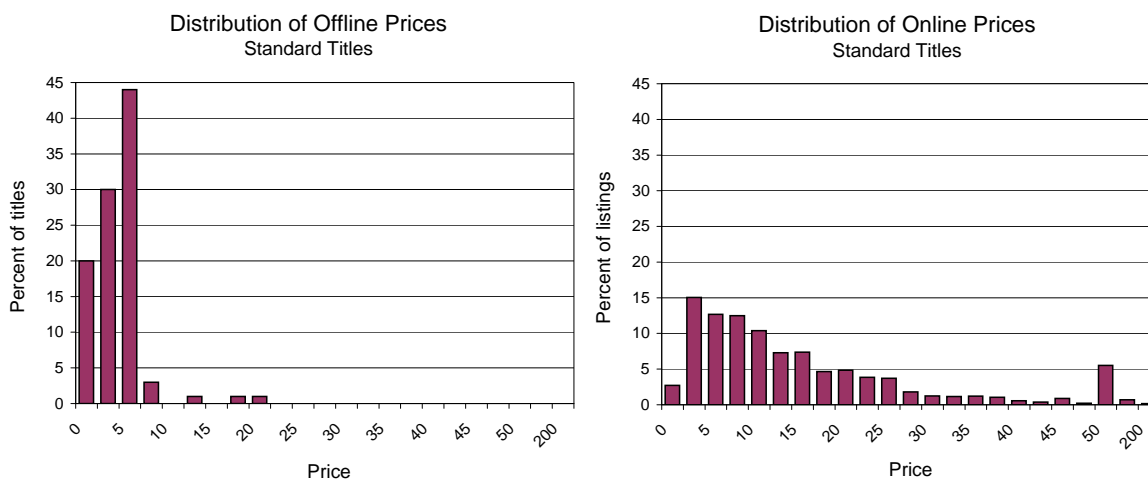


Figure 2: Offline and online prices for standard titles in 2009

The contrast between the upper tails is consistent with our model’s prediction for how offline and online prices would compare if online consumers arrive at a higher rate and/or have higher valuations. At the low end of price distribution we do not see much evidence of a thick lower tail that might be produced by a strong competition effect.

To provide a clearer picture of the lower-tail comparison the left panel of figure 3 presents a histogram of the *PlaceInDist* variable. (Recall that this variable is defined as the fraction of online prices that are below the offline price for each title.) The most striking feature is a very large mass point at 0: for 54% of the titles the price at which the book was found in a physical bookstore was lower than every single online price! (This occurs despite the fact

<sup>10</sup>To keep the sample composition the same the figure presents an unweighted average across titles of histograms of the prices at which each title is offered.

<sup>11</sup>To show the full extent of the distribution we have added three extra categories – \$50-\$100, \$100-\$200, and over \$200 – at the right side of the histogram. The apparent bump in the distribution is a consequence of the different scaling.

that we had found an average of 15.3 online prices for the standard titles.) Beyond this the pattern looks roughly like another quarter of offline books are offered at a price around the 20th percentile of the online price distribution and the remaining 20% spread fairly evenly over the the upper 70 percentiles of the online distribution. Overall, the patterns suggests that the increased search rate/higher valuation effect is much more important than the competition effect for these titles.

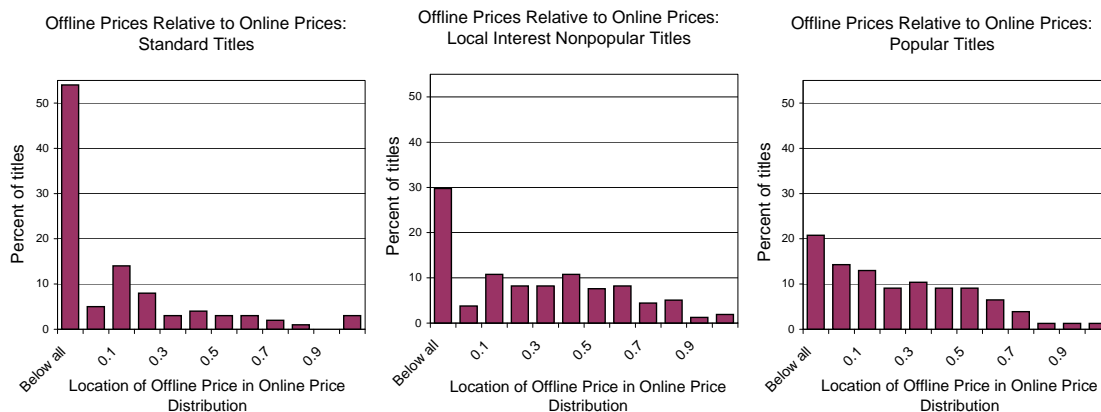


Figure 3: Offline prices relative to online prices for the same title

## 4.2 Offline and online prices for local interest titles in 2009

We now turn our attention to local interest books and note that there are substantial differences in price distributions and the differences seem consistent with a match-quality model. Our presumption on match quality was that the incremental benefits of selling used books online may be much less important for “local interest” books. Indeed, one could imagine that the highest-value match for a titles like *The Mount Vernon Street Warrens: A Boston Story, 1860-1910, New England Rediscovered* (a collection of photographs), and *Boston Catholics: A History of the Church and Its People* might be a tourist who has just walked into a Boston used bookstore looking for something to read that evening. Consistent with this presumption we will show here that offline prices for local interest titles look more like the online prices we saw in the previous section.

Our sample contains 158 titles which we classified as being of “local interest” and which did not meet our threshold for being labeled as “popular.” The mean offline price for these titles is \$18.86. Average online prices are again higher, but the difference is much smaller: the mean across titles of the mean online price is \$28.40.

Figure 4 provides more details on the offline and online price distributions. The left

panel reveals that the distribution of offline prices for local interest titles shares some features with the distribution of online prices for standard titles: the largest number of prices fall in the \$7.50-\$9.99 bin; and there is a substantial upper tail of prices including 26 books with prices from \$20 to \$49.99, and 9 books with prices above \$50. The distribution of online prices for these titles does again appear to have a thicker upper tail, but the online-offline difference is not nearly as large. The online distribution also has a slightly higher percentage of listings at prices below \$5, but there is nothing to suggest that the competition effect is very strong.

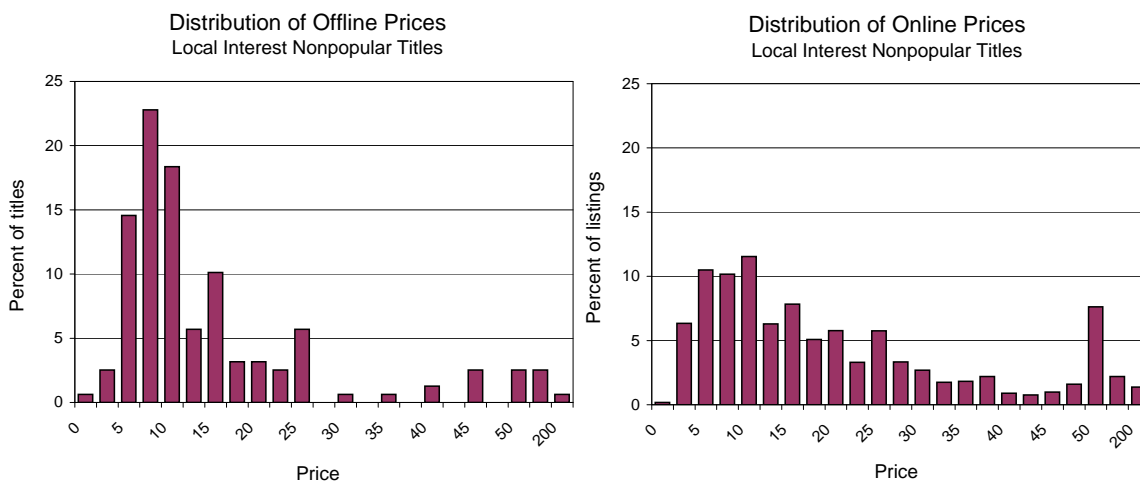


Figure 4: Offline and online prices for nonpopular local interest titles in 2009

The middle panel of figure 3 included a histogram showing where in the online price distribution for each title the offline copy falls. Here we see that about 30% of the offline copies are cheaper than any online copy. For the other 70% of titles the offline prices look a lot like random draws from the online distribution although the highest prices are a bit underrepresented.

### 4.3 Offline and online prices for popular titles in 2009

We now turn to the final subsample: popular books. Again, we will note that online-offline differences and comparisons to the earlier data on standard title generally appear consistent with a match-quality model.

Recall that we labeled 77 books as “popular” on the basis of there being at least 50 copies offered through AbeBooks. Our prior was that two differences between these books and standard titles would be most salient. First, the greater number of searchers (and sellers) might make the competition effect more important. Second, the distribution of

consumer valuations might have less of an upper tail because consumers may be quite willing to switch from one detective novel and also sometimes have the option of simply buying a new copy of the book in paperback. Popular books prices are mostly similar to standard book prices at offline bookstores: the mean price is \$4.89. The left panel of figure 5 shows that 14% of these books are selling for below \$2.50 with the vast majority (70%) being between \$2.50-\$7.49. None is priced above \$18.

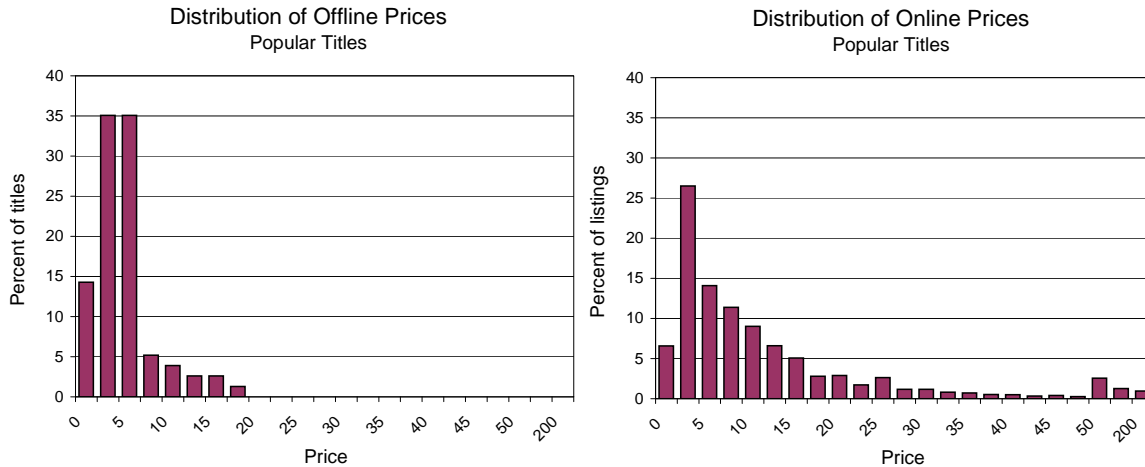


Figure 5: Offline and online prices for standard titles in 2009

Our most basic finding about online prices being higher than offline prices is again present. The mean across titles of the mean of the online prices for each title is once again much higher at \$21.23. Although the prediction that the online-offline gap should be smaller for popular titles does not hold up in this comparison of means, the mean for popular titles is heavily influenced by a few outliers and the online-offline gap would substantially smaller for popular titles if we drop the extremely high-priced listings from both subsamples. For example, dropping prices of \$600 and above removes sixteen listings for popular titles and no listings for standard titles. The average of the mean online price for a popular title would then drop to \$10.85 whereas the comparable figure for a standard title would remain at \$17.74.

The price histograms again illustrate that the online data again have a thicker upper tail than the offline data. This thickness is somewhat less pronounced here than it was for standard titles: on average 18% of listings are priced above \$20 whereas the comparable figure for standard titles was 27%. One other difference between popular and standard titles is that is that the online distribution for popular books has a larger concentration of low prices: about one-third of the listings are prices below \$5. The more pronounced lower

tail is consistent with the hypothesis that the competition effect may be more powerful for these titles.

The right panel of figure 3 shows that for about 20% of titles the offline price we found was below all online prices. This is a strikingly large number given that each title had at least 50 online listings. Meanwhile the remaining prices look like they are mostly drawn from the bottom two-thirds of the online price distribution for the corresponding title. A comparison of the left and right panels provides another sense of the degree to which the online-offline gap is narrower here than it was for standard titles.

#### 4.4 Regression analysis of offline-online price differences

In the preceding sections we used a set of figures to illustrate the online-offline price gap for standard, popular, and local interest books and noted apparent differences across the different groups of books. In this section we verify the significance of some of these patterns by regressing the *PlaceInDist* variable on book characteristics.

The first column of Table 2 presents coefficient estimates from an OLS regression. The second column presents estimates from a Tobit regression which treats values of zero and one as censored observations. We noted earlier that the distribution of consumer valuations for “popular” books might be thinner because potential purchasers can buy many of these books new in paperback and/or substitute to similar books. The effect of an increase in the consumer arrival rate is greater when the distribution of valuations has a thick upper tail, so the arrival effect that bolsters online prices should be smaller for popular books. The coefficient estimate of 0.11 in the first column indicates that offline prices are indeed higher in the online price distribution – by 11 percentiles on average – for the popular books. The estimate from the Tobit model is larger at 0.21 and even more highly significant.

Variable	Dependent variable: <i>PlaceInDist</i>			
	OLS		Tobit	
	Coef.	SE	Coef.	SE
<i>Popular</i>	0.11	(0.04)	0.21	(0.06)
<i>LocalInt</i> × <i>Close</i>	0.17	(0.04)	0.27	(0.06)
<i>LocalInt</i> × <i>Far</i>	0.08	(0.05)	0.17	(0.08)
Constant	0.16	(0.03)	-0.01	(0.04)
Num. Obs.	335		335	
$R^2$ (or pseudo $R^2$ )	0.06		0.06	

Table 2: Variation in offline-online prices with book characteristics

Local interest books located in physical bookstores close to their area of interest may

have both a relatively high arrival rate of interested consumers and a relatively high distribution of consumer valuations. Again, this should lead to relatively high offline prices. The 0.17 coefficient estimate on the *LocalInterest*  $\times$  *Close* variable indicates that this is true for local interest books in used bookstores within 100 miles of the location of interest. The tobit estimate, 0.27, is again larger and more highly significant.

One would not expect misplaced local interest books to benefit in the same way. Here, the regression results are less in line with the model. In the OLS estimation the coefficient on *LocalInterest*  $\times$  *Far* is about half of the coefficient on *LocalInterest*  $\times$  *Close*, and the standard error is such that we can neither reject that the effect is zero, nor that it is as large as that for local interest books sold close to their area of interest. In the Tobit model, however, the estimate a bit more than 60% of the size of the estimated coefficient on *LocalInterest*  $\times$  *Close* and is significant at the 5% level. This suggests that a portion of the differences between local interest and other books noted earlier may be due to unobserved book characteristics.

#### 4.5 Within-title price distributions

The figures in the previous section illustrated how price have changed over the past few years by presenting averages of the price histograms of hundreds of distinct titles. The averaging illuminates some general trends, but washes out information on the within-title variation in prices. In this section, we illustrate these changes by presenting prices distributions for three “typical” titles.

To identify “typical” price distributions we performed a cluster analysis which divides the titles into three groups in such a way so that a set of characteristics of each title’s price distribution is closer to the mean for its group than to the mean for any other group. For characteristics we used the log of the lowest, 10th, 20th, ..., 90th, and maximum prices and the ratios of the 10th, 20th, and 30th percentile prices to the minimum price.<sup>12</sup> The cluster analysis divided the titles into three groups containing 125, 109, and 69 titles. We then chose a typical element of each of these clusters by choosing the title whose distribution was closest to the cluster mean in the set of characteristics on which the clustering is based.

The left panel of figure 6 is a histogram of prices for the typical title in the largest cluster, *An Introduction to Massachusetts Birds*, a 32 page paperback published by the

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<sup>12</sup>The estimation uses Stata’s “cluster kmeans” command which is a random algorithm not a deterministic one. The number of elements in each cluster varied somewhat on different runs, but the identity of the “typical” element of each cluster appears to be fairly stable. We included the ratios in addition to the percentiles to increase the focus of the clustering on the shape of the lower tail. Only titles with at least four online prices were included.



Massachusetts Audubon Society in 1975 that has long been out of print. There are ten online listings for this title. Most are fairly close to the lowest price – the distribution starts \$3.50, \$4, \$5, \$6, and \$6.75 – but there is not a huge spike at the lower end. The upper tail is fairly thin with a single listing at \$22.70 being more than twice as high as the second-highest price of \$11.30.

The center panel of figure 6 is a histogram of prices for the typical title in the second cluster, the hardcover version of *Alexander Hamilton* by Ron Chernow.<sup>13</sup> For this title there is fairly tight group of six listings around the lowest price: the first bin in the figure consists of copies offered at \$2.95, \$2.95, \$4.14, \$4.24, \$4.24, and \$4.48. But beyond this the distribution is more spread out with the largest number of offers falling in the \$10 to \$12.49 bin. There is also an upper tail of prices including 6 between \$20 and \$30 and 4 between \$30 and \$45. There is some correlation between price and condition: the 4 most expensive copies are all in “fine” or “as new” condition. But most of the upper tail does not seem to be attributable to differences in the conditions of the books, e.g. the six copies between \$20 and \$30 include 2 copies in “poor” condition, 2 in “very good”, 1 in “fine”, and 1 in “as new”, whereas the five of the six copies offered at less than \$5 are “very good” copies.

The right panel of figure 6 presents a histogram for a typical title in our third cluster, *The Reign of George III, 1760 - 1815*, a hardcover first published the by the Oxford University Press in 1960 as part of its Oxford History of England series.<sup>14</sup> Here again we see a cluster of listings close to the lowest price: one in very good condition at \$10.99, a good copy at \$12.03, and two poor copies at \$12.09. But the lowest price is not nearly as low as it is for the typical books in the other clusters and the rest of the distribution is also more spread out. There is a clear correlation between price and condition – the eight most expensive listings are all in very good condition or better. None are signed copies, but some might be distinguished by other unobserved characteristics such as being a first edition or having an intact dust jacket.

The fact that the price distributions for typical titles in the more spread-out clusters still include a small group of sellers with prices very close to the lowest price suggests that some firms are competing to attract a segment of shoppers. The variation in condition

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<sup>13</sup>This book was a best-seller when released in 2004 and a paperback version was released in 2005. Both are still in print with list prices of \$35 and \$20, respectively.

<sup>14</sup>In 2013 it is again available new – presumably via a print-on-demand technology – at a very high list price of \$175, but is currently offered by Amazon.com and BN.com at just \$45. The rise of print-on-demand is a recent phenomenon and we assume few, if any, of the books in our sample were available via print-on-demand in 2009.

among the low-priced listings suggests that book condition may not be very important to these consumers. The upper tail has some relation to condition, but mostly appears to be another example of price dispersion on the Internet for fairly homogeneous products.

Although the three typical books we’ve examined here are of different types – the first is a nonpopular local interest book, the second is a popular book, and the third is a standard book – the clusters are not closely aligned with title types. For example, cluster 1 includes 42 standard titles, 41 nonpopular local interest titles, and 42 popular titles.

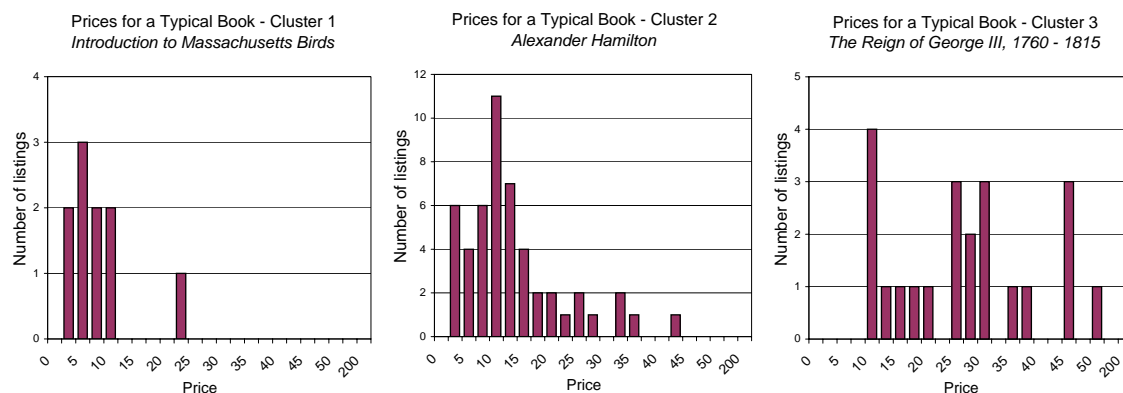


Figure 6: Online prices for three “typical” titles in 2009

#### 4.6 Online prices: 2009 and 2012

Amazon’s integration of AbeBooks listings may have substantially increased the number of shoppers who viewed them. In this section, we compare online prices from 2009 and 2012 and note changes in the price distribution in line with the predicted effects of such an increase.

Recall that in our theory section (e.g. Figure 1) we noted that an increase in the proportion of shoppers will have an impact that is different in different parts of the price distribution. At the lower end it pulls down prices and may lead several firms to price below the former lower bound of the price distribution. But in the upper part of the distribution it should have almost no impact (as firms setting high prices are mostly ignoring the shopper segment). The upper left panel of figure 7 illustrates how prices of standard titles changed between 2009 and 2012. The gray histogram is the histogram of 2009 prices we saw previously in figure 2. The outlined bars superimposed on top of this distribution are a corresponding histogram of prices from November of 2012. At the low end of the distribution we see a striking change in the distribution of the predicted type: there is a

dramatic increase in the proportion of listings below \$2.50. Meanwhile, the upper tail of the distribution appears not to have changed much. The other two histograms in the figure illustrate the changes in the price distributions for local interest and popular books. In each case we again see an increase in the proportion of listings priced below \$2.50. The absolute increase is a bit smaller in the local interest case, although it is large in percentage terms given that almost no local interest books were listed at such a low price in 2009. In both cases we also again see little change in the upper part of the distribution. This is particularly true for the popular histogram in which almost all of the growth in prices below \$2.50 seems to come out of the \$2.50-to-\$5 bin. We conclude that the pattern of the lower tail having been pulled down while the upper part of the distribution changes less is fairly consistent across the different sets of titles. This is very much in line with what we would expect if Amazon’s integration of used book listings increased the size of the shopper population.

## 4.7 Online demand

In this section we provide some evidence on demand by looking at whether listings present in November of 2012 were removed by the merchants by the time of our January 2013 data collection.

In 2012-2013 large professional sellers play a big role on AbeBooks.com. The majority of the 2067 online retailers in our November 2012 dataset have listings for just one or two of our 318 titles, but these small-scale sellers only account for 15% of the total listings.<sup>15</sup> At the other extreme, 45 firms we’ll refer to as “power” sellers have listings for more than 25 of the titles including 16 firms that have listings for at more than 50. The power sellers play a particularly big role at the top of Abebooks.com’s lists. In our November 2012 data, 55% of the titles have a power seller in the first position and the proportion of power sellers remains above 30% in each of the top 25 slots.

Although we do not have any sales data, we are able to see a proxy: whether a listing in our November 2012 sample is removed by January of 2013.<sup>16</sup> We presume that most books that disappear do so either because the book was sold (through Abebooks or otherwise)

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<sup>15</sup>These statistics are for only 318 of the millions of published titles so even sellers that appear to be small-scale merchants in our data may have many, many listings on Abebooks. We examine a smaller set of titles here than in previous sections because we omit very popular titles (those with more than 300 listings) for which we did not collect complete listings data.

<sup>16</sup>Listings do not have a permanent identifier, so what we observe more precisely is whether the seller no longer lists a copy of the same title in the same condition. Given this matching strategy we drop from this analysis all instances in which the same seller had multiple copies in a title-condition cell in November 2012, all print-on demand listings, all signed copies, and the very popular titles for which we did not collect all listings in our 2012 & 2013 data collections.

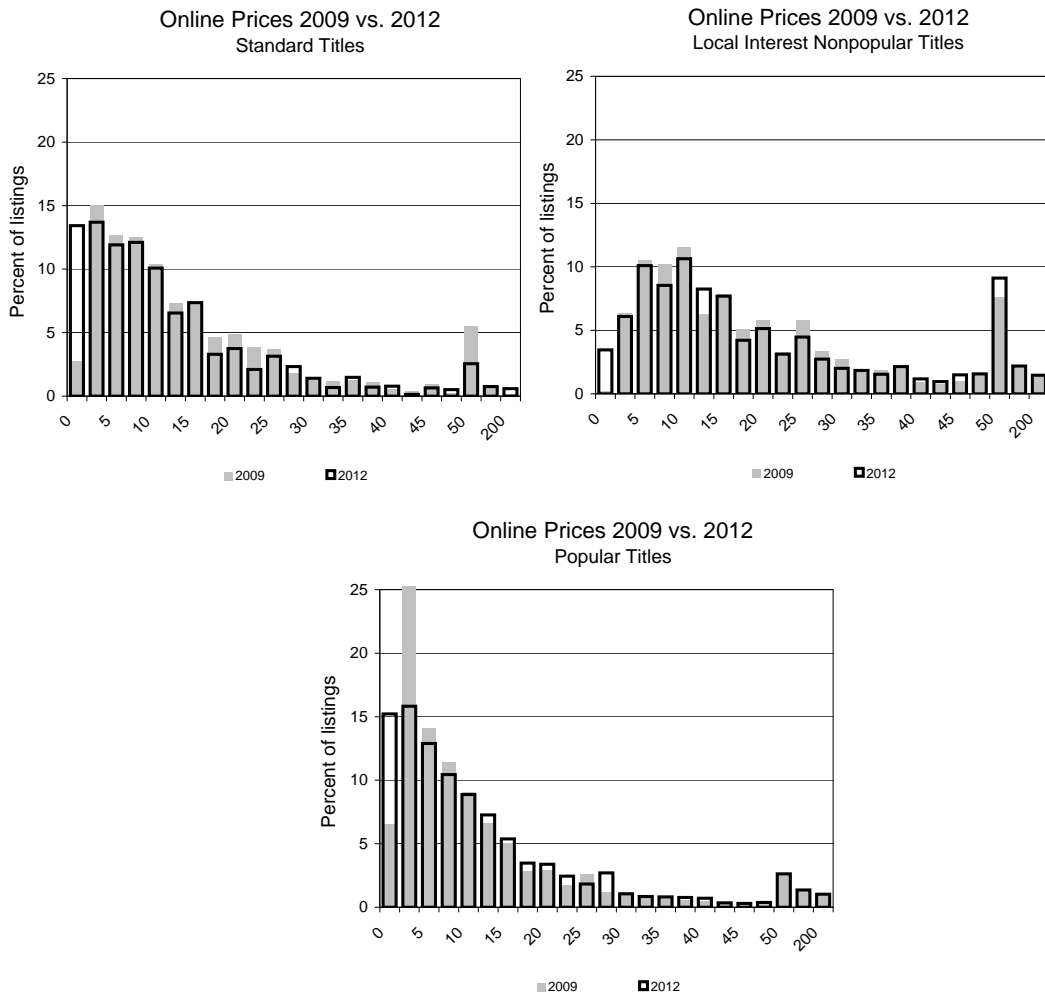


Figure 7: Comparison of 2009 and 2012 online prices

or because the seller decided to withdraw from listing on Abebooks. The latter is hard for us to detect when sellers have just one or two listings, but fortunately this is just a small fraction of listings, and sales rates are such that we can identify fairly well whether larger sellers exited simply looking whether all of their November 2012 listings have disappeared by January of 2013. For example, of the 203 sellers with exactly 3 listings in our November 2012 dataset, 168 have none of their copies disappear, 19 have one disappear, 2 have two disappear, and 14 have all three disappear.<sup>17</sup> Given that only 2 firms sold two of their three listings, we presume that all or almost all of the 14 firms that had all listings disappear left the Abebooks platform (or changed their name). We drop all listings by the 32 firms with three or more listings who have all of their listings disappear. Summary statistics indicate that our disappearance rates for very small scale sellers probably reflect a similar exit rate which we have not been able to clean out. Mean disappearance rates for listings by sellers with just one or two listings in our sample are 10% and 12%, whereas the disappearance rate for listings by sellers with three to ten listings is about 6%. Power sellers sell books at a substantially higher rate – over 30% of their listings disappear – but in part this reflects that they sell many popular books and set low prices.

We presume that listings that are very far down on Abebooks lists are unlikely to sell through the website, and hence restrict our statistical analyses to a dataset of listings that were among the 50 lowest-priced listings on Abebooks in 2012. This leaves a final estimation sample of 5282 listings for 318 titles.

Figure 8 presents histograms illustrating the relationship between listing-removal and order in which listings would appear when one sorts on shipping-inclusive price.<sup>18</sup> The left panel illustrating the relationship between listing-removal and item prices for standard titles. The x-axis gives the rank within the title of the shipping-inclusive price. The height of the bars indicate the average rate of disappearance for listings at that rank.<sup>19</sup> The figure suggests that sales rates are substantial for the lowest-price listings and that sales rates are quite price/rank sensitive. Listings in the top two positions disappear in the two month span about one-third of time. Listings in positions 3-5 disappear about 25% of the time. Disappearance rates fall to about 15% in the lower part of the top 10, and then appear to be 5-10% for titles in the second 10, although the rank-specific means are quite noisy by

<sup>17</sup>Similarly, 11 firms with 4 or 5 listings have all of their listings disappear, whereas only one firm with 4 or 5 listings has all but one listing disappear.

<sup>18</sup>This is the default ordering on Abebooks, but others are possible as well. Our orderings may not match what a consumer would have seen when prices (in dollars and cents) are identical.

<sup>19</sup>We have cut off the figures where the sample size falls below 25 because the estimates of the (small) disappearance probabilities become very noisy by that point. In this case, the figure presents data for ranks 1 through 21.

this point. Recall that the slope of this curve should be less than the causal effect of the price rank on demand. Disappearances reflect both sales through the search engine and outside of it, and firms would be expected to choose relatively high prices when they have a high outside sales.

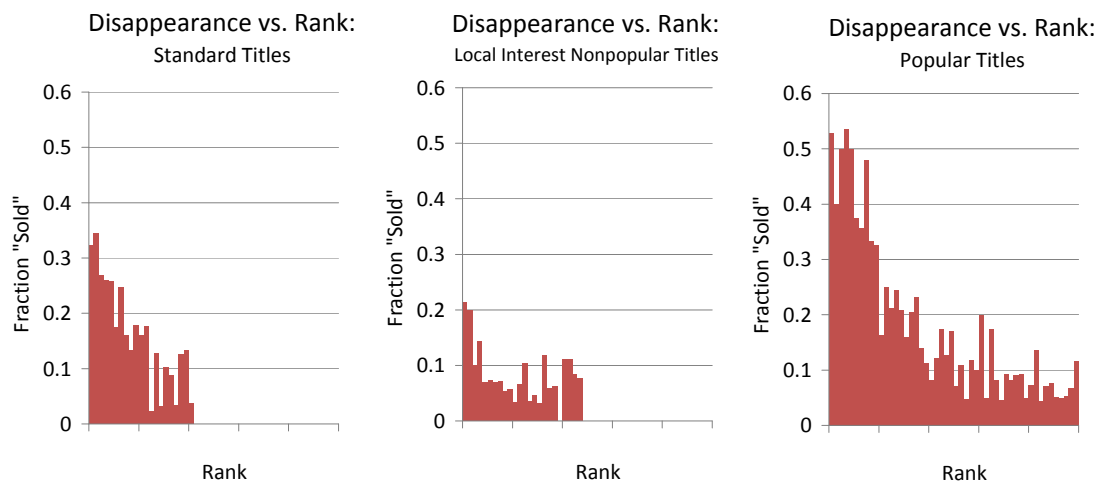


Figure 8: A demand proxy: removals of online price listings

The middle panel presents a similar histogram for nonpopular local interest titles. Sales rates are somewhat lower for these titles. Disappearance rates are about 20% at the top two ranks, about 10-15% at the next two ranks, and then fall to 5-10% in the lower part of the top 10. The right panel presents results for popular titles. Here, disappearance rates are substantially higher. They start at close to 50% for listings in the top 5 positions. Beyond this point they drop off fairly sharply: they are around 30-40% in ranks 6-10, a little over 20% in the next 10, and a little over 10% for listings with ranks in the 21-30 range. Sample sizes don't drop off as rapidly here, so we have extended this figure out through rank 50. The somewhat odd shape of the leftmost part of the graph – being roughly flat for the first few ranks and then dropping off rapidly – may reflect the difference between our ranks and what the typical consumer saw. We don't know how listings with identical prices were sorted by Abebooks and there also may be a great deal of churning in the price order among the top-ranked titles (which typically have prices differing by just a few cents).<sup>20</sup>

Table 3 presents statistical analyses that provide additional detail on the patterns. The first column presents estimates of a logit model in which the probability that a listing will disappear is a function of the listing's rank and condition. (It also includes two title-level

<sup>20</sup>Another potential bias is that disappearances could underestimate sales if a seller replaces a sold copy of a book with another copy in the same condition.

controls and one seller-level covariate, the number of distinct titles in our full dataset for which the seller has at least one listing.) The coefficient on  $\log(\text{Rank})$  is highly significant. Its magnitude implies that increasing  $\log(\text{Rank})$  by one unit, e.g. moving from *Rank* 1 to *Rank* 2.7 or *Rank* 2.7 to 7.3, is associated with a 58% decrease in the probability of disappearance. This suggests that demand is highly elastic when prices are tightly bunched. In the second column we include both the rank of the listing and the shipping-inclusive price. The two are fairly collinear, but nonetheless each is highly significant in this regression. The magnitude of the rank effect is somewhat smaller – increasing  $\log(\text{Rank})$  by one unit is now associated with a 39% decrease in the disappearance rate. But this is augmented by the (fairly modest) price effect – a 10% increase in price is associated with a 4.6% decrease in the disappearance rate.

The *Condition* variable is also significant in both versions. It indicates that a listing that is one condition better, e.g. from “good” to “very good” will have a about a 10% higher disappearance rate. The coefficient on  $\log(\text{Storetitles})$  is also significant, reflecting that power sellers appear to sell many more copies even after we control for rank/price differences and the title popularity. These specifications use just two controls for popularity: the number of listings for the title in the full dataset and the log of the lowest price at which the title is offered.

The third and fourth columns present estimates from models which instead use title fixed effects to control for differences across titles.<sup>21</sup> The estimated coefficients on the price effects are similar, with the point estimate on the price effect a little larger and those on the rank effect a little smaller.

The final three columns reestimate this model on three subsamples: standard, non-popular local interest, and popular titles. In the smaller samples it is harder to separately identify the price and rank effects and not all coefficients are significant. The disappearance-price rank relationship seems to be somewhat weaker and book condition appears to matter less for standard titles. Power sellers do better in all three samples, but the coefficient on  $\log(\text{Storetitles})$  is no longer significant in the local interest subsample.

## 5 A Structural Model of the Market

In the model we discussed earlier, online prices differ from offline prices for two offsetting reasons: increases in consumer arrival rates and distributions of valuations tend to increase online prices; and increased competition brings online prices down. The welfare effects

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<sup>21</sup>121 of the 318 titles in the previous regression are dropped because none or all of the listings disappear.

Variable	Dependent Variable: <i>Disappear</i>						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
<i>log(Rank)</i>	-0.67 (0.05)	-0.44 (0.06)	-0.77 (0.05)	-0.32 (0.09)	-0.10 (0.17)	-0.51 (0.21)	-0.27 (0.12)
<i>log(Price)</i>		-0.53 (0.10)		-0.92 (0.15)	-0.74 (0.23)	-0.55 (0.31)	-1.54 (0.25)
<i>Condition</i>	0.10 (0.04)	0.13 (0.04)	0.12 (0.04)	0.17 (0.04)	0.01 (0.07)	0.17 (0.10)	0.29 (0.07)
<i>log(StoreTitles)</i>	0.39 (0.04)	0.31 (0.04)	0.34 (0.04)	0.25 (0.04)	0.30 (0.08)	0.13 (0.09)	0.22 (0.07)
Constant	-2.90 (0.34)	-2.10 (0.37)					
<i>log(MinPrice)</i>	-0.40 (0.09)	0.02 (0.12)					
<i>log(TitleListings)</i>	0.43 (0.06)	0.25 (0.07)					
Title fixed effects	No	No	Yes	Yes	Yes	Yes	Yes
Titles included	All	All	All	All	Std.	Local	Popular
Number of obs.	5282	5282	4330	4330	1119	1137	2074
Pseudo R2	0.135	0.142	0.143	0.157	0.133	0.122	0.203

The table reports coefficient estimates and standard errors from logit regressions with an indicator for whether a listing was removed between November 3, 2012 and January 5, 2013 as the dependent variable. The sample includes the (up to 50) lowest priced listings for 318 titles.

Table 3: Logit estimates of the listing disappearance process



of online sales depend on the magnitudes of the underlying gross effects: the increase in consumer arrival rates; the increase in consumer valuations; the equilibrium delay before sales occur; etc. In this section we develop and estimate a structural model which includes all of these effects. We note that features of the model make it amenable to estimation via a simulated maximum likelihood. Our estimates indicate that customer arrival rates were substantially higher at online stores by 2009 and suggest that Internet sales led to substantial increases in both profits and consumer surplus.

## 5.1 A structural framework

In this section we discuss an empirical model closely related to that discussed in our theory section and note that aspects of the model facilitate estimation.

Consider a model similar to that of section 2 in which  $I + 1$  populations of consumers shop for book  $k$  at stores  $i = 1, 2, \dots, I$ . One of these is a population of shoppers who arrive at Poisson rate  $\gamma_{0k}$ . Shoppers observe all prices and purchase from firm  $i$  at the instant at which they arrive with probability  $D_k^o(p_{ik}, p_{-ik}; X_{ik}, \Lambda, \beta_{ik})$ , where  $X_{ik}$  is a vector of characteristics of store  $i$  and/or title  $k$ ,  $\Lambda$  is a vector of parameters to be estimated and  $\beta_{ik}$  is a vector of unobserved random coefficients. Assume that the arrival rate  $\gamma_{0k}$  and random coefficient vector  $\beta_{ik}$  are draws from distributions that may depend on the parameter vector  $\Lambda$ .

The other  $I$  populations are nonshoppers: nonshoppers from population  $i$  arrive at firm  $i$  at Poisson rate  $\gamma_{ik}$ . Suppose that they purchase upon arrival with probability  $D_{ik}^m(p_i; X_{ik}, \Lambda, \beta_{ik})$ . Again, the  $\gamma_{ik}$  and  $\beta_{ik}$  are random variables with a distribution that may depend on  $\Lambda$ .

On the firm side assume that firms choose the prices that would maximize expected profits in a stationary dynamic model like that of section 2, i.e. assume that  $p_{ik}$  is chosen to maximize

$$\pi_i(p_{ik}, p_{-ik}) \equiv \frac{p_{ik}(\gamma_{ik}D_k^m(p_i) + \gamma_{0k}D_k^o(p_{ik}, p_{-ik}))}{r + \gamma_{ik}D_k^m(p_{ik}) + \gamma_{0k}D_k^o(p_{ik}, p_{-ik})},$$

where we have omitted the characteristics and parameters from the arguments for readability.

Suppose that we are given data on a set of books  $k = 1, 2, \dots, K$ . This data will take two distinct forms. For some titles we observe just the vector of prices  $(p_{1k}, p_{2k}, \dots, p_{Ik})$ . For other titles we observe both prices and an indicator for whether the title sells in a given time period:  $(p_{1k}, q_{1k}, \dots, p_{Ik}, q_{Ik})$ . We wish to estimate the parameter vector  $\Lambda$ .

One observation about this model that will facilitate estimation is that the first order condition for firm  $i$ 's title  $k$  price to be optimal,

$$\begin{aligned} 0 &= rp_{ik}\gamma_{ik}D^{m'}(p_{ik}) + r\gamma_{ik}D^m(p_{ik}) + \gamma_{ik}^2D^m(p_{ik})^2 \\ &\quad + rp_{ik}\gamma_{0k}\frac{\partial D^o}{\partial p_i}(p_{ik}, p_{-ik}) + r\gamma_{0k}D^o(p_{ik}, p_{-ik}) + \gamma_{0k}^2D^o(p_{ik}, p_{-ik})^2 \\ &\quad + 2\gamma_{0k}\gamma_{ik}D^m(p_{ik})D^o(p_{ik}, p_{-ik}), \end{aligned}$$

is a quadratic function of  $\gamma_{ik}$  once one fixes  $\gamma_{0k}$ , the parameters affecting  $D^m(p_{ik})$ , and  $D^o(p_{ik}, p_{-ik})$ , and values for the random coefficients. Specifically, this FOC is of the form  $a\gamma_{ik}^2 + b\gamma_{ik} + c = 0$  for

$$\begin{aligned} a(p_{ik}, X_{ik}; \Lambda, \beta_{ik}) &= D^m(p_{ik})^2 \\ b(p_{ik}, X_{ik}; \Lambda, \beta_{ik}) &= rp_{ik}D^{m'}(p_{ik}) + rD^m(p_{ik}) + 2\gamma_{0k}D^m(p_{ik})D^o(p_{ik}, p_{-ik}) \\ c(p_{ik}, X_{ik}; \Lambda, \beta_{ik}) &= rp_{ik}\gamma_{0k}\frac{\partial D^o}{\partial p_i}(p_{ik}, p_{-ik}) + r\gamma_{0k}D^o(p_{ik}, p_{-ik}) + \gamma_{0k}^2D^o(p_{ik}, p_{-ik})^2 \end{aligned}$$

Under some conditions ( $b > 0$ ,  $c < 0$ ) only the larger root of this quadratic will be positive. When this occurs, we can calculate the conditional likelihood of each price observation  $p_{ik}$  (conditional the parameters,  $X_{ik}$ , and random coefficients) by backing out the unique  $\gamma_{ik}$  which makes  $p_{ik}$  optimal and then computing the likelihood via

$$L(p_{ik}|\gamma_{0k}, X_{ik}, \Lambda, \beta_{ik}) = L(\gamma_{ik}|\gamma_{0k}, X_{ik}, \Lambda, \beta_{ik})\frac{1}{\frac{\partial g}{\partial \gamma}(\gamma_{ik})},$$

where  $g$  is the best-response pricing function with  $g(\gamma_{ik}) = p_{ik}$ . By implicitly differentiating the FOC we find that

$$\frac{\partial g}{\partial \gamma_{ik}}(\gamma_{ik}) = -\frac{2\gamma_{ik}a(p_{ik}) + b(p_{ik})}{\frac{\partial a}{\partial p_{ik}}\gamma_{ik}^2 + \frac{\partial b}{\partial p_{ik}}\gamma_{ik} + \frac{\partial c}{\partial p_{ik}}}.$$

Another aspect of our model that facilitates estimation is that the one-to-one correspondence between the observed  $p_{ik}$  and unobserved  $\gamma_{ik}$  also makes it easy to account for endogeneity when using the demand data. Given the observed  $p_{ik}$  and an inferred  $\gamma_{ik}$ , the arrival rate of consumers who would buy book  $k$  from store  $i$  is

$$d_{ik} \equiv \gamma_{0k}D^o(p_{ik}, p_{-ik}) + \gamma_{ik}D^m(p_{ik})$$

Hence the probability that the book will be sold in a  $\Delta t$  time interval is

$$E(q_{ik}|p_{ik}, p_{-ik}, \gamma_{0k}, \Lambda, \beta_{ik}) = 1 - e^{-d_{ik}\Delta t}.$$

The joint likelihood of observed pairs  $(p_{ik}, q_{ik})$  is simply the product of this expression and our earlier expression for the likelihood of  $p_{ik}$ .

Together these two observations suggest a simple procedure for simulated maximum likelihood estimation. Given any potential parameter vector  $\Lambda$  we take random draws for any random coefficients (which may vary by title or by listing). Given these random coefficients we compute the joint likelihood of each observed price vector  $(p_{1k}, \dots, p_{Ik})$  and of each observed price/quantity vector  $(p_{1k}, q_{1k}, \dots, p_{Ik}, q_{Ik})$  using the above formulas. Summing across the draws of the random coefficients gives the unconditional likelihood. Parameter estimates are obtained by maximizing this likelihood over the parameter space.

## 5.2 Empirical specification

To estimate arrival rates and demand in the used book market and explore how they have changed with the shift to online sales we implement a parsimonious version of the model including only as many parameters and random coefficients as seemed necessary to estimate quantities of interest and match the main features of the data.

We assume that the arrival rate of shoppers varies only with the “popularity” of a title and the year (2009 versus 2012):

$$\gamma_{0k} = \gamma_0 \text{Popularity}_k^{\gamma_0^N} \Delta \gamma_0^{2012 I(t=2012)}.$$

The  $\text{Popularity}_k$  variable is the ratio between the count of listings for title  $k$  in the 2012 online data and the mean of this count across listings. We assume that shoppers have logit-style preferences: consumer  $j$  gets utility

$$u_{ijk} = \begin{cases} X_k \Lambda - \alpha \delta_k p_{ik} + \epsilon_{ijk} & \text{if } i \text{ purchases book } k \text{ from store } i \\ X_k \Lambda + \beta_{0k} + \epsilon_{ijk} & \text{if } i \text{ does not purchase book } k \end{cases},$$

where the  $\epsilon_{ijk}$  are independent random variables with a type 1 extreme value distribution. The demand for firm  $i$ 's offering is then

$$D_k^o(p_{ik}; p_{-ik}) = \frac{e^{-\alpha \delta_k p_{ik}}}{e^{\beta_{0k}} + \sum_{\ell} e^{-\alpha \delta_k p_{\ell k}}}.$$

The parameters  $\delta_k$  let the price-sensitivity vary across books which will help the model fit data in which price levels vary substantially across books. We will adopt a random coefficients specification which allows the unobserved outside good utilities  $\beta_{0k}$  to be normally distributed across titles. This helps to fit data in which the fraction of listings that sell varies substantially across titles and also helps the model explain why one firm sometimes substantially undercuts all other firms.

The arrival rate of nonshoppers is similarly allowed to vary with popularity, the year, and whether a store is online/offline. We assume that it also varies randomly across store-titles – a store's price is an increasing function of rate at which it is visited by nonshoppers

and it is through the random variation in  $\gamma_{ik}$  that the model can account for each observed price as a best response. Formally, the arrival rate is

$$\gamma_{ik} = z_{ik} \text{Popularity}_k^{\gamma_i^N} \Delta \gamma_i^{2012} I(t=2012) \Delta \gamma_i^{\text{off}} I(\text{offline}),$$

where the  $z_{ik}$  are iid gamma-distributed random variables with mean  $\mu_{\gamma_i}$  and standard deviation  $\sigma_{\gamma_i}$ . We assume that nonshopper demand curves have the CES form. In utility terms, this amounts to assuming that a nonshopper  $j$  considering buying book  $k$  from store  $i$  gets utility

$$u_{ikj} = \begin{cases} v_j - \delta_k p_{ik} & \text{if he buys.} \\ 0 & \text{if he doesn't} \end{cases},$$

where the  $v_j$  are heterogeneous across consumers with density  $f(v_j) = h\eta v^{-\eta-1}$  on  $[h^{1/\eta}, \infty]$ . We assume that  $\eta > 1$  (otherwise the monopoly price is infinite) and that  $h > 0$  is sufficiently small so that all observed prices are in the support of the value distribution. With this assumption the probability that a shopper purchases at the observed price is

$$D^m(p_{ik}) = h(\delta_{ik} p_{ik})^{-\eta}.$$

The model description above has more parameters than we are able to estimate. There are two issues of identification: the arrival rate  $\gamma_{ik}$  of nonshoppers cannot be separately identified from the multiplicative constant  $h$  in nonshopper demand; and all profit functions only depend on ratios  $\gamma/r$ . And as a practical matter we are also unable to estimate the large number of book fixed effects  $\delta_k$  that shift the level of equilibrium prices for each title. Accordingly, we have chosen to fix some parameters in our estimation. We fix  $r = 0.05$  so that arrival rates should be thought of as arrivals over a period of one year. We set the constant  $h$  in the shopper demand equation to one.<sup>22</sup> And finally we implicitly fix the  $\delta_k$  at a different value for each book by scaling the prices for each book so that the lowest 2009 online price is equal to one and then setting each  $\delta_k$  to one.

This produces a model with 12 parameters to be estimated:  $(\gamma_0, \Delta \gamma_0^{2012}, \gamma_0^N, \alpha, \mu_\beta, \sigma_\beta, \mu_{\gamma_i}, \sigma_{\gamma_i}, \Delta \gamma_i^{2012}, \gamma_i^N, \eta, \Delta \gamma_i^{\text{off}})$ . We estimate these parameters on a dataset containing 313 books which had valid listings in all four of our data collection waves: they were found in an offline store in 2009 and had listings successfully scraped from AbeBooks.com in all three online collections.<sup>23</sup> The demand data  $q_{ik}$  are inferred by comparing the November 2012 and

<sup>22</sup>We treat demand as being  $p^{-\eta}$  even when this expression is greater than one and hence inconsistent with the demand being a probability of purchase given arrival. Note, however, that the same equations could always have been made consistent with the probability interpretation simply by choosing a smaller value of  $h$  and scaling up the consumer arrival rate while keeping their product constant.

<sup>23</sup>For our structural analysis we also drop all listings priced above \$50 and any title that does not have at least two listings.

January 2013 listings, and are used only for books for which our 2013 data collection was complete. The estimation follows the procedure noted above with the “outside options”  $\beta_{0k}$  as the only random coefficients.<sup>24</sup>

### 5.3 Estimates of arrival rates and demand

Table 4 presents estimates of the parameters of our structural model. The left half of the table reports estimates related to the nonshoppers. The most basic finding is that the arrival rate of nonshoppers at online stores appears to be quite low. The  $\hat{\mu}_{\gamma_i} = 0.06$  estimate indicates a firm with a typical listing should expect that a nonshopper willing to purchase the good at the lowest price in 2009 online data for that title will arrive approximately once every 16 years. The  $\hat{\sigma}_{\gamma_i} = 0.04$  estimate indicates that there is some idiosyncratic variance around this, with some firms having essentially no nonshoppers and others having somewhat more. The  $\hat{\gamma}_i^N = 0.14$  estimate indicates that arrival rates are higher for more popular titles, but it is not a very big effect, e.g. a title that has twice as many listings as average has about a ten percent higher (per listing) arrival rate of nonshoppers. The year dummy indicates that these arrival rates did not change between 2009 and 2012.

Parameter	Coef.Est.	SE	Parameter	Coef.Est.	SE
Nonshopper arrival			Shopper arrival		
$\mu_{\gamma_i}$	0.06		$\gamma_0$	29.3	
$\sigma_{\gamma_i}$	0.04		$\Delta\gamma_0^{2012}$	1.52	
$\Delta\gamma_i^{2012}$	1.01		$\gamma_0^N$	1.18	
$\gamma_i^N$	0.14				
Offline arrival 2009			Shopper utility		
$\Delta\gamma_i^{\text{off}}$	0.36		$\mu_\beta$	-7.74	
Nonshopper utility			$\sigma_\beta$	8.61	
$\eta$	1.15		$\alpha$	12.9	

Table 4: Estimates of structural model parameters

While nonshopper arrival rates at online stores appear to be modest, the coefficient directly below this indicates that they are still substantially higher than arrival rates at offline stores. The 0.36 estimate for  $\hat{\Delta}\gamma_i^{\text{off}}$  indicates that 2009 offline arrival rates we only

<sup>24</sup>With just one random coefficient relevant to each title the “simulated” maximum likelihood becomes just a numerical integration over the unknown coefficient. We perform this integration by evaluating the likelihood for 50 values of the random coefficient spaced evenly in CDF space. For some parameters the model is cannot rationalize some observations (in which one firm sets a price substantially below the second lowest price) using any positive  $\gamma_{ik}$ ). When this happens we use a penalty function,  $L(p_{ik}|X_{ik}, \Lambda) = e^{-10+10|\gamma_{ik}|}$  that increases in the distance between the (negative)  $\gamma_{ik}$  that would make the first-order condition for profit-maximization satisfied and the nearest value that is in the support of the distribution (which is zero).

about 36% of online arrival rates, or about 0.02 consumers per year for the typical listing. (Note, however, that prices and demand are scaled so that potential consumer buys with probability one if he sees a price equal to the lowest 2009 online price. Offline firms that set lower prices will sell at a somewhat higher probability.) Such a difference in arrival rates would lead to substantial differences in the expected welfare gains produced by an eventual sale. Of course, it should be kept in mind that unlike in the online world these arrival rates are estimated without any quantity data and instead reflect just that lower offline prices can be rationalized in our model only by a lower consumer arrival rate.

The final estimate on the left side is an estimate of the elasticity of demand of the nonshoppers. The estimated elasticity of demand is -1.15. A CES demand curve with this elasticity has a very thick upper tail. This will lead to estimates that each sales to a nonshoppers are generates a great deal of consumer surplus.

The right half of the table reports estimates related to the population of online shoppers. When interpreting these results, keep in mind that we have allowed for unobserved heterogeneity in size of the shopper population by introducing heterogeneity in the utility of the “outside” option rather than directly in the arrival rate. The estimated mean and variance of the outside good utility indicate that there is a great deal of unobserved heterogeneity. For about one-quarter of titles, the majority of “shoppers” would purchase from one of the online firms. But only about 1% of those shopping for the median title are estimated to purchase, and many titles have essentially no shoppers willing to purchase at the observed prices.

The estimated shopper arrival coefficient  $\hat{\gamma}_0 = 29.3$  indicates that some titles of average popularity do have twenty or more shoppers arriving per year. This is dramatically higher than the rate at which nonshoppers are estimated to arrive. As noted earlier, however, it is only a minority of titles that have similar arrival rates. The median title is estimated to have a shopper arrival rate that is only a few times larger than each firm’s nonshopper arrival rate, and other titles are estimated to have very few shoppers at all. This estimate reflects a basic fact about demand noted earlier: we observe many sales of some titles, but zero sales over a two-month period for about one-third of the titles in our sample.

The  $\hat{\gamma}_0^N = 1.18$  estimate indicates that the number of shoppers increases more than proportionately to a title’s popularity. This can be thought of as similar to the nonshopper estimates because the estimate there was of the number of nonshoppers arriving at a single firm, whereas here it is of the total size of the shopper population. It does, however, mean that the potential benefit of attracting shoppers is a more important consideration

for firms selling popular titles. The estimate of  $\hat{\Delta}\gamma_0^{2012} = 1.52$  indicates that the size of the shopper population increased by about 50% between 2009 and 2012. This is smaller than we would have guessed given the difference in magnitudes between AbeBooks’s and Amazon’s traffic, but we do not have any direct measurements of the extent to which Amazon’s incorporation of AbeBooks’s listings increased traffic and it could be that most Amazon used book shoppers are more concentrated in textbooks than in the types of books in our dataset.

The price coefficient  $\hat{\alpha} = 12.9$  indicates that online shoppers are very price sensitive. In most cases (excluding, for example, when the “outside option” is unusually bad) this implies that a firm with a price close to the lowest listed price will see its demand go down by about 13% if it raises its price by 1%. A consequence of this price sensitivity and our logit functional form is that a standard welfare calculation will indicate that shoppers who purchase the book do not get a great deal of consumer surplus. One could in principle avoid this implication by putting heterogeneity directly into the the shopper arrival rate and estimating a nested logit or other more flexible demand function that let consumers be very price-sensitive when comparing different online listings but yet price insensitive when comparing listings to the outside good. But in practice, our data do not make it possible to estimate such a flexible specification.

## 5.4 Estimating welfare gains

In this section we examine both welfare gains from a shift from offline to online used book sales and the division of these gains between consumers and firms. Welfare gains occur when books are sold to consumers with higher valuations and/or books are sold more quickly. Online retailers must be better off if the number of nonshoppers (and the distribution of their valuations) increases, but the magnitude of the gain will be affected by the size of these increases and the relative sizes of the shopper and nonshopper populations.

Given an estimated parameter vector  $\hat{\Lambda}$ , the average per-listing welfare generated by the listings for title  $k$  can be calculated by integrating over the posterior distribution of the unobserved random coefficient  $\beta_{0k}$ :

$$E(W_k|\hat{\Lambda}) = \frac{1}{I_k} \int_{\beta} \left( E(CS_k|\hat{\Lambda}, \beta) + \sum_i E(\pi(p_{ik}, p_{-ik})|\hat{\Lambda}, \beta) \right) f(\beta|p_{1k}, \dots, q_{nk}) d\beta,$$

where  $I_k$  is the number of listings for title  $k$ ,  $CS_k$ , is the total discounted consumer surplus generated by the eventual sales of all the listings and  $\pi$  is the discounted expected profit that the firm listing copy  $i$  will earn.

The profit term can be computed using the same profit functions we use in estimating the model. Given the price  $p_{ik}$ , a value  $\beta_{0k}$  for the outside good utility, and the other estimated parameters we back out a value for  $\gamma_{ik}$ . Expected profits are then simply

$$E(\pi(p_{ik}, p_{-ik} | \hat{\Lambda}, \beta)) = \frac{p_{ik}(\gamma_{ik}D^m(p_{ik}) + \gamma_{0k}D^o(p_{ik}, p_{-ik}))}{r + \gamma_{ik}D^m(p_{ik}) + \gamma_{0k}D^o(p_{ik}, p_{-ik})}$$

Consumer surplus is a little more complicated. It is a sum of consumer surplus from sales to nonshoppers and sales to shoppers. The two are most naturally calculated in different ways. Expected total consumer surplus from sales to nonshoppers can be calculated similarly to how we calculated profits:

$$\begin{aligned} E(CS_k^{ns}) &= \sum_i E(e^{-rt_i}) \text{Prob}\{i \text{ sells to a nonshopper}\} E(v - p_{ik} | v > p_{ik}) \\ &= \sum_i \frac{\gamma_{ik}D^m(p_{ik}) + \gamma_{0k}D^o(p_{ik}, p_{-ik})}{r + \gamma_{ik}D^m(p_{ik}) + \gamma_{0k}D^o(p_{ik}, p_{-ik})} \frac{\gamma_{ik}D^m(p_{ik})}{\gamma_{ik}D^m(p_{ik}) + \gamma_{0k}D^o(p_{ik}, p_{-ik})} \frac{p_{ik}}{\eta - 1}. \end{aligned}$$

The consumer surplus that accrues to shoppers, on the other hand, is easier to calculate by thinking about the present value of the flow consumer surplus that accrues as shoppers arrive because consumers prefer choosing among the  $I_k$  goods at the observed prices to being forced to buy the outside good:

$$\begin{aligned} E(CS_k^s) &= \int_0^\infty \gamma_{0k} (E(CS(p_{1k}, \dots, p_{I_k k}) - E(CS(\infty, \dots, \infty))) e^{-rt} dt \\ &= \frac{\gamma_{0k}}{r} \frac{1}{\alpha} \left( \log(e^\beta + \sum_i e^{-\alpha p_{ik}}) - \beta \right). \end{aligned}$$

The final step here takes advantage of the well known formula for the logit inclusive value to calculate how the expected consumer surplus of each shopper increases due to the presence of the inside goods.

## 5.5 Welfare gains from Internet sales

In this section we present profit and welfare estimates calculated using the above methodology. Among our main findings are that the model estimates suggest that consumer surplus is quite large and online sales generated both substantially higher profits and substantially higher consumer surplus than offline sales. An increase in the number of listings between 2009 and 2012 may have lead to an additional welfare increase, although per-listing profits especially are estimated to have declined somewhat from the 2009 level.

The first row of Table 5 presents estimates of the expected gross profit per listing. More precisely, it is the mean across the 313 titles in that have valid online listings data in both



2009 and 2012 of the average across listings of the estimated gross profit given the listing’s price and our estimated demand parameters. (These are “gross” profits in that they do not account for the acquisition cost of the books being sold.) A first finding, visible in the first column, is that average per-listing profits are estimated to have been fairly low in the offline world, just \$1.37 per listing. This is the product of the mean price for the titles, \$10.21, and a discount factor representing the value of  $E(e^{-0.05t})$  at the estimated parameters. The estimated discount factor of 0.13 reflects our estimates that many books would take decades to sell: offline arrival rates are about one-third of online arrival rates which themselves are only about 0.06 customers per year. The second column gives comparable figures for the 2009 online listings. It illustrates the dramatic increase in profits from moving online: per listing gross profits are estimated to be well over twice as high at \$3.25. The higher gross profits reflect both higher average prices and a higher estimated sales rate which reduces the extent to which the eventual sales are discounted. Note, however, that the three-times higher arrival rate does not reduce the effective discount factor as much as one might think: the relevant discount factor is a price-weighted average and high-priced listings take longer to sell. The final column presents estimates for the 2012 listings. The estimates indicate that per-listing profits are still well above the 2009 offline profit level, although not as high as the 2009 online profits. This reflects both that average prices and price-weighted waiting times to sell are intermediate. The waiting time effect reflects the model’s prediction that for many titles high priced firms are now very unlikely to sell to a shopper.

Average value per listing	2009 offline listings	2009 online listings	2012 online listings
Gross profit	<b>\$1.37</b>	<b>\$3.25</b>	<b>\$2.42</b>
(Price)	\$10.21	\$15.04	\$13.80
(Discounting)	0.13	0.22	0.18
Consumer surplus	<b>\$8.85</b>	<b>\$16.40</b>	<b>\$13.79</b>
(Nonshoppers)	\$8.85	\$15.69	\$13.41
(Shoppers)		\$0.71	\$0.38
Welfare	<b>\$10.21</b>	<b>\$19.65</b>	<b>\$16.21</b>

Table 5: Profit and welfare estimates

In thinking about the reliability of these estimates it should be noted that the 2012

figures are estimated from better data – it is only in 2012 that we have a proxy for the rate at which listings are sold. The 2009 vs. 2012 online comparison reflects both the observed fact that average online prices were higher (recall that price distributions were otherwise similar but 2012 had more low-priced listings), and the structural model’s inferences about demand: the similar upper tails suggest that nonshopper arrival rates were similar in 2009, and the demand model infers that the growth of low-priced listings would have reduced the number of sales that high-priced firms make to shoppers. The 2009 offline profit estimates are even more heroic. We know prices were lower, but beyond that are relying on the model’s inference that firms set lower prices because they were facing lower demand.

The second row of the table presents estimates of consumer surplus. Here, the estimates indicate that consumers also benefitted substantially from the shift to online sales. In 2009 online listings are estimated to generate, on average, almost twice consumer surplus (per listing) as offline listings. As noted in the introduction, the naive intuition that higher online prices suggest that consumers are not benefitting from online sales misses the basic point that profits and consumer surplus can both be higher if Internet sales result in higher match quality and faster sales. The estimates indicate that this is true to an extreme: consumers are estimated to capture most of the total surplus generated by both online and offline sales, and in 2009 consumer surplus per listing is estimated to be almost twice as high for online sales. The estimates that consumer surplus is so much higher than profits reflects the distribution of prices. The model rationalizes the coexistence of low and high prices via a demand curve with a very thick upper tail, which then makes the average valuation of consumers who purchase very high. The thickness of the uppermost part of the tail, of course, relies on functional form assumptions, and one could also worry that some high prices are not actually profit-maximizing. For this reason, the precise magnitudes here should be taken with a grain of salt. Another limitation of our model, however, works in the other direction. In assuming a simple logit specification for demand, we have assumed that consumers who are very price-sensitive when comparing online listings are equally price sensitive in comparing listings to the outside option of not purchasing. This implies that they are getting relatively little consumer surplus. It would be preferable to estimate a model with more flexible substitution patterns, e.g. a nested logit model with the outside good in a separate nest, but unfortunately we do not have enough data to make this feasible.

The third row of the table presents estimates of total welfare. These are simply the sum of the quantities in the previous two rows and therefore again have the same pattern. In 2009 welfare per listing is estimated to be approximately twice as high for online listings as

for offline listings. Per listing welfare is estimated to be somewhat lower in 2012.

## 6 Conclusion

A number of previous studies have noted that the Internet has not transformed retail markets as some forecast: price declines have been more moderate than revolutionary and the “law of one price” has not come to pass. We began this paper by noting that the Internet market for used books shows these effects in the extreme: prices increased in a strong sense and there is tremendous price dispersion. We feel that this makes the Internet market for used books a nice environment in which to try to gain insight into the mechanisms through which the Internet affects retail markets, and noted that basic facts do not necessarily indicate that the Internet has failed to live up to its promise. If Internet search allows consumers to find products that are much better matched to their tastes, then it leads to an increase in demand which can lead to higher prices in a variety of models (particularly for goods like out-of-print books for which supply is fairly inelastic).

The match-quality-increased-demand theory is very simple, so to provide evidence in its favor we devoted a substantial part of our paper to developing less obvious implications that could be examined to help assess its relevance. We examined these implications using three sources of variation. First, we examined how price distributions – rather than just price levels – differ between the online and offline markets. Here, our primary supporting observation was that the online price distribution for standard titles has a thick upper tail where the offline distribution had none. Second, we examined how price distributions differed for different types of used books. Here, we noted that price increases were smaller for popular books (which one would expect if the valuation distribution had less of an upper tail and there is more competition) and that there was already an upper tail of prices for local interest books in physical bookstores. One of our favorite characterizations of the latter result is that it appears as if the Internet has made all books of local interest. Third, we examined how online price distributions changed between 2009 and 2012. Here, we noted that the Amazon-induced increase in viewership of aggregated listings would be expected to increase the number of sellers offering very low prices but have little impact on the upper part of the price distribution, and found that this was strikingly true in the data. Our demand analysis also revealed patterns that seem consistent with the assumptions of our model: there is a concentration of demand among the top-ranked firms as one would expect from a price-sensitive shopper segment; but firms with much higher prices also appear to have some probability of making a sale.

The structure of our model – in particular the use of one-dimensional unobserved heterogeneity and the assumption that firms maximize relative to steady-state beliefs – makes it relatively easy to estimate structurally. The one-to-one mapping between unobserved consumer arrival rates and observed prices lets makes it easy to control for endogeneity in demand and to estimate the model via simulated maximum likelihood. And consumer surplus and welfare are easily calculated from the estimated parameters by computing some things on a title-by-title basis and others on a consumer-by-consumer basis. Our implementation of the model suggests that there were substantial increases in both profits and consumer surplus from the move to online sales of used books. Amazon’s subsequent incorporation of used-book listings seems to have reduced book dealer profits somewhat, but they are still much higher than they were in the offline world.

Our analysis has a number of limitations that could provide opportunities for future research. On the theory side it would be interesting to analyze a similar dynamic pricing problem without the steady-state beliefs we’ve imposed in the model: there could be interesting swings in pricing as duopolists hold off on selling in hopes of becoming a monopolist and then lower prices substantially when entry occurs and makes this less likely. On the empirical side we think that our simplifications are a useful combination that could used to make other analyses tractable, but think that it would also be worth exploring generalizing our model in other ways and allowing for multidimensional heterogeneity among firms. With regard to used books, we think that among the most important elements we have not incorporated is a relation between market prices and the flow of used books into used book dealers. Building out the model in this direction would also be useful for understanding differences in how different retail markets have been affected by the Internet growth.

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