

CONSUMER SEARCH AND PRICING BEHAVIOR IN INTERNET MARKETS *

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Abstract

Despite the mixed empirical evidence, many economists hold the view that Internet will promote competition, thereby lowering prices and price dispersion and increasing welfare. One of the main reasons is that consumers find it easier to search on the Internet, thereby comparing the different price offers that are available. This article presents an overview of the existing empirical literature and provides a search model that helps understand some of the forces behind the mixed empirical evidence. The search model has two types of consumers: those who are fully informed (for example, because they use search engines) and those who are not (they search themselves). More search intensity is reflected then in two parameters: a reduction in search cost for those who search themselves and/or an increase in the search engine rate of adoption (an increase in the fraction of consumers who use search engines). The comparative statics results derived from the model may explain the controversial empirical evidence found so far.

Keywords: Internet, price dispersion, search, search agents

JEL Classification: D40, D83, L13

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1 Introduction

Throughout economic history, changes in technology have had a substantial impact on consumers' search and transportation costs and, consequently, on the size of the relevant market. One example is the progressive decline in transportation costs that historically has taken place through the use of faster means of transportation (sailing ships, machine ships, trains, cars, airplanes, etc.). This reduction in transportation costs has made it possible for consumers to search for products in markets that were previously beyond their horizon. In our present times, the increased use of Internet can be viewed in a similar way. Due to a reduction in search costs, Internet allows consumers to become active in markets where they were not active before.

The general consensus among academics and leading businessmen seems to be that increased use of Internet will lower consumers' search costs and consequently intensify price competition. Internet is thus regarded as reducing commodity prices and promoting economic efficiency. Bakos (1997), for example, argues that:¹

“electronic marketplaces are likely to move commodity markets closer to the classical ideal of a Walrasian auctioneer where buyers are costlessly and fully informed about seller prices. . . . we expect that electronic marketplaces typically will sway equilibria in commodity markets to favor the buyers, will promote price competition among sellers, and will reduce sellers' market power.”

Moreover, Jeffrey P. Bezos of Amazon.com has argued that:

“We on the Internet should be terrified of customers because they are loyal to us right up to the point that someone else offers a better service. The power shifts to the consumer online.”²

This paper is an attempt to put these quotations into perspective. We first give an overview of the relevant empirical literature. This literature provides a mixed view of the effectiveness of online markets in bringing prices down to competitive levels. We then present a simple endogenous search model that identifies basic market conditions that may help explain and organize the mixed empirical evidence. By doing so, we develop a more cautious view on the economic implications of electronic marketplaces than the consensus view expressed in the above quotes.

¹See also Bailey and Bakos (1997), and Vulkan (1999: F69-70).

²Quoted in Victoria Griffith (1999).

The model's economy has firms producing a homogeneous product at a unit cost r and compete to sell their good to a number of consumers. There are two types of consumers: *informed* buyers who incur no search cost, and *less-informed* consumers who have positive search cost c . We shall use the percentage of informed consumers in the economy as a proxy for the rate of adoption of search engines. For simplicity, all consumers have identical willingness-to-pay $v > c + r$. We will refer to $(v - r)/c$ as the *relative size of the purchase*. Firms simultaneously choose prices and announce them on the web. Less-informed consumers decide how many searches to make before buying. These buyers can also abstain from searching when they expect search not to be worthwhile. In equilibrium, consumer expectations are fulfilled. Hence, the interaction between firms and buyers is modelled as a simultaneous move game, where (in equilibrium) consumers' search activity impinges on the prices quoted by firms, and the price setting behavior of firms influences buyers' search activity.

There are three types of price dispersed equilibria in our economy: (i) an equilibrium with *low* search intensity, i.e., where less-informed consumers randomize between one search and no search; (ii) an equilibrium with *moderate* search intensity, i.e., where less-informed buyers search for one price; and (iii) a *high* search intensity equilibrium, i.e., where consumers randomize between one search and two searches. Relative size of the purchase and the rate of adoption of search engines in the Internet market determine buyers' search incentives. A first lesson our analysis yields is the existence of a correlation between buyers' search propensity and product's value. That is, a high search intensity equilibrium arises when the relative size of the purchase is large, *ceteris paribus*. In contrast, a low or a moderate search intensity equilibrium results when search cost is relatively important compared to the size of the purchase.

Our second main observation pertains to comparative statics results. We find that the impact of improved search technology on market transparency critically depends on market characteristics. We pinpoint the nature of this dependence in more detail below. Consider first that improved search technology results in a decline in search cost c , *ceteris paribus*. When both the size of the purchase and the search engines adoption rate are low, expected price-to-cost margins rise as c falls because more consumers who do not compare prices enter the market. Price dispersion, in contrast, increases when search cost is high initially, and falls otherwise. On the other hand, when the relative size of the purchase is high, expected price-to-cost margins and price dispersion unambiguously decline with c because more buyers exercise price comparisons in this case. In between, when the relative size of the purchase is not very low and not very high, price-to-cost

margins and price dispersion are unaffected by a change in c .

Second, consider that improved search technology results in an increase in the search engine rate of adoption. When the size of the purchase is low and the adoption rate of search engines is also low initially, an increase in the number of informed buyers leaves expected price-to-cost margins and price dispersion unchanged. When the rate of adoption of search engines in the market is quite high initially, in contrast, an increase in the number of informed buyers reduces average price-to-cost margins and price dispersion. Finally, when the size of the purchase is large, expected price-to-cost margins and price dispersion are (again) insensitive to changes in the number of informed buyers.

The remainder of the article is organized as follows. Section 2 provides a more detailed overview of the relevant literature. Here, we first discuss the different empirical studies that have been carried out so far concerning prices and price dispersion on the Internet. We then briefly discuss the consumer search literature and other more theoretical approaches to studying online markets. Section 3 describes the simple search model we use and its equilibria. Section 4 gives the comparative statics analysis of the model and relates the results to the findings of other studies. We conclude in that section that the mixed empirical evidence found in other studies can be explained by our finding from the comparative statics that firms' pricing behavior depends on market characteristics. However, other studies do not take into account the specific market characteristics that we find to be important. In Section 5 we conclude and we discuss some of our ideas for an empirical analysis that is able to control for the theoretical forces that are relevant.

2 Overview of the Relevant Literature

A study of the implications of the easiness with which consumers may search and compare firms' offerings on the Internet on the competitiveness of online markets, has two main branches of literature to discuss. First, there is a large and relatively recent empirical literature on prices and price dispersion in online markets. Second, there is a large theoretical literature on consumer search. In this section, we first discuss these two branches of literature before we briefly dwell upon other issues related to online markets that have attracted the attention from economists.

The turn of the millennium has seen many empirical studies investigating whether Internet markets bring market prices closer to their competitive levels. The commonly held theoretical point of view, as indicated by the two quotes from the Introduction, seemed to be that as it is easier for consumers to compare firms' offerings, consumers will exercise more countervailing market power, which should lead to lower market prices and less price dispersion. Below, we will see that

empirical studies do not unambiguously support this view. Concerning *price levels* in electronic markets, some studies, notably Lee (1998) and Lee *et al.* (1999) on cars, and Bailey (1998) on books and CDs, find that they are higher than corresponding prices in conventional markets. Lee (1998) was one of the first to study the impact of the Internet on price levels. He compares prices in online auctions for second hand cars to similar prices in conventional auctions. The fact that he found higher online prices should be considered with some care as (i) second-hand cars are not a homogeneous good (and quality may be higher in online auctions compared to conventional auctions) and (ii) auctions may very well function in a different way from retail markets due to the fact that in auctions the good is sold to the bidder with the highest valuation. These potential problems with the interpretation of the results do not arise in Bailey (1998), since books and CDs are entirely homogeneous goods. His observations could be due to a low rate of adoption of search engines in Internet markets at that point in time. Other analyses, Friberg *et al.* (2000) and Clay *et al.* (2002) on books, report that prices in online and physical stores are quite similar. The study of Friberg *et al.* (2000) is interesting in this context as they take into account the shipping and handling fees that are charged on online purchases. Not taking these additional fees results in the conclusion that online prices are lower, the difference being very well accounted for by the size of the shipping and handling fees that are charged. Finally, Brynjolfsson and Smith (2000) in a study on books and CDs find prices to be lower in electronic markets, even when taking into account the additional online fees that are charged.³

On *price dispersion*, the effect of moving markets online also seems to be empirically ambiguous. Price dispersion is typically explained in the literature with reference to search costs and arises as some consumers do not search more than once while others do search more often. A reduction in search costs associated with online sales should bring search costs down and therefore should reduce (at first sight) the amount of price dispersion. Bailey (1998) and Brynjolfsson and Smith (2000), however, find that price dispersion for books and CDs is not lower online than in traditional outlets. According to Brynjolfsson and Smith (2000) online price differences average up to 33% for books and 25% for CDs. Bailey (1998) notes that the opposite holds for software and that in these markets online price dispersion seems to be lower. Other studies also emphasize that online prices exhibit substantial dispersion (Baye and Morgan, 2001; Brown and Goolsbee, 2002; Clay *et al.*, 2002).⁴ The study by Clemons *et al.* (2002) is also interesting in this respect. They find that

³Reports by consultant companies Ernst & Young, Forrester Research and Goldman Sachs have also reached opposite conclusions (OECD, 1999: 73).

⁴See Smith *et al.* (2000) for an overview of some of these empirical findings and a discussion of the different

online airline tickets may differ as much as 20% across different agents, even when controlling for observable product heterogeneity.

Another interesting observation in the context of search and online markets can be found in the empirical study by Eric Johnson *et al.* (2004). These authors study data on how many times people search (i.e., how many sites they visit) before making a purchase. Johnson *et al.* (2004) report that travel shoppers search substantially more than CD shoppers and book purchasers. Incipient research accounting for consumers search behavior on the Internet finds that 70% of CD shoppers, 70% of book purchasers and 36% of travel buyers were observed to visit just one site. The main issue to observe is that it is easy to visit an Internet site, but it still takes some time to find a particular book or CD and to order it. For a few dollars purchase, it does not seem to be worthwhile to search over and over again. Since higher search activity is naturally associated with lower price levels one would expect lower price-cost margins for products whose value is higher. This may explain an empirical result found by Clay *et al.* (2001), namely that bestseller books in online markets are generally more discounted than books at random. From the viewpoint of our analysis, search is more intense in the market for bestseller books as buyers value them more.⁵

The other literature that is relevant to our study is the one on consumer search. There is a vast literature on this subject and we refer to Stiglitz (1989) and Stahl (1996) for surveys of the early literature. We will restrict ourselves to an overview of two classic papers in the search literature: Burdett and Judd (1983) and Stahl (1989).⁶ Burdett and Judd present a competitive market with firms pricing non-strategically and consumers search non-sequentially, i.e., they have to decide how many firms to sample before they see the results of their search activities. The model has only less-informed consumers who get a first price quotation for free. They show that equilibrium price dispersion may occur in competitive markets when consumers randomize between searching for two prices and searching for one price, in a non-sequential fashion. Our analysis presented in the next two sections also studies non-sequential search and the price dispersed equilibria we obtain are similar in nature. Our model is, however, more suited for studying the implications of the growth of Internet use for the following two reasons. First, we allow for the presence of fully

methodologies employed.

⁵Sorensen (2000) presents similar evidence in a study of price dispersion in *physical* markets for prescription drugs. He finds that mean prices and price dispersion are sensitive to the characteristics of the drug therapy. In particular, long (multi-month) prescriptions mean prices and price dispersion are lower as compared to regular drug therapies. Seen from our model viewpoint, the market for long treatment drugs would be in an equilibrium with relatively lots of search compared to the market for regular prescriptions.

⁶An early paper with a model similar to ours is Varian (1980); however, he did not consider endogenous non-sequential consumers search. Fershtman and Fishman (1992) study a dynamic version of Burdett and Judd (1983).

informed consumers (consumers without search costs). This implies that, in contrast to Burdett and Judd, our model does not have a monopoly price equilibrium and that all the equilibria of our model exhibit price dispersion. More importantly, the increase in the search engine rate of adoption makes it important to study the impact of a growing number of fully informed consumers. Second, Burdett and Judd assume that each consumer makes at least one search. As argued above, consumers are steadily entering electronic markets and thus we think that in the context of the Internet discussion, it is important to allow for the possibility that consumers (previously) were not searching, or were searching with low intensity.

Stahl (1989) studies a search model where firms price strategically and less-informed buyers search sequentially, i.e., they first observe one price and then decide whether or not to observe a second price, and so on. The first price quotation is observed for free, which implies that every buyer makes at least one search. Moreover, under the optimal sequential search rule a consumer continues searching if, and only if, the observed prices are above a certain reservation price. This implies that in equilibrium no firm charges prices above the reservation price so that, in fact, in every equilibrium buyers search only once. The unique equilibrium of Stahl's model displays properties that are qualitatively similar to properties of our moderate or high search intensity equilibrium. The sequential search model cannot, however, explain why there is more search in some markets than in others, a feature that is captured in our model by the presence of low and high search intensity equilibria. Using the qualitative properties of these two equilibria allows us to explain some of the empirical findings concerning electronic marketplaces.⁷

Of course, apart from changes in search parameters in a homogeneous market there are many other issues that are relevant when comparing online to more conventional markets. Recently, a few papers have appeared that reflect in a more formal way on the changes in the nature of price competition due to the introduction of Internet. Some of these papers, Bakos (1997) and Lal and Sarvary (1999) among others, study heterogeneous goods markets, as they argue that in homogeneous markets it is evident that a reduction in search cost will intensify price competition. As already indicated, our paper argues that this is not necessarily the case.

⁷Morgan and Manning (1985) have derived optimal search strategies which combine features of the fixed-sample-size search strategy and the sequential search strategy. Our search method seems more adequate when price observations come after some delay. One of the authors has been recently looking for an apartment in Rotterdam. In this market one must first register at a number of Real State agents electronically to be able to receive offers.

3 Results from a Simple Search Model

We present a simple search model which is used to explain some of the different observations concerning Internet markets. Consider a market for a homogeneous good. On the supply side of the market there are two firms.⁸ Firms produce the good at constant returns to scale with identical unit cost equal to r . There is a unit mass of buyers who wish to purchase at most a single unit of the good. A fraction λ of the consumers search for prices costlessly, $0 < \lambda < 1$. We will refer to these buyers as *informed* and we will use this variable as a proxy for the rate of adoption of search engines. The other buyers must pay search cost $c > 0$ to observe a price quotation. These buyers, referred to as *less-informed*, may decide to obtain several price quotations, say $n \geq 0$, in which case they incur search cost equal to nc . Informed consumers buy the good from the lowest priced store, while less-informed ones acquire it from the store with the sampled lowest price. The maximum price any buyer is willing to pay for the good is v , with $v > c + r$. We shall refer to $(v - r)/c$ as the *relative size of the purchase*.

Firms and buyers play a simultaneous moves game. An individual firm chooses its price taking price choices of the rivals as well as consumers' search behavior as given. Buyers form conjectures about the distribution of prices in the market and decide how many prices to observe before purchasing from the store with the lowest observed price. Let $F(p)$ denote the distribution of prices charged by a firm. Let μ_n denote the probability with which a less-informed buyer searches for n price quotations. Let $\pi(\cdot)$ be the profits attained by a firm. We only consider symmetric equilibria. An equilibrium is a pair $\{F(p), \{\mu_n\}_{n=0}^N\}$ such that (a) $\pi(p) = \bar{\pi}$ for all p in the support of $F(p)$, (b) $\pi(p) \leq \bar{\pi}$ for all p , and (c) $\{\mu_n\}_{n=0}^N$ describes the optimal search behavior of less-informed buyers given that their conjectures about the price distribution are correct.

Janssen and Moraga-González (2004) show that the following alternatives exhaust the equilibrium possibilities of less-informed buyers' search behavior: (a) they search with *low intensity*, i.e., $0 < \mu_1 < 1$, $\mu_0 + \mu_1 = 1$, (b) they search with *moderate intensity*, i.e., $\mu_1 = 1$, and finally (c) they search with *high intensity*, i.e., $0 < \mu_1 \leq 1$, $\mu_1 + \mu_2 = 1$. This holds for an arbitrary number of firms N . We will study each of these three equilibrium configurations in turn.

Case a: Low search intensity

Consider that less-informed buyers randomize between searching for one price and not searching

⁸A full analysis of the N firm case including all the derivations of some of the claims we make here can be found in Janssen and Moraga-González (2004).

at all, i.e., $\mu_0 > 0$, $\mu_0 + \mu_1 = 1$. Let $F(p_i)$ be the probability that a firm charges a price that is smaller than p_i . The expected payoff to firm i of charging price p_i when the rival chooses a random pricing strategy according to the cumulative distribution $F(\cdot)$ is in this case

$$\pi_i(p_i, F(\cdot)) = (p_i - r) \left[\frac{(1 - \lambda)\mu_1}{2} + \lambda(1 - F(p_i)) \right]. \quad (1)$$

This profit expression is easily interpreted. Firm i obtains a per consumer profit of $p_i - r$. The expected demand faced by a firm stems from the two different groups of consumers. Firm i attracts the fully informed consumers when it charges a lower price than the rival, which happens with probability $1 - F(p_i)$. The firm also serves the less-informed consumers whenever they actively search for one price, which happens with probability μ_1 , and, particularly, when they visit its store, which occurs with probability one half.

In equilibrium, a firm must be indifferent between charging any price in the support of F . The maximum price a firm will ever charge is v since no buyer who observed a price above his/her reservation price would acquire the good. Further, the upper bound of the price distribution cannot be lower than v because a firm charging the upper bound would gain by slightly raising its price. Thus, it must be the case that $F(v) = 1$, and $F(p) < 1$, for all $p < v$. Any price in the support of F must then satisfy $\pi_i(p_i, F(\cdot)) = \pi_i(v)$, which yields

$$F(p) = \frac{2\lambda + (1 - \lambda)\mu_1}{2\lambda} - \frac{(1 - \lambda)\mu_1}{2\lambda} \frac{v - r}{p - r}. \quad (2)$$

Since F is a distribution function there must be some \underline{p} for which $F(\underline{p}) = 0$. Solving for \underline{p} one obtains the lower bound of the price distribution $\underline{p} = ((1 - \lambda)\mu_1(v - r)) / (2\lambda + (1 - \lambda)\mu_1) + r$.

A mixed strategy over the support $\underline{p} \leq p \leq v$ according to the cumulative distribution function F specified above is an equilibrium if and only if consumers are indeed indifferent between searching for one price and not searching at all. Therefore, it must be the case that $v - E[p] - c = 0$, where E denotes the expectation operator.⁹ In other words, the following condition must be satisfied:¹⁰

$$1 - \frac{(1 - \lambda)\mu_1}{2\lambda} \ln \left(\frac{2\lambda + (1 - \lambda)\mu_1}{(1 - \lambda)\mu_1} \right) = \frac{c}{v - r} \quad (3)$$

The LHS of this equation represents the additional gains to a consumer from searching once (given that he does not search at all). The RHS gives the relative cost of an additional search. In a low

⁹It must further be checked that it is not profitable for consumers to search more than once, i.e., that $v - E[\min\{p_1, p_2\}] - 2c < 0$.

¹⁰For current and future reference, let $H(p) = a - b(v - r)/(p - r)$ be a distribution function in the support $b(v - r)/a + r \leq p \leq v$, with $a - b = 1$. Then $E[p] = b(v - r) \ln[a/b] + r$, $E[\min\{p_1, p_2\}] = 2b(v - r)(1 - b \ln[a/b]) + r$ and $E[\max\{p_1, p_2\}] = 2b(v - r)[(1 + b) \ln[a/b] - 1] + r$.

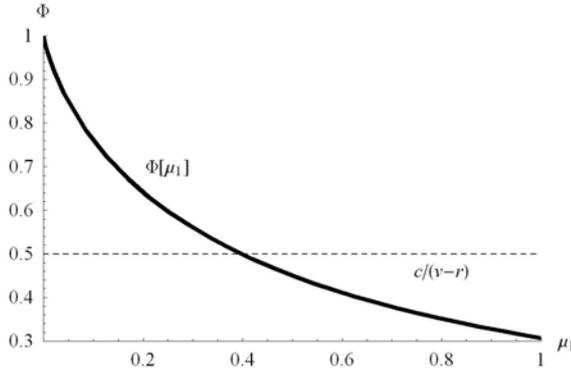


Figure 1: Buyers randomize between one search and no search ($\lambda = \frac{1}{3}$)

search intensity equilibrium, these two must be equal. Figure 1 gives a graphical representation of the two sides of the equation, where the LHS of equation (3) is denoted as $\Phi(\mu_1; \lambda)$. It is easy to see that whenever $c/(v-r)$ is not too small, a low search intensity equilibrium exists.

Case b: High search intensity

We now turn to the case where less-informed consumers randomize between searching for one price and searching for two prices.¹¹ The expected payoff to firm i from charging price p_i when the rival chooses a random pricing strategy according to the cumulative distribution function $F(\cdot)$ and less-informed consumers search as specified above is

$$\pi_i(p_i, F(p)) = (p_i - r) \left[\frac{(1-\lambda)\mu_1}{2} + (\lambda + (1-\lambda)(1-\mu_1))(1-F(p_i)) \right]. \quad (4)$$

This function is easily interpreted along the lines explained above.

In equilibrium, a firm must be indifferent between charging any price in the support of F . The same arguments employed above allow us to argue that $F(v) = 1$, and $F(p) < 1$, for all $p < v$. Any price in the support of F must satisfy $\pi_i(p_i, F(\cdot)) = \pi_i(v)$, which yields

$$F(p) = \frac{2 - (1-\lambda)\mu_1}{2(1 - (1-\lambda)\mu_1)} - \frac{(1-\lambda)\mu_1}{2(1 - (1-\lambda)\mu_1)} \frac{v-r}{p-r}. \quad (5)$$

Solving $F(\underline{p}) = 0$ for \underline{p} yields the lower bound of the equilibrium price distribution.

In this case, a mixed strategy over the support $\underline{p} \leq p \leq v$ according to (5) is an equilibrium if and only if less-informed buyers are indeed indifferent between searching for only one price and

¹¹For ease of exposition, we maintain the notation used so far in the sense that μ_1 denotes the probability with which less-informed buyers search for one price. However, unlike in case *a* above, $1 - \mu_1$ denotes now the probability with which these consumers search for two prices, i.e., μ_2 .

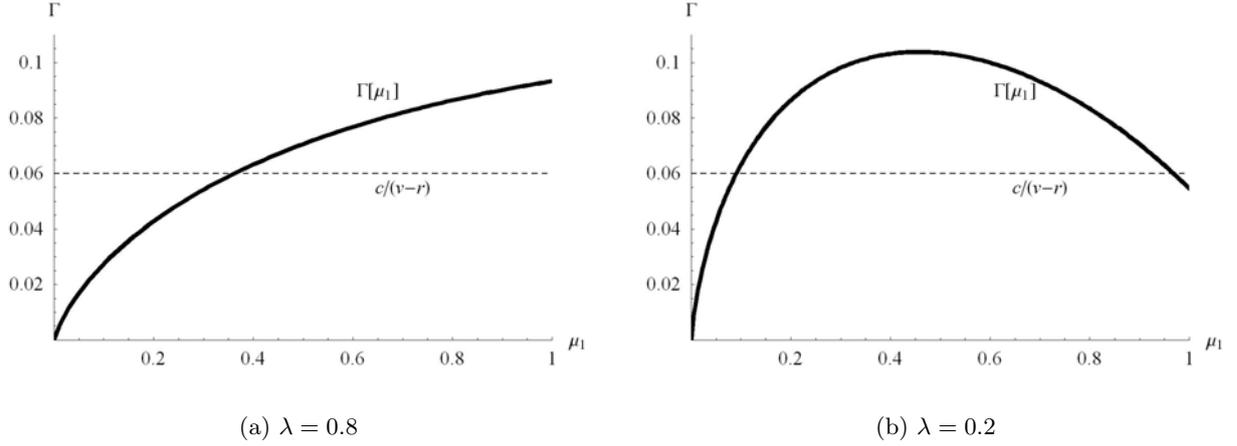


Figure 2: Buyers randomize between one search and two searches

searching for two prices.¹² Therefore it must be the case that $v - E[p] - c = v - E[\min\{p_1, p_2\}] - 2c$, which yields (see footnote 10):

$$\frac{(1 - \lambda)\mu_1}{2(1 - (1 - \lambda)\mu_1)} \left[\frac{1}{1 - (1 - \lambda)\mu_1} \ln \left(\frac{2 - (1 - \lambda)\mu_1}{(1 - \lambda)\mu_1} \right) - 2 \right] = \frac{c}{v - r}. \quad (6)$$

This equilibrium condition has a similar interpretation as the one for the low search intensity equilibrium. The LHS of this equation represents the additional gains to a consumer from making one search more (given that he has already searched once), while the RHS gives the relative cost of an additional search. To represent condition (6), let us denote its LHS by $\Gamma(\mu_1; \lambda)$. When the percentage of informed consumers is large enough, Γ is an increasing and concave function of μ_1 , as represented in Figure 2(a) ($\lambda = 0.8$). A high search intensity equilibrium is given by the intersection of curve Γ with the line $c/(v - r)$. When, in contrast, the percentage of informed consumers is small, the curve $\Gamma(\mu_1)$ is first increasing and then decreasing. The shape of Γ when λ is relatively small is illustrated in Figure 2(b) ($\lambda = 0.2$).

Case c: Moderate search intensity

We finally turn to the case where less-informed consumers search for one price with probability one. Derivations for this case are similar to the computations above and therefore omitted. The equilibrium distribution function for this case can be obtained by plugging $\mu_1 = 1$ in either of the cases *a* and *b* above discussed. A mixed strategy distribution function $F(p) = (1 + \lambda)/2\lambda - (1 - \lambda)(v - r)/(2\lambda(p - r))$ is part of an equilibrium if less-informed consumers indeed find it optimal to

¹²We must additionally be sure that no consumer gains by making no search, i.e., it must be the case that $v - E[p] - c > 0$. This is trivially satisfied.

search only once. Therefore, the following conditions two must hold: (i) $v - E[p] - c \geq 0$ and (ii) $v - E[p] - c \geq v - E[\min\{p_1, p_2\}] - 2c$.

The three possible equilibria are illustrated in Figures 3(a) and 3(b). Figure 3(a) exhibits a market where $\lambda = 0.8$. In this case, for large search cost parameters, for instance $c_1/(v - r)$, there is a unique equilibrium where less-informed buyers search with low intensity. As search cost falls, these consumers find it beneficial to search more intensively. Indeed, for intermediate search cost levels, for example $c_2/(v - r)$, the only equilibrium is such that less-informed buyers search for one price with probability one. Finally, when search cost is sufficiently low, for instance $c_3/(v - r)$, buyers search with high intensity in equilibrium. The bold lines depict the loci of equilibrium points.¹³

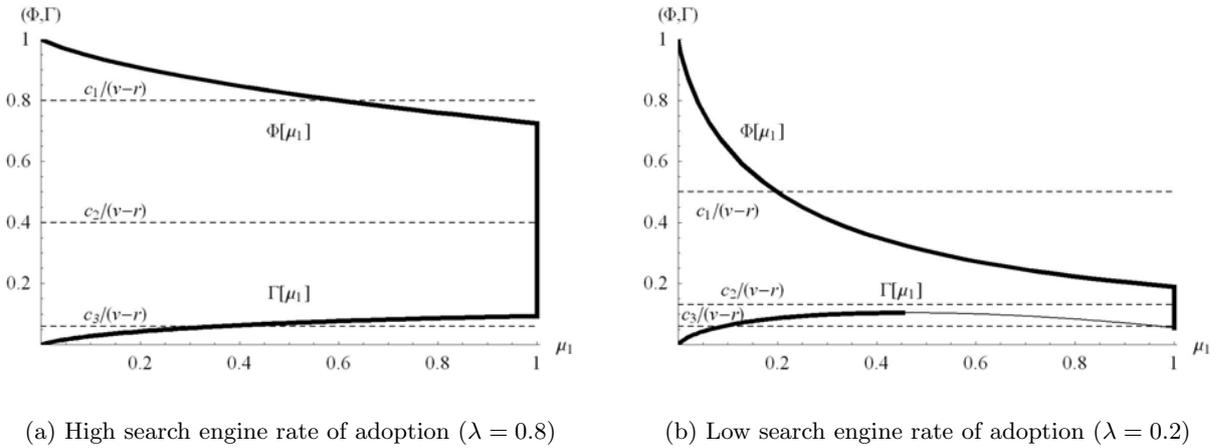


Figure 3: Equilibrium conditions

Figure 3(b) illustrates a case where the rate of adoption of search engines is low ($\lambda = 0.2$). In this case, for high and intermediate search cost, for example $c_1/(v - r)$, there is a single equilibrium where consumers search with low intensity. However, for a relatively low search cost $c_2/(v - r)$, there is a single moderate intensity equilibrium. For $c_3/(v - r)$, there are two equilibria: one in which buyers search with moderate intensity and another in which they search with high intensity. Finally, for extremely low search costs, there is just one equilibrium with high search intensity. As before, the bold lines depict the loci of equilibrium points.¹⁴

The analysis above yield the insight that whether the economy is in a low, moderate or high

¹³To help to interpret these graphs recall that $1 - \mu_1 = \mu_2$ in a high search intensity equilibrium, while $1 - \mu_1 = \mu_0$ in a low search intensity equilibrium.

¹⁴We note that for very low rate of adoption of search engines and for very low search costs, there may be an equilibrium with low search intensity and an equilibrium with high search intensity.

search intensity equilibrium depends on two critical model parameters: (i) the size of the purchase compared to the search cost $c/(v - r)$, and (ii) the search engine rate of adoption λ . In real markets, there is a marked difference between buyers' search intensity for different products (cf., the reference to Johnson et al. (2004) in the Introduction). Our basic model is able to explain this difference in terms of the exogenous parameters.

4 Comparative Statics

In this section we study the impact of changes in the parameters of the model. As argued above, a change in the search technology can be captured in our model either by a decline in c , or by an increase in the rate of adoption of search engines λ . We shall see that the influence of these parameters depends on the intensity with which less-informed buyers search in equilibrium.

The comparative statics results of a change in search technology are summarized in Table 1. In the table expected prices, price dispersion, profits and welfare are represented by p^e , p^d , π , and W respectively. An upwards (downwards) arrow means that the variable under consideration increases (falls); two arrows together means that the variable may increase or decrease and this depends on the initial value of the parameter; the symbol “—” means that the variable remains constant. In the discussion below explaining the results summarized in the table, we focus on explaining the empirical studies. Therefore, we concentrate on the implications of a change in search technology on expected prices and price dispersion. As a measure of price dispersion we take the difference between the expected maximum price and the expected minimum price.¹⁵ The implications for firms' profits and social welfare are discussed in footnotes.

	Low				Moderate				High			
	p^e	p^d	π	W	p^e	p^d	π	W	p^e	p^d	π	W
$\downarrow c$	\uparrow	$\uparrow\downarrow$	\uparrow	\uparrow	—	—	—	\uparrow	\downarrow	\downarrow	\downarrow	$\uparrow\downarrow$
$\uparrow \lambda$	—	—	\uparrow	\uparrow	\downarrow	$\uparrow\downarrow$	\downarrow	\uparrow	—	—	—	\uparrow

Table 1: Summary of comparative statics results

The following facts prove useful in the discussion that follows. Both price distributions given in (2) and (5) are of the form $H(p) = a - b(v - r)/(p - r)$ with support $b(v - r)/a + r \leq p \leq v$, and with $a - b = 1$. Then:

¹⁵There is a mathematical property that makes this measure attractive in our setting, namely, $E[\max\{p_1, p_2\}] - E[\min\{p_1, p_2\}] = 2(E[p] - E[\min\{p_1, p_2\}])$. Many of the aforementioned empirical papers have used this measure of dispersion; considering price variance instead complicates the analysis without bringing about additional insights.

Fact 1: $\frac{dE[p]}{db} > 0$

Fact 2: $\frac{dE[\min\{p_1, p_2\}]}{db} > 0$.

Fact 3: $\frac{d(E[\max\{p_1, p_2\}] - E[\min\{p_1, p_2\}])}{db} > 0$ if and only if $b < \bar{b} \simeq 0.28763$.

From equations (2) and (5) it follows that b is a measure of the equilibrium fraction of consumers who search only once relative to the number of consumers who search twice. In other words, it measures the fraction of active buyers over which firms have monopoly power.

4.1 The effects of a reduction in search cost c

Expected prices:

Consider first that less-informed consumers search with low intensity in equilibrium. Since $v - E[p] - c = 0$ in a low search intensity equilibrium, the price that less-informed buyers expect increases as c falls! To understand the intuition behind this surprising result let us point out that, as Figure 1 shows, the intensity with which less-informed consumers search in this type of equilibrium rises as c falls. Note further that these consumers are precisely those who do not exercise price comparisons, and thus they are prepared to accept higher prices. Consequently, a fall in c gives sellers incentives to charge higher prices more frequently, which in turn raises expected prices. Our next observation has to do with the expected price faced by the informed consumers, i.e., $E[\min\{p_1, p_2\}]$. It turns out that increased activity of the less-informed buyers exerts a negative externality on the informed ones. Indeed, a decline in c also increases the expected minimum price. This is readily seen by employing Fact 2 and noting that $b = (1 - \lambda)\mu_1/2\lambda$ in this equilibrium.¹⁶

Suppose now that less-informed consumers search with moderate intensity in equilibrium. Observe that a small change in c leaves less-informed buyers' behavior unchanged. Consequently expected prices remain constant.¹⁷

Finally, consider that less-informed consumers search with high intensity in equilibrium. Figures 2(a) and 2(b) show that a decline in c raises the probability with which less-informed buyers search for two prices, i.e., $d\mu_1/dc > 0$. Since price comparisons are more frequent as c falls, price

¹⁶It is straightforward to see now how firms' profits and social welfare are affected by a decline in c in a low search intensity equilibrium. Note that profits are proportional to the intensity with which less-informed buyers search: $\pi = (v - r)(1 - \lambda)\mu_1/2$ (see equation (1)). Then it is obvious that firms' profits rise with c . Social welfare, $W = \lambda(v - r) + (v - r - c)(1 - \lambda)\mu_1$ in this case, also increases. Note, however, that the additional surplus generated by a fall in c is fully captured by the firms!

¹⁷It is also obvious that firms' profits remain constant with c in a moderate search intensity equilibrium. Social welfare, $W = \lambda(v - r) + (v - r - c)(1 - \lambda)$ in this case, however rises because less-informed consumers incur lower costs to discover prices.

competition between firms is fostered. Thus, one would expect expected prices to fall with c . Indeed $b = (1 - \lambda) \mu_1 / [2(1 - (1 - \lambda) \mu_1)]$ in this type of equilibrium and it is readily seen that $db/d\mu_1 = (1 - \lambda) / [2(1 - (1 - \lambda) \mu_1)^2] > 0$. This together with the Facts above prove that mean prices for both types of consumers decrease with c .¹⁸

Price dispersion:

Consider first that consumers search with low intensity in equilibrium. As previously noted, a decline in c increases the shopping activity of the less-informed buyers μ_1 . Since $b = (1 - \lambda) \mu_1 / 2\lambda$, this implies that b increases as c decreases. Using Fact 3, it is easy to see that price dispersion rises as c decreases if and only if b is small. The fraction of consumers b who search only once can be small for two reasons: first, when λ is large, and second, when many less-informed consumers do not find it worthwhile to search (which occurs when c is relatively large). A search cost reduction brings more price-insensitive buyers to the market, which gives incentives to raise prices. Recall that price dispersion arises due to the existence of two groups of consumers who are asymmetrically informed, and that firms make substantial profits basically by expropriating the less-informed consumers. When there are many informed consumers, an individual firm will try to keep them by and thus will randomize prices to balance these two conflicting interests. As a consequence, price dispersion increases. In contrast, when there are few informed consumers firms do not need to care so much about them and thus price dispersion does not necessarily increase with a fall in c .

Suppose now that less-informed buyers search with moderate intensity in equilibrium. As observed previously, a small change in c leaves less-informed consumers' behavior unchanged and thus price dispersion remains constant.

Finally, consider that less-informed consumers search with high intensity in equilibrium. Since $E[p] - E[\min\{p_1, p_2\}] = c$ in this equilibrium, from footnote 15 it follows that $E[\max\{p_1, p_2\}] - E[\min\{p_1, p_2\}] = 2c$. Consequently, price dispersion decreases as the search cost falls.

¹⁸Note that equilibrium profits in a high search intensity equilibrium are $\pi = (v - r)(1 - \lambda)\mu_1/2$ (see equation (4)). As expected, profits decline with c because μ_1 does so. Interestingly, a fall in c does not increase social welfare necessarily. The reason is that the increased search activity of the less-informed consumers may be excessive from a social welfare viewpoint. This can be seen by noting that welfare is $W = \lambda(v - r) + (1 - \lambda)(v - r - 2c + \mu_1 c)$ in this case. Thus $dW/dc = (1 - \lambda)(-2 + \mu_1 + c d\mu_1/dc)$. The sign of this derivative depends on the parameters of the model. To provide an instance in which welfare declines after a decrease in c , consider a market setting where $\lambda = 14/15$, $v = 1$ and $r = 0$. Consider that search costs are initially $c = 0.055$. In the equilibrium with high search intensity, less-informed buyers would search for two prices with probability 0.0756452, and social welfare would be 0.996056, approximately. A reduction in search cost from 0.055 to 0.054 would increase the incentives to search of the less-informed consumers, who would thus search for two prices with higher probability, 0.105676 approximately. From a social perspective, however, the increased search intensity brought about by the search cost reduction is excessive and welfare attains a lower level, 0.99602 approximately.

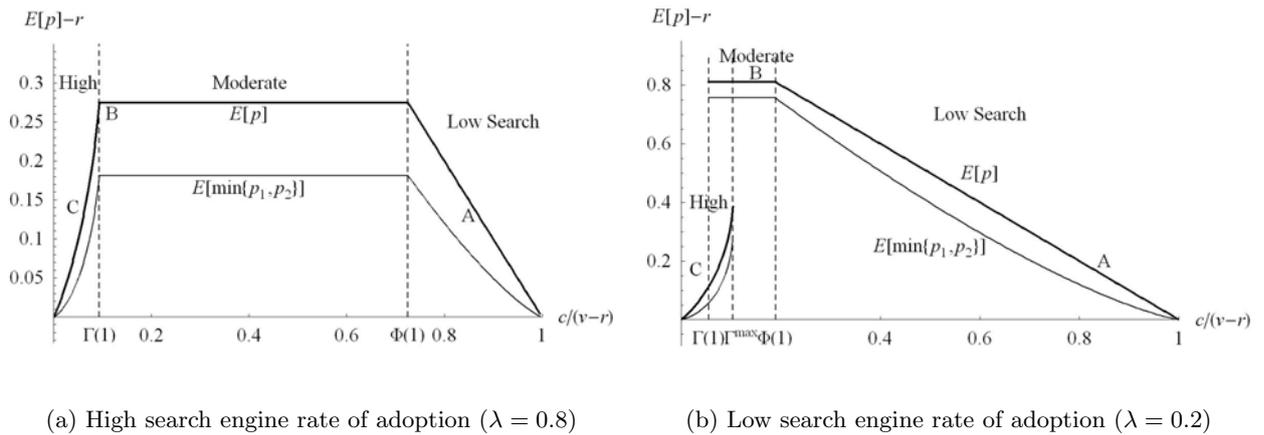


Figure 4: The impact of lower search cost c

Overview of partial results:

Previous observations regarding the impact of a search cost reduction on expected prices and price dispersion are gathered in Figure 4(a) and 4(b). In Figure 4(a) we have simulated an economy where the number of informed consumers is large ($\lambda = 0.8$). This graph depicts expected price (thicker curve) and expected minimum price (thinner curve) as a function of relative search cost. As noted above, for any given value of $c/(v - r)$, the vertical distance between the two lines constitutes a measure of actual price dispersion. When search cost lies in the interval $(\Phi(1), 1)$, less-informed consumers search with low intensity in equilibrium. In this region, expected prices and price dispersion increase as the search cost falls, as indicated above. For search cost values in between $\Gamma(1)$ and $\Phi(1)$ it pays less-informed consumers to search for one price with probability one. In this region a decline in search cost has no impact on expected prices and price dispersion. Finally, when search cost lies in the interval $(0, \Gamma(1))$, it pays less-informed consumers to search for two prices with positive probability. As the search cost falls in this region the frequency with which price comparisons occur in the market increases, which fosters competition between the firms. Consequently, expected prices and price dispersion decline. Eventually, as search cost approaches zero mean prices converge to marginal cost.

It might be argued that moving markets online does not marginally decrease search costs but does so dramatically. Upon observing Figure 4(a) one sees that even a dramatic change in search cost does not necessarily decrease price dispersion and mean prices. To see this, consider for instance a search cost reduction from A to B. Even though this is an enormous decline of about 80%, mean

prices and price dispersion increase. In contrast consider a smaller cost fall from B to C of about 60%. This cost reduction decreases mean prices and price dispersion. These observations illustrate that one cannot conclude that a large search cost reduction will enhance market efficiency without taking into account the market status quo.

Figure 4(b) complements our previous exposition by presenting equilibrium expected prices for a case with a lower rate of adoption of search engines ($\lambda = 0.2$). Figure 4(b) has the distinctive feature that for some parametrical values there are multiple equilibria. In particular, when search cost lies in the interval $(\Gamma(1), \Gamma^{\max})$ one may have a moderate search equilibrium with high expected prices, or a high search intensity equilibrium with lower mean prices. (This is the reason why Figure 4(b) exhibits a discontinuity in expected prices; see also Figure 2(b).) Thus, less-informed consumers face a coordination problem. It pays to search intensively if the others do so, otherwise it is worth to search only once. As argued above, observing price dispersion and expected prices at the search cost levels A, B and C one can state that a dramatic decline in search cost need not increase market transparency.

As explained in the Introduction, we see these results as a possible explanation why Bailey (1998) find higher online prices for books and CDs compared to off-line, while almost equal online and off-line prices for software. For books and CDs the relative size of the purchase is small compared to the search cost and in 1996, 1997 the rate of adoption of search engines was probably low. Thus, one would expect a low or a moderate intensity equilibrium to be in place. In such a case, the comparison between the online channel and the off-line one would be captured by a decline in c and thus would produce higher or equal expected prices. In contrast, for software one may reasonably expect a moderate or a high search intensity equilibrium, since product value and rate of adoption of search engines seem to be greater for this product. This may explain why software online prices were not found to be much higher compared to their off-line counterparts and, further, why price dispersion was found to be lower. Brynjolfsson and Smith (1999) found books and CDs prices to be lower online than off-line. Since they took a sample of prices much later than Bailey did, it may be the case that they were looking at a market with a larger search engine rate of adoption. This market may be in a high search intensity equilibrium and thus a decline in search cost would lower expected prices and price dispersion.

4.2 An increase in the rate of adoption of search engines λ

Another manner to capture changes in search technology is to consider that the fraction of consumers using search engines increases.

Expected prices:

Consider first that less-informed consumers search with low intensity in equilibrium. Since $v - E[p] - c = 0$ in equilibrium, and since neither v nor c varies, expected price must remain constant. It is worth to disentangle the incidence of changes in λ on less-informed consumers search incentives and firms pricing decisions. Notice first that an increase in the search engine rate of adoption has in principle a pro-competitive effect. *Ceteris paribus*, firms would tend to charge lower prices with higher probability. One can apply the implicit function theorem to equation (3) to obtain

$$\frac{d\mu_1}{d\lambda} = \frac{\mu_1}{\lambda(1-\lambda)} > 0, \quad (7)$$

which means that an increase in λ results in an increase in the search intensity of the less-informed consumers μ_1 . This is obviously due to the fact that more informed consumers in the market makes searching more attractive for the less-informed consumers, as the former buyers put pressure on firms to reduce prices. This in turn implies that the number of price insensitive buyers rises, which gives firms incentives to raise prices. Interestingly, these two opposite forces cancel out so that expected prices remain constant! We also observe that the price informed consumers expect, i.e., $E[\min\{p_1, p_2\}]$, does not change with λ either. To see this, note that in this case $b = (1-\lambda)\mu_1/2\lambda$. Using equation (7), just a little algebra shows that $db/d\lambda = 0$, which implies that the expected minimum price remains constant too!¹⁹

Suppose now that less-informed buyers search with moderate intensity. Notice that an increase in λ does not alter the behavior of less-informed buyers. Consequently, since more consumers exercise price comparisons, the economy becomes more competitive. The price expected by the less-informed consumers obviously falls. This is readily seen using the Facts above and noting that $b = (1-\lambda)/2\lambda$ in this case, and therefore $db/d\lambda = -1/2\lambda^2 < 0$. Analogously, using Fact 2, one

¹⁹Since expected prices remain constant and more less-informed consumers are active when λ rises, one would expect firms' profits to increase. Remember that $\pi = (v-r)(1-\lambda)\mu_1/2$ in this case. The impact of an increase in λ is given by $d\pi/d\lambda = (v-r)[(1-\lambda)d\mu_1/d\lambda - \mu_1]/2$. Using (7) we obtain $d\pi/d\lambda = (v-r)\mu_1(1-\lambda)/2\lambda > 0$, i.e., an increase in λ increases firms' profits!

We finally observe that social welfare increases with λ due to the increased activity of the less-informed consumers (note that $(1-\lambda)\mu_1$ rises). To see this, remember that $W = \lambda(v-r) + (v-r-c)(1-\lambda)\mu_1$ in this case. Using (7) we can compute $dW/d\lambda = v-r + (v-r-c)\mu_1(1-\lambda)/\lambda > 0$. Note, however, that a great deal of the increase in social welfare is captured by the firms.

proves that the price expected by the informed buyers also declines.²⁰

Finally, consider that less-informed buyers search with high intensity in equilibrium. As noticed above, when λ goes up firms tend to charge lower prices with higher probability. Applying the implicit function theorem to equation (6), one obtains

$$\frac{d\mu_1}{d\lambda} = \frac{\mu_1}{1-\lambda} > 0, \quad (8)$$

which means that less-informed buyers search less intensively as λ rises. The decreased search activity of these consumers implies that the frequency with which price comparisons occur diminishes. Surprisingly, it turns out that the behavior of less-informed buyers compensates away the pressure that the presence of relatively more informed consumers puts on the firms to cut prices. To see this, note that $b = (1-\lambda)\mu_1/(2(1-(1-\lambda)\mu_1))$ in this case. Using equation (8), it is easily seen that $db/d\lambda = 0$. This implies that neither the price expected by less-informed consumers who search only once, nor the price expected by buyers who search twice changes!²¹

Price dispersion:

Consider first the economy is in a low search intensity equilibrium. As shown above the pro-competitive effects of an increase in λ are offset by the increased activity of less-informed consumers. This in turn implies that changes in λ have no incidence on price dispersion!

Suppose now that less-informed buyers search with moderate intensity in equilibrium. As shown above $db/d\lambda < 0$, which implies that the influence of λ on price dispersion is ambiguous (Fact 3). When the number of informed consumers is large initially then an increase in λ decreases price dispersion. In contrast, when λ is small initially then an increase in λ raises price dispersion. The intuitive argument has been explained above.

Finally consider the economy is in a high search intensity equilibrium. In this case the pro-competitive effects of an increase in λ are entirely offset by a decrease in the search activity of the less-informed buyers. Consequently changes in λ have no impact on price dispersion.

Overview of partial results:

²⁰From the previous remarks it is readily understood that firm profits, $\pi = (v-r)(1-\lambda)/2$ in this case, decline with λ . In contrast, social welfare, $W = v-r-c(1-\lambda)$ here, rises with λ since fewer consumers incur search costs.

²¹An increase in λ also turns out not to have influence on firms' profits. Remember that $\pi = (v-r)(1-\lambda)\mu_1/2$ in a high search intensity equilibrium and it is readily checked that $d\pi/d\lambda = 0$. In regard to social welfare, remember that $W = \lambda(v-r) + (1-\lambda)(v-r-2c+\mu_1c)$ in this case. A little algebra shows that $dW/d\lambda = 2c > 0$, which implies that welfare rises with λ . Two factors explain this. First observe that fewer consumers pay search costs when λ rises. Second, less-informed consumers search less intensively and the economy further saves in search costs. Remarkably, the additional surplus is captured by the consumers.

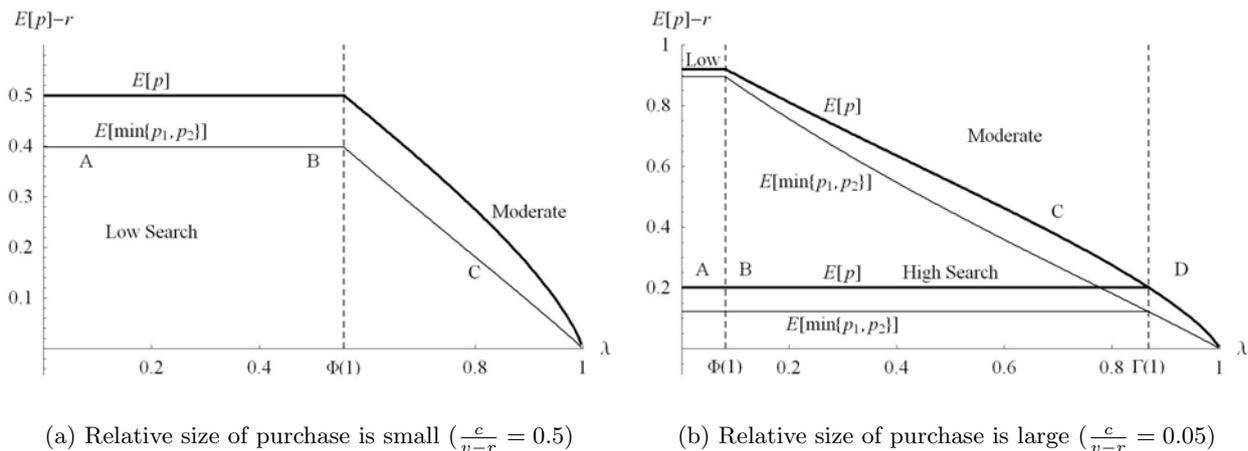


Figure 5: The impact of the search engine rate of adoption λ

Previous discussions regarding the influence of changes in the number of informed buyers on expected prices and price dispersion are gathered in Figures 5(a) and 5(b). Figure 5(a) simulates an economy where product's valuation is relatively low compared to search cost ($c/(v-r) = 0.5$). The figure depicts expected price (thicker curve) and expected minimum price (thinner curve) as a function of λ . Recall that for any given λ , the vertical distance between the two curves provides a measure of price dispersion. Observe that when λ lies in the interval $(0, \Phi(1))$ market equilibrium exhibits low search intensity. In this case, the pro-competitive effects of an increase in λ are entirely offset by the search behavior of less-informed buyers and so expected prices and price dispersion remain constant. When the rate of adoption of search engines is large enough, $\Phi(1) < \lambda < 1$, less-informed consumers search with moderate intensity in equilibrium and prices decline smoothly to marginal cost as λ rises.

In Figure 5(b) we have simulated an economy where search cost is low ($c/(v-r) = 0.05$). We first observe that there may be multiple equilibria in this case. For instance, for a λ level depicted by point A there are two equilibria: one with low search intensity and one with high search intensity. For λ levels given by the points B and C there are also two equilibria: one with moderate search intensity and one with high search intensity. Finally, for a λ level given by point D there is a single moderate search equilibrium. Observe that when there is multiplicity of equilibria a high search intensity equilibrium leads to lower expected prices. Thus, less-informed consumers face a coordination problem. If a high search intensity equilibrium prevails in the economy expected prices and price dispersion are insensitive to changes in λ , as noted above. It may also happen that the nature of buyers' coordination is such that they do not search so much. Then, if λ lies

in the interval $(0, \Phi(1))$, the economy would be in a low search intensity equilibrium and changes in λ have no influence on expected prices and price dispersion. If, instead, λ lies in between $\Phi(1)$ and $\Gamma(1)$, consumers would search with moderate intensity and an increase in λ would reduce mean prices. However, it would decrease price dispersion only if λ is sufficiently great to begin with. In summary, Figure 5(b) illustrates that while price levels do not increase with respect to λ , it may very well be the case that price dispersion rises.

A final remark regarding Figure 5(b) is that a high search intensity equilibrium may exhibit greater price dispersion than a low or moderate search intensity equilibrium. Therefore mean prices and price dispersion need not be perfectly correlated.

We believe that search engine rate of adoption may explain why Bailey (1998) found higher online prices for books and CDs sold in 1996 and 1997 while Brynjolfsson and Smith (1999) found the opposite for a sample of books sold in 1998 and 1999. The same applies to the study of Brown and Goolsbee (2000) who argue that there is no evidence that Internet usage reduced prices of life insurance policies before comparison websites emerged and proliferated. When the rate of adoption of search engines is low, we note that the pro-competitive effects of marginal increases of informed buyers are entirely offset by economizing behavior of less-informed buyers. As the adoption rate of search engines increases, search propensity rises and further increases in λ result in greater transparency.

5 Conclusions and Discussion

In a model that concentrates on the search aspect of (online) markets, we have investigated whether improved search technology fosters competition and consequently lowers commodity prices and raises social welfare, as commonly argued. We have found that the impact of Internet usage on the efficiency of commodity markets may be subtler than previously thought.

Our first primary finding relates to the intensity with which buyers search in equilibrium. We have found that product's value relative to search cost as well as the search engine rate of adoption are the determinants of consumers' search incentives. More precisely, for a given search cost, buyers' search incentives are (weakly) monotonic in product's value and non-monotonic in the search engine rate of adoption. The direct implication of this observation is that price-cost margins and price dispersion need not be low in all online commodity markets. Whether they are low or high depends on how much buyers search, which in turn depends on market characteristics.

Our second major finding is that the comparative statics effects of improved search technology

on commodity markets depend on the manner it is modelled, i.e., on whether improved search technology is regarded as lowering unit search costs, or as increasing search engine rate of adoption. Moreover, these effects are influenced by the intensity with which consumers search in the status quo equilibrium, and hence by initial market characteristics. A unit search cost reduction may result in higher, equal or lower mean prices and price dispersion depending on whether consumers initially search with low, moderate or high intensity, respectively. In contrast, expected prices and price dispersion (weakly) decrease as the search engine rate of adoption rises, irrespective of the buyers' search activity. The latter two remarks suggest that the long run impact of Internet usage on commodity markets will be sensitive to the extent to which search engines are adopted and become central places of information exchange.

As argued in the main body of this paper, our results may help understand the controversial empirical findings reported so far. Perhaps more interesting is the fact that, as suggested by our research, future empirical studies assessing the impact of Internet usage on market efficiency should take into consideration market characteristics such as product's value and the search engine rate of adoption more explicitly. A first attempt to such an analysis is provided by Janssen, Moraga-González and Wildenbeest (2004). Contrarily to most empirical studies carried out so far, this paper adopts a fully structural approach. The theoretical restrictions derived from firm and consumer behavior in a consumer search model similar to the one discussed in Section 3 of this paper are directly tested using price data collected from the Internet. The parameters of the model are first estimated by maximum likelihood and in turn used to test whether the model does well in explaining real world data. Moreover, using the equilibrium conditions on search behavior, it is possible to estimate the search cost of uninformed consumers. Then provided that the model does well in explaining the data, the estimates shed light on how market characteristics affect consumer and firm behavior. Janssen, Moraga-González and Wildenbeest (2004) find that the high search intensity equilibrium is particularly capable of explaining observed prices of online computer hardware in a manner that is consistent with the underlying theoretical model for almost all products included in the analysis.

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