Information Asymmetry and Search Intensity*

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Abstract

The existing studies on consumer search agree that consumers are worse-off when they do not observe sellers’ production marginal cost than when they do. In this paper we challenge this conclusion. Employing a canonical model of simultaneous search, we show that it may be favorable for consumer to not observe the production marginal cost. The reason is that, in expectation, consumer search more intensely when they do not know sellers’ production marginal cost than when they know it. More intense search imposes higher competitive pressure on sellers, which in turn benefits consumers through lower prices.

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1 Introduction

The literature on consumer search has improved our understanding of the imperfect competition by assigning a central role to consumers’ search behavior. Within this field, one conclusion seems well-established: consumers are worse-off when they do not observe sellers’ production marginal costs than when they observe those costs.\footnote{The only exception is Janssen et al. (2017) who show numerically that the opposite may be true.} This conclusion holds in a wide range of markets. Examples include markets where exogenous parameters, or shocks, determine sellers’ production marginal costs (e.g., Dana (1994), Janssen et al. (2011), Duffie et al. (2017)), markets where consumers make repeated purchases (e.g., Yang and Ye (2008), Tappata (2009)), and vertical industries where sellers buy production inputs from profit maximizing manufacturers and, therefore, manufacturers’ wholesale prices determine sellers’ production costs (e.g., Janssen and Shelegia (2015), Garcia et al. (2017), Janssen (2020)). Moreover, the main result of these studies seems to be independent of the search protocol. For instance, Dana (1994) and Janssen and Shelegia (2015) employ models of sequential search, whereas Yang and Ye (2008) and Tappata (2009) apply models of simultaneous search. Also the empirical papers seem to apply this conclusion to explain their results (e.g., Tappata (2009)).

This paper challenges the widespread consensus that consumers benefit from observing sellers’ production costs. To demonstrate that, we employ a canonical search model of Burdett and Judd (1983). It is a one shot-game where oligopoly sellers simultaneously set prices and consumers choose their search intensity. Sellers are identical, produce homogeneous goods and compete on prices. The production marginal cost in the industry is a random draw from a commonly known distribution. Sellers observe the production cost but consumers do not, which results in the information asymmetry. Without knowing prices (in addition to the production marginal cost), consumers need to engage in costly nonsequential search, also known as simultaneous search and fixed-sample-size search, and discover a price of at least one firm in order to make purchases. Each consumer chooses a number of firms to search, searches exactly the chosen number of firms and then terminates the search. We compare market outcomes of this model with that of a model where consumers observe the production marginal cost.

Our main finding is that consumers are better-off when they do not observe the produc-
tion marginal cost than when they do. The intuition lies in consumers’ search behavior. In expectation consumers search more intensely when there is information asymmetry on sellers’ production marginal costs than when there is not. More intense search means that consumers are more able to compare different offers, which in turn implies stronger competition. Strong competition clearly benefits consumers. This benefit is so high that their welfare is higher than without the information asymmetry although they spend more resources on search.

To understand why consumer search more intensely with the information asymmetry than without it, it helps to consider a case without the information asymmetry. Specifically, buyers search intensity is decreasing and concave in the production marginal cost. The concavity is due to the fact that an increase in the production marginal cost has two negative effects on the level of price dispersion. The direct effect arises because of the fact that, consumers’ search behavior being fixed, the gap between the monopoly price and the production marginal cost declines with the production marginal cost. This reduces a range of prices that sellers can set and, in particular, the support of the equilibrium price distribution shortens with the lowest price in the support getting closer to the monopoly price. There is also an indirect effect: firms take into account consumers’ search strategy when pricing. Firms expect the share of price-comparing consumers to drop owing to the above direct effect. The reason is that consumers have less incentive to search and compare prices if sellers’ prices do not differ much. Firms thus have incentive to charge prices closer to the monopoly price, which even further reduces price dispersion. The direct- and indirect-effects go hand in hand with reduction of the level of price dispersion, which in turn causes concavity of the search intensity in the production marginal cost. Owing to this concavity, it then follows by Jensen’s inequality that the expected search intensity when consumers observe the production marginal cost is lower than the search intensity for a given expected production marginal cost, i.e., the search intensity with the information asymmetry.

This result has important implications in real-world markets. A set of such markets are over-the-counter markets. In these markets benchmarks, such as LIBOR and EU-

\footnote{For sufficiently small search costs, in equilibrium sellers set prices from a symmetric price distribution that is monotone in its compact support with the monopoly price being the highest price for any realization of the production marginal cost.}
RIBOR, aggregate and report interbank borrowing rates on the daily basis. They thus serve as a proxy of sellers’ production costs. It is argued that benchmarks resolve the information asymmetry on the cost of trading between dealers (who are sellers in our model) and traders (who are buyers in our model) and improve market traders’ well-being (Duffie et al. (2017)). However, our main result warns that the benchmarks may improve dealers’ profit at the expense of traders’ well-being. This seems plausible as in many over-the-counter markets, benchmarks are created by dealers’ initiative rather than that of a public institution.

Other examples of real-world markets, where our main result may be relevant, include mortgage markets and consumer financial markets. In these markets, as in over-the-counter markets, buyers need to spend time to learn sellers’ offers. Furthermore buyers wish to quickly gather information about offers and it takes time to observe the search outcome, which makes simultaneous search a more attractive protocol than sequential search (Morgan and Manning (1985)).

The rest of the paper is organized as follows. The next section discusses studies that are closely related to our paper. In Section 3 we lay out the model. In sections 4 and 5 we undertake equilibrium analysis and compare market outcomes with the information asymmetry on the production marginal cost to those without it, respectively. In Section 6 we show that our main results are robust to different model extension. The final section concludes.

2 Related Literature

Our paper contributes mainly to literature on consumer search with information asymmetry on the production marginal cost. Within this field, Dana (1994) is closest to our study. The author analyzes a model that is identical to ours in all aspects, except for the search protocol. He employs sequential search. Thus at each decision node, a consumer needs to decide whether to make a purchase at the lowest observed price (if there are any), to search one more firm (if there are any non-searched firms left), or drop out of the market. If consumers do not observe sellers’ production marginal costs, they update their beliefs about the production cost each time after discovering a new price according to Bayes’ rule. Sellers can then signal their production costs through their prices. In equilibrium
sellers partially trick consumers into believing that their production marginal cost is high by charging high prices even though the production marginal cost is low. This trick does not work if consumers observe the marginal cost of production. As a result, sellers have more market power with the information asymmetry on the production marginal cost than without it. Whereas Dana (1994) considers bimodal distribution of production marginal costs, Janssen et al. (2011) extend it to a continuous distribution of production marginal costs with a compact support. Duffie et al. (2017) further extend the model by making the first search costly. Finally, Janssen et al. (2017) consider a duopoly version of Dana (1994)’s model and employ a so-called non-reservation price equilibrium which resolves a problem of equilibrium non-existence for certain parameter values. The authors report that in non-reservation price equilibrium, the information asymmetry can be beneficial for consumers, but this result is based on numerical simulations.

Sellers in our model do not have opportunity to signal their production costs via prices because the search is simultaneous. The reason is that in a model of simultaneous search, search intensity is independent of the prices discovered along the search path.

Another set of related studies include papers which examine dynamic models of search where consumers make repeated purchases. Tappata (2009) employs a model identical to ours, but the static game is played over infinitely many periods. The industry production marginal cost evolves according to Markov process across periods. As production costs are correlated across periods and consumers observe past realizations of production costs, they form expectations on the current realization of the production cost. If they expect the current production marginal cost to be high, they search less intensely, and if they expect low marginal cost of production they search more intensely. The reason is that the level of price dispersion is lower with a high production marginal cost than with a low cost, as the range of prices that sellers can set—measured by the gap between the production marginal cost and the monopoly price—is lower in the former case than in the latter case. As a result of this, prices increase fast when the production marginal cost rises but decrease slowly when the cost falls—a phenomenon known as rockets-and-feathers. In contrast if consumers observed current realization of the production marginal cost, prices would have adjusted instantly to both an increase and a decrease in the cost. Therefore, consumers are worse-off when they do not observe the production marginal cost than when they do. Yang and Ye (2008) study a variation of this model where consumers do
not observe even the past realizations of the production marginal cost.\(^3\)

In our one-shot game, a mechanism discussed in the previous paragraph is clearly absent. It is, however, possible to extend our model to a dynamic setting where sellers’ marginal costs of production are not correlated across periods. In this case our main result holds.

Our paper is also related to papers on consumer search in vertical industries with downward sloping consumer demand. Janssen and Shelegia (2015) introduce a monopolist manufacturer to a sequential search model as in Dana (1994). The manufacturer’s wholesale price is sellers’ production marginal costs as sellers buy the manufacturer’s product and convert it into a final good. Consumers do not observe the wholesale price of the manufacturer, i.e., they do not know sellers’ production marginal costs. However, in equilibrium consumers have correct beliefs about the wholesale price. The traditional notion is that the problem of double marginalization should disappear if there are multiple sellers in the market. However, Janssen and Shelegia (2015) show that if consumers have arbitrarily small search costs (i.e., when they vanish in the limit), manufacturer chooses a wholesale price that is higher than the standard monopoly price. The reason is that if a manufacturer deviates to a wholesale price higher than one that is conjectured by consumers, sellers cannot increase their prices without inducing more search. If sellers were to raise their prices as a response to a higher wholesale price, consumers would believe that it must be sellers that deviated (and not the manufacturer). Thus, consumers would search further after observing a high price. This inability of sellers to raise prices as the wholesale price increases makes manufacturers’ demand less responsive, which allows the manufacturer to squeeze out sellers’ profits. As a result, the equilibrium wholesale price is higher than the standard monopoly price. This clearly harms consumers. Note however that such a mechanism would certainly be absent if consumers observed the wholesale price. Garcia et al. (2017) extend the model by assuming that there are multiple manufacturers and sellers, just like consumers, need to engage in costly search in order to discover wholesale prices. Janssen (2020) allows a manufacturer to employ two-part tar-

\(^{3}\text{Cabral and Fishman (2012) propose a dynamic search model with groups types of firms to explain the rockets-and-feather phenomenon. However, this result occurs only when changes in production costs over time are small. If such changes are large, the authors show, an opposite results holds: prices adjust to a decrease in the production marginal cost and do not respond to an increase in the production marginal cost. Hence, the overall impact of the information asymmetry on consumer welfare is ambiguous.}\)
iffs and Janssen and Reshidi (2020) permit a manufacturer to price discriminate among sellers.\footnote{A polemical assumption in these studies is that, although consumers do not know sellers’ production marginal costs, they know manufacturers’ production costs.}

Finally, Sobolev (2017) studies search markets where each firm’s marginal cost of production is an independent random draw. As each firm observes only its own production marginal cost, there is no such information asymmetry between the sellers and buyers as we have it in our paper. The author shows that firms can raise their profits by submitting their production costs to a benchmark which publishes the average of the submitted costs. The author shows that the driving force of this result is partial resolution of production cost uncertainty among sellers. Unlike Sobolev (2017) we focus on the role of benchmarks that resolve information asymmetry between buyers and sellers.

3 Model

Our model is an extension of Burdett and Judd (1983). \(N \geq 2\) number of identical firms supply homogeneous goods to a unit mass of consumers. Production marginal cost is a random draw from \(\{c_1, c_2, ..., c_K\}\), where \(0 \leq c_1 \leq ... \leq c_K < \infty\), according to probability mass function (PMF) \(f\), so that \(f_k\) represents the probability that the production marginal cost equals to \(c_k\) for \(k \in \{1, ..., K\}\). Sellers observe their production costs and compete on prices. Price \(p^j(c_k)\) represents firm \(j\)’s strategy for given production cost \(c_k\). As we allow for mixed strategies, let \(x^j_k(p)\) be the probability that firm \(j\) charges a price above \(p\) and the support of the price distribution be \([p_k, p_{k+1}]\), when the production marginal cost is \(c_k\).

Each consumer wishes to consume a unit of a product which she values at \(v(>c_K)\). Buyers, unlike sellers, do not observe the production marginal cost. They also do not know prices. To make a purchase a consumer has to learn at least one price through costly search. Search is simultaneous. A consumer chooses \(m\) number of firms to search and having searched all \(m\) firms she terminates the search. It costs \(s\) to obtain a price quote. To ensure full participation we let searching one firm to be free. Therefore, searching \(m\) number of firms entails a total cost of \((m-1)s\). Since mixed-strategies are allowed, we let \(q(m)\) stand for the probability that a buyer searches \(m\) firms and so \(\sum_{m=1}^N q(m) = 1.\footnote{As searching one firm is free, not searching at all is always a weakly dominated strategy.}
The timing of the game is as follows. First, the production marginal cost is realized. Second, firms observe the production marginal cost and simultaneously set prices. Third, consumers—without knowing prices and production marginal cost—search. Consumers who observe at least one price may make purchases.

The solution concept is Bayesian-Nash equilibrium (BNE). Letting $x_k^{-j}$ be the strategies of all firms other than firm $j$, $\Pi_j^k(p, x_k^{-j})$ be the expected profit that price $p$ yields to firm $j$ and $\Pi_k \geq 0$ be some constant, a BNE is a collection of price distributions $(x_k^j)^N_{j=1}$ for each $c_k$ and search probabilities $q(m)$ such that (i) $\Pi_j^k(p, x_k^{-j}) \leq \Pi_k$ for all $p$, (ii) $\Pi_j^k(p, x_k^{-j}) \geq \Pi_k$ for $p \in [p_k, \bar{p}_k]$, and (iii) consumers searching for $m$ firms do not obtain lower utility than searching for any number of firms.

4 Equilibrium

Equilibrium analysis consists of two parts. In the first part we examine our main model where buyers do not observe the production marginal cost. We later analyze a model which differs from our main model in that buyers observe the production marginal cost.

4.1 Unobserved Production Marginal Cost

We start the equilibrium analysis by noting that there always exists an equilibrium where all buyers search one firm and all firms charge the monopoly price (Diamond (1971)), a result is known as the Diamond paradox. The reasoning is as follows. Suppose that buyers expect all firms to price their products at the monopoly price. It is then optimal for buyers to search one firm. If, however, buyers do not compare prices, the monopoly price is the optimal price, which justifies buyers’ above expectation.

Proposition 1. There always exists a BNE where buyers search one firm and firms charge the monopoly price.

The Diamond paradox is known to be fragile to model assumption. It ceases to exist if, for example, one introduces a small share of price-comparing buyers. We thus turn our attention to BNEs where some buyers search more than one firms, which we call a BNE with active search. Existence of such equilibrium is robust to small changes in model assumption.
Our first observation is that in equilibrium with active search a positive share of consumers search only one firm. The reasoning is by contradiction. If all buyers observe at least two prices, they will buy at the lowest observed price. No firm then wishes to be one with the highest price. If two or more firms tie at some price higher than the production marginal cost, it pays off for one of them to slightly undercut its price. As a result of these two arguments, the optimal price must be equal to the production marginal cost. However, if prices equal to the production marginal cost, buyers do not want to search more than one firm, a contradiction.

**Lemma 1.** *In a BNE with active search, some buyers must search one firm.*

A consequence of the lemma is that in equilibrium with active search, firms play mixed-strategy pricing for any realization of the production marginal cost (e.g., Baye et al. (1992)). This happens because of two opposing forces that affect a firm’s pricing policy. One of them is due to price-comparing buyers whose share must be strictly positive in equilibrium with active search. The opposing force is due to buyers who search only one firm and whose share is also positive as Lemma 1 shows. Each firm wishes to raise its price to ripoff buyers who observe only its offer, but at the same time each firm wishes to lower its price to attract price-comparing consumers. An interaction of these two opposing forces gives rise to a mixed-strategy pricing.

If buyers expect dispersed prices and searching one firm is part of an equilibrium with active search, price-comparing consumers search exactly two firms in equilibrium. To understand the reasoning one needs to compare the added benefit of searching an additional firm to its cost. The added benefit of searching an additional firm decreases with the number of searched firms for any non-degenerate price distribution. Formally, if we let $X(p)$ be the *ex-ante* probability that consumers expects a firm to charge a price above $p$, then $1 - (1 - X(p))^m$ is the distribution of the minimum of $m$ prices. Call is $m$th order statistic. The difference between the $m$th and $m + 1$th order statistic is then $X^m(p)(1 - X(p))$. This difference is clearly decreasing in $m$, which proves that the added benefit of searching an additional firm is decreasing with the number of searched firms. However, as the cost of searching an additional firm is constant, it must be that either all consumers search the same number of firms or they must randomize over searching two adjacent numbers of firms. Since in equilibrium (with active search) some consumers discover only
one price and the rest of them compare different prices, these price-comparing consumers must search exactly two firms.

**Lemma 2.** In a BNE with active search, some of consumers searche one firm and the rest, two firms.

The lemma helps us to determine properties of the equilibrium price distribution for each realization of the production marginal cost. First, it has been established that for any given production marginal cost, firms draw prices from the same unique price distribution (see, e.g., Burdett and Judd (1983), Johnen and Ronayne (forthcoming)).

We will thus drop firm-specific indices from the equilibrium price distributions. Second, the price distribution cannot have atoms. If it did have an atom, undercutting would be profitable. Third, the price distribution cannot have flat regions in the support. If it did, an individual firm would strictly prefer the highest price in that flat region to the lowest price in the same region as its expected demand would be the same at those prices. Fourth, the highest price in the support of the equilibrium price distribution must be equal to the monopoly price $v$. If the highest price was greater than the monopoly price, a firm does not make any sales at that price. If the highest price was lower than the monopoly price, a firm can profitable deviate to the monopoly price as in both cases it sells only to buyers who observe its price only.

In the light of those four properties we are now ready to derive the equilibrium price distribution for a given production marginal cost. For a given $c_k$, if firm $j$ charges price $p$, its expected profit is

$$
\Pi_j(p, x_k^{-j}) = \left(1 - \frac{q^U}{N} + \frac{2q^U}{N}x_k(p)\right) (p - c_k),
$$

where we let $q^U \equiv q(2)$ and so $q(1) = 1 - q^U$ to simplify the notation. The first term in the large brackets represent the share of consumers that search one firm and happen to

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6The full proof is given by Johnen and Ronayne (forthcoming). To understand the intuition, consider a case where price comparing consumers observe three prices instead to two prices. This means that each firm competes with two other firms for the price-comparing buyers. It is then possible to show that it is optimal for one of the firms to always charge the monopoly price, while the other two compete head-to-head by drawing prices from the same distribution that continuously increases in its support. However, if price comparing buyers observe exactly two prices, then each firm has to compete head-to-head to every other firm. This eliminates a firm’s incentive to always charge the monopoly price, as its rivals will always undercut.
visit the firm under question. These consumers make a purchase at any price below the monopoly price. The second term in the large brackets stands for the share of consumers who search two firms and happen to visit the firm under question as well as another competitor. These consumers buy firm $j$’s product if its price is lower than the rival firm’s price (as well as the monopoly price).

As any firm is indifferent of choosing any price in the support of the equilibrium price distribution and prefers these price to those which are not in the support, we equalize the above expected profit to the expected profit that the monopoly price and obtain

$$x_k(p) = \frac{1 - q^U}{2q^U} \left( \frac{v - c_k}{p - c_k} - 1 \right) \text{ with support } \left[ p_k, v \right], \quad (1)$$

where $p_k$ solves $x_k(p_k) = 1$. It is useful to work with inverse function $p_k(x)$ which in equilibrium satisfies $p_k(x) = (1 - q^U)(v - c_k)/(1 - q^U + 2q^U x) + c_k$.

It is now left to check whether an individual consumer is indifferent between searching one firm and searching two firms given the price distributions in (1). Searching one firm yields an expected payoff equal to

$$v + \sum_{k=1}^{K} f_k \int_{p_k}^{v} px_k'(p)dp = v - \sum_{k=1}^{K} f_k \int_{0}^{1} p_k(x)dx,$$

where we changed the variable of integration to obtain the equality. Searching two firms yields an expected payoff equal to

$$v + 2 \sum_{k=1}^{K} f_k \int_{p_k}^{v} px_k(p)x_k'(p)dp - s = v - 2 \sum_{k=1}^{K} f_k \int_{0}^{1} p_k(x)xdx - s.$$

These two payoffs must be equal for an individual buyer to be indifferent between searching one firm and searching two firms. Equalizing the payoffs we obtain

$$\sum_{k=1}^{K} f_k \int_{0}^{1} p_k(x)(1 - 2x)dx = s. \quad (2)$$

The challenge is then to show that there exists $0 < q^U < 1$ that solves this equation. The following proposition demonstrates that such $q^U$ exists for small search costs.

**Proposition 2.** Suppose buyers do not observe the production marginal cost. Then, for
any $N \geq 2$ and $f$, there exists $\bar{s} > 0$ such that for $s < \bar{s}$ there exist two BNEs with active search given by $((x_k)_{k=1}^K, q^U)$ where $x_k$ is determined by (1) for each $k \in \{1, \ldots, K\}$ and $q^U$ by (2).

The proof is in the appendix and the intuition is as follows. In the appendix we show that the expected benefit of searching the second firm, which is given by the left-hand side of (2), is positive and concave in the search intensity $q^U \in (0, 1)$. Moreover, the expected benefit of searching the second firm vanishes as the share of price-comparing consumers either disappears or converges to one. Intuitively, this makes sense as firms have incentive to charge the monopoly price if the share of price-comparing buyers vanishes (recall the Diamond paradox) and the price equal to the production marginal cost if all buyers compare prices (recall the argument behind Lemma 1). These facts imply that the expected benefit of searching the second firm is inverse U-shaped with respect to the search intensity as illustrated by the solid curve in Figure 1. Then, for small search costs there exist two equilibria. In Figure 1 these equilibria are represented by the intersections of the solid curve and the dashed line representing the search cost.

![Figure 1](image_url)

**Figure 1:** Illustration of BNEs for $N = 2$, $v = 1$, $s = 0.05$, $K = 2$, $c_1 = 0$, $c_2 = 0.4$ and $f_1 = 0.5$.

One can argue that only one of the two equilibria is stable in a sense that if the actual search intensity is in the neighborhood of the equilibrium search intensity, then
consumers optimally adjust their search intensity to the equilibrium one.\textsuperscript{7} The question is then, which equilibrium is stable? The following corollary provides an answer.

**Corollary 1.** Of the two BNEs in Proposition 2, one characterized by a higher search intensity is stable.

The reasoning is as follows. Consider an equilibrium given by a high search intensity, i.e., the right-most intersection of the two curves in Figure 1. If the actual search intensity falls slightly short of the equilibrium one, the expected benefit of searching the second firm is higher than the cost of doing so. Therefore, buyers have incentive to search more intensely. If, in contrast, the actual search intensity is higher than the equilibrium one, the expected benefit of searching the second firm is lower than the cost of doing so. As a result, buyers have incentive to search less intensely. By applying similar arguments, it is easily established that the equilibrium characterized by a lower search intensity is unstable.

### 4.2 Observed Production Marginal Cost

We now turn to examining a case where both firms and buyers observe the production marginal cost. This allows buyer to condition their search strategies on the realized production marginal cost. If the marginal cost of production is $c_k$, the resulting *ex-interim* game is a special case of our main model where buyers do not observe the production marginal cost and $f_k = 1$. Therefore, we employ Nash equilibrium (NE) as a solution concept. Also we can apply our analysis in the previous subsection to analyze the case where buyers observe the realization of the production marginal cost. To avoid repetition, we omit parts of the analysis which directly follow from those in the previous subsection.

Let $q(c_k)$ represent the probability that consumers search two firms when the marginal cost of production is $c_k$, and so the probability that buyers search one firm is $1 - q(c_k)$. Then, the equilibrium consists of $(x_k, q(c_k))$ for each realization of $k \in \{1, ..., K\}$. Follow-

\textsuperscript{7}Formally, let $A_\varepsilon = \{\tilde{q} \in \mathbb{R} : |\tilde{q} - q^U| < \varepsilon\}$ be the neighborhood of an equilibrium $q^U$ for $\varepsilon > 0$ and $\varepsilon \rightarrow 0$. Then a perturbed search intensity $q'$ is any search intensity in that neighborhood, i.e., $q' \in A_\varepsilon$. If $q^U$ is a part of a stable equilibrium and the actual search intensity is $q'$, the search intensity converges to the equilibrium one.
ing the line of argument in the previous subsection, we can establish that

\[ x_k(p) = \frac{1 - q(c_k)}{2q(c_k)} \left( \frac{v - c_k}{p - c_k} - 1 \right) \]  
where \( c_k \) solves \( x_k(c_k) = 1 \). Using an inverse function \( p_k(x) \) that satisfies \( p_k(x) = (1 - q(c_k))(v - c_k)/(1 - q(c_k) + 2q(c_k)x) + c_k \) in equilibrium, we write an equation that determines the equilibrium search intensity:

\[ \int_0^1 p_k(x)(1 - 2x)dx = s. \]  

We are now ready to state the main result of this subsection in the following corollary, which is a direct consequence of propositions 1 and 2.

**Corollary 2.** Suppose buyers observe the production marginal cost.

(i) There always exists the Diamond-paradox equilibrium.

(ii) For each \( k = \{1, \ldots, K\} \), there exists \( \bar{s}_k > 0 \) such that for \( s \leq \bar{s}_k \) there exist two NEs with active search given by \( (x_k, q(c_k)) \) which are determined by (3) and (4).

(iii) Of the two NEs with active search for each \( k \in \{1, \ldots, K\} \), one with a higher search intensity is stable.

Two questions arise naturally. One is, how \( \bar{s}_k \)s are related to each other? The other is, how \( \bar{s}_k \)s are related to \( \bar{s} \) in Proposition 2? The following corollary answers the both questions.

**Corollary 3.** We have (i) \( \bar{s}_1 > \bar{s}_2 > \cdots > \bar{s}_K \) and (ii) \( \bar{s} = \sum_{k=1}^{K} f_k \bar{s}_k \).

The proof is in the appendix and the intuition is as follows. Recall from the discussion of Proposition 2 that the added (expected) benefit of searching the second firm is concave in the search intensity (also observe Figure 1). This means that there is a unique value of the search intensity which maximizes the added benefit of searching the second firm. In the appendix we show that this unique value of the search intensity, which maximizes the added benefit of searching the second firm, is independent of the production marginal cost. Moreover, the maximum value of the added benefit of searching the second firm is linearly decreasing in the marginal cost of production. This last observation implies the
first part of the corollary and, along the observation before it, also results in the corollary’ second part.

Figure 1 helps to illustrate this point. The dotted and dash-dotted curves represent the added benefit of searching the second firm when the production marginal cost is low (i.e., \( c_1 = 0 \)) and when it is high (\( c_2 = 0.1 \)), respectively, and when consumers observe them. The vertical line stands for the search intensity at which the added benefit of searching the second firm is maximized in these two cases as well as in the case with the information asymmetry.

## 5 Welfare Analysis

We are now in a position to examine the role of the information asymmetry on the production marginal cost: firms observing their marginal cost of production and buyers not observing it. The following proposition states the main result of this section.

**Proposition 3.** Suppose \( s \leq \bar{s}_K \) and consider stable equilibria with active search. Then, in expectation

(i) consumers search more,

(ii) the consumer surplus is higher,

(iii) the firm profit is lower, and

(iv) the total surplus is lower,

when consumers do not observe the marginal cost of production than when they do.

The proof is in the appendix. To understand the intuition behind (i), it is useful to consider consumers’ search intensity when they observe the production marginal cost. In the appendix we show that this search intensity is decreasing and concave in the production marginal cost. The reasoning is as follows. As the production marginal cost rises while all else remains the same, the level of price dispersion shrinks. This is because the range of prices firms can set—which is the difference between the monopoly price and the production marginal cost—decreases and, in particular, it gets closer to the monopoly price. A low level of price dispersion means that prices do not differ much across sellers.
This in turn implies that consumers have less incentive to search and compare prices. If the share of price-comparing consumers falls, sellers have incentive to charge high prices, namely prices closer to the monopoly price. As a result, price dispersion shrinks even more, which in turn causes less search. This explains why consumers’ search intensity falls fast as the production marginal cost rises, i.e., why it is decreasing and concave with respect to the production marginal cost.

By Jensen’s inequality it then follows that the expected search intensity when consumers observe the marginal cost of production is lower than the search intensity given the expected production marginal cost. Formally we have that $\mathbb{E}[q(c_k)] < q(\mathbb{E}[c_k])$ where the expectation is with respect to the production marginal cost. However, we know that in our model with information asymmetry, consumers take into account the expected production marginal cost when deciding on their search intensity. Then, the search intensity under the information asymmetry equals to $q(\mathbb{E}[c_k])$, meaning that consumers search more intensely with the information asymmetry than without it.

Intuition behind (ii) and (iii) is easily understood together. Recall that the equilibrium firm profit equals to $\sum_{k=1}^{K} f_k(1-q(c_k))(v-c_k)/N$ when consumers observe the production marginal cost and to $\sum_{k=1}^{K} f_k(1-q^U)(v-c_k)/N$ when they do not. Also firms’ market power is measured by $(1-q(c_k))/(2q(c_k))$ and $(1-q^U)/(2q^U)$ respectively in models without and with the information asymmetry. Notice that the equilibrium profits and firms’ market power decrease with the respective search intensities. This makes sense since competition gets stronger as the share of price-comparing consumers rises. From (i) we know that $q^U = q(\mathbb{E}[c_k])$ and thus the expected search intensity with the information asymmetry is higher than that without it. Since competition is more intense with higher search intensity, firms’ market power is (in expectation) lower with the information asymmetry than without it. Stronger competition is detrimental for firm profit but clearly benefits consumers as they make purchases at lower prices.

The reasoning behind (iv) follows directly from (i). Notice that if all consumers make purchase, the total surplus depends only on the total costs spent on search. From (i) we know that consumers search more intensely and hence incur higher search costs in total when they do not observe the production marginal cost than when they do. Therefore the total surplus is lower in the former case than in the latter.

Proposition 3 has an important implication on firms’ incentive to disclose information
on the production marginal cost. It implies that firms have incentive to disclose the realization of the production marginal cost.

**Corollary 4.** Suppose that \( s \leq \bar{s}_K \), consider stable equilibria with active search, and assume that information disclosure is free. If consumers do not observe the production marginal cost, firm have incentive to disclose such information to consumers.

The reasoning is as follows. It is clear that firms choose to disclose their production marginal cost if they need to simultaneously decide whether to do so before the realization of the production marginal cost. If, however, firms can choose their disclosure strategy after the realization of the production marginal cost, we can employ the following algorithm to show “full unraveling.” Consider first a case where the production marginal cost obtains its higher value. If this information is not disclosed to consumers, their search intensity is given by \( q^U \) as in Proposition 2. If, in contrast, firms inform buyers about the production marginal cost, we know that buyers search less intensely than \( q^U \). Since firms market power is higher when they disclose the information than when they do not, they choose to disclose. Consider next a case where the production marginal cost obtains its second highest value. Just like in the previous case, firms have incentive to disclose this information to mitigate search. We can continue the argument in a similar manner to see that firms have incentive to disclose information for all, but the lowest, value-realizations of the production marginal cost. Consumers correctly conjecture that if there is no information disclosure, the production marginal cost must have obtained its lowest value.

We next provide sufficient conditions under which the resolution of the information asymmetry between sellers and consumers improves consumers’ well-being.

**Proposition 4.** Suppose \( s > \bar{s} \) meaning that there is no equilibrium with active search when consumers do not observe the production marginal cost. Then, in expectation

(i) consumers search (weakly) less,

(ii) the consumer surplus is (weakly) lower,

(iii) the firm profit is (weakly) higher, and

(iv) the total surplus is (weakly) higher
when consumers do not observe the production marginal cost than when they do. All these results hold strictly if $s < \bar{s}_1$.

The reasoning is fairly simple. If the search cost is high enough, i.e., $s > \bar{s}$, the only equilibrium with the information asymmetry is the Diamond paradox. In that equilibrium consumers search one firm and sellers charge the monopoly price. However, if consumers observe the production marginal cost, there may exist an equilibrium with active search for small values of the production marginal cost. Formally it may be that $s < \bar{s}_1$, $s > \bar{s}$ and $f_1 > 0$. This possibility of the equilibrium with active search results in lower profit and higher consumer welfare when consumers observe the production marginal cost.

This result is reminiscent of the main result in Duffie et al. (2017) when it comes to the search intensity. In line with our result in Proposition 4 the authors show that consumers may search more intensely when they observe the production marginal cost than when they do not, given a moderately high search cost.

6 Extensions

With this section we show that our main result—consumers benefiting from information asymmetry on the production marginal cost—is robust to different model extensions. We present three different variations of the model. In the next subsection we assume that the production marginal cost is random draw from atomless distribution with compact support. Subsection 6.2 presents a case where searching each firm is costly, including the first firm. The final subsection incorporates into the main model a small share of price-comparing consumers.

We relegate extensive analysis of the final two subsection to the appendix in order to avoid repetition. In our analysis we do not establish uniqueness of a stable equilibrium with active search, although we focus on such equilibria.

6.1 Continuous Distribution of Production Marginal Cost

We next extend our model to continuous distribution of production marginal cost. We assume that $F$ has no mass points or gaps in its compact support $[\underline{c}, \bar{c}]$ where $0 \leq \underline{c} < \bar{c} < \bar{v}$. The rest of the model remains unchanged.
For equilibrium analysis we can employ the same line of argument as in Section 4. Correspondingly we can also employ the same techniques to prove the main results. The only qualitatively inconsequential difference we need to take care of is a replacement of summation signs with corresponding integral signs whenever we wish to take an expectation with respect to the production marginal cost. As a result, all our results in the main model follow: a stable equilibrium with active search existing for small search costs both when consumers observe the production marginal cost and when they do not; and the information asymmetry on the production marginal cost benefiting consumers.

6.2 Truly Costly Search

In the main model we assumed that searching one firm was free in order to ensure full consumer participation. In this subsection we presume that searching any firm entails a search cost of \( s \).\(^8\) Formally, if a consumer searches \( m \) firms she then incurs a total cost of \( ms \). Therefore it may happen that some consumers decide to not search at all in equilibrium.

This additional change in the model does not affect our main results. Existence of stable equilibria with active search is determined by the same conditions as in the main model. Our main result in Proposition 3—that consumers are better-off with the information asymmetry than without it for small search costs—remains true.

There is only one additional condition that is required to ensure existence of stable equilibria with active search. We need to show that in stable equilibria with active search, consumer prefer searching one or two firms to not searching at all. This is indeed the case as we demonstrate it in Appendix B.1.

Each search being costly is qualitatively consequential if the search cost is high. Consider, for example, a case where consumers do not observe the production marginal cost and the search cost is so high that equilibrium with active search does not exist, i.e., \( s > \bar{s} \). In equilibrium consumers do not search at all. This is different from equilibrium of our main model where consumers search one firm and make purchases at the monopoly price—the Diamond paradox. The reason why consumers do not search with each search being costly is as follows. If consumers do not search and do not compare prices, firms

\(^8\)Janssen et al. (2005) is the first paper to examine the first search being costly in a sequential search model.
optimally set the monopoly price. If, however, firms charge the monopoly price, it is optimal for consumer to not search and this justifies firms’ expectation that consumers do not compare prices.

Due to this different characteristic of the Diamond paradox, some of our results in Proposition 4 does not hold in the current extension. Specifically for high search costs, i.e., $s > \bar{s}$, there is no trade when consumers do not observe the production marginal cost. As a consequence the total surplus and firm profit are (weakly) lower when consumers do not observe the marginal cost of production than when they do. This result is in line with the main result in Duffie et al. (2017).

6.3 Price-comparing Consumers

In this subsection we show that our main results do not change qualitatively if we introduce a small share of price-comparing consumers. Specifically we assume that a positive but small share of consumers, given by $\lambda > 0$, always compare multiple prices. For simplicity we let these consumers observe two prices and buy outright at the lowest of the observed prices.\(^9\)

In Appendix B.2 we show that the market outcome within the current model converges to those of the main model as the share of price-comparing consumers vanishes. It then means that for sufficiently small share of price-comparing buyers, results of the current model must be qualitatively the same as those of the main model.

7 Conclusion

We see the paper to be the first to identify the favorable impact of information asymmetry on the production marginal cost on competition and consumer welfare in search markets. Our result does not only challenge a theoretical conclusion that seems to be agreed upon in consumer search literature, but also has real-world implication markets with small search costs.  

\(^9\)It is generally possible to let price-comparing consumers to observe any number of multiple prices (and at most $N$ number of prices). Independent of exactly how many price these consumers compare, the market becomes more competitive as the share of price-comparing buyers increases. In an extreme case if the share of price-comparing consumers vanishes, the model collapses to our main model and the market outcomes are the same as those of the main model.
A Proofs

A.1 Proof of Proposition 2

To show the existence, we rewrite (2) by using $p_k(x)$ as

$$
\sum_{k=1}^{K} f_k \int_0^1 \left( \frac{(1-q^U)(v-c_k)}{1-q^U+2q^U x} + c_k \right) (1-2x)dx = s. \quad (A.1)
$$

It then suffices to show the following facts: (i) that the LHS of (A.1) is positive for any $0 < q^U < 1$, (ii) is strictly concave in $q^U \in (0,1)$, (iii) converges to zero both as $q^U \downarrow 0$ and as $q^U \uparrow 1$. The LHS is indeed positive as for each $k \in \{1,\ldots,K\}$ we have

$$
\int_0^1 (1-2x) \left( \frac{(1-q^U)(v-c_k)}{1-q^U+2q^U x} + c_k \right) dx
$$

It is positive for any $0 \leq q^U < 1$, and as $q^U \downarrow 0$ and as $q^U \uparrow 1$. The LHS is indeed concave in $q^U$. We differentiate (1) twice w.r.t. $q^U$ to obtain the inequality. To establish concavity of the LHS of (A.1) in $q^U \in (0,1)$, we differentiate $(1-q^U)/(1-q^U+2q^U x)$ twice w.r.t. $q^U$ and as $q^U \downarrow 0$ and as $q^U \uparrow 1$. The LHS is indeed positive for any $0 \leq q^U < 1$. This shows that the LHS of (A.1) is indeed concave in $q^U \in (0,1)$. We finally observe that the LHS of (A.1) converges to zero both as $q^U \downarrow 0$

$$
\sum_{k=1}^{K} f_k \int_0^1 \left( \frac{(1-q^U)(v-c_k)}{1-q^U+2q^U x} + c_k \right) (1-2x)dx = \sum_{k=1}^{K} f_k \int_0^1 v(1-2x)dx = 0
$$

and as $q^U \uparrow 1$

$$
\lim_{q^U \uparrow 1} \sum_{k=1}^{K} f_k \int_0^1 \left( \frac{(1-q^U)(v-c_k)}{1-q^U+2q^U x} + c_k \right) (1-2x)dx = \sum_{k=1}^{K} f_k c_k \int_0^1 (1-2x)dx = 0.
$$

From facts (i), (ii) and (iii), the proof of the proposition immediately follows.
A.2 Proof of Corollary 3

(i) We start the proof by noting that

\[
\bar{s}_k = \max_{q(c_k)} \left\{ \int_0^1 \left( \frac{(1 - q(c_k))(v - c_k)}{1 - q(c_k) + 2q(c_k)x} + c_k \right) (1 - 2x)dx \right\} \\
= \max_{q(c_k)} \left\{ (v - c_k) \left( \ln \left( \frac{1 + q(c_k)}{1 - q(c_k)} \right) - 2q(c_k) \right) \frac{1 - q(c_k)}{2q(c_k)^2} \right\},
\]

(A.2)

where we simply employed integration to obtain the second line and \(q(c_k)^2 := [q(c_k)]^2\). We next establish two facts: (a) the unique value of \(q(c_k) \in (0, 1)\) that maximizes the expression in the curly brackets in (A.2) does not depend on \(c_k\) and (b) \(\bar{s}_k\) decreases in \(c_k\). To prove (a), we note that the expression in the curly brackets in (A.2) is concave in \(q(c_k)\), which follows from the proof of Proposition 2. Then, there exists a unique value of \(q(c_k) \in (0, 1)\), denoted by \(q^*\), that maximizes that expression in the curly brackets. This \(q^*\) solves

\[
\frac{\partial(v - c_k) \left( \ln \left( \frac{1 + q(c_k)}{1 - q(c_k)} \right) - 2q(c_k) \right) \frac{1 - q(c_k)}{2q(c_k)^2}}{\partial q(c_k)} \bigg|_{q(c_k) = q^*} = 0,
\]

or taking the derivative and simplifying

\[
(v - c_k) \frac{q^*^2 - q^* - 2}{2q^*^3(1 + q^*)} = 0.
\]

It is easy to see that \(q^*\) is independent of \(c_k\) which establishes fact (a). To prove fact (b), we rewrite (A.2) as

\[
\bar{s}_k = (v - c_k) \left( \ln \left( \frac{1 + q^*_k}{1 - q^*_k} \right) - 2q^*_k \right) \frac{1 - q^*_k}{2q^*_k^2}.
\]

(A.3)

It is easily observed that \(\bar{s}_k\) is decreasing in \(c_k\). This completes the proof of part (i) of the corollary.

(ii) Like in part (i), we start noting that

\[
\bar{s} = \max_{q^{U^+}} \left\{ \sum_{k=1}^K f_k \int_0^1 \left( \frac{(1 - q^{U^+})(v - c_k)}{1 - q^{U^+} + 2q^{U^+}x} + c_k \right) (1 - 2x)dx \right\} \\
= \max_{q^{U^+}} \left\{ \sum_{k=1}^K f_k(v - c_k) \left( \ln \left( \frac{1 + q^{U^+}}{1 - q^{U^+}} \right) - 2q^{U^+} \right) \frac{1 - q^{U^+}}{2(q^{U^+})^2} \right\}.
\]

(A.4)

Following a line of argument similar to that in part (i), one can establish that there exists a unique value of \(q^{U^+} \in (0, 1)\) that maximizes that expression in the curly brackets (noting that the expression in the curly brackets is concave in \(q^{U^+} \in (0, 1)\)) and this unique value is independent of \(c_k\).s. It then follows that this unique value of \(q^{U^+}\) is equal to \(q^*\). This means that \(\bar{s}\) is the weighted average of \(s_k\)s. Part (ii) of the corollary is complete.
A.3 Proof of Proposition 3

To prove (i) we will first show that \( q(c_k) \) is decreasing and concave in \( c_k \). Second, letting \( \bar{q} = \sum_{k=1}^{K} f_k c_k \) and noting that \( q(\bar{q}) = q^{U} \), we will employ Jensen’s inequality to demonstrate that show that \( \sum_{k=1}^{K} f_k q(c_k) > q(\bar{q}) = q^{U} \).

Letting
\[
A := \left( \ln \left( \frac{1 + q(c_k)}{1 - q(c_k)} \right) - 2q(c_k) \right) \frac{1 - q(c_k)}{2q(c_k)^2},
\]
we observe that the equilibrium \( q(c_k) \) solves \( A(v - c_k) = s \). Next, noting that in equilibrium it must be that \( d(v - c_k)A/dc_k = 0 \), we obtain
\[
\frac{dq(c_k)}{dc_k} = \frac{A}{(v - c_k)\partial A/\partial q(c_k)}, \tag{A.5}
\]
which is negative as \( \partial A/\partial q(c_k) < 0 \) in a stable equilibrium. Differentiation of the both sides of the equation by \( c_k \) once again yields
\[
\frac{d^2 q(c_k)}{dc_k^2} = \left( \frac{\partial A}{\partial q(c_k)} \right)^2 \frac{dq(c_k)}{dc_k} (v - c_k) - A \left( -\frac{\partial A}{\partial q(c_k)} + (v - c_k) \frac{\partial^2 A}{\partial q(c_k)^2} \frac{dq(c_k)}{dc_k} \right) \left[ (v - c_k) \frac{\partial A}{\partial q(c_k)} \right]^2. \tag{A.6}
\]
This is negative if the numerator of the RHS is negative. Note that the first term in the numerator is negative, as \( dq(c_k)/dc_k \) is negative. The expression in the large brackets of the second term in the numerator is positive as \( \partial A/\partial q(c_k) < 0 \) and \( \partial^2 A/\partial q(c_k)^2 < 0 \) which follows from proof of Proposition 2 that the expected benefit of searching the second firm is concave in the search intensity, \( q(c_k) \).\(^{10}\) This means that the numerator is indeed

\(^{10}\text{Alternatively, we can prove that } \partial^2 A/\partial q(c_k)^2 < 0 \text{ by directly differentiating } A \text{ twice w.r.t. } q(c_k). \text{ Then, the inequality to be proved is}
\]
\[
\frac{(1 + q(c_k))^2(3 - q(c_k))(1 - q(c_k))\ln \left( \frac{1 + q(c_k)}{1 - q(c_k)} \right) - 2q(c_k)(3 + 2q(c_k) - 3q(c_k)^2 - q(c_k)^3)}{q(c_k)^4(1 - q(c_k))(1 + q(c_k))^2} < 0
\]
for \( 0 < q(c_k) < 1 \). The inequality holds if it numerator is negative, or
\[
\ln \left( \frac{1 + q(c_k)}{1 - q(c_k)} \right) < \frac{2q(c_k)(3 + 2q(c_k) - 3q(c_k)^2 - q(c_k)^3)}{q(c_k)^4(3 - q(c_k))(1 - q(c_k))} \tag{A.7}
\]
Since both sides of the inequality converge to zero as \( q(c_k) \downarrow 0 \) and go to infinity as \( q(c_k) \uparrow 1 \), the inequality holds for any \( 0 < q(c_k) < 1 \) if the derivative of its LHS w.r.t. \( q(c_k) \) is less positive than that of the RHS. The respective derivatives are \( 2/(1 - q(c_k)^2) \) and \( 2(9 + 3q(c_k) - 14q(c_k)^2 + 2q(c_k)^3 - q(c_k)^4 + 5q(c_k)^5)/(1 + q(c_k))^3(3 - q(c_k))^2(1 - q(c_k))^2 \). Noting that \( 0 < 2/(1 - q(c_k)^2) \) for any \( 0 < q(c_k) < 1 \), we observe that the former derivative is less positive than the latter for any \( 0 < q(c_k) < 1 \) if \( 9 + 3q(c_k) - 14q(c_k)^2 + 2q(c_k)^3 - q(c_k)^4 + 5q(c_k)^5 > (1 + q(c_k))^2(3 - q(c_k))^2(1 - q(c_k)) \), which can be simplified as \( 2q(c_k)^3(2 - 3q(c_k) + 3q(c_k)^2) > 0 \). It is easily verified that the last inequality is true for any \( 0 < q(c_k) < 1 \). This shows that the derivative of the LHS (A.7) w.r.t. \( q(c_k) \) is less positive than that of the RHS. This in turn, along with the above limit results, proves that the inequality in (A.7) is true, or
negative, and therefore $d^2q(c_k)/dc_k^2 < 0$ meaning that $q(c_k)$ is concave in $c_k$.

Concavity of $q(c_k)$ implies that $\sum_{k=1}^{K} f_k q(c_k) < q(\overline{\pi})$. However, as $q(\overline{\pi})$ is independent of actual realization of the production marginal cost and solves

$$\left(\ln \left(\frac{1 + q(\overline{\pi})}{1 - q(\overline{\pi})}\right) - 2q(\overline{\pi})\right) \frac{1 - q(\overline{\pi})}{2q(\overline{\pi})^2} \sum_{k=1}^{K} (v - c_k) = s,$$

it must be that $q(\overline{\pi}) = q^U$. It then follows that $\sum_{k=1}^{K} f_k q(c_k) < q(\overline{\pi}) = q^U$, which completes the proof of the case where $\overline{\pi}_K < s$.

To prove (ii) we will show that the ex-interim equilibrium consumer surplus, when consumer observe the production marginal cost, is concave in $c_k$. We will then continue by demonstrating that the hypothetical consumer surplus for the production marginal cost equal to $\overline{\pi}$ equal to that with the information asymmetry on the production marginal cost and greater than the ex-ante equilibrium consumer surplus without the information asymmetry.

If consumers observe the production marginal cost, their equilibrium (ex-interim) surplus is

$$CS(c_k) = v - \int_0^1 p_k(x)(1 - q(c_k) + q(c_k)2x)dx - q(c_k)s$$

$$= v - \int_0^1 p_k(x)dx$$

$$= \left[1 - \frac{1 - q(c_k)}{2q(c_k)} \ln \left(\frac{1 + q(c_k)}{1 - q(c_k)}\right)\right](v - c_k)$$

$$= B(v - c_k),$$

where we used (2) to obtain the second equality, simple algebraic manipulations to obtain the third equality, and let $B := 1 - \frac{1 - q(c_k)}{2q(c_k)} \ln \left(\frac{1 + q(c_k)}{1 - q(c_k)}\right)$ to obtain the last equality. To show that this consumer surplus is concave in $c_k$ we differentiate it twice w.r.t. $c_k$

$$\frac{d^2B(v - c_k)}{dc_k^2} = \frac{d}{dc_k}\left(-B + \frac{\partial B}{\partial q(c_k)}(v - c_k)\frac{dq(c_k)}{dc_k}\right) = \frac{d}{dc_k}\left(-B + \frac{\partial B}{\partial q(c_k)} \times \frac{A}{\frac{\partial A}{\partial q(c_k)}}\right)$$

$$= \frac{\partial}{\partial q(c_k)}\left(-B + \frac{\partial B}{\partial q(c_k)} \times \frac{A}{\frac{\partial A}{\partial q(c_k)}}\right)\frac{dq(c_k)}{dc_k}$$

$$= \left(-\frac{\partial B}{\partial q(c_k)} + \frac{\partial B}{\partial q(c_k)} \times \frac{\partial^2 B}{\partial q^2(c_k)} \frac{A}{\frac{\partial A}{\partial q(c_k)}}\right)\frac{dq(c_k)}{dc_k}$$

$$A \frac{\partial^2 B}{\partial q^2(c_k)} \frac{\partial A}{\partial q(c_k)} - \frac{\partial B}{\partial q(c_k)} \frac{\partial A}{\partial q(c_k)} \frac{\partial^2 A}{\partial q^2(c_k)} \times \frac{dq(c_k)}{dc_k},$$

where we used (A.5) to obtain the second equality in the first line. Since $dq(c_k)/dc_k < 0$, that $\partial^2 A/\partial q(c_k)^2 < 0$. 
the inequality can be rewritten (after some algebraic manipulations) as
\[
\frac{\partial^2 B}{\partial q^2(c_k)} \frac{\partial A}{\partial q(c_k)} - \frac{\partial B}{\partial q(c_k)} \frac{\partial^2 A}{\partial q^2(c_k)} > 0. \tag{A.8}
\]

As
\[
\frac{\partial A}{\partial q(c_k)} = \frac{2q(c_k)(2 + q(c_k)) - (2 + q(c_k) - q^2(c_k)) \ln \left(\frac{1 + q(c_k)}{1 - q(c_k)}\right)}{2q^3(c_k)(1 + q(c_k))},
\]
\[
\frac{\partial^2 A}{\partial q(c_k)^2} = \frac{(1 + q(c_k))^2(3 - q(c_k))(1 - q(c_k)) \ln \left(\frac{1 + q(c_k)}{1 - q(c_k)}\right) - 2q(c_k)(3 + 2q(c_k) - 3q(c_k)^2 - q(c_k)^3)}{q(c_k)^4(1 - q(c_k))(1 + q(c_k))^2},
\]
\[
\frac{\partial B}{\partial q(c_k)} = \frac{(1 + q(c_k)) \ln \left(\frac{1 + q(c_k)}{1 - q(c_k)}\right) - 2q(c_k)}{2q(c_k)^2(1 + q(c_k))},
\]
\[
\frac{\partial^2 B}{\partial q(c_k)^2} = \frac{2q(c_k)(1 + q(c_k) - q(c_k)^2)}{(1 - q(c_k))^2(1 + q(c_k))^2} - \left[\ln \left(\frac{1 + q(c_k)}{1 - q(c_k)}\right)\right]^2
\]
the inequality can be rewritten (after some algebraic manipulations) as
\[
\frac{-4(1 - 2q(c_k))q(c_k)^2 + 2q(c_k)(2 - q(c_k) - q(c_k)^2) \ln \left(\frac{1 + q(c_k)}{1 - q(c_k)}\right) - (1 - q(c_k))(1 + q(c_k))^2 \left[\ln \left(\frac{1 + q(c_k)}{1 - q(c_k)}\right)\right]^2}{2q(c_k)^6(1 - q(c_k))(1 + q(c_k))^2} > 0.
\]

As the denominator of the LHS is positive for any \(0 < q(c_k) < 1\), the inequality is true if the numerator of the LHS is negative. As the numerator is a quadratic expression of \(\ln((1 - q)/(1 + q))\), we verify that the numerator is negative if the following system of inequalities is true:

\[
\begin{align*}
\ln \left(\frac{1 + q(c_k)}{1 - q(c_k)}\right) &> \frac{2q(c_k) + q(c_k)^2}{(1 + q(c_k))^2} - \frac{q(c_k)^2}{(1 + q(c_k))^2} \sqrt{\frac{9 + 7q(c_k)}{1 - q(c_k)}}, \\
\ln \left(\frac{1 + q(c_k)}{1 - q(c_k)}\right) &< \frac{2q(c_k) + q(c_k)^2}{(1 + q(c_k))^2} + \frac{q(c_k)^2}{(1 + q(c_k))^2} \sqrt{\frac{9 + 7q(c_k)}{1 - q(c_k)}}.
\end{align*}
\]

As \(\sqrt{\frac{9 + 7q(c_k)}{1 - q(c_k)}} > 1\), the first inequality is certainly true if \(\ln \left(\frac{1 + q(c_k)}{1 - q(c_k)}\right) > \frac{2q(c_k)}{(1 + q(c_k))^2}\). This inequality holds as, first, both sides of this inequality converge to zero as \(q(c_k) \downarrow 0\); second, its LHS goes to infinity and RHS approaches 1/2 as \(q(c_k) \uparrow 1\); and third, the derivative of the LHS, which is \(\frac{2(1 - q(c_k))}{(1 + q(c_k))^2}(> 0)\), is greater than 2 and that of the RHS, which is \(\frac{(1 + q(c_k))}{(1 + q(c_k))^2}(> 0)\), is lower than 2 for any \(0 < q(c_k) < 1\).

Letting \(z := (1 - q(c_k))/(1 + q(c_k))\) where \(z > 1\) for \(0 < q(c_k) < 1\), we rewrite the second inequality in the above system of inequalities as
\[
\ln(z) < \frac{3z^2 - 2z - 1 + (z - 1)^2\sqrt{1 + 8z}}{4z^2}, \quad \text{for } z > 1.
\]

We prove the inequality with the help of the following three facts. First, both sides of the inequality are continuous in \(z > 1\). Second, both sides of the inequality converge to zero as \(z \downarrow 1\) and go to infinity as \(z \to \infty\). Finally, the LHS of the inequality is increasing
more slowly than the RHS as the derivative of the LHS, which is $1/z$ for $z > 1$, is smaller than that of the RHS, which is $(z-1)\sqrt{1+8z}/(2z^3\sqrt{1+8z})$ for $z > 1$:

$$\sqrt{1+8z}(2z+1)(z-1) < (z-1)(1+6z+2z^2),$$

$$\sqrt{1+8z}(2z+1) < (1+6z+2z^2),$$

square both sides to obtain,

$$1+z2z+36z^2+32z^3 < 1+12z+40z^2+24z^3+4z^4,$$

$$0 < 4z^2(z-1)^2.$$

The arguments in the previous two paragraphs establish that the system of the inequality holds for any $0 < q(c_k) < 1$. This, in turn, proves that the inequality in (A.8) is true for any $0 < q(c_k) < 1$, which means that the equilibrium (ex-interim) consumer surplus when they observe $c_k$—namely $B(v-c_k)$—is concave in $c_k$.

Concavity of the ex-interim equilibrium consumer surplus when they observe the production marginal cost means that

$$\sum_{k=1}^{K} f_k CS(c_k) = \sum_{k=1}^{K} f_k \left[ 1 - \frac{1-q(c_k)}{2q(c_k)} \ln \left( \frac{1+q(c_k)}{1-q(c_k)} \right) \right] (v-c_k)$$

$$< \left[ 1 - \frac{1-q(\bar{c})}{2q(\bar{c})} \ln \left( \frac{1+q(\bar{c})}{1-q(\bar{c})} \right) \right] (v-\bar{c}) = CS(\bar{c}).$$

However, we know that $q(\bar{c}) = q^U$ and therefore $CS(\bar{c})$ equals to the consumer surplus when consumers do not observe the production marginal cost. This completes the proof of part (ii).

To prove (iii) we first show that the equilibrium ex-interim profit, when consumers observe the marginal cost of production, is increasing and convex in $c_k$. This implies that the corresponding equilibrium ex-ante profit is lower than the profit given the expected production marginal cost, which coincides with equilibrium ex-ante profit where consumers do not observe the production marginal cost.

Let $\pi(c_k)$ be the equilibrium profit when $c_k$ is realized and buyers observe this realization, and so let $\Pi^Q := \sum_{k=1}^{K} f_k \pi(c_k)$ be the expected equilibrium profit. We will show the following facts: $d\pi(c_k)/dc_k > 0$ and $d^2\pi(c_k)/dc_k^2 > 0$. As $\pi(c_k) = (1-q(c_k))(v-c_k)$, we have that

$$\frac{d\pi(c_k)}{dc_k} = -(1-q(c_k)) - (v-c_k) \frac{dq(c_k)}{dc_k} = -(1-q(c_k)) - \frac{A}{\partial A/\partial q(c_k)},$$

which is positive if $-(1-q(c_k))dA/dq(c_k) - A < 0$ as $\partial A/\partial q(c_k) < 0$. Substituting the values of $dA/dq(c_k)$ and $A$ and applying simple algebraic manipulations, we rewrite the inequality as $\ln((1+q(c_k))/(1-q(c_k))) < q(c_k)(2-q(c_k)^2)/(1-q(c_k)^2)$. Since both sides of the inequality converge to zero as $q(c_k) \downarrow 0$ and go to infinity as $q(c_k) \uparrow 1$, the inequality holds for any $0 < q(c_k) < 1$ if the derivative of the LHS w.r.t. $q(c_k)$ is less positive than that of the RHS. These derivatives are $2/(1-q(c_k)^2)$ and $(2-q(c_k)^2+q(c_k)^4)/(1-q(c_k)^2)^2$, respectively; both are strictly positive for $0 < q(c_k) < 1$; and the former is smaller than the latter as $2 < (2-q(c_k)^2+q(c_k)^4)/(1-q(c_k)^2)^2$, which is easily verified to be true. This proves that the derivative of the LHS of our initial inequality is less positive than that of the RHS, which in turn proves that our initial inequality holds. This means that
\[ d\pi(c_k)/dc_k > 0. \]

We next note that

\[
\frac{d^2\pi(c_k)}{dc_k^2} = \frac{d}{dc_k} \left( -(1 - q(c_k)) - \frac{A}{\partial A/\partial q(c_k)} \right) = \frac{\partial}{\partial q(c_k)} \left( -(1 - q(c_k)) - \frac{A}{\partial A/\partial q(c_k)} \right) \frac{dq(c_k)}{dc_k}
\]

\[
= \left( 1 - \left( \frac{\partial A}{\partial q(c_k)} \right)^2 - A \frac{\partial^2 A}{\partial q(c_k)^2} \right) \frac{dq(c_k)}{dc_k} = \frac{A \frac{\partial^2 A}{\partial q(c_k)^2}}{\left( \frac{\partial A}{\partial q(c_k)} \right)^2} \times \frac{dq(c_k)}{dc_k},
\]

which is positive as \( \partial^2 A/\partial q(c_k)^2 < 0 \) for \( 0 < q(c_k) < 1 \), which follows from the proof of Proposition 2. It is then indeed that \( d^2\pi(c_k)/dc_k^2 > 0 \), or \( \pi(c_k) \) is convex in \( c_k \).

Convexity of \( \pi(c_k) \) w.r.t. \( c_k \) implies that for any non-degenerate \( f \), it must be that

\[
\sum_{k=1}^{K} f_k \pi(c_k) > \pi(\bar{c}),
\]

which is why \( \Pi^{O} = \sum_{k=1}^{K} f_k \pi(c_k) > \Pi^{U} \). This completes the proof of the proposition for \( s \leq \bar{s}_k \).

**B Additional Analysis**

**B.1 Truly Costly Search**

To prove existence of a unique stable equilibrium with active search, it suffices to demonstrate that in equilibrium, searching yields a non-negative payoff. We first consider a case where consumers observe the production marginal cost. We then consider a case where consumers do not observe the production marginal cost.

Suppose consumers observe the production marginal cost. We then have the following result which is reminiscent to Corollary 2.

**Corollary 5.** Suppose buyers observe the production marginal cost.

(i) There always exists the Diamond-paradox equilibrium.

(ii) For each \( k = \{1, ..., K\} \), there exists \( \bar{s}_k > 0 \) such that for \( s \leq \bar{s}_k \) there exists a unique stable NEs with active search given in Corollary 2.

**Proof.** To prove the corollary, it suffices to show that for in a unique stable NE with active search, searching one firm yields a positive expected payoff. For any \( c_k \), we know from the proof of Proposition 3 that searching one firm (or two firms) yields an expected payoff equal to

\[
\left[ 1 - \frac{1 - q(c_k)}{2q(c_k)} \ln \left( \frac{1 + q(c_k)}{1 - q(c_k)} \right) \right] (v - c_k) - s.
\]
As the expected price is decreasing in \( q(c_k) \) and the search intensity is decreasing in \( s \), the above expected payoff is not lower than

\[
1 - \frac{1 - q^*}{2q^*} \ln \left( \frac{1 + q^*}{1 - q^*} \right) (v - c_k) - s_k,
\]

where \( q^* \) is the lowest possible search intensity in equilibrium with active search (recall the proof of Corollary 3). Using (A.3), we rewrite the above expression representing the lowest expected payoff (after applying simple algebraic manipulations) as

\[
\left( 1 + 2\eta - 2\eta \ln \left( 1 + \frac{1}{\eta} \right) - 2\eta^2 \ln \left( 1 + \frac{1}{\eta} \right) \right) (v - c_k),
\]

where \( \eta := (1 - q^*)/(2q^*) \) and so \( \eta > 0 \) for any \( 0 < q^* < 1 \). This lowest payoff is positive if

\[
\frac{1 + 2\eta}{2\eta(1 + \eta)} - \ln \left( 1 + \frac{1}{\eta} \right) \geq 0. \tag{B.1}
\]

We note the following facts about the LHS of the inequality. First, it is easily verified that the LHS is continuous in \( \eta > 0 \). Second, as \( \lim_{\eta \to \infty} \frac{1+2\eta}{2(1+\eta)} = 1 \) and \( \lim_{\eta \to \infty} \eta \ln \left( 1 + \frac{1}{\eta} \right) = \lim_{z \downarrow 0} \frac{\ln(1+z)}{z} = \lim_{z \downarrow 0} \frac{1}{1+z} = 1 \), it follows that

\[
\lim_{\eta \to \infty} \left[ \frac{1 + 2\eta}{2\eta(1 + \eta)} - \ln \left( 1 + \frac{1}{\eta} \right) \right] = \lim_{\eta \to \infty} \frac{1+2\eta}{2(1+\eta)} - \frac{\eta \ln \left( 1 + \frac{1}{\eta} \right)}{\eta} = 0.
\]

Third, the derivative of the LHS of (B.1) w.r.t. \( \eta \) is \(-1/(2\eta^2(1+\eta)^2)\) which is negative for any \( \eta > 0 \). These three facts establish that the LHS of (B.1) is decreasing in \( \eta \) and converges to zero as \( \eta \to \infty \). Therefore, the LHS of (B.1) must be positive for any \( \eta > 0 \), i.e., the inequality is true. The inequality implies that the lowest possible payoff in a stable equilibrium with active search must be positive. This means that consumers prefer searching to not searching in a stable equilibrium with active search.

The proof of the corollary is now complete.

Suppose now that consumers do not observe the production marginal cost. We then have the following result.

**Corollary 6.** Suppose buyers do not observe the production marginal cost.

(i) There always exists the Diamond-paradox equilibrium.

(ii) There exists \( \overline{s} > 0 \), such that for \( s < \overline{s} \) there exist a unique stable BNE given in Proposition 2.

*Proof.* The proof follows a line of argument similar to the case where consumers observe the marginal cost of production. Specifically in a stable equilibrium with active search, a
searching consumer obtains an expected payoff not lower than

$$\left[ 1 - \frac{1 - q^*}{2q^*} \ln \left( \frac{1 + q^*}{1 - q^*} \right) \right] \sum_{k=1}^{K} f_k(v - c_k) - \bar{s}$$

$$= \left( 1 + 2\eta - 2\eta \ln \left( 1 + \frac{1}{\eta} \right) - 2\eta^2 \ln \left( 1 + \frac{1}{\eta} \right) \right) \sum_{k=1}^{K} f_k(v - c_k),$$

where we obtained the equality by using A.4. We know that this payoff is positive from the case with the information asymmetry. This proves that consumer payoff with search is positive in a stable equilibrium with active search.

The proof of the corollary is now complete.

B.2 Price-comparing Consumers

In this subsection we provide full analysis of the model presented in Section 6.3. Recall that the only difference of that model from our main model is the presence of $\lambda > 0$ share of price-comparing consumers, where $\lambda$ is small. We will call the rest of the consumers costly consumers as they need to incur search costs to compare prices. Our analysis consists of two parts. We first identify conditions under which stable equilibria where costly consumers actively search, namely equilibria with active search. We then show that the information asymmetry on the production marginal cost benefits costly consumers.

We start the equilibrium analysis with the case where consumers observe the production marginal cost. An equilibrium with active search is determined by two conditions. One is that an individual firm must be indifferent of setting any price in the support of the equilibrium price distribution and prefer these price to ones outside the support. Call it equal profit condition. The other conditions is that an individual costly consumers must be indifferent between searching one firm and searching two firms. Call it indifference condition. If we let

$$\mu(q(c_k)) := \frac{(1 - \lambda)(1 - q(c_k))}{2[(1 - \lambda)(1 - q(c_k)) + \lambda]}$$

be the share of consumers who observe one price over the share of price-comparing consumers, the equal profit condition yields

$$x_k(p) = \mu(q(c_k)) \left( \frac{v - c}{p - c} - 1 \right) \text{ with support } \left[ p_k, v \right], \quad (B.2)$$

where $p_k$ solves $x_k(p) = 1$. If we let

$$p_k(x) := \frac{\mu(q(c_k))}{\mu(q(c_k)) + x}(v - c_k) + c_k$$

be the inverse function, the indifference condition yields

$$\int_0^1 p_k(x)(1 - 2x)dx = s. \quad (B.3)$$
We are not ready to state the equilibrium result.

**Proposition 5.** Suppose buyers observe the production marginal cost. For each $k = \{1, ..., K\}$ and sufficiently small search costs, a stable NE with active search exists and is given by $(x_k, q(c_k))$ which are determined by (B.2) and (B.3).

**Proof.** A stable NE with active search exists for small search costs, if the LHS of (B.3), which represents the added benefit of searching the second firm, is positive in $0 < q(c_k) < 1$ and converges to zero as $q(c_k) \uparrow 1$.

To show the former fact we first note that the LHS of (B.3) equals to

$$\mu(q(c_k)) \left( [1 + 2\mu(q(c_k))] \ln \left( 1 + \frac{1}{\mu(q(c_k))} \right) - 2 \right) (v - c_k).$$

This is positive in $q(c_k) \in (0, 1)$ if the terms in the large brackets are positive for $\mu(c_k) > 0$, or if $\ln \left( 1 + \frac{1}{\mu(q(c_k))} \right) > \frac{2}{1 + 2\mu(q(c_k))}$. As for $\mu(q(c_k)) \downarrow 0$ this latter inequality clearly holds, while the LHS and the RHS both approach 0 as $\mu(q(c_k)) \to \infty$, this inequality holds for all $\mu(q(c_k)) > 0$ if the derivative of the LHS is more negative than that of the RHS. The derivates of the LHS is $-\frac{1}{\mu(q(c_k))} \frac{1}{1 + 1 + 2\mu(q(c_k))}$, while the derivates of the RHS is $-\frac{2}{(1 + 2\mu(q(c_k)))^2}$. It is easy to see that the former derivates is smaller than the latter. This establishes that the inequality holds for any $\mu(q(c_k)) > 0$, or $0 < q(c_k) < 1$, which in turn means that the LHS of (B.3) is positive for any $0 < q(c_k) < 1$.

To show that the LHS of (B.3) converges to zero as $q(c_k) \uparrow 1$, it suffices to show that is converges to zero as $\mu(q(c_k)) \downarrow 0$. As

$$\lim_{\mu(q(c_k)) \downarrow 0} \mu(q(c_k)) \ln \left( 1 + \frac{1}{\mu(q(c_k))} \right) = \lim_{z \to \infty} \ln(1 + z) = \lim_{z \to \infty} \frac{1}{1 + z} = 0,$$

we indeed have that

$$\lim_{\mu(q(c_k)) \downarrow 0} \mu(q(c_k)) \left( [1 + 2\mu(q(c_k))] \ln \left( 1 + \frac{1}{\mu(q(c_k))} \right) - 2 \right) = \lim_{\mu(q(c_k)) \downarrow 0} \mu(q(c_k)) \ln \left( 1 + \frac{1}{\mu(q(c_k))} \right) + 2 \lim_{\mu(q(c_k)) \downarrow 0} \mu(q(c_k))^2 \ln \left( 1 + \frac{1}{\mu(q(c_k))} \right)$$

$$= \lim_{\mu(q(c_k)) \downarrow 0} \mu(q(c_k))$$

$$= 0.$$

The proof of the proposition is now complete. \qed

We continue our equilibrium analysis by considering the case where consumers do not observe the production marginal cost. Like in the case where consumers observe the production marginal cost, a stable equilibrium with active search is determined by firms’ $K$ number of equal profit conditions—an equal profit condition for each realization of the production marginal cost—and consumers’ indifference condition. If we let $\mu(q^U) := (1 - \lambda)(1 - q^U)/\left[ 2(1-\lambda)(1-q^U) + 2\lambda \right]$, equal profit condition for $c_k$ renders

$$x_k(p) = \mu(q^U) \left( \frac{v - c}{p - c} - 1 \right) \text{ with support } [p_k, v] \quad (B.4)$$
and with $x_k(p_k) = 1$. Using the inverse function

$$p_k(x) := \frac{\mu(q^U)}{\mu(q^U) + x}(v - c_k) + c_k,$$

we note that the indifference condition renders

$$\sum_{k=1}^{K} f_k \int_{0}^{1} p_k(x)(1 - 2x)dx = s. \tag{B.5}$$

We are now in a position to state the equilibrium result with the information asymmetry on the production marginal cost.

**Proposition 6.** Suppose buyers do not observe the production marginal cost. For sufficiently small search costs, there exists a stable BNE with active search given by $((x_k)_{k=1}^{K}, q^U)$ where each $x_k$ is determined by (B.4) and $q^U$ by (B.5).

**Proof.** The proof follows a line of argument similar to the proof of Proposition 5. Specifically it suffices to show that the LHS of (B.5) is positive for any $\mu(q^U) > 0$ and converges to zero as $\mu(q^U) \downarrow 0$.

We first rewrite the LHS of (B.5) as

$$\sum_{k=1}^{K} f_k \mu(q^U) \left( [1 + 2\mu(q^U)] \ln \left( 1 + \frac{1}{\mu(q^U)} \right) - 2 \right) (v - c_k).$$

However, we know from the proof of Proposition 5 that the terms under the summation sign are positive for any $\mu(q^U) > 0$. We also know that those terms converge to zero as $\mu(q^U) \downarrow 0$. Thus the proof of the proposition is complete.

We now turn our attention to the welfare analysis. The main result is stated in the following proposition.

**Proposition 7.** For sufficiently small search costs and the share of price-comparing consumers, in equilibrium

(i) consumers search less intensely,

(ii) surplus of costly consumers is lower,

(iii) firm profit is higher, and

(iv) total surplus is higher

in expectation when consumers observe the production marginal cost than when they do not.

**Proof.** To prove the proposition it is useful to let $\phi := 2\lambda/(1 - \lambda)$ so that $\mu(q(c_k)) = (1 - q(c_k)) / (2q(c_k) + \phi)$. We can then rewrite (B.3) as

$$\int_{0}^{1} \left( \frac{1 - q(c_k)}{1 - q(c_k) + (2q(c_k) + \phi)x} (v - c) + c_k \right) (1 - 2x)dx = s.$$
Notice that this equation is continuous in $\lambda \in [0, 1)$ and converges to (4) as $\lambda \downarrow 0$, or $\phi \downarrow 0$. It then follows that for sufficiently small $\lambda$, all our results in the main body of the paper must hold. This completes the proof of the proposition.
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