Consumer Search in Service Markets.

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Abstract

We analyze a market, where a firm's marginal cost of serving a consumer depends on the consumer's characteristics. Consumers are laymen and don't know their relevant characteristics, while firms are experts and can learn the characteristics through a diagnosis. Firms choose whether to publicly display a price for all consumers or whether to make an offer only after the diagnosis. We find that two equilibria can coexist. Either all firms display a price equal to average marginal cost or no firm displays a price and charges the respective monopoly price to each type of consumer.

Keywords: credence goods, cost based price discrimination, consumer search, price commitment.

1 Introduction

In credence good markets, where a firm's marginal cost depends on the consumer's characteristics, firms commonly refrain from publicly displaying prices (for instance on their homepage or storefront) and commonly refuse to make price offers over the phone. Instead, firms require consumers to schedule an appointment, at which an expert determines the relevant characteristics and the consequent cost of serving the consumer. Only after learning its marginal cost, the firm makes an offer. Even if the appointment is free of charge, the process entails a substantial opportunity cost for the consumer, which makes it costly to compare prices in the market. This raises the question, why in a competitive market firms don't publicly display prices in an effort to attract consumers away from firms that don't display prices. The existing credence

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good literature either assumes that prices are exogenous (Pitchik and Schotter, 1987; Sülzle and Wambach, 2005) or that firms have to publicly announce prices (Wolinsky, 1993; Taylor, 1995; Glazer and McGuire, 1996; Fong, 2005; Dulleck and Kerschbamer, 2006), hence cannot account for the observation that firms commonly don't display prices.

In this paper we present a model where firms not displaying prices arises as an equilibrium of a one-shot game, hence without invoking tacit collusion in an intertemporal setting. We assume that consumers can be divided into a finite number of distinct types, depending on a firm's marginal cost of serving the consumer. Consumers are laymen and don't know their type, hence don't know a firm's cost of serving them. This setting describes a typical credence good. Examples for credence goods are medical and cosmetic services (where cost depend on the consumer's physical characteristics), construction and home improvement (where cost depend on the characteristics of the land or building), custom IT services (where cost depend on the existing IT infrastructure) and repair and restoration (where cost depend on the condition of the object). In our model an arbitrary number of competing firms chooses simultaneously whether to publicly display a single price or whether to not display a price and only make an offer after the consumer had an appointment and the marginal cost is known to the firm. We assume that firms have to charge the displayed price to all consumers, for instance due to legal requirements or due to (unmodeled) reputation concerns, hence firms either publicly commit or don't commit to a price. Since consumers cannot verify their own type, firms cannot credibly commit to a different price for each type. After observing which firms committed and the prices of committed firms at no cost, consumers sequentially search firms. Consumers incur a search cost even when visiting a committed firm, because the search cost captures the ordeal of the diagnosis, which has to be conducted by committed and non-committed firms alike.

We find that this market has two types of equilibria. First, there is a *competitive equilibrium* where at least two firms commit to charging expected marginal cost to all consumers and all consumers visit these firms. The competitive equilibrium always exists. Second, there is the *monopolistic equilibrium*, where no firm commits to a price and then firms charge the corresponding monopoly price to each type of consumer. In the absence of commitment, firms can charge monopoly prices, since search frictions prevent price competition. In order to prevent market collapse à la Diamond (1971), we assume that consumers learn their valuation for the good only after inspecting the good for the first time.[1] The monopolistic equilibrium is sus-

[1] Alternatively, we could assume that valuations are known ex ante, but the first search is free,

tained by consumers' expectations about non-committed firms' prices in the presence of committed firms. We say that consumer expectations are *optimistic*, if they rationally expect non-committed firms to make better offers than committed firms on average, and *pessimistic* otherwise. If consumers are generally optimistic, in order to attract consumers away from competitors, a firm would have to commit to a relatively low price, at which consumers can no longer be rationally optimistic. However, at that price the deviating firm makes less than the equally shared monopoly profits it would enjoy otherwise, such that the deviation isn't profitable. We find that the monopolistic equilibrium exists if the number of firms is sufficiently low, if costs are sufficiently dispersed and if high cost type consumers are relatively more common than low cost types. Surprisingly, the monopolistic equilibrium is less likely to exist as search cost increase. The intuition goes as follows. In the presence of committed firms, non-committed firms never price more than the search cost above the lowest commitment price, as they would otherwise lose the consumer to a committed firm. If search cost are large, the difference between a non-committed firm's highest price and the lowest commitment price is large, making it less beneficial to visit a non-committed firm over a committed firm. This in turn allows a deviating firm to attract consumers at a higher commitment price.

We find that both consumer and total surplus can be larger under either equilibrium. Hence, mandating price commitments indiscriminately in these markets could backfire. For uniformly distributed valuations we identify a simple statistic, namely the normalized standard deviation of the cost distribution ($\frac{\mathrm{SD}[c]}{\bar{v}-\mathbb{E}[c]}$), which completely determines which equilibrium has higher consumer and total surplus. We find that the monopolistic equilibrium is more likely to yield higher consumer and total surplus if costs are more dispersed and if costs are large relative to consumer valuations.

The remainder of the paper proceeds as follows. Section 2 discusses the related literature. Section 3 outlines the basic model. Section 4 identifies the equilibria of the market. Section 5 compares consumer and total surplus of these equilibria. In Section 6 we consider extensions to the baseline model. Section 7 concludes.

2 Related Literature

In their extensive review of the theoretical credence good literature, Dulleck and Kerschbamer (2006) categorize credence good markets into whether firms are *liable* for providing a functioning good or successful service and whether consumers can *verify*

which would yield the same results.

the treatment they received.[2] We assume that firms are liable, such that problems of "undertreatment" don't arise, where the firm provides no or insufficient treatment, but claims otherwise. Furthermore, we assume that consumers cannot verify the treatment they received, which means firms always use the cheapest treatment that does the job. This reduces the problem to firms overcharging consumers, meaning the firm claims a more costly treatment is required, but provides the (equally effective) cheap treatment instead. The seminal papers for this kind of credence good market is Wolinsky (1993). Therein, firms publicly announce a discrete menu of prices, one for each type of consumer, but can freely choose from that menu upon visit of the consumer, unconstrained by the consumer's type. Consumers incur a search cost s when visiting a firm and all consumers have the same valuation v (known to firms). If firms would not announce price menus, the unique equilibrium is market collapse, where firms charge v such that it is not worth incurring s to visit a firm. Hence, even if firms weren't required to announce prices, they would optimally do so. To our knowledge, we provide the first model of a credence good market where firms can choose whether to announce prices and optimally choose not to, as it is commonly observed.

Besides the credence good literature, this paper is closely related to the literature on consumer search where consumers are uncertain about firms' marginal cost due to industry wide cost shocks (Benabou and Gertner, 1993; Dana, 1994; Tappata, 2009; Janssen et al., 2011, 2017). Note that a model of industry wide cost shocks, where marginal cost are the same across firms in every state of the world, is formally identical to our framework. In both cases, consumers are uncertain about a firm's marginal cost and, in absence of commitment, firms make a price offer conditional on the cost realization. Since firms maximize expected profits, they behave the same in a market where the realized marginal cost is identical across consumers and where the marginal cost is independently realized across consumer. In contrast to our paper, this literature assumes that a fraction of consumers has no search cost, so called shoppers, in order to prevent market collapse. This leads to a mixed pricing strategy of firms and a complicated search strategy for consumers, who learn about the cost realization incrementally as they search different firms and receive different price offers. This literature however does not consider the incentives of firms to commit to a single price across states of the world, in order to attract consumers.[3] Hence, under a different reading of our paper, we contribute to the literature of consumer search

[2] The term "treatment" is used broadly to refer to the procedure employed by the firm to produce the good or to provide the service.

[3] For instance, a gas station could advertise that they will charge a fixed price per unit of gas for the coming year, independent of the current oil price.

under industry wide cost shocks by extending the model to allow firms to commit to prices.

Finally, there exists some literature on consumer search with price advertisement (Robert and Stahl, 1993; Anderson and Renault, 2006; Janssen and Non, 2008) and consumer search with price commitment (Obradovits, 2014; Myatt and Ronayne, 2019). In both strands of literature, marginal costs are identical across consumers and common knowledge. Advertisement, unlike commitment, is costly for firms and only reaches a fraction of consumers. Unlike in our model, where firms could inform consumers about prices at no cost but choose not to, firms want to inform consumers about prices in order to prevent market collapse. Both Obradovits (2014) and Myatt and Ronayne (2019) consider a two stage Varian (1980) model of search, where all consumers are either shoppers or captive to a given firm. Firms commit to an upper bound in the first stage and, after observing commitment decisions of competing firms, choose a price below their upper bound in the second stage. Note that commitment does not serve to inform consumers about prices and does not influence second period demand per se, since shoppers observe all prices at no cost and captives only observe the price of their firm, independent of whether firms commit or not. Instead, commitment only restricts the choice set of the firm in the second stage and thereby signals other firms the second stage equilibrium the firm intends to play.

3 Model

There are $n \geq 2$ identical firms, each producing a single homogeneous good or service, and a unit mass of consumers, each with unit demand. Consumers differ in how much it costs a firm to serve them and can be divided into $k \geq 2$ distinct groups. A firm incurs a marginal cost c_ω when serving a consumer of type $\omega \in \Omega := \{1, ..., k\}$, where c_ω is identical across firms and $c_1 < c_2 < ... < c_k$. We denote the fraction of consumers with cost c_ω by λ_ω such that $\sum_{\omega=1}^{k} \lambda_\omega = 1$. While c_1 to c_k are public knowledge, consumers are layman and don't know their own cost type ω, hence cannot infer a firm's cost c_ω of serving them. Firms are experts and learn a consumer's ω through a diagnosis once the consumer visits the firm. In order to visit a firm and undergo a diagnosis, a consumer has to incur an opportunity cost $s > 0$. Firms cannot serve a consumer without running a diagnosis beforehand, so in order to obtain the good the consumer has to incur s at least once.

A consumer's valuation v for the good is distributed according to F, independent of ω, and realized only after the consumer visits a firm and inspects the good for the first time. Since the good is identical across firms, visiting additional firms does not reveal additional information to the consumer about her valuation.[4] We assume that F is continuous and $(1-F)^{-1}$ is convex, which ensures that monopoly profits are single peaked.[5] Furthermore, we normalize the outside option of consumers to 0, such that in absence of competition a consumer would buy if and only if the price was weakly below her valuation.

The market plays out in two stages, a *commitment stage* and a *search stage*. In the commitment stage, each firm simultaneously decides whether to commit to a price that it has to charge to all consumers (for instance by displaying a price on their homepage) or whether to not commit, thus retaining the ability to make a price offer dependent on ω. Formally, firm j chooses $a_j \in \mathbb{R}_+ \cup \{nc\}$, where $a_j \in \mathbb{R}_+$ means that firm j commits to charging a_j and $a_j = nc$ means that firm j does not commit to a price. The decisions of the commitment stage $(a_1, ..., a_n)$ are observed by all firms and consumers, making the subsequent search stage a subgame. Note that consumers observe the price of a committed firm at no cost.[6]

In the search stage, consumers search firms sequentially with costless recall. Consumers can identify firms by their decision in the commitment stage and can choose the order in which they visit these firms. However, firms with identical decisions in the commitment stage are indistinguishable to the consumer and are visited with equal probability. A firm does not observe which firms the consumer has visited previously. Upon visit of a consumer at a firm, events unfold in the following order. (i) The consumer incurs s and the firm learns ω. If it is the consumer's first search, she learns v. (ii) If the firm did not make a commitment in the first stage, it chooses a price. A committed firm has to offer the price it committed to and is formally not a player in the search stage. (iii) Finally, the consumer decides whether to buy from any of the previously visited firms, search the next firm or leave the market without purchase.

3.1 Discussion of our modeling assumptions

Non-committed firms can price more flexibly than committed firms in two ways. First, non-committed firms can price discriminate, whereas committed firms have to charge a uniform price to all types of consumers. Second, non-committed firms can

[4] This is in contrast to the literature on horizontal differentiation (Wolinsky, 1986; Anderson and Renault, 1999), where goods differ across firms, such that upon visit at a firm the consumer only learns her valuation for the good offered by that firm.

[5] This assumption is weaker than log-concavity of $1-F$ (Caplin and Nalebuff, 1991).

[6] We think of the cost of learning a committed firm's price (e.g. by visiting the firm's homepage) as negligible compared to s, as s captures the ordeal of making an appointment, visiting the firm and undergoing a diagnosis.

deviate from the price expected by consumers, potentially unpunished due to the presence of search frictions, whereas a committed firm's price is necessarily in line with consumers' expectations. Note that in our framework, firms could not credibly commit to a price for each type of consumer, because consumers cannot verify their own cost type. Therefore, a firm could overcharge a low cost consumer by alleging the consumer is a high cost type and charging the corresponding high price. Hence, in our framework the ability to price discriminate requires the flexibility to choose a price in the search stage.

We could allow firms to commit to a reduced flexibility, for instance by committing to a range of prices. This complicates the analysis, as the consumer has to form expectations about the prices of both committed and non-committed firms. We therefore consider commitment to a single price as the baseline model and deal with more sophisticated forms of commitment in the extensions. Commitment to a single price is plausible when more complex commitments aren't feasible or when consumers expect committed firms to always charge the highest price from the set of prices they committed to.[7]

4 Equilibria

Our solution concept is pure strategy *Perfect Bayesian Equilibrium* (PBE), where firms play symmetric strategies in the search stage and consumers' out-of-equilibrium beliefs satisfy the intuitive criterion (Cho and Kreps, 1987). We derive the possible equilibria of this market by backward induction, hence we identify the equilibria of each search stage, before going back to the commitment stage. We begin by analyzing the subgame $(nc, ..., nc)$, which arises after no firm committed. This subgame is also representative of markets where commitment is not possible, for instance because displayed prices are not legally binding.

4.1 A Market without Commitment

A firm j's strategy in the search stage is a (potentially mixed) price $p_j(\omega)$ for each cost type $\omega \in \Omega$. A consumer first has to decide whether to make an initial search or not. If the consumer participates in the market, she decides after each search whether to buy from any of the previously visited firms, search on or leave the market without purchase. Note that consumers cannot decide which firms to search, since in this subgame all firms made the same decision in the commitment stage

[7]We later show that such an expectation can be rational, when semi-committed firms aren't visited in equilibrium and have specific out-of-equilibrium beliefs.

and are therefore indistinguishable to the consumer. Since firms produce identical goods, the consumer will never buy from a previously visited firm that didn't make the lowest offer. Furthermore, the consumer will never take the lowest offer if it is strictly above her valuation and never leave the market without purchase if the lowest offer is strictly below her valuation. Hence, the only non-trivial decision of the consumer is whether to search on. Whether an additional search is worth the cost s depends on the consumer's expectations about firm's pricing strategies and the consumer's belief regarding her own cost type, $\mu \in \triangle\Omega$. The consumer learns about her cost type through the prices charged by firms and updates μ after each visit, given her expectations about firms' pricing strategies.

While the consumer in principle faces a complex search problem, the complexity reduces significantly if the consumer expects firms to play pure and symmetric strategies. If every firm charges an identical price to a given type of consumer, there is no benefit from visiting more than one firm. In the following, we show that there exist equilibria in pure and symmetric strategies at which consumers make an initial search. We then show that only one of these equilibria satisfies the intuitive criterion.

Let $p^* : \Omega \mapsto \mathbb{R}_+$ denote the equilibrium pricing strategy of every firm. Since the consumer expects to search once at most, she participates in the market if the expected surplus from a single search is greater than s, the cost of a single search. Note that a consumer initially faces uncertainty both about how much she will like the good and, due to the uncertainty about her cost type, how much the firm will charge. We denote a consumer's expected surplus from visiting a single firm that charges a known price p by $CS(p) := \int_p^\infty (v-p)dF(v)$. Consumers participate in the market if and only if

$$\sum_{\omega=1}^{k} \lambda_\omega CS(p^*(\omega)) \geq s. \tag{1}$$

If there is at least one ω such that $F(p^*(\omega)) < 1$, then there exists an s sufficiently small such that (1) is satisfied. From now on we assume that (1) is satisfied, hence all consumers make an initial search.[8]

In order to identify p^* we consider a firm's incentive to deviate. Let $D(p^*, p) \in [0, 1]$ denote the purchasing probability of a consumer after offering a price p given the expected pricing strategy p^*. In order for p^* to be an equilibrium, a firm cannot increase their profit from consumers of cost type ω by deviating, formally

$$D(p^*, p^*(\omega))(p^*(\omega) - c_\omega) \geq D(p^*, p)(p - c_\omega), \tag{2}$$

[8]Since consumers are ex ante identical, either all consumers search or none.

for any $p \in \mathbb{R}_+$ and $\omega \in \Omega$.

If there was only a single firm in the market, a consumer would buy if and only if $v \geq p$, independent of her expectations p^*, and hence a hypothetical monopolist would face a purchasing probability $D^m(p) := 1 - F(p)$. Under competition, the firm could lose consumers with valuations above p to competing firms and hence $D(p^*, p) \leq D^m(p)$. Whether a consumer searches on after observing a deviation depends on the out-of-equilibrium beliefs of the consumer regarding her cost type. In the following we identify three cases where a deviating firm does not lose consumers to its competitors, no matter the out-of-equilibrium beliefs of consumers.

Lemma 1. $D(p^*, p) = D^m(p)$ whenever

i) $p \in \{p^*(\omega) : \omega \in \Omega\}$.

ii) $p < p^*(\omega)$ and the consumer is of cost type ω.

iii) $p < p^*(\alpha) + s$ where $\alpha := \arg\min_{\omega \in \Omega} p^*(\omega)$.

In i) the firm deviates to a price that is being charged in equilibrium, but that is not the equilibrium price of the consumer's cost type. For example, the firm charges $p^*(2)$ to a consumer of type 1. Since the consumer does not detect the deviation, she must believe that she is of type 2 and hence believes other firms will charge $p^*(2)$ as well, making additional searches futile. In ii) the firm deviates to a price below the equilibrium price of the consumer's cost type. This might induce the out-of-equilibrium belief that the consumer is of a cost type with an even lower equilibrium price. However, even if the consumer searches on, other firms will offer the larger equilibrium price and the consumer will eventually buy from the deviating firm. In iii) the firm deviates to a price slightly above the lowest price charged in equilibrium, denoted by $p^*(\alpha)$. Visiting another firm is never worth the additional search cost s, since at the very best the next firm will charge $p^*(\alpha)$.

We denote monopoly profits by $\Pi_\omega(p) := D^m(p)(p - c_\omega)$ and the monopoly price by $p^m_\omega := \arg\max_p \Pi_\omega(p)$. Our assumptions on F ensure that $\Pi_\omega(p)$ is single peaked for all ω. Hence, if a firm can deviate marginally closer to p^m_ω without losing consumers to competing firms it has a profitable deviation and p^* cannot be an equilibrium. Together with Lemma 1 this imposes the following two restrictions on p^*.

Lemma 2. $p^*(\omega) \leq p^m_\omega$ for all $\omega \in \Omega$.

Proof. This follows immediately from Lemma 1 ii. If the equilibrium price for some type of consumer would be above the monopoly price, a firm could simply deviate downwards to the monopoly price without losing consumers to competing firms and generate maximal profits. $\square$

Lemma 3. $p^*(\alpha) = p^m_\alpha$.

Proof. By Lemma 2 the lowest price charged in equilibrium has to be weakly below the monopoly price of the corresponding cost type, p^m_α. If $p^*(\alpha)$ was strictly below p^m_α then a firm could deviate upwards by up to s and not lose consumers to competing firms (Lemma 1 iii). Getting closer to p^m_α without losing consumers to competing firms would make this a profitable deviation, hence $p^*(\alpha)$ cannot be strictly below p^m_α. □

Without any restrictions on out-of-equilibrium beliefs, infinitely many pricing strategies can be supported as an equilibrium. Consider for example $k = 2$ and assume $p^m_1 + s < p^m_2$. If $p^*(1) = p^m_1$ then any $p^*(2) \in (p^m_1 + s, p^m_2]$ constitutes a pure strategy PBE of this subgame. These equilibria can be supported by the out-of-equilibrium belief of the consumer that she is certainly of type 1 after observing a deviation. If the consumer sees a price above $p^m_1 + s$ other than $p^*(2)$, then she expects the next firm to charge p^m_1, hence it is worth the additional search cost to visit the next firm. If the consumer is of type 2, the next firm offers $p^*(2)$ and hence a upward deviation from $p^*(2)$ will certainly lose the consumer.

This game between the firm and the consumer resembles the basic sender-receiver game of Cho and Kreps (1987) and hence the intuitive criterion applies. The firm (sender) has private information about a state of the world ω that is pay-off relevant to the consumer (receiver). Upon receiving a price (message) that is out-of-equilibrium, the consumer has to form a belief about ω. The intuitive criterion rules out beliefs that assign probability to ω where the firm could not possibly profit from the deviation, no matter the belief of the consumer. Note that if $p^*(\omega) = p^m_\omega$ then any deviation strictly decreases profits, even under the most favorable belief of the consumer. This immediately leads us to the following proposition.

Proposition 1. $p^*(\omega) = p^m_\omega$ for all $\omega \in \Omega$ is the unique PBE in pure and symmetric strategies which satisfies the intuitive criterion where consumers participate in the market.

Proof. By Lemma 3 the lowest equilibrium price must be the monopoly price of the corresponding cost type. By Lemma 2 the second lowest equilibrium price must be weakly below the monopoly price of the corresponding cost type. Assume the second lowest equilibrium price, denoted $p^*(\beta)$, is strictly below the monopoly price p^m_β and the firm deviates upwards by up to s when facing a consumer of type β. Since the deviation could never be profitable for a firm facing a consumer of type α and it could be profitable for a firm facing a consumer of type β, the intuitive criterion rules out beliefs that put probability on type α. Hence, the best price the consumer can hope to receive from the next firm is $p^*(\beta)$ and an additional search is not worth the search cost. Therefore, the second lowest equilibrium price must be the monopoly price as well. The same argument goes through for the third lowest equilibrium price and so on until every cost type receives the corresponding monopoly price. □

In summary, if no firm commits to a price, then firms charge the monopoly price to each type of consumer and share monopoly profits. Consumers search once if search cost are sufficiently low.

4.1.1 More discussion of our modeling assumptions

While the inspection good aspect in our model isn't intrinsically linked to our research question, we require some way to prevent a hold-up problem in the spirit of Diamond (1971). If consumers would know their valuation before making their first search, then given some expected pricing strategy p^*, consumers with valuations below $p^*(\alpha) + s$ would not participate in the market. Upon visit of a type α consumer, a firm could deviate upwards by s, since the consumer's valuation would certainly be above $p^*(\alpha) + s$ and the consumer would not find it beneficial to incur an addition s to buy at $p^*(\alpha)$ from the next firm. This unravels until expected prices are so high that no consumer searches and the market collapses. For firms to make any profits, they would have to commit to a price. Since the purpose of this paper is to explain the observation that in many markets firms do not commit, we are in need of a search model that permits an active market after $(nc, ..., nc)$. Consumers learning v only after they made their search means that firms cannot infer the valuation from the fact that the consumer has visited. The consumer might be indifferent between buying and not buying at $p^*(\alpha)$ and even a marginal upward deviation might lose the consumers.

Alternatively, we could assume that consumers know their valuation before their first search and that the first search is free. Then all consumers make an initial search independent of v and firms can't infer valuations either. All the results of this section follow through and the unique equilibrium is that firms charge the monopoly price to each cost type. The results of succeeding sections follow through as well.

4.2 A Market with some Commitment

In this section we identify the equilibria of the search stage when at least one firm has committed to a price. Trivially, if two firms committed to different prices, it is never optimal for a consumer to visit the firm committed to the higher price. For that reason, we denote the lowest price among the committed firms by $\underline{p}$, ignore firms committed to prices strictly above $\underline{p}$ and refer to firms committed to $\underline{p}$ simply as *committed firms*. Furthermore, if all firms committed to a price, trivially consumers visit the firms committed to the lowest price. Therefore, for the rest of this section we consider subgames where at least one firm did not commit in the commitment stage. As in the previous section, p^* refers to the pure and symmetric equilibrium pricing strategy of non-committed firms.

Whether consumers find it optimal to visit non-committed firms depends on consumers' expectations regarding non-committed firm's prices. We say that consumers expectations are *optimistic* when they believe that non-committed firms price below $\underline{p}$ sufficiently often, such that visiting non-committed firms at any point in the search stage is optimal. Otherwise, we say that consumers expectations are *pessimistic*. Analogously, an *optimistic equilibrium* is one where non-committed firms are visited at some point in equilibrium and a *pessimistic equilibrium* is one where they are never visited in equilibrium.

4.2.1 Pessimistic equilibria

All pessimistic equilibria have an identical outcome, namely that consumers visit a committed firm, buy if $v \geq \underline{p}$ and leave the market without purchase otherwise. For this reason, we identify only one pessimistic equilibrium. For the pessimistic equilibrium to exist in a subgame (characterized by $\underline{p}$) the following must hold.

$$CS(\underline{p}) \geq s. \tag{3}$$

If $F(\underline{p}) < 1$ then there exists an s small enough to satisfy (3). For the rest of this section, we restrict attention to cases where (3) is satisfied.

We claim that $p^*(\omega) = \max\{\underline{p}, c_\omega\}$ is an equilibrium pricing strategy of non-committed firms. If consumers expect non-committed firms to charge $p^*(\omega) = \max\{\underline{p}, c_\omega\}$, then consumers optimally never visit non-committed firms. Since non-committed firms are never visited on the equilibrium path, upon visit a non-committed firm has to form an out-of-equilibrium belief regarding the valuation of the consumer and the previous offers received by the consumer. One out-of-equilibrium belief that supports this equilibrium is that consumers have already visited a committed firm, hence have an offer of $\underline{p}$ in their pocket, and have a valuation distributed above $\underline{p}$.[9] Since consumers have an offer of $\underline{p}$ in their pocket, the firm will certainly lose the

[9]Note that the intuitive criterion would rule out beliefs that put probability on valuations in $[0, c_1+s)$, as consumers with such valuations would never benefit of an additional search, independent of the firm's belief. Hence, the belief that visiting consumers have high valuations is somewhat reasonable.

consumer if it prices above $\underline{p}$. Therefore the firm will only price above $\underline{p}$ if $\underline{p} < c_\omega$. Since the consumer has a valuation above $\underline{p}$, the firm has no reason to undercut the committed firm, as the consumer will buy from the non-committed firm at $\underline{p}$.[10]

Note that the pessimistic equilibrium exists in every subgame with both committed and non-committed firms, even if $\underline{p}$ is large, as long as s is sufficiently small.

4.2.2 Optimistic equilibrium

In an optimistic equilibrium, non-committed firms are visited by some consumers, either because all consumers visit non-committed firms first or because consumers visit committed firms first, but sometimes find it optimal to search a non-committed firm afterwards. It turns out that the latter can never happen in equilibrium.

Lemma 4. If it is beneficial to visit a non-committed firm after visiting a committed firm, then it is even better to visit the non-committed firm first.

Proof. Upon visit at a committed firm, the consumer learns her valuation but learns nothing about her type. The net benefit of an additional search at a non-committed firm for a consumer with $v \geq \underline{p}$ is the expected discount she receives net of search cost,

$$B(p^*, \underline{p}) := \sum_{\omega=1}^{k} \lambda_\omega \mathbb{1}_{\underline{p} > p^*(\omega)} (\underline{p} - p^*(\omega)) - s.$$

Since $B(p^*, \underline{p})$ does not depend on v, either all consumers with $v \geq \underline{p}$ find it optimal to additionally search a non-committed firm or none. Hence, if $B(p^*, \underline{p}) > 0$ then no consumer will buy at their first visit at a committed firm, because either $v < \underline{p}$, in which case they would never buy at the committed firm, or $v \geq \underline{p}$ and it is optimal to search on. Since consumers know they will never buy at their first visit at a committed firm, they can save on search cost by first visiting a non-committed firm instead. □

By Lemma 4 the only candidate for an optimistic equilibrium is one where consumers visit a non-committed firm first. As in Section 4.1 we identify p^* of such an equilibrium by considering firms' incentives to deviate. For the most part, the results of Section 4.1 go through, with the caveat that $D(p^*, p) = 0$ for $p > \underline{p} + s$, since a consumer can always purchase from a committed firm at an effective price of $\underline{p} + s$. On the other hand, if a consumer receives an offer below $\underline{p} + s$ from the

[10] We implicitly assume that if a consumer has received identical offers, she will buy from the last firm that made the offer. This assumption is without loss of generality, as if it were otherwise, the last firm would not have a best response.

non-committed firm, she will never go on to visit a committed firm. This implies that if $c_\omega < \underline{p} + s$ then $p^*(\omega)$ cannot be greater than $\underline{p} + s$ as otherwise a non-committed firm would deviate to a price below $\underline{p} + s$ and even if consumers search on other non-committed firms they would eventually buy from the deviating firm. While the presence of committed firms pushes prices of non-committed firms down to $\underline{p}+s$, the mechanisms described in Section 4.1 push prices up to the monopoly price whenever the monopoly price is below $\underline{p} + s$. These forces pin down the following equilibrium outcome.

Proposition 2. In any optimistic equilibrium, the pricing strategy of non-committed firms is

$$p^*(\omega) = \begin{cases} p^m_\omega & p^m_\omega \leq \underline{p} + s \\ \underline{p} + s & p^m_\omega > \underline{p} + s \geq c_\omega \\ b & \underline{p} + s < c_\omega \end{cases},$$

where $b > \underline{p} + s$ to deter consumers from purchase. Furthermore, non-committed firms are visited first.

The proof is similar to the proof of Proposition 1 and therefore omitted. Note that in an optimistic equilibrium, committed firms never make a profit and might even make a loss, as they are only visited by consumers with cost above $\underline{p}$.

Next we identify the conditions under which an optimistic equilibrium exists in the search stage. Note that the existence of an optimistic equilibrium in a wide range of subgames is detrimental to the existence of an equilibrium where no firm commits in the commitment stage. Deviation from $(nc, ..., nc)$ in the commitment stage can only be deterred by punishing a firm committed to a high price with the optimistic equilibrium in the search stage. Whether or not the optimistic equilibrium exists in a subgame depends on whether the consumer's surplus from first searching a non-committed firm charging p^* is greater than the consumer's surplus from searching a committed firm.[11] For notational convenience we assume that $p^m_1 < p^m_2 < ... < p^m_k$.[12] Then, the optimistic equilibrium exists in a subgame if and only if

$$\sum_{\omega=1}^{\psi} \lambda_\omega CS^m_\omega + \sum_{\omega=\psi+1}^{k} \lambda_\omega CS(\underline{p} + s) \geq CS(\underline{p}), \tag{4}$$

[11] Note that by Lemma 4 it is never optimal to first search a committed firm with the intend to search on sometimes and hence it is sufficient to compare the surplus from only visiting a committed firm to the surplus from first visiting a non-committed firm.

[12] This holds whenever the pass-through rate from marginal cost to the monopoly price is positive, which in turn is the case whenever marginal revenue is downward sloping, which is a standard assumption in the literature (Bulow and Pfleiderer, 1983; Chen and Schwartz, 2015).

where $CS_\omega^m := CS(p_\omega^m)$ and ψ such that $p_\psi^m < \underline{p}+s \leq p_{\psi+1}^m$. Note that the consumer's surplus from visiting a non-committed firm is $CS(\underline{p}+s)$ even if the firm charges above $\underline{p}+s$, since incurring an additional s and buying at $\underline{p}$ from the committed firm is effectively the same as buying from a non-committed firm at $\underline{p}+s$.

Next, we identify the set of $\underline{p}$ for which (4) is satisfied. First note that (4) is trivially satisfied if $\underline{p} \geq p_k^m$, as the consumer will never receive a better offer from the committed firm. Similarly, (4) is trivially violated if $\underline{p} \leq p_1^m$, as the consumer will never receive a better offer from the non-committed firm. Therefore, interesting cases are $\underline{p} \in (p_1^m, p_k^m)$. Second, we find that (4) has a single crossing property, meaning there exists a $d \in (p_1^m, p_k^m)$ such that (4) is satisfied if and only if $\underline{p} \geq d$. We prove this in Appendix A. Third, we find that d is monotonically increasing in s. To see this, consider (4) for $\underline{p} = d$:

$$\sum_{\omega=1}^{\psi} \lambda_\omega CS_\omega^m + \sum_{\omega=\psi+1}^{k} \lambda_\omega CS(d+s) = CS(d). \tag{5}$$

Increasing s, while holding everything else constant, decreases the left hand side of (5) while the right hand side remains the same. Due to the single crossing property of (4), the right hand side decreases faster in d than the left hand side, so in order to achieve equality d must increase. To emphasize this relation, we write $d(s)$ from now on and denote the bounds of $d(s)$ by $\underline{d}$ and $\bar{d}$. For $s \to 0$, $d(s) \to p_1^m$ and hence $\underline{d} = p_1^m$. The intuition is that if s is close to 0, a non-committed firm never makes a worse offer than a committed firm. So for a consumer to be indifferent between the two firms, a committed firm must never make a worse offer than a non-committed firm, which is the case when $\underline{p} \leq p_1^m$. Next, we consider $\bar{d}$. If s increases, then ψ increases and more types receive the monopoly price rather than $\underline{p}+s$. From some s onward, the non-committed firm only charges monopoly prices and hence $\bar{d}$ solves

$$\sum_{\omega=1}^{k} \lambda_\omega CS_\omega^m = CS(\bar{d}). \tag{6}$$

Note that $CS(p)$ is convex in p.[13] In order for (6) to be satisfied, $\bar{d} < \sum_{\omega=1}^{k} \lambda_\omega p_\omega^m$, meaning the optimistic equilibrium certainly exists if the lowest commitment price is above the average monopoly price.

In summary, the optimistic equilibrium exists whenever $\underline{p} \geq d(s)$ where $d(s)$ is monotonically increases in s from p_1^m to $\bar{d} < \sum_{\omega=1}^{k} \lambda_\omega p_\omega^m$. This concludes the analysis of the subgames. In the following section, we identify the equilibria of the commitment stage.

[13] $\frac{\partial CS(p)}{\partial p} = -D^m(p)$ and $D^m(p)$ is downward sloping.

4.3 Equilibria of the Commitment Stage

We identify two equilibrium candidates of the commitment stage, the *competitive equilibrium* and the *monopolistic equilibrium*. In the competitive equilibrium at least two firms commit to expected cost $\mathbb{E}[c] := \sum_{\omega=1}^{k} \lambda_\omega c_\omega$ and the pessimistic equilibrium is played in every subgame other than $(nc, ..., nc)$. The competitive equilibrium always exists. Deviating below $\mathbb{E}[c]$ in the commitment stage would induce a loss and deviating away from $\mathbb{E}[c]$ would leave at least one other firm committed to $\mathbb{E}[c]$ from which the consumer can buy, hence no firm has a profitable deviation. In the monopolistic equilibrium no firm commits and the optimistic equilibrium is played in every subgame where it exists. We identify the conditions for the existence of the monopolistic equilibrium later in this section. Note that $\underline{p} > \mathbb{E}[c]$ cannot be an equilibrium of the commitment stage, because either consumers are pessimistic, in which case it would be profitable for a firm to deviate to committing to a price slightly below $\underline{p}$, or consumers are optimistic, in which case it would be profitable for committed firms to deviate to no commitment.[14]

Next we identify the conditions under which the monopolistic equilibrium exists. Let $\Pi_\omega^m := \Pi_\omega(p_\omega^m)$ denote maximal monopoly profits from consumers of type ω. If no firm commits, then firms equally share $\sum_{\omega=1}^{k} \lambda_\omega \Pi_\omega^m$ among them. If a firm deviates and commits to a price p at which it attracts consumers, then the firm's profit is $\sum_{\omega=1}^{k} \lambda_\omega \Pi_\omega(p)$, which is identical to $D^m(p)(p - \mathbb{E}[c])$, the profit of a monopolist pricing at p when marginal cost are $\mathbb{E}[c]$. We denote profits from uniformly pricing at p by $\Pi_{\mathbb{E}[c]}(p) := D^m(p)(p - \mathbb{E}[c])$. The monopolistic equilibrium exists if and only if

$$\frac{1}{n} \sum_{\omega=1}^{k} \lambda_\omega \Pi_\omega^m \geq \Pi_{\mathbb{E}[c]}(p), \tag{7}$$

for all $p < d(s)$. Let $p_{\mathbb{E}[c]}^m := \arg\max_p \Pi_{\mathbb{E}[c]}(p)$ denote the optimal uniform price. If $d(s) > p_{\mathbb{E}[c]}^m$, then deviating to the optimal uniform price attracts all consumers, so for the monopolistic equilibrium to exist, (7) has to be satisfied for $p = p_{\mathbb{E}[c]}^m$. If on the other hand $d(s) \leq p_{\mathbb{E}[c]}^m$, then the deviation which yields the highest profit is commitment to a price just below $d(s)$. We can show that $d(s) \leq p_{\mathbb{E}[c]}^m$ for a wide range of demand functions. Let CS_c^m denote the monopoly consumer surplus at marginal cost c.

[14] Note that we restrict attention to equilibria where consumers either have pessimistic expectations in every subgame or have optimistic expectations in every subgame where it is rationally possible. Conceptually strange equilibria can arise when we allow consumers expectations to vary arbitrarily across subgames. An example is provided in Appendix B.

Lemma 5. If CS_c^m convex in c then $d(s) \leq p^m_{\mathbb{E}[c]}$.

Proof. Assume CS_c^m convex in c. Then

$$\sum_{\omega=1}^{k} \lambda_\omega CS_\omega^m \geq CS^m_{\mathbb{E}[c]}, \tag{8}$$

where $CS^m_{\mathbb{E}[c]} := CS(p^m_{\mathbb{E}[c]})$. Hence, consumer surplus is higher under monopolistic price discrimination than under monopolistic uniform pricing. Note that the left hand side of (8) is weakly lower than what consumers would receive if non-committed firms would cap their prices at $p^m_{\mathbb{E}[c]} + s$, as it is the case in the optimistic equilibrium with $\underline{p} = p^m_{\mathbb{E}[c]}$ (see condition (4) for comparison). Hence, if a firm would deviate from $(nc, ..., nc)$ by committing to $p^m_{\mathbb{E}[c]}$ it would not attract consumers and therefore $d(s) \leq p^m_{\mathbb{E}[c]}$. □

In their investigation of cost based price discrimination, Chen and Schwartz (2015) identify common demand functions for which CS_c^m is strictly convex. What follows are the corresponding distributions of consumer valuations. CS_c^m is strictly convex in c if:

i) $F(p) = \frac{(\bar{v}-\underline{v})^a - (\bar{v}-p)^a}{(\bar{v}-\underline{v})^a}$ with $a > 0$ for $p \in [\underline{v}, \bar{v}]$.[15]

ii) $F(p) = 1 - e^{-ap}$ with $a > 0$ for $p \in [0, \infty)$.

iii) v is normally distributed with mean 0, logistically distributed with mean 0 or log-normally distributed with mean 1.

By Lemma 5, if CS_c^m is strictly convex in c then the monopolistic equilibrium exists if and only if

$$\frac{1}{n}\sum_{\omega=1}^{k} \lambda_\omega \Pi_\omega^m \geq \Pi_{\mathbb{E}[c]}(d(s)). \tag{9}$$

Inequality (9) informs us about the characteristics of markets where we should expect a monopolistic equilibrium to emerge. First, the monopolistic equilibrium becomes harder to sustain with more firms in the market. If more firms have to share monopoly profits, a deviation that attracts all consumers becomes more favourable. However, if $d(s) < \mathbb{E}[c]$, then any deviation that would attract consumers would also induce a loss, in which case the monopolistic equilibrium exists for any number of firms. $d(s) < \mathbb{E}[c]$ is the case if for example $s \to 0$ and $p_1^m < \mathbb{E}[c]$. Second, search cost play an interesting role in sustaining the monopolistic equilibrium. In the absence of any search cost

[15]Note that this collapses to the uniform distribution for $\alpha = 1$.

($s = 0$), firms price each type ω at the marginal cost c_ω in equilibrium. Hence, the presence of search frictions is necessary for firms to enjoy not only monopoly profits, but any profits. However, as search frictions increase, maximal deviation profits $\Pi_{\mathbb{E}[c]}(d(s))$ increase and the set of parameters for which the monopolistic equilibrium exists shrinks. The intuition goes as follows. If search frictions increase, then non-committed firms can charge higher mark-ups without losing the consumer to a committed firm, which in turn makes it less beneficial to visit non-committed firms over committed firms in the first place. Hence, a firm can attract consumers away from non-committed firms by committing to relatively high prices, meaning deviations from non-commitment become more attractive. Finally, we consider how the distribution of cost relates to the existence of the monopolistic equilibrium when $s \to 0$. When costs become more dispersed, then $\sum_{\omega=1}^{k} \lambda_\omega \Pi_\omega^m - \Pi_{\mathbb{E}[c]}(d(s))$ increases and the monopolistic equilibrium is more likely to exist. If low costs type make up a larger fraction of consumers compared to high cost types, then the monopolistic equilibrium is less likely to exist. To see this, consider $\lambda_1 \to 1$. Then both $\sum_{\omega=1}^{k} \lambda_\omega \Pi_\omega^m$ and $\Pi_{\mathbb{E}[c]}(p_1^m)$ converge to Π_1^m and hence (9) is violated. In summary, the monopolistic equilibrium is more likely to exist in markets with few firms, low but positive search frictions, highly dispersed cost and when high cost types are relatively more common than low cost types.

5 Welfare

In this section we compare consumer surplus and total surplus between the monopolistic and competitive equilibrium. Since firms make no profits in the competitive equilibrium, trivially profits are larger in the monopolistic equilibrium. We show that consumer and total surplus can be larger under either equilibrium. As a first step we compare our setting to the existing literature. Chen and Schwartz (2015) find that when monopoly consumer surplus is convex in marginal cost, both consumer surplus and total surplus are larger when a monopoly price discriminates between cost types rather than pricing uniformly to all cost types. On the other hand, in a perfectly competitive market, cost based price discrimination, where each type is priced at its marginal cost, always yields higher consumer and total surplus than uniformly pricing at expected cost. This is due to the fact that consumer surplus is convex in price and that under both pricing schemes firms make no profits. The equilibria of our market require us to compare surplus under monopoly price discrimination (i.e. the monopolistic equilibrium) to surplus under uniform pricing in a perfectly competitive market (i.e. the competitive equilibrium). To our knowledge this has not been done by the literature and the analysis neither reduces to the curvature of the demand function (as in Chen and Schwartz (2015)) nor is it trivial (like the comparison between uniform and differential pricing under perfect competition).

Assume for now that the monopolistic equilibrium exists. Consumer surplus is larger under the monopolistic equilibrium than the competitive equilibrium if and only if

$$\Delta CS := \sum_{\omega=1}^{k} \lambda_\omega CS_\omega^m - CS(\mathbb{E}[c]) \geq 0 \tag{10}$$

and total surplus is larger if

$$\Delta TS := \sum_{\omega=1}^{k} \lambda_\omega \left(\Pi_\omega^m + CS_\omega^m\right) - CS(\mathbb{E}[c]) \geq 0. \tag{11}$$

First, note that ΔCS and ΔTS don't depend on the number of firms, as equilibrium prices are independent of the number of firms, conditional on the monopolistic equilibrium existing. Second, note that ΔCS and ΔTS don't depend on the search cost s, since in both equilibria, every consumer pays s exactly once. Therefore, ΔCS and ΔTS depend only on the distribution of valuations F and the distribution of costs $((c_1, ..., c_k), (\lambda_1, ..., \lambda_k))$, conditional on the monopolistic equilibrium existing. We denote by $\text{Var}[c]$ the variance and by $\text{SD}[c] := \sqrt{\text{Var}[c]}$ the standard deviation of the cost distribution.

Proposition 3. If CS_c^m is convex in c, then both ΔCS and ΔTS increase in $\text{Var}[c]$.

Proof. First, we consider the effect of a mean preserving spread on ΔCS. Since CS_c^m is assumed to be convex in c, the expectation of CS_c^m with respect to the cost distribution must increase with a mean preserving spread.[16] $CS(\mathbb{E}[c])$ is unaffected by a mean preserving spread. This concludes that ΔCS must increase. If monopoly consumer surplus is convex in cost, then total surplus is convex in cost as well (see conditions A1a and A1b in Chen and Schwartz (2015)). Hence the same argument goes through for ΔTS. □

Proposition 3 says that for a range of common demand functions (see Section 4.3), the relative social desirability of the monopolistic equilibrium (compared to the competitive equilibrium) increases as cost become more dispersed. To be able quantify the exact amount of cost dispersion necessary for the monopolistic equilibrium

[16]The proof of this statement is analogous to the proof of equivalence of second order stochastic dominance and a mean preserving spread. See for instance Proposition 6.D.2. in Mas-Colell et al. (1995)

to yield higher consumer or total surplus, we have to make assumptions on the demand. We find that if valuations are distributed uniformly on $[0, \bar{v}]$, then there exists a measure of cost dispersion

$$\sigma := \frac{\mathrm{SD}\,[c]}{\bar{v} - \mathbb{E}[c]}$$

that uniquely determines the relative social desirability of the two equilibria.

Proposition 4. The monopolistic equilibrium yields higher consumer surplus (condition (10)) if and only if $\sigma \geq \sqrt{3}$ and higher total surplus (condition (11)) if and only if $\sigma \geq \frac{1}{\sqrt{3}}$.

We prove this and all further results on uniformly distributed valuations in Appendix C.

Until now we have compared consumer and total surplus under the assumption that the monopolistic equilibrium exists, i.e. the parameters of the market satisfy (9). However, if for instance the monopolistic equilibrium would only exist whenever it was socially desirable, then there wouldn't be a need for a policy intervention. Conversely, if the monopolistic equilibrium would only exist in a parameter range where the competitive equilibrium yields higher surplus, then welfare could be improved by indiscriminately mandating price commitments in markets where firms currently don't post prices. We show in the following that neither of these cases obtains, such that for the range of parameters where both equilibria co-exists, either equilibrium can yield higher consumer or total surplus. Hence, in order to determine whether mandating price commitments increases welfare, the policy maker requires detailed information about the market, namely estimates of valuations, the cost distribution and the number of active firms.

A sufficient condition for the existence of the monopolistic equilibrium is condition (9) with large search cost such that $d(s) = \bar{d}$. For uniformly distributed valuations, this yields $\sigma \geq \sqrt{\left(\frac{2n}{1+n}\right)^2 - 1}$. Note that the right hand side is monotonically increasing in n and greater than $\frac{1}{\sqrt{3}}$ even for $n = 2$. Hence, if search costs are very large (relative to consumer valuations and marginal cost) and a market is in the monopolistic equilibrium, we can conclude that monopolistic equilibrium is indeed socially desirable and policy intervention is uncalled for. Next we consider the case of small search cost, such that $d(s) \approx \underline{d} = p_1^m$. We find that condition (9) cannot be expressed in terms of σ, which is why we resort to a graphical analysis for a simple version of the model. In Figure 1 we plot the parameter space for $s \to 0$, $n = 2$, $k = 2$, $c_1 = 0$ and $\bar{v} = 1$, where λ_2 and c_2 naturally vary between 0 and 1. The green line represents the necessary and sufficient condition for the existence of the monopolistic equilibrium (9), such that the colored areas right of the green line are

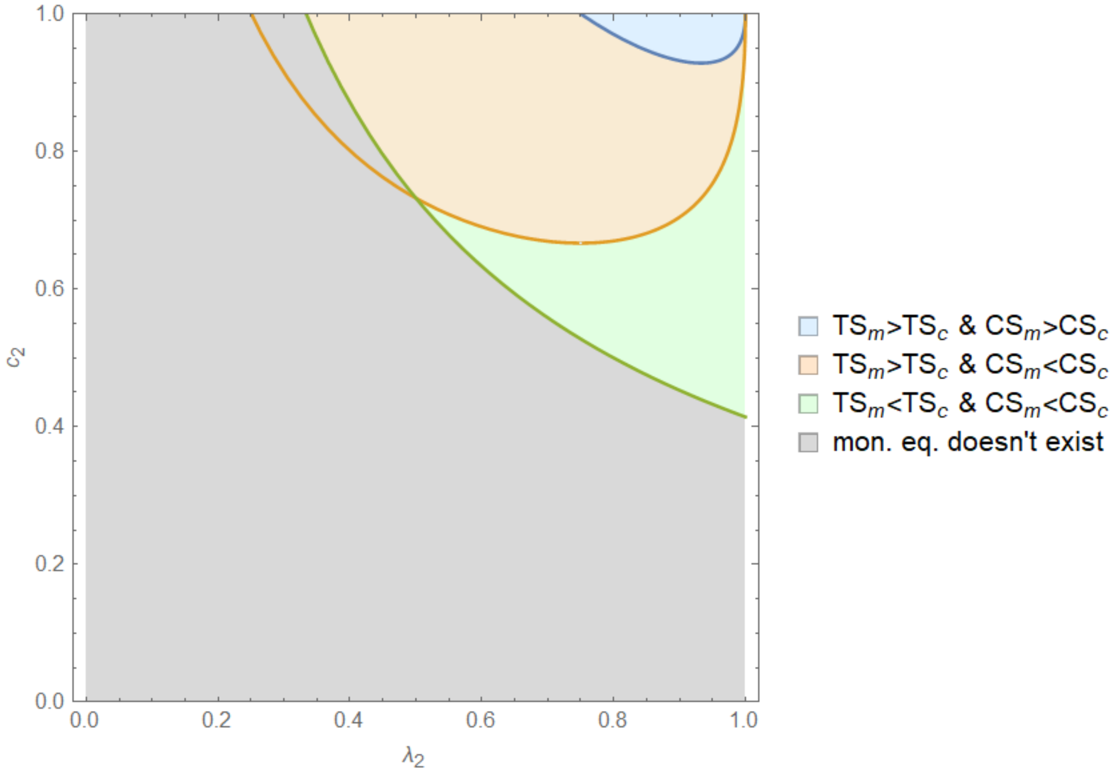

Figure 1: Existence and surplus of equilibria.

the relevant parameters where both equilibria co-exist. The orange line represents the condition $\sigma = \frac{1}{\sqrt{3}}$ and the blue line the condition $\sigma = \sqrt{3}$, such that in the green area both total and consumer surplus are larger under the competitive equilibrium, in the orange area total surplus is larger under the monopolistic and consumer surplus is larger under the competitive equilibrium and in the blue area both total and consumer surplus are larger under the monopolistic equilibrium.

6 Extensions

6.1 Commitment to an upper bound

Assume that instead of committing to a single price, firms can commit to an upper bound and price freely below the upper bound once the consumer has visited and the firm has learned the consumer's cost type. Let $\underline{p}$ denote the lowest upper bound in a subgame. One might think that consumers never visit non-committed firms, as committed firms can offer monopoly prices below $\underline{p}$ as well, but are forced to charge $\underline{p}$ when the monopoly price is above. However, if consumers believe that committed firms charge $\underline{p}$ to every type of consumer, even if $p^m_\omega < \underline{p}$, then committed firms aren't visited in equilibrium of subgames where $\underline{p} > d(s)$. If committed firms aren't visited in equilibrium, then upon visit, the committed firm has to form an out-of-equilibrium belief regarding previous offers and the valuation of the consumer. If the firm believes that the consumer has received a previous offer of $\underline{p}$ and has a valuation certainly above $\underline{p}$, then charging $\underline{p}$ is the best response. Hence, a consumer's expectation that committed firms always price at the upper bound is rational. This allows the monopolistic equilibrium to survive, when firms can commit to an upper bound.

6.2 Correlated outside options

For some goods and services, the outside option of the consumer is correlated with the consumer's cost type. A typical example is a patient that has a condition, which can vary in its severity. If the condition is more severe, then it is more costly for the doctor to treat the patient and it is more costly for the patient to leave the condition untreated. To incorporate this into our model, assume that the outside option of a consumers with type ω is $-\theta c_\omega$ where $\theta \in \mathbb{R}_+$. Note that for $\theta = 0$ we have the baseline model. In absence of competition, the consumer would buy if $v - p \geq -\theta c_\omega$. Since the consumer does not know her type, she does not know her outside option either and relies on the price to infer her type. This opens up incentives for firms that face low cost consumers to charge the equilibrium price of a high cost consumer, since it raises the consumer's valuation. If θ is sufficiently small and if firms charge monopoly prices, then the decrease in demand from charging the high cost monopoly price to a low cost consumer is still sufficiently large such that firms are better off charging the monopoly price corresponding to the consumers true type. Hence, the results of the baseline model follow through as long as θ isn't too large.

7 Conclusion

In some markets, firms refuse to inform consumers about their prices, until after the consumer has incurred a substantial search cost. This makes it hard for consumers to compare prices, which allows firms to charge high prices. But why don't firms try to capture the market, by being more transparent? One obvious explanation, which we did not address in this paper, is that firms play a repeated game and tacitly collude. While this explanation is quite plausible, we provide a mechanism that does not rely on a folk theorem result, as the folk theorem can justify nearly any outcome in a repeated game. We propose a straight forward and simple model, and show that the refusal to share information about prices arises as an equilibrium, without repeated interaction of firms. Our analysis touches on a wide range of research areas: credence goods, industry wide cost shocks, price advertisement and commitment, cost based price discrimination. However, our research question is novel and hence we cannot compare our results to the existing literature. We hope that this article sparks interest and motivates further research on the role of price commitment in credence good markets.

Appendix A

In this section we show that (4) has a single crossing property by showing that

$$g(\underline{p}) := \sum_{\omega=1}^{\psi} \lambda_\omega CS_\omega^m + \sum_{\omega=\psi+1}^{k} \lambda_\omega CS(\underline{p}+s) - CS(\underline{p}) \tag{12}$$

is monotonically increasing in $\underline{p}$. Note that even though ψ depends on $\underline{p}$, it is unaffected by a marginal change unless $\underline{p} = p_\omega^m - s$ for some ω. If g has positive slope both left and right of $p_\omega^m - s$, then g is monotonically increasing over the relevant domain (p_1^m, p_k^m). Taking the first derivative we find

$$g'(\underline{p}) = -\left(\sum_{\omega=\psi+1}^{k} \lambda_\omega\right) D^m(\underline{p}+s) + D^m(\underline{p}). \tag{13}$$

Since $D^m(\underline{p}+s) < D^m(\underline{p})$ and $\sum_{\omega=\psi+1}^{k} \lambda_\omega < 1$, $g'(\underline{p}) > 0$.

Appendix B

In this section we provide an example of a conceptually strange equilibrium which can arise when consumers expectations vary arbitrarily across subgames. Assume $k = 3$, $s \to 0$ and that $\mathbb{E}[c] > p_1^m$. Since $d \approx p_1^m$ for $s \to 0$, $\mathbb{E}[c] > p_1^m$ implies that in every subgame where $\underline{p} \geq \mathbb{E}[c]$ and one or two firms committed, consumers can rationally have optimistic expectations. Now consider the following consumer expectations. Whenever two firms are committed, consumers are optimistic, and when only one firm is committed consumers are pessimistic. Hence, any commitment stage where two firms are committed and one firm isn't committed is an equilibrium of this game. The firm that didn't commit has no incentive to deviate, as it is already visited by all consumers. Deviating to a different price, doesn't change the outcome of a committed firm, it will not be visited either way. Deviating to no commitment will change consumers' expectations to be pessimistic and again the firm will not be visited. Hence the two committed firms don't have an incentive to deviate either.

Appendix C

This section contains proofs for welfare and existence under uniformly distributed valuations. First we show that (10) collapses to (**??**) when valuations are uniformly distributed on $[0, \bar{v}]$.

$$\begin{aligned}
\sum_{\omega\in\Omega} \lambda_\omega \frac{1}{2\bar{v}} \left(\bar{v} - p^m_\omega\right)^2 &\geq \frac{1}{2\bar{v}} \left(\bar{v} - \mathbb{E}[c]\right)^2 \\
\sum_{\omega\in\Omega} \lambda_\omega \frac{1}{8\bar{v}} \left(\bar{v} - c_\omega\right)^2 &\geq \frac{1}{2\bar{v}} \left(\bar{v} - \mathbb{E}[c]\right)^2 \\
\frac{1}{4} \sum_{\omega\in\Omega} \lambda_\omega (\bar{v} - c_\omega)^2 &\geq \left(\bar{v} - \mathbb{E}[c]\right)^2 \\
\mathbb{E}\left[(\bar{v} - c)^2\right] &\geq 4\mathbb{E}[\bar{v} - c]^2 \\
\text{Var}\left[\bar{v} - c\right] &\geq 3\mathbb{E}[\bar{v} - c]^2 \\
\frac{\text{SD}\left[c\right]}{\bar{v} - \mathbb{E}[c]} &\geq \sqrt{3}.
\end{aligned} \tag{14}$$

Next we show that (11) collapses to (**??**).

$$\begin{aligned}
\sum_{\omega\in\Omega} \lambda_\omega \left(\frac{1}{2\bar{v}} \left(\bar{v} - p^m_\omega\right)^2 + \left(1 - \frac{p^m_\omega}{\bar{v}}\right)\left(p^m_\omega - c_\omega\right)\right) &\geq \frac{1}{2\bar{v}} \left(\bar{v} - \mathbb{E}[c]\right)^2 \\
\sum_{\omega\in\Omega} \lambda_\omega \left(\frac{1}{8\bar{v}} \left(\bar{v} - c_\omega\right)^2 + \frac{1}{4\bar{v}} \left(\bar{v} - c_\omega\right)^2\right) &\geq \frac{1}{2\bar{v}} \left(\bar{v} - \mathbb{E}[c]\right)^2 \\
\frac{3}{4} \sum_{\omega\in\Omega} \lambda_\omega (\bar{v} - c_\omega)^2 &\geq \left(\bar{v} - \mathbb{E}[c]\right)^2 \\
\mathbb{E}\left[(\bar{v} - c)^2\right] &\geq \frac{4}{3}\mathbb{E}[\bar{v} - c]^2 \\
\text{Var}\left[\bar{v} - c\right] &\geq \frac{1}{3}\mathbb{E}[\bar{v} - c]^2 \\
\frac{\text{SD}\left[c\right]}{\bar{v} - \mathbb{E}[c]} &\geq \frac{1}{\sqrt{3}}.
\end{aligned} \tag{15}$$

Finally we show that (9) collapses to (**??**) for $d(s) = \bar{d}$. $\bar{d}$ solves

$$\int_{\bar{d}}^{\infty} (v - \bar{d}) dF(v) = \sum_{\omega\in\Omega} \lambda_\omega \int_{p^m_\omega}^{\infty} (v - p^m_\omega) dF(v). \tag{16}$$

For valuations uniformly distributed on $[0, \bar{v}]$ this yields

$$
\begin{aligned}
\frac{1}{2\bar{v}}(\bar{v}-\bar{d})^2 &= \sum_{\omega\in\Omega}\lambda_\omega \frac{1}{2\bar{v}}(\bar{v}-p_\omega^m)^2 \\
\bar{v}-\bar{d} &= \sqrt{\sum_{\omega\in\Omega}\lambda_\omega(\bar{v}-p_\omega^m)^2} \\
\bar{d} &= \bar{v}-\frac{1}{2}\sqrt{\sum_{\omega\in\Omega}\lambda_\omega(\bar{v}-c_\omega)^2} \\
\bar{d} &= \bar{v}-\frac{1}{2}\sqrt{\mathbb{E}\left[(\bar{v}-c)^2\right]}.
\end{aligned}
\tag{17}
$$

Substituting $\bar{d}$ into (9) gives

$$
\begin{aligned}
\frac{1}{4\bar{v}n}\mathbb{E}\left[(\bar{v}-c)^2\right] &\geq \left(1-\frac{\bar{v}-\frac{1}{2}\sqrt{\mathbb{E}\left[(\bar{v}-c)^2\right]}}{\bar{v}}\right)\left(\bar{v}-\frac{1}{2}\sqrt{\mathbb{E}\left[(\bar{v}-c)^2\right]}-\mathbb{E}[c]\right) \\
\frac{1}{2n}\mathbb{E}\left[(\bar{v}-c)^2\right] &\geq \sqrt{\mathbb{E}\left[(\bar{v}-c)^2\right]}\left(\bar{v}-\frac{1}{2}\sqrt{\mathbb{E}\left[(\bar{v}-c)^2\right]}-\mathbb{E}[c]\right) \\
\frac{1}{2n}\sqrt{\mathbb{E}\left[(\bar{v}-c)^2\right]} &\geq \bar{v}-\frac{1}{2}\sqrt{\mathbb{E}\left[(\bar{v}-c)^2\right]}-\mathbb{E}[c] \\
\frac{1+n}{2n}\sqrt{\mathbb{E}\left[(\bar{v}-c)^2\right]} &\geq \mathbb{E}[\bar{v}-c] \\
\mathbb{E}\left[(\bar{v}-c)^2\right] &\geq \left(\frac{2n}{1+n}\right)^2\mathbb{E}[\bar{v}-c]^2 \\
\mathrm{Var}[c] &\geq \left(\left(\frac{2n}{1+n}\right)^2-1\right)\mathbb{E}[\bar{v}-c]^2 \\
\frac{\mathrm{SD}[c]}{\bar{v}-\mathbb{E}[c]} &\geq \sqrt{\left(\frac{2n}{1+n}\right)^2-1}.
\end{aligned}
\tag{18}
$$

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