Price Transparency and Consumer Search in Service Markets*

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Abstract

In many service markets, a firm's marginal cost of providing service depends on consumer-specific characteristics. Additionally, expert firms can often better judge consumers' relevant characteristics than the consumers themselves. This paper explores the consequences of this informational asymmetry on price transparency. Firms can choose whether to display a single price for all consumers or to make individualized offers after learning the consumer's characteristics. We find that an equilibrium can exist in which no firm displays a price, resulting in monopoly prices and profits. Remarkably, this equilibrium can be better for consumers compared to pricing at the expected marginal cost.

Keywords: price transparency, cost-based differential pricing, consumer search, price commitment, credence goods.

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1 Introduction

An extensive literature on consumer search suggests that improving consumers' access to pricing information increases competition among firms, leading to reduced prices and improved welfare. Therefore, the topic of price transparency holds significant relevance as a policy concern. The advent of online stores and price comparison tools might have improved price transparency across various markets in recent years. Yet, it appears that service markets are lagging behind. For example, a report by the United Kingdom's Competition & Markets Authority revealed that a mere 17% of legal service providers published prices online.[1] Another example is health services, where price transparency is a frequent subject of regulatory efforts.[2]

The persistence of opaque pricing schemes in the digital era, where price information could be easily disseminated by firms, is somewhat puzzling. One would expect that in markets lacking price transparency, firms would be motivated to disclose their prices in order to divert consumers from their competitors. A readily available answer to this puzzle is that firms, instead of directly colluding on prices, collude on hiding prices, which raises search costs and, in turn, increases profits. However, this explanation applies to services and tangible goods alike. We are interested in exploring alternative mechanisms, taking into account the peculiarities of service markets.

One potential explanation for service providers' reluctance to share pricing information lies in the variability of cost based on consumer-specific characteristics. Providing the same service to different consumers may require providers to employ different *procedures*, which may vary in cost. A provider could publish a menu stating a price for each distinct procedure. However, in many service markets, consumers lack the technical expertise to discern the appropriateness of a procedure for their condition or to verify the procedure's execution post-service.

A typical example of the information asymmetry described above is found in health services. Patients typically do not know which medical procedure is appropriate for their specific condition. Hence, even if medical service providers were to disclose pric-

[1] https://www.gov.uk/cma-cases/legal-services-market-study (Accessed April 4, 2024).

[2] For recent examples of regulation in the U.S. health sector see the Hospital Price Transparency rule (https://www.cms.gov/priorities/key-initiatives/hospital-price-transparency, Accessed April 4, 2024) and the No Surprise Act (https://www.cms.gov/medical-bill-rights, Accessed April 4, 2024).

ing information for all possible procedures, patients could neither accurately predict the final price of treatment nor evaluate whether the most cost-effective procedure was utilized. Note that healthcare expenditures constitute a significant part of the GDP, accounting for 17.3% of the U.S. GDP in 2022.[3] Furthermore, the information asymmetry we explore is present in many other service markets, such as legal services, repair services, IT services, cosmetic services, and home improvement.

Goods and services that exhibit such an information asymmetry are referred to as *credence goods* (Dulleck & Kerschbamer, 2006). The existing literature on credence goods assumes either that prices are exogenous or that firms have to display prices publicly. Hence, it cannot account for a lack of price transparency in these markets.

To understand firms' incentives to display prices in a credence goods market, we propose the following model. Consumers differ in their *cost type*, a characteristic of which they are unaware and which determines a firm's cost of service. Firms can choose whether to publicly display a single price for the service or not.[4] Displaying a price has two effects. First, it informs consumers about the price of that firm at no cost to the consumer. In contrast, to learn the price of a firm that doesn't display a price, the consumer has to pay a search cost. Second, it commits the firm to charging this price to consumers irrespective of the consumer's cost type. In contrast, if a firm chooses not to display a price, it can charge a different price to each type of consumer.

Under these conditions, displaying a price to attract consumers presents a trade-off to the firm: serve a larger consumer base at a uniform price or serve a smaller consumer base with cost-based differential pricing. Furthermore, the impact of price transparency on welfare becomes unclear. Mandating firms to display a single price for their services might indeed stimulate competition. However, it cannot decrease prices to marginal costs for each distinct consumer.

We find that an equilibrium can exist where no firm displays a price. If no firm displays a price, then, because of search frictions, firms charge the respective monopoly price to each type of consumer. This allows firms to share monopoly profits among

[3]https://www.cms.gov/data-research/statistics-trends-and-reports/national-health-expenditure-data/historical (Accessed April 4, 2024).

[4]Under the information asymmetry we consider, firms cannot credibly commit to a menu. We elaborate on this point later in this section.

them. We call this the *monopolistic equilibrium*. Note the close similarities to the model of consumer search by Diamond (1971). Now consider a deviation of a firm to displaying a price, with the intention of attracting consumers away from its competitors. As this deviation is observed by the other firms, they can adjust their pricing strategy and will price at most the search cost above the displayed price of the deviating firm. If there was just a single cost type, such as in Diamond (1971), then displaying a price just slightly below the monopoly price would attract all consumers, and the deviating firm would receive close to monopoly profits. However, as there are multiple cost types, there are multiple monopoly prices. If the displayed price is above some of these monopoly prices, it can still be beneficial for a consumer to visit a flexible (i.e., non-committed) firm over the committed firm. We find that there is a threshold between the lowest and highest monopoly price, such that a deviating firm attracts consumers if and only if its price is below this threshold. Depending on the parameters of the model, it is possible that pricing below this threshold yields lower profits than the shared monopoly profits. In that case, a firm has no incentive to deviate to displaying a price, explaining the lack of price transparency in service markets.

The monopolistic equilibrium does not always exist. Conditions favorable for existence are a smaller number of firms and more dispersed costs. Furthermore, we find an interesting relationship between existence and search cost. While a strictly positive search cost is necessary for firms to enjoy any profits, the monopolistic equilibrium exists for a smaller parameter space as search costs increase. The reason is as follows. As search costs decrease, visiting flexible firms in the presence of committed firms becomes more attractive, as flexible firms price at most the search cost above the lowest displayed price. Hence, to attract consumers, a deviating firm would have to display an even lower price, making a deviation less attractive.

Besides the monopolistic equilibrium, there always exists a *competitive equilibrium*, where all firms display a price equal to the expected marginal cost. Note that pricing at expected marginal cost would also result from a policy that requires firms to display a single price for the service. Therefore, for our analysis of welfare, we consider pricing at expected marginal cost as the benchmark, against which we compare the monopolistic equilibrium. We find that in the region of the parameter space, where both equilibria co-exist, the monopolistic equilibrium can yield not only higher total surplus but also higher consumer surplus. To see this, assume that for some consumers the cost of service is so large that the expected marginal cost exceeds the monopoly price for consumers with low cost of service. Then, low-cost consumers are better off under the monopolistic equilibrium than the competitive equilibrium. In aggregate, the benefit to low-cost consumers can outweigh the detriment of high-cost consumers. Whether this is indeed the case depends on the level of cost dispersion. For uniformly distributed valuations, we identify a simple statistic, namely the normalized standard deviation of the cost distribution. This statistic completely determines which of the two equilibria has higher consumer and total surplus. For the monopolistic equilibrium to yield higher welfare, the statistic needs to be sufficiently large. Hence, the conditions that make the existence of the monopolistic equilibrium more likely make the monopolistic equilibrium more desirable as well.

We now come back to the case of firms displaying a menu. If consumers lack the knowledge of which procedure is appropriate for their condition, then a menu would not allow consumers to predict the price of service accurately. Furthermore, if consumers are not able to verify the procedure's execution post-service, then firms could deceive consumers by claiming that a more expensive procedure was performed. Under these conditions, firms cannot credibly commit to a menu. Instead, displaying a menu would amount to displaying a set of prices. We consider this case as an extension to the basic model in Section 5.1. When committing to a set of prices, a firm can choose any price from the set after the consumer has visited the firm and the firm has learned the consumer's cost type. We show that under some conditions, consumers can rationally believe that a committed firm will always charge the highest price from its set. This ensures that the results from the basic model go through, at least qualitatively.

Another extension is explored in Section 5.2. In the basic model, we assume that a consumer's valuation and their cost type are realized independently and that all consumers have the same outside option (normalized to 0). While we consider this to be a natural base-line for many of the markets we have in mind (e.g. IT services, cosmetic services, home improvement), it is less plausible in markets for medical services, where the cost of treatment is oftentimes positively correlated with the seriousness of the patient's medical condition. In the second extension, we take this into account by assuming that the consumer's outside option is negatively proportional to the cost of the procedure that is appropriate for their type. This means that forgoing treatment is worse for high-cost types with a more serious medical condition than it is for low-cost types with a less serious medical condition. We show that the results of the basic model go through as long as the factor of proportionality is sufficiently small.

1.1 Literature

This paper connects to multiple strands of literature. First, the market we describe is a specific kind of *credence good* market, according to the classification by Dulleck and Kerschbamer (2006). The defining feature of a credence good is the presence of an information asymmetry, where the firm knows more about the relevant characteristics of consumers than the consumers themselves.[5] In contrast to our paper, the existing credence good literature either assumes that prices are exogenous (Pitchik & Schotter, 1987; Sülzle & Wambach, 2005) or that firms have to publicly announce prices for procedures (Wolinsky, 1993; Taylor, 1995; Glazer & McGuire, 1996; Fong, 2005; Dulleck & Kerschbamer, 2006). Hence, none of the existing credence good literature can account for service markets, where firms do not disclose any information on prices before the consumer's visit.

Second, 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 & Gertner, 1993; Dana, 1994; Tappata, 2009; Janssen et al., 2011, 2017). Note that a model of industry-wide cost shocks, where marginal costs 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 the absence

[5]Some confusion about the term 'credence good' might arise from a competing definition by Darby and Karni (1973), which distinguishes between search, experience and credence goods. While the consumer learns the value of an experience good after purchase, the value of a credence good is "expensive to judge even after purchase" (Darby & Karni, 1973, p. 69). Note that in our model, consumers learn the value before purchase. Hence, there is little relation to experience goods and credence goods in this sense.

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 consumers. In contrast to our paper, this literature assumes that a fraction of consumers have 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 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. Hence, under a different reading of our paper, we contribute to the literature on consumer search under industry-wide cost shocks by extending the model to allow firms to commit to prices.

Third, there is a small literature that considers the welfare implications of cost-based differential pricing (Chen & Schwartz, 2015; Chen et al., 2021). This literature compares uniform pricing to differential pricing, conditional on a given level of competition. However, the equilibria of our model require us to compare competitive uniform pricing to monopolistic differential pricing. Nevertheless, we are able to build on some of the insights in Chen and Schwartz (2015).

Finally, this paper is related to the literature on consumer search with price advertisement (Robert & Stahl, 1993; Anderson & Renault, 2006; Janssen & Non, 2008) and consumer search with price commitment (Obradovits, 2014; Myatt & 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 the 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.

2 Model

Consider a market with $n \geq 2$ identical firms and a unit mass of consumers. Each firm offers a single, homogeneous service to consumers, for which consumers have unit demand. Consumer i has a cost type τ_i and a valuation for the service v_i. The cost type determines a firm's cost of serving this consumer. For ease of exposition, we assume that there are two cost types: l (for *low*) and h (for *high*).[6] We denote by c_τ a firm's cost of serving a consumer of cost type $\tau \in \{l, h\}$ and assume $0 \leq c_l < c_h$. Note that the cost of serving a given consumer is identical across firms. The fraction of type l consumers is denoted by λ, where $\lambda \in (0, 1)$. Consumers' valuations are drawn independently from a distribution F with support $[0, \bar{v})$, where $\bar{v}$ could be infinite. If $\bar{v}$ is finite, we assume $\bar{v} > c_l$. Note that a consumer's cost type and valuation are assumed to be independent. We denote the density of F by f, assume that f is continuously differentiable, and assume that $(1 - F)^{-1}$ is convex.[7] Furthermore, we normalize each consumer's outside option to 0.

The market plays out in two stages: a *commitment stage* and a *search stage*. In the commitment stage, each firm simultaneously chooses an action from the set $\mathbb{R}_+ \cup \{\emptyset\}$. Let a_j denote the action of Firm j. If $a_j \in \mathbb{R}_+$, then Firm j publicly displays the price a_j and thereby commits to charging a_j to all consumers in the subsequent stage, irrespective of their cost type. We call such firms *committed firms*. If $a_j = \emptyset$, then Firm j displays no price and makes no such commitment. We call such firms *flexible firms*. The decisions of the commitment stage $(a_1, ..., a_n)$ are observed by all firms and consumers, making the subsequent stage a subgame.

At the beginning of the search stage, flexible firms simultaneously choose a price

[6] The extension to more than two cost types is straight forward. See Appendix B.

[7] Convexity of $(1 - F)^{-1}$ ensures that monopoly profits are quasi-concave and is weaker than the assumption of log-concavity of $1 - F$ (Caplin & Nalebuff, 1991).

vector consisting of a price for each cost type. Let $(p_{j,l}, p_{j,h})$ denote the price vector chosen by Firm j. This decision is neither observed by consumers nor by any other firm. Then, consumers search firms sequentially with search cost $s > 0$ and costless recall. Consumers can only buy from firms which they have visited and consumers incur s when visiting committed firms as well.[8] Consumers can identify firms by their decision in the commitment stage and can choose the order in which they visit these firms. Firms with identical decisions in the commitment stage are indistinguishable to consumers and are visited with equal probability. We assume that a consumer's valuation is realized on their first visit at any firm, hence only after they've incurred the search cost for the first time.[9] Consumers do not observe their own cost type and do not observe the price that a flexible firm would have offered if they were a different cost type. Instead, consumers update their belief about their cost type, given the offers they receive from flexible firms and the expectations about these firms' pricing strategies. To summarize, a visit of Consumer i at Firm j unfolds as follows.

1. Consumer i incurs the search cost s.
2. If Firm j is the first firm visited by Consumer i, then Consumer i learns v_i.
3. Firm j offers the service at a price p, where $p = p_{j,\tau_i}$ if j is flexible and $p = a_j$ if j is committed.
4. Given the offer p, the consumer updates their belief about their cost type.
5. The consumer decides whether to buy from Firm j at price p, search another firm, buy from any previously visited firm, or leave the market without purchase.

3 Equilibria

The firms' decisions in the commitment stage can create three distinct market environments in the search stage. When all firms display a price, we speak of a *committed*

[8] This is because a firm can only serve a consumer after it has learned the consumer's type, which requires a visit from the consumer.

[9] Alternatively, we could assume that consumers know their valuation from the start and that the first search is free. We show in Appendix C that the equilibria we identify persist under this alternative model.

market. A committed market resembles Bertrand competition, as consumers will simply buy from the cheapest firm. When no firm displays a price, we speak of a *flexible market*. A flexible market is reminiscent of Diamond (1971), where consumers sequentially search identical firms for the lowest price. However, the presence of different cost types in our model complicates the analysis, as consumers have to form and update beliefs about their cost type. Finally, we are in a *partially committed market*, when there are both committed and flexible firms present. In comparison to a flexible market, the presence of committed firms creates an additional outside option for consumers. This effectively creates a price ceiling, as flexible firms cannot profitably charge more than the search cost above the lowest displayed price.

Whether or not a firm finds it beneficial to display a price depends on the firm's profits in the ensuing market environments. Since the search stage is a subgame, we solve for an equilibrium by backwards induction. First, we determine the possible equilibria for each of the three environments of the search stage. Then, taking the outcome of the search stage as given, we determine the equilibria of the commitment stage.

We restrict attention to perfect Bayesian equilibria in pure and symmetric strategies, both for the search and the commitment stage. This restriction leaves two kind of equilibrium candidates, one where all firms display a price and one where no firm displays a price. Even though a partially committed market will not arise on any equilibrium path, it is crucial for understanding firms incentive to deviate in the commitment stage.

Besides focusing on pure and symmetric equilibria, we impose two additional equilibrium refinements. First, we assume that consumers have *passive beliefs* about the prices of flexible firms. This means that when a consumer observes a deviation by a flexible firm in the search stage, they do not change their expectations about the pricing strategy of other flexible firms. Second, we assume that consumers' beliefs about their cost type satisfy the *intuitive criterion* (Cho & Kreps, 1987). Specifically, when a consumer observes a deviation by a flexible firm in the search stage, which could not possibly be profitable under some cost type, the consumer's belief assigns zero probability to this cost type.[10]

[10]The intuitive criterion is applicable, as the interaction between the consumer and the firm resem-

3.1 Search Stage

3.1.1 Committed Market

We begin with committed markets, where all firms display a price. We denote by $\underline{p}$ the lowest price displayed among all firms. Consumers will either search once or not at all. Since consumers are initially uncertain about their valuation, they have to compare the expected surplus from buying at $\underline{p}$ with s. Let $CS(p) := \int_p^\infty (v-p)dF(v)$, such that $CS(p)$ denotes the expected surplus of visiting a firm charging p. If

$$CS(\underline{p}) \geq s \tag{1}$$

then there exists an equilibrium where each consumer i randomly visits a firm displaying $\underline{p}$, buys if $v_i \geq \underline{p}$ and leaves the market without purchase otherwise. Let $c_e := \lambda c_l + (1-\lambda)c_h$ denote the expected marginal cost. Each firm committed to $\underline{p}$ receives an equal share of the industry profits

$$\left(1 - F\left(\underline{p}\right)\right)\left(\underline{p} - c_e\right).$$

If $CS(\underline{p}) \leq s$, then there exists an equilibrium where consumers don't make an initial search and firms make no profits. These are the only possible equilibria.

3.1.2 Flexible Market

In the flexible market, each firm initially chooses a price vector. Since we restrict attention to equilibria in pure and symmetric strategies, we consider equilibrium candidates where all firms choose an identical vector (p_l, p_h). We then characterize the search behavior of consumers who expect firms to price according to (p_l, p_h) and consider a firm's incentive to deviate. If a firm has no incentive to deviate from its pricing strategy, we have identified an equilibrium.

Consumers initially expect all firms to charge the same price, hence expect to search at most once. Let

$$\Delta ES(p_l, p_h) := \lambda CS(p_l) + (1-\lambda)CS(p_h) - s$$

bles the original sender-receiver game. The firm is the sender, having private information about the state of the world, which is the consumer's cost type. The state is pay-off relevant for the consumer, as it determines what other firms will charge.

denote the expected surplus net of search cost. Consumers make an initial search if $\Delta ES(p_l, p_h) \geq 0$. Assume this holds. As firms are indistinguishable in the flexible market, each consumer i will randomly select one of the firms for an initial visit. Upon visit at the first firm, the consumer learns v_i, receives an offer, and updates their belief about their cost type using Bayes rule whenever possible. We denote by $\mu_i \in [0,1]$ the consumer's belief that they are of the low-cost type. If the consumer receives an offer of either p_l or p_h, they believe with certainty that they are of the corresponding cost type (assuming $p_l \neq p_h$). They buy if v_i is above the offer and leave the market without purchase otherwise, as they expect to receive the same offer from any of the other firms.

If the firm has deviated to a price p^d that is neither p_l nor p_h, then we are out of equilibrium and the consumer's beliefs, both about their cost type and the pricing strategy of other firms, are not determined by Bayes rule. With passive beliefs about other firms' prices and for some belief $\mu_i \in [0,1]$ about their cost type, the consumer will search an additional firm if and only if the expected gain in surplus is greater than the search cost.[11] Formally,

$$\mu_i \max\{v_i - p_l, v_i - p^d, 0\} + (1-\mu_i) \max\{v_i - p_h, v_i - p^d, 0\} - \max\{v_i - p^d, 0\} \geq s.$$

Independent of v_i and μ_i, an additional search is never beneficial if $p^d < \min\{p_l, p_h\} + s$. This means that a firm can deviate away from the lower price by up to the search cost, without losing the consumer to a competing firm. Furthermore, since consumers do not observe deviations of firms they do not visit, a firm cannot attract additional consumers for a visit through a deviation. Hence, for the fraction of $1/n$ consumers that initially visit the firm and for prices locally around the lower price, the firm acts like a monopolist and receives expected profits of

$$\Pi_\tau(p) := (1 - F(p))(p - c_\tau)$$

per consumer of type $\tau \in \{l, h\}$. Let $p^m_\tau := \arg\max_p \Pi_\tau(p)$ denote the monopoly price for type τ consumers.[12] Our assumptions on F imply that $\Pi_\tau(p)$ is single-peaked,

[11] Without passive beliefs, nearly any pricing strategy can be supported in equilibrium, by the belief that all other firms have deviated to charging low prices.

[12] If $c_h > \bar{v}$ then let p^m_h denote c_h.

hence increases as p moves closer to p_τ^m, and that $p_l^m < p_h^m$. Therefore, unless $p_l = p_l^m$, a firm has a profitable deviation.

Lemma 1. In any equilibrium of the flexible market where consumers make an initial search, $p_l = p_l^m$ and $p_h > p_l$.

For a detailed proof, see Appendix A.

The mechanism that pushes the equilibrium price for low-cost consumers towards the monopoly price is the same as in Diamond (1971). When facing a slight deviation, the consumer does not find it profitable to incur the search cost for visiting another firm, and hence, the price must maximize monopoly profits for firms to not have an incentive to deviate. Note that this argument does not apply to the price charged to high-cost consumers. Assume that $p_h^m > p_l^m + s$ and consider $p_h \in [p_l^m + s, p_h^m)$. If a firm deviates slightly upward from p_h, then whether an additional search is beneficial depends on the consumer's belief μ_i. One could punish a deviating firm with the belief that the consumer is certainly a low-cost type ($\mu_i = 1$). However, the intuitive criterion rules out such beliefs. As a firm could not possibly increase its profits from low-cost consumers when $p_l = p_l^m$, the intuitive criterion implies that $\mu_i = 0$ after the consumer observes a deviation that could be profitable if they were a high-cost type. Therefore, unless $p_h = p_h^m$, a firm has a profitable deviation. Note that in addition to the equilibrium where firms charge monopoly prices, there always exists an equilibrium where consumers do not search. The following proposition states all equilibria of the flexible market.

Proposition 1. In the flexible market there exists at most two equilibria.

(i) There exists an equilibrium where firms price sufficiently high such that consumers do not search, i.e., $\Delta ES(p_l, p_h) \leq 0$, and the market collapses.

(ii) If $\Delta ES(p_l^m, p_h^m) \geq 0$, then there exists an equilibrium where firms choose monopoly prices, i.e., $p_\tau = p_\tau^m$ for $\tau \in \{l, h\}$, and consumers search exactly once.

For a detailed proof, see Appendix A.

Finally, we consider firms' profits in the equilibrium where consumers search. Let $\Pi_\tau^m := \Pi_\tau(p_\tau^m)$ denote monopoly profits from consumers of type τ. Each firm earns an equal share of the monopoly profits, which is

$$\frac{1}{n}\left(\lambda\Pi_l^m + (1-\lambda)\Pi_h^m\right).$$

This concludes the analysis of the flexible market.

3.1.3 Partially Committed Market

Finally, we come to the analysis of partially committed markets, where both flexible and committed firms are present. As in the previous sections, $\underline{p}$ refers to the lowest displayed price, and (p_l, p_h) refers to the pure and symmetric pricing strategy of flexible firms. Consumers will never visit firms displaying a price above $\underline{p}$ and we, therefore, ignore these firms from now on. Taking $\underline{p}$ as given, we describe the search behavior of consumers who expect all flexible firms to charge (p_l, p_h) and then consider flexible firms' incentives to deviate from this pricing strategy.

We begin with the trivial case where both p_l and p_h are above $\underline{p}$. Then consumers have no reason to visit flexible firms, as they never make a better offer than committed firms. A flexible firm cannot attract consumers by lowering prices in the search stage, because a deviation from the pricing strategy is unobserved. We call this a *pessimistic equilibrium*, as it is supported by consumers' pessimistic expectations about the prices of flexible firms. Either expected consumer surplus is above the search cost, in which case committed firms are visited by consumers, or it is not, in which case the market collapses.

Next, we consider equilibria where flexible firms are visited by at least some consumers on the equilibrium path. We call these *optimistic equilibria*, as they require consumers to be sufficiently optimistic about the prices of flexible firms. Note that consumers are identical before the first search, as they have the same prior beliefs about their type and their valuation. Therefore, our restriction to pure and symmetric equilibria implies that all consumers take the same initial action. This leaves two candidates for optimistic equilibria. Either (i) all consumers initially visit flexible firms or (ii) all consumers initially visit committed firms and then some consumers make an additional visit at flexible firms. The following lemma rules out equilibria of the second kind.

Lemma 2. Fix $\underline{p}$, p_l, and p_h. Assume there exists a $v_i \in [0, \bar{v})$, such that Consumer i would benefit from visiting a flexible firm, after already having visited a committed firm. Then under the optimal search strategy, consumers would either visit a flexible firm first or not participate in the market at all.

We prove Lemma 2 in Appendix A.

Above we have shown that in any optimistic equilibrium, flexible firms are visited first. Next, we consider the pricing strategy of flexible firms in such an equilibrium. We build on the insights of Section 3.1.2. Under passive beliefs, firms have an incentive to deviate unless $p_l = p_l^m$. Given $p_l = p_l^m$ and the intuitive criterion, firms can slightly deviate away from p_h without losing the consumer to a competing firm, and hence, p_h must maximize monopoly profits. However, in contrast to Section 3.1.2 there is no demand at prices above $\underline{p} + s$, as consumers would be better off paying s to visit a committed firm and buying at $\underline{p}$. Hence, p_h must maximize $D_{\underline{p}}(p)(p - c_h)$ where

$$D_{\underline{p}}(p) := \begin{cases} 1 - F(p) & \text{for } p \leq \underline{p} + s \\ 0 & \text{otherwise} \end{cases}.$$

Finally, if $\underline{p} + s < c_h$ then the firm wants to deter consumers from buying. While any price above $\underline{p} + s$ would have the desired effect, we simplify notation and assume that, in this case, firms charge p_h^m. Note that committed firms are only visited if the price of a flexible firm is strictly above $\underline{p} + s$. Since this occurs only if $\underline{p} + s < c_h$, committed firms never make a profit and might even make a loss. The following lemma summarizes the above conditions on the optimistic equilibrium.

Lemma 3. If there exists an optimistic equilibrium, then in this equilibrium $p_l = p_l^m$ and

$$p_h = \begin{cases} \underline{p} + s & \text{if } p_h^m \geq \underline{p} + s \geq c_h \\ p_h^m & \text{otherwise} \end{cases}.$$

In this equilibrium, committed firms make no profits.

Next, we identify the conditions under which an optimistic equilibrium exists. We begin by stating a necessary condition, namely, that consumers are better off first searching a flexible firm compared to only searching a committed firm. Note that the expected surplus of high-cost consumers facing a price strictly above $\underline{p}+s$ is $CS(\underline{p}+s)$, as consumers can pay s to visit a committed firm and buy at $\underline{p}$. Hence, the condition is given by

$$\lambda CS(p_l^m) + (1-\lambda)CS(\min\{\underline{p}+s, p_h^m\}) \geq CS(\underline{p}). \tag{2}$$

Note that (2) is trivially satisfied if $\underline{p} \geq p_h^m$, as the consumer will never receive a better offer from the committed firm. Similarly, (2) is trivially violated if $\underline{p} \leq p_l^m$, as the consumer will never receive a better offer from the flexible firm. Therefore, interesting cases are $\underline{p} \in (p_l^m, p_h^m)$. We find that (2) has a single crossing property, meaning there exists a threshold $t \in (p_1^m, p_h^m)$ such that (2) is satisfied if and only if $\underline{p} \geq t$. We prove this in Appendix A. The threshold t is the unique solution to the equation

$$\lambda CS(p_l^m) + (1-\lambda)CS(\min\{t+s, p_h^m\}) = CS(t). \tag{3}$$

We analyze t further down in this section.

Note that by Lemma 2, it can never be optimal to first search a committed firm and then sometimes, depending on the valuation, make an additional visit at a flexible firm. Hence, besides the two search strategies compared by (2), the only other candidate for the optimal search strategy is to not search at all. Therefore, an optimistic equilibrium exists if and only if both $\underline{p} \geq t$ and $\Delta ES(p_l^m, \min\{\underline{p}+s, p_h^m\}) \geq 0$. We summarize the possible equilibria of partially committed markets in the following proposition.

Proposition 2. *In any partially committed market, there exists at most three equilibria.*

(i) *If $CS(\underline{p}) \geq s$, then there exists a pessimistic equilibrium where each consumer visits a firm committed to $\underline{p}$, buys if $v_i \geq \underline{p}$, and leaves the market without purchase otherwise. Flexible firms price sufficiently high to never be visited.*

(ii) *If $CS(\underline{p}) \leq s$, then there exists a pessimistic equilibrium where consumers don't make an initial search, and the market collapses. Flexible firms price sufficiently high to never be visited.*

(iii) *If $\underline{p} \geq t$ and $\Delta ES(p_l^m, \min\{\underline{p}+s, p_h^m\}) \geq 0$, then there exists an optimistic equilibrium where each consumer initially visits a flexible firm. Committed firms do not make a profit. Flexible firms price as described in Lemma 3.*

We now come back to the threshold t. We find that t is weakly monotonically increasing in s. To see this, consider (3). Increasing s, while holding the other parameters fixed, weakly decreases the left-hand side of (3) while the right-hand side remains the same. Due to the single crossing property of (2), the right-hand side decreases faster in t than the left-hand side, so in order to achieve equality, t must increase. Denote the bounds of t in relation to s by $\underline{t}$ and $\bar{t}$. It is easy to see that for $s \to 0$, $t \to p_l^m$ and hence $\underline{t} = p_l^m$. On the other hand, if s is sufficiently large, then $\min\{t + s, p_h^m\} = p_h^m$ and hence $\bar{t}$ solves

$$\lambda CS(p_l^m) + (1 - \lambda)CS(p_h^m) = CS(\bar{t}). \tag{4}$$

Additionally, we know that $\bar{t} \leq \lambda p_l^m + (1 - \lambda)p_h^m$ by the fact that $CS(p)$ is convex in p.[13]

This concludes the analysis of the search stage. In the following section, we identify the equilibria of the commitment stage.

3.2 Commitment Stage

Now that we have determined the outcomes of the different markets, we come back to the commitment stage to understand firms' incentives to display a price. Note that our restriction to pure and symmetric equilibria greatly restricts the space of equilibrium candidates. Either all firms display the same price in the commitment stage or no firm displays a price.

First, consider the equilibrium candidate where every firm displays the same price $\underline{p}$. If $\underline{p}$ is above the expected marginal cost c_e, then a firm can increase its profit by slightly decreasing its displayed price and thereby attracting all consumers. Hence, the only candidate is $\underline{p} = c_e$. Deviating to not displaying a price would result in a partially committed market. If consumers are pessimistic, which they could rationally be in every partially committed market, this deviation will not result in any profit for the deviating firm. Therefore, every firm displaying a price of c_e is an equilibrium. We call this the *competitive equilibrium*, as all firms price at (expected) marginal cost and make no profits.

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

Proposition 3 (Competitive Equilibrium)**.** There exists an equilibrium where all firms display a price of c_e. In this equilibrium, firms make no profits.

Next, consider the equilibrium candidate where no firm displays a price in the commitment stage. Assume $\Delta ES(p_l^m, p_h^m) \geq 0$, such that on the equilibrium path, this results in a flexible market where each firm earns an equal share of the monopoly profits. Whether a firm finds it beneficial to deviate to displaying a price depends on its profits in the resulting partially committed market. In an effort to deter a deviation, we specify that the optimistic equilibrium is played in all partially committed markets where it exists. In a partially committed market where the optimistic equilibrium doesn't exist, the pessimistic equilibrium is played. Let Π^* denote the highest profits of a firm among all partially committed markets that can be reached through a unilateral deviation of that firm. If these profits are still lower than the shared monopoly profits, then no firm displaying a price is an equilibrium. We call this the *monopolistic equilibrium*, as all firms charge the respective monopoly price to each type of consumer and share monopoly profits.

Proposition 4 (Monopolistic Equilibrium)**.** If $\Delta ES(p_l^m, p_h^m) \geq 0$ and

$$\Delta\Pi := \frac{1}{n}\left(\lambda\Pi_l^m + (1-\lambda)\Pi_h^m\right) - \Pi^* \geq 0$$

then there exists an equilibrium where no firm displays a price. In this equilibrium, each firm earns an equal share of the monopoly profits, i.e., $\frac{1}{n}\left(\lambda\Pi_l^m + (1-\lambda)\Pi_h^m\right)$.

In order to understand the conditions for which the monopolistic equilibrium exists, we need to determine Π^*. For the deviating firm to make a profit, it must display a price $\underline{p}$ below t, leading to a market where the optimistic equilibrium doesn't exist. Note that from $\Delta ES(p_l^m, p_h^m) \geq 0$ and (4) it follows that $CS(\underline{p}) \geq s$ for all $\underline{p} \leq t$. Hence, the only equilibrium in such a partially committed market is the pessimistic one, where all consumers visit the deviating firm and where this firm makes a profit of

$$\lambda\Pi_l(\underline{p}) + (1-\lambda)\Pi_h(\underline{p}) \equiv \left(1 - F\left(\underline{p}\right)\right)\left(\underline{p} - c_e\right).$$

Consider the case $t > c_e$ such that $\Pi^* > 0$. Then there are two candidates for optimal deviations leading to Π^*. Let $p^m(c) := \arg\max_p (1 - F(p))(p - c)$.[14] If $p^m(c_e) < t$,

[14] If $c \geq \bar{v}$ then let $p^m(c)$ denote c.

then the optimal deviation is to display the price $p^m(c_e)$ in the commitment stage. If $p^m(c_e) \geq t$, then the optimal deviation is to display a price just below t in the commitment stage, as our assumptions of F ensure that profits are single-peaked. We find that if $\partial p^m(c)/\partial c$, the pass-through rate from marginal cost to the monopoly price, is non-increasing in c, then $p^m(c_e) \geq t$.

Lemma 4. If $p^m(c)$ is concave then $p^m(c_e) \geq t$ and

$$\Pi^* = \max\{(1 - F(t))(t - c_e), 0\}.$$

Proof. If $p^m(c)$ is concave, then $\lambda p^m(c_l) + (1-\lambda)p^m(c_h) \leq p^m(\lambda c_l + (1-\lambda)c_h)$. Since $t \leq \lambda p^m(c_l) + (1-\lambda)p^m(c_h)$, this implies $t \leq p^m(c_e)$. □

Note that $p^m(c)$ is concave for many common demand functions, for instance, all demand functions with a constant cost pass-through rate (see Bulow and Pfleiderer (1983)).

In the remainder of this section, we discuss how $\Delta\Pi$ depends on the primitives of the model. We assume throughout that $p^m(c)$ is indeed concave such that

$$\Delta\Pi = \frac{1}{n}\left(\lambda\Pi_l^m + (1-\lambda)\Pi_h^m\right) - \max\{(1 - F(t))(t - c_e), 0\}.$$

First, it is easy to see that $\Delta\Pi$ is decreasing in the number of firms n. In a flexible market, monopoly profits are shared among firms, whereas the best deviation will attract all consumers and hence deviation profits are independent of the number of competitors.

Second, consider the relation between $\Delta\Pi$ and s. As shown in Section 3.1.3, t is weakly increasing in s. The intuition is that, as s increases, flexible firms can charge more on top of $\underline{p}$ without losing the consumer to a committed firm. This, in turn, makes it less beneficial to visit flexible firms in the first place, increasing t. Since t is assumed to be below $p^m(c_e)$, increasing t increases deviation profits $(1 - F(t))(t - c_e)$. Hence, $\Delta\Pi$ is weakly decreasing in s.

Third, consider the extreme case where λ is close to 0 (resp. 1). Since consumers expect to be of the high-cost type (resp. low-cost type) with near certainty, a deviating firm can attract consumers by pricing closely below p_h^m (resp. p_l^m). See (3) to confirm that $t \to p_h^m$ (reps. $t \to p_l^m$) as $\lambda \to 0$ (reps. $\lambda \to 1$). Since the deviating firm serves nearly only high-cost (resp. low-cost) consumers, it earns close to monopoly profits. In the flexible market, on the other hand, firms would have to share these same monopoly profits. Hence, as $\lambda \to 0$ (reps. $\lambda \to 1$), $\Delta\Pi \to -\frac{n-1}{n}\Pi_h^m$ (reps. $\Delta\Pi \to -\frac{n-1}{n}\Pi_l^m$).

The following proposition summarizes these results.

Proposition 5. Let $p^m(c)$ be concave. Then $\Delta\Pi$ strictly decreases in n and weakly decreases in s. Furthermore, for λ sufficiently close to 1, $\Delta\Pi < 0$ and if $\Pi_h^m > 0$, then for λ sufficiently close to 0, $\Delta\Pi < 0$ as well.

Finally, we consider $\Delta\Pi$ for s close to 0. This simplifies the analysis in two ways. First, it ensures $\Delta ES(p_l^m, p_h^m) \geq 0$, and hence, the monopolistic equilibrium exists if and only if $\Delta\Pi \geq 0$. Second, it pins down t, as we have shown in Section 3.1.3 that $t \to p_l^m$ as $s \to 0$. We find that for both λ and c_h, the existence of the monopolistic equilibrium can be approximated by a threshold condition with arbitrary precision.

Proposition 6. Let $p^m(c)$ be concave. Then for every $\varepsilon > 0$ there exists an $s > 0$ such that the following holds.

(i) There exists $\bar{c}_h$ such that $\Delta\Pi > 0$ if $c_h \geq \bar{c}_h + \varepsilon$ and $\Delta\Pi < 0$ if $c_h \leq \bar{c}_h - \varepsilon$.

(ii) There exists $\bar{\lambda}$ such that $\Delta\Pi < 0$ if $\lambda \geq \bar{\lambda} + \varepsilon$ and $\Delta\Pi > 0$ if $\lambda \in [\varepsilon, \bar{\lambda} - \varepsilon]$.

We prove Proposition 6 in Appendix A. We illustrate the proposition with the following example. Assume $c_l = 0$, $n = 2$, $s = 10^{-4}$ and that valuations are uniformly distributed on $[0, 1]$. Then the free parameters are c_h and λ. The grey area in Figure 1 indicates the parameter space under which the monopolistic equilibrium exists. Indeed, for each λ the monopolistic equilibrium exists if and only if c_h is above some threshold. For large λ, this threshold is above 1, i.e., the highest possible valuation in this example. Furthermore, for each c_h the monopolistic equilibrium exists if λ is below some threshold, but not too close to 0. Note that for small c_h, $\bar{\lambda}$ is below 2ε such that the monopolistic equilibrium doesn't exist for any $\lambda \in (0, 1)$. To gain some intuition for this result, note that the deviating firm serves consumers with an average cost c_e at the monopoly price for c_l. Hence, a deviation becomes unattractive if c_e is sufficiently far above c_l, which is the case if either c_h is large or if λ is low.

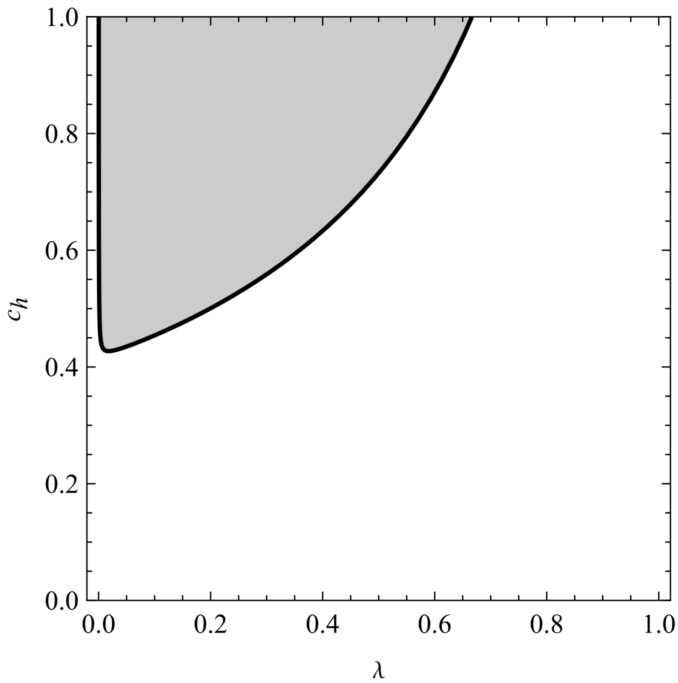

Figure 1: Existence of the monopolisitc equilibrium.

4 Welfare

In this section, we compare consumer surplus and total surplus between the monopolistic and competitive equilibrium. As a first step, we compare our setting to the existing literature on cost-based differential pricing. Chen and Schwartz (2015) find that when monopoly consumer surplus is convex in marginal cost, both consumer surplus and total surplus are larger under monopolistic cost-based differential pricing compared to monopolistic uniform pricing across cost types. In a perfectly competitive market, cost-based differential pricing 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 setting require us to compare surplus under monopolistic differential pricing (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.

Assume for now that the monopolistic equilibrium exists. Let $CS_\tau^m := CS(p_\tau^m)$ such that CS_τ^m is consumer surplus for type τ consumers under the monopoly price. Consumer surplus is larger under the monopolistic equilibrium than the competitive equilibrium if and only if

$$\Delta CS := \lambda CS_l^m + (1-\lambda)CS_h^m - CS(c_e) \geq 0 \tag{5}$$

and total surplus is larger if and only if

$$\Delta TS := \lambda \left(CS_l^m + \Pi_l^m\right) + (1-\lambda)\left(CS_h^m + \Pi_h^m\right) - CS(c_e) \geq 0. \tag{6}$$

First, note that neither ΔCS nor ΔTS depends on the number of firms, as equilibrium prices are independent of the number of firms (conditional on the monopolistic equilibrium existing). Second, note that neither ΔCS nor ΔTS depends on the search cost, as every consumer searches in either equilibrium exactly once. Therefore, conditional on the monopolistic equilibrium existing, ΔCS and ΔTS depends only on the distribution of valuations F and the distribution of costs (c_l, c_h, λ). We denote by $\text{Var}[c] := \lambda c_l^2 + (1-\lambda)c_h^2 - c_e^2$ the variance and by $\text{SD}[c] := \sqrt{\text{Var}[c]}$ the standard deviation of the cost distribution. Note that a mean preserving spread of the cost distribution neither changes consumer nor total surplus of the competitive equilibrium. How it affects surplus in the monopolistic equilibrium depends on the curvature of the monopoly price with respect to marginal cost, $p^m(c)$.

Proposition 7. Assume $CS(p^m(c))$ is convex in c. A mean preserving spread of the cost distribution increases both ΔCS and ΔTS.

We prove Proposition 7 in Appendix A. Chen and Schwartz (2015) shows that $CS(p^m(c))$ is convex in c for many common demand functions. Note that $CS(p^m(c))$ is always convex in c if $p^m(c)$ is concave.

Proposition 7 informs us that the relative social desirability of the monopolistic equilibrium (compared to the competitive equilibrium) increases as costs become more dispersed. To be able to quantify the exact amount of cost dispersion necessary for the monopolistic equilibrium 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

$$\sigma := \frac{\text{SD}\,[c]}{\bar{v} - c_e}$$

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

Proposition 8. Assume valuations are uniformly distributed on $[0, \bar{v}]$. Then $\Delta CS \geq 0$ if and only if $\sigma \geq \sqrt{3}$ and $\Delta TS \geq 0$ if and only if $\sigma \geq \frac{1}{\sqrt{3}}$.

We prove Proposition 8 in Appendix A. The proof easily generalizes to more than two cost types. Hence, when valuations are uniformly distributed, the conditions hold true for any distribution of cost types.

Until now we have compared consumer and total surplus under the assumption that the monopolistic equilibrium exists. 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. Even when restricting attention to uniformly distributed valuations, either equilibrium can yield higher consumer or total surplus in the range of parameters where both equilibria co-exist.

We continue with the example given in Section 3, where $c_l = 0$, $n = 2$, $s = 10^{-4}$ and where valuations are uniformly distributed on $[0, 1]$. Figure 2 partitions the parameter space for λ and c_h based on existence of the monopolistic equilibrium and social desirability of the monopolistic equilibrium relative to the competitive equilibrium. As before, the monopolistic equilibrium exists in the area above the solid curve. The dashed curve represents the condition $\sigma = \frac{1}{\sqrt{3}}$, such that above the dashed curve, total surplus is larger under the monopolistic equilibrium. The dotted curve represents $\sigma = \sqrt{3}$, such that above the dotted curve, consumer surplus is larger under the monopolistic equilibrium. The example confirms that, indeed, either equilibrium can yield higher consumer or total surplus in the range of parameters where both equilibria co-exist.

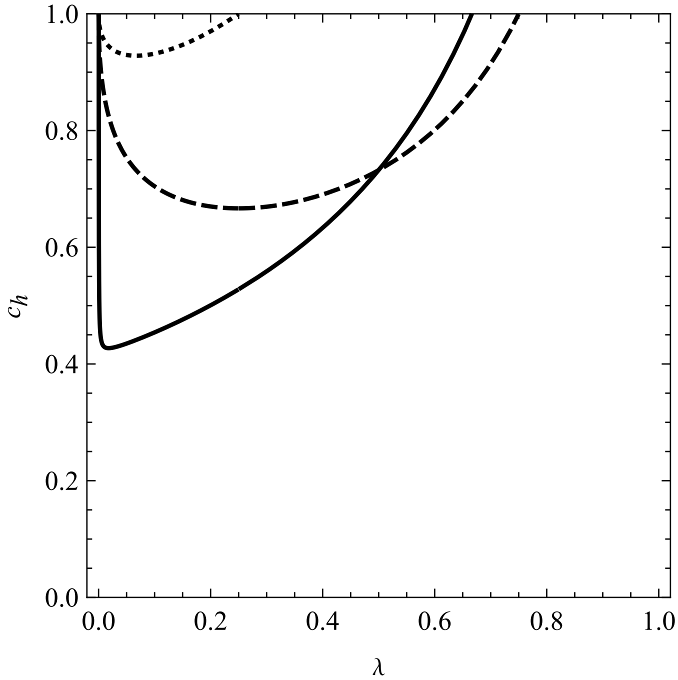

Figure 2: Existence and surplus of equilibria.

5 Robustness

5.1 Commitment to Sets

In this section, we consider the case where firms, instead of committing to a single price, can commit to a set of prices, from which they can freely choose in the search stage. Note that commitment to a menu, in the sense of a pricing strategy $p(\tau)$, cannot be enforced. Consumers do not learn their type and hence could not confirm whether they were charged the price corresponding to their type or corresponding to any other type.

We now formally present the model. In the commitment stage, each Firm j simultaneously chooses an action A_j, where A_j is a compact subset of $\mathbb{R}_+$. If $A_j \neq \emptyset$, then Firm j publicly displays a set of prices A_j and thereby commits to charging a price from the set in the subsequent stage. Note that if A_j has two or more elements, the firm could choose different prices for different cost types. We still refer to these firms as committed firms, as they made some commitment rather than none. If $A_j = \emptyset$, then Firm j displays no price and makes no such commitment. At the beginning of the search stage, both committed and flexible firms choose a pricing strategy $(p_{j,l}, p_{j,h})$, where $(p_{j,l}, p_{j,h}) \in \mathbb{R}_+^2$ if Firm j is flexible and $(p_{j,l}, p_{j,h}) \in A_j^2$ if Firm j is committed. We show that both the competitive and the monopolistic equilibrium survive in this framework.

We begin with the competitive equilibrium. Assume that on the equilibrium path, all firms commit to the singleton set $\{c_e\}$. Consider a deviation of Firm j in the commitment stage to A_j with $\max A_j > c_e$. If the maximal element of A_j was below c_e, the firm could never make a profit from this deviation. The deviation can be deterred by consumer expectations that Firm j will charge $\max A_j$ to both types in the search stage. With these expectations, consumers never visit Firm j, and hence, the deviating firm makes no profits.

Next, consider the monopolistic equilibrium and a deviation of Firm j to A_j in the commitment stage. If $\max A_j \geq t$, then an equilibrium analogous to the optimistic equilibrium of Section 3.1.3 exists. The flexible firms choose prices as described in Lemma 3. Firm j chooses the pricing strategy $(\max A_j, \max A_j)$ and consumers never visit this firm unless $c_h > \max A_j + s$. If $c_h > \max A_j + s$, the deviating firm would make a loss in any case. Hence, assume $c_h \leq \max A_j + s$. Because the committed firm is not visited on the equilibrium path, a deviation to a different pricing strategy in the search stage would be unobserved by consumers. If $\max A_j < t$, then only the pessimistic equilibrium as described in Section 3.1.3 exists and the deviating firm could make a profit. Note that maximal deviation profits are higher compared to the baseline model, as the committed firm can charge $p_l^m < t$ to low-cost consumers. Hence, the monopolistic equilibrium exists for a smaller region of the parameter space.

5.2 Correlated Outside Options

For some goods and services, the outside option of consumers is correlated with consumers' cost types. A typical example is a medical 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 consumer with type τ is $-\phi c_\tau$ where $\phi \geq 0$. In the absence of competition, the consumer would buy if $v - p \geq -\phi c_\tau$. Note that for $\phi = 0$, this reduces to the baseline model.

Since consumers are assumed to not know their type, we assume that they don't know their outside option either. Instead, they infer both their type and outside option from the price they are being offered by a flexible firm. In a flexible market, this opens up incentives for firms to charge the equilibrium price of high-cost consumers to low-cost consumers in order to deceive consumers into believing that they are of the high-cost type, effectively raising the consumer's valuation. Let $p_\tau^m := \arg\max_p (1 - F(p - \phi c_\tau))(p - c_\tau)$. If ϕ is sufficiently small, then

$$(1 - F(p_l^m - \phi c_l))(p_l^m - c_l) \geq (1 - F(p_h^m - \phi c_h))(p_h^m - c_l)$$

and firms are still better off charging the corresponding monopoly price to each cost type. Similarly, if ϕ is sufficiently small, then the optimistic equilibrium of a partially committed market persists. Hence, the results of the baseline model go through as long as ϕ isn't too large.

6 Conclusion

In this paper, we propose a model of service markets to explain why, in some markets, firms do not publicly display prices. Our explanation does not rely on collusion in an infinitely repeated setting. Instead, it hinges on an information asymmetry between firms and consumers. Consumers differ in their cost type, which determines the firms' marginal cost of serving a consumer. Firms know a consumer's cost type, whereas consumers do not. Displaying a price comes with the consequence of serving all consumers at that price. This situation enables an equilibrium where no firm displays a price. Because firms can react to displayed prices, they charge at most the search cost above the displayed price. To attract consumers, the deviating firm must display a price so low that it would be better off sharing monopoly profits. The existence of this equilibrium requires that costs are sufficiently dispersed. The social desirability of this equilibrium, relative to pricing at the expected marginal cost, depends on the level of cost dispersion as well. In fact, if costs are sufficiently dispersed, even consumers benefit from firms not displaying prices compared to a price-transparent market.

The information asymmetry plays a crucial role in our model. To see this, assume consumers would know their own type. Then, each type would constitute a separate market. The model would then reduce to Diamond (1971), with the possibility of committing to a price. If no firm displays a price, then a firm could attract all consumers by displaying a price slightly below the monopoly price. The unique equilibrium outcome of such a market would be that of Bertrand competition, i.e., at least two firms announce a price equal to the marginal cost.

In our model, firms cannot credibly commit to a menu, i.e., a price for each type. This is because consumers do not learn their type even after the service has been provided. A firm could deceive a consumer by claiming that the consumer was of the cost type associated with the highest price on the menu. Therefore, displaying a menu reduces to displaying a set of prices, which does not qualitatively change the results, as we have shown. If firms could credibly commit to a menu, then there could not be an equilibrium where no firm displays prices. A firm could attract all consumers by displaying a price slightly below the monopoly price for each type.

Our explanation relies on the fact that firms make profits in the absence of displayed prices. This necessitates some assumptions to prevent a hold-up problem, such as in Diamond (1971). If consumers knew their valuation before the first search, then the only equilibrium of a flexible market would be market collapse. Firms would then display a price to prevent market collapse, and hence, the model could not explain a lack of price transparency. Therefore, we assume that consumers learn their valuation after the first search, meaning the service is a search (or inspection) good. We believe this to be a reasonable assumption in the context of credence goods. Only after a consultation with the service provider can the consumer fully understand the personal value of the service. The model is similar to Wolinsky (1986), where firms are horizontally differentiated and consumers learn a firm-specific match value after inspecting the product of a given firm. We abstract from horizontal differentiation and assume that the same value is realized for all firms. A model similar to ours can be found in Preuss (2023). To show that this assumption doesn't drive our results, we have analyzed an alternative model, where consumers know their valuation before the first search, and the first search is free. We haven't chosen this as the baseline model as more equilibria arise in partially committed markets, which complicates the analysis.

Next, we discuss the role of search cost in our model. For a firm to provide the service, it first has to learn the consumer's type. This typically requires the consumer to provide the firm with information, for example, by physically visiting a store or by filling out a questionnaire. We interpret the search cost s as the consumer's ordeal of providing this information. We have assumed that consumers can observe displayed prices at no cost. The rationale is that the cost of learning a displayed price, for instance, through a visit to a website, is negligible compared to the ordeal of providing information. However, an equilibrium where no firm displays a price exists, even if there was a separate search cost for learning displayed prices. If no firm displays a price, consumers do not search for displayed prices. Hence, a deviation to displaying a price would go unobserved and not attract any consumers.

Finally, we consider the policy implications of our model. Our analysis suggests that indiscriminately mandating firms to display a single price for the service may backfire. In markets with high levels of cost dispersion, consumers might benefit from a lack of price transparency. Alternatively, consider a more nuanced policy that mandates that firms display a price for each procedure. A recent example of such a policy would be the U.S. Hospital Price Transparency regulation. In the context of our model, this would have the same effect as mandating firms to display a single price for the service. Competitive pressures would drive the price of each procedure to the expected marginal cost across procedures. Decreasing the price of a cheaper procedure below this expected marginal cost would not attract additional consumers, as they would rationally expect the firm to charge expected marginal cost in any case. This result hinges on firms' ability to deceive consumers about their actual condition and the procedures performed. Note that consumer deception in markets for credence goods is a persistent issue. For example, research by Gottschalk et al. (2020) indicates that 28% of Zurich dentists recommended unnecessary treatments in their study. Therefore, to ensure the effectiveness of price transparency regulations, it is crucial to implement safeguards that prevent deceptive practices by service providers.

Appendix A

Proof of Lemma 1

First, consider $p_h > p_l$. If $p_l \neq p_l^m$, then the firm can deviate $\varepsilon < s$ closer to p_l^m

when facing a low-cost consumer without losing the consumer to a competitor. As this would present a profitable deviation, it must be that $p_l = p_l^m$.

Second, we rule out $p_h \leq p_l$. If $p_h \leq p_l$ and $p_h \neq p_h^m$, then again, the firm can profitably deviate $\varepsilon < s$ closer to p_h^m when facing a high-cost consumer. So assume $p_h = p_h^m$ and note that $p_l^m < p_h^m$. Hence $p_l^m < p_h \leq p_l$ and the firm can profitably deviate to p_l^m when facing a low-cost consumer. Therefore $p_h > p_l$, which concludes the proof.

Proof of Proposition 1

By Lemma 1, $p_l = p_l^m$ in any equilibrium. So assume $p_h \neq p_h^m$ and consider a deviation $\varepsilon < s$ closer to p_h^m when facing a high-cost consumer. This deviation could be profitable when facing a high-cost consumer (e.g., if they would believe they are a high-cost type). Hence, the intuitive criterion implies $\mu = 0$, making the deviation indeed profitable. For (p_l^m, p_h^m), there is no profitable deviation, as firms make maximal profits. This concludes the proof.

Proof of Lemma 2

Upon visit at a committed firm, the consumer learns her valuation but learns nothing about her type. The net benefit of visiting a flexible firm in addition is given by

$$B(v_i) := \lambda \max\{v_i - p_l, v_i - \underline{p}, 0\} + (1-\lambda)\max\{v_i - p_h, v_i - \underline{p}, 0\} - \max\{v_i - \underline{p}, 0\} - s.$$

Note that $B(v_i)$ is increasing in v_i up to $\underline{p}$ and is constant from then on. Hence, for any consumer to additionally search a flexible firm it must be that $B(\underline{p}) \geq 0$. This implies that every consumer who does not make an additional visit at a flexible firm must leave the market without purchase, as their valuation is below $\underline{p}$, such that they wouldn't buy from the committed firm. Hence, if there exists a consumer who would benefit from visiting a flexible firm after already having visited a committed firm, then no consumer would buy at their initial visit at a committed firm. Then, it would be an ex-ante better strategy for consumers to first visit a flexible firm over first visiting a committed firm, as they would sometimes save on search costs. This concludes the proof.

Proof of single crossing property

We show that (2) has a single crossing property. Define

$$g(\underline{p}) := \lambda CS(p_l^m) + (1-\lambda)CS(\min\{\underline{p}+s, p_h^m\}) - CS(\underline{p}). \tag{7}$$

Note that $g(p_l^m) < 0$ and $g(p_h^m) > 0$. If g is monotonically increasing, then (2) has a single crossing property. Taking the first derivative we find

$$g'(\underline{p}) = -(1-\lambda)\big(1 - F(\underline{p}+s)\big) + \big(1 - F(\underline{p})\big) \tag{8}$$

for $\underline{p} < p_h^m - s$ and $g'(\underline{p}) = 1 - F(\underline{p})$ for $\underline{p} > p_h^m - s$. Since $1 - F(\underline{p}) \geq 0$ and $\big(1 - F(\underline{p})\big) \geq \big(1 - F(\underline{p}+s)\big)$, $g'(\underline{p}) \geq 0$ for all $\underline{p}$. This concludes the proof.

Proof of Proposition 6

We begin with the proof of Part i). We prove this part of the proposition by showing that shared monopoly profits and deviation profits have a single crossing property in c_h when s is small. Shared monopoly profits are given by

$$\Pi_{\text{shared}} := \frac{1}{n}\left(\lambda\Pi_l^m + (1-\lambda)\Pi_h^m\right).$$

For every $\varepsilon > 0$ there exists a sufficiently small s such that for $c_h \geq \varepsilon$, deviation profits are at most ε away from

$$(1 - F(p_l^m))(p_l^m - c_e).$$

Hence, deviations profits are approximately linear in c_h, decreasing and 0 for $c_h \geq \frac{p_l^m - \lambda c_l}{1-\lambda}$. Shared monopoly profits are decreasing in c_h to a lower bound of $\frac{1}{n}\lambda\Pi_l^m > 0$. Finally, we show that shared monopoly profits are convex in c_h, which then implies that they intersect the approximation of deviation profits exactly once. Note that by definition of $p^m(c)$,

$$f\left(p^m(c)\right)\left(p^m(c) - c\right) = \left(1 - F(p^m(c)\right).$$

Substituting this expression in $\partial\Pi_{\text{shared}}/\partial c_h$ gives

$$\partial\Pi_{\text{shared}}/\partial c_h = -\frac{1}{n}(1-\lambda)(1 - F(p^m(c_h))).$$

The second derivative is then $\frac{1-\lambda}{n} f(p^m(c_h))\frac{\partial p^m(c_h)}{\partial c_h} \geq 0$. This concludes the proof of Proposition 6 i).

Next, we prove Part ii). As pointed out before, for every $\varepsilon > 0$ there exists a sufficiently small s such that for $c_h \geq \varepsilon$, deviation profits are at most ε away from $(1 - F(p_l^m))(p_l^m - c_e)$. Then $\Delta\Pi$ is approximately linear in λ with the exception of $\lambda < \varepsilon$ and intersects the horizontal axis at most once. This concludes the proof.

Proof of Proposition 7

First, we consider the effect of a mean preserving spread of the cost distribution on ΔCS. $CS(c_e)$ is unaffected by a mean preserving spread. If $CS(p^m(c))$ is convex in c, then $\lambda CS_l^m + (1-\lambda)CS_h^m$ increases with a mean preserving spread. The argument is the same as in the case of risk preferences and second-order stochastic dominance.[15] This implies that ΔCS must increase. Chen and Schwartz (2015) (Conditions A1a and A1b) show that if monopoly consumer surplus is convex in cost, then total surplus is convex in cost as well. Hence the same argument goes through for ΔTS. This concludes the proof.

Proof of Proposition 8

First, we show that (5) collapses to $\sigma \geq \sqrt{3}$ when valuations are uniformly distributed on $[0, \bar{v}]$. For uniformly distributed valuations, $CS(p) = \frac{1}{2\bar{v}}(\bar{v} - p)^2$ and $p^m(c) = \frac{\bar{v}+c}{2}$. Substituting in (5) gives

$$\begin{aligned} \lambda \frac{1}{2\bar{v}} \left(\bar{v} - p_l^m\right)^2 + (1-\lambda) \frac{1}{2\bar{v}} \left(\bar{v} - p_h^m\right)^2 &\geq \frac{1}{2\bar{v}} \left(\bar{v} - c_e\right)^2 \\ \lambda \frac{1}{4} \left(\bar{v} - c_l\right)^2 + (1-\lambda) \frac{1}{4} \left(\bar{v} - c_h\right)^2 &\geq \left(\bar{v} - c_e\right)^2 \\ \mathbb{E}\left[(\bar{v} - c)^2\right] &\geq 4\mathbb{E}[\bar{v} - c]^2 \\ \text{Var}\left[\bar{v} - c\right] &\geq 3\mathbb{E}[\bar{v} - c]^2 \\ \frac{\text{SD}\left[c\right]}{\bar{v} - c_e} &\geq \sqrt{3}. \end{aligned}$$

Next, we show that (6) collapses to $\sigma \geq \frac{1}{\sqrt{3}}$. Let $\lambda_l := \lambda$ and $\lambda_h := 1 - \lambda$.

[15] See for instance Proposition 6.D.2. in Mas-Colell et al. (1995).

$$\sum_{\tau\in\{l,h\}} \lambda_\tau \left(\frac{1}{2\bar{v}}\left(\bar{v}-p_\tau^m\right)^2 + \left(1-\frac{p_\tau^m}{\bar{v}}\right)\left(p_\tau^m - c_\tau\right)\right) \geq \frac{1}{2\bar{v}}\left(\bar{v}-c_e\right)^2$$

$$\sum_{\tau\in\{l,h\}} \lambda_\tau \left(\frac{1}{8\bar{v}}\left(\bar{v}-c_\tau\right)^2 + \frac{1}{4\bar{v}}\left(\bar{v}-c_\tau\right)^2\right) \geq \frac{1}{2\bar{v}}\left(\bar{v}-c_e\right)^2$$

$$\frac{3}{4}\sum_{\tau\in\{l,h\}} \lambda_\tau(\bar{v}-c_\tau)^2 \geq \left(\bar{v}-c_e\right)^2$$

$$\mathbb{E}\left[(\bar{v}-c)^2\right] \geq \frac{4}{3}\mathbb{E}[\bar{v}-c]^2$$

$$\mathrm{Var}\left[\bar{v}-c\right] \geq \frac{1}{3}\mathbb{E}[\bar{v}-c]^2$$

$$\frac{\mathrm{SD}\left[c\right]}{\bar{v}-c_e} \geq \frac{1}{\sqrt{3}}.$$

This concludes the proof.

Appendix B

In this section, we consider the case of more than two cost types. To save on notation, we equate a consumer's cost type τ with the firm's cost of serving this consumer c_τ. Hence, a consumer's cost type is an element of $\mathbb{R}_+$. Cost types, or simply costs, are distributed with c.d.f. G, such that $G(c)$ is the fraction of consumers with an associated cost of weakly less than c. Let $C \subseteq \mathbb{R}_+$ denote the support of G and assume that C is closed. We define $\underline{c} = \min C$. Note that this notation encompasses the case of finitely many cost types as well.

Committed Market

The equilibrium, where all consumers visit firms displaying the lowest displayed price $\underline{p}$, still exists. Expected costs are now given by $c_e := \int_0^\infty c dG(c)$.

Flexible Market

Let $p : C \to \mathbb{R}_+$ denote the pure and symmetric pricing strategy of flexible firms. Let $p^m(c) := \arg\max_p \left(1 - F\left(p\right)\right)\left(p - c\right)$ denote the monopoly price for cost type c.

Note that a firm can deviate to any price in $\{p(c) : c \in C\}$ without losing the consumer to a competing firm. So assume a firm deviates to a price that is not in

$\{p(c) : c \in C\}$. Let $C' := \{c \in C : p(c) \neq p^m(c)\}$. Under passive beliefs and the intuitive criterion, the strongest possible punishment is that consumers believe that the next firm will charge $\arg\inf_{c\in C'} p(c)$. First, assume $\arg\min_{c\in C'} p(c)$ exists and denote it by c'. Then a firm can deviate by up to s away when facing a consumer of type c', without losing the consumer to a competing firm. Since $p(c') \neq p^m(c')$, the firm has an incentive to do so. Second, assume $\arg\min_{c\in C'} p(c)$ doesn't exists. Then there must exist a $c' \in C'$, such that $p(c') < \arg\inf_{c\in C'} p(c) + s$. In this case, a firm can deviate by up to $\arg\inf_{c\in C'} p(c) + s - p(c')$ away when facing a consumer of type c', without losing the consumer to a competing firm. Since $p(c') \neq p^m(c')$, the firm has an incentive to do so. This shows that the only pricing strategy for which firms have no incentive to deviate is $p(c) \equiv p^m(c)$.

Partially Committed Market

Clearly, the pessimistic equilibrium still exists. Furthermore, Lemma 2 holds true without caveats. Hence, the only other equilibrium candidate is the optimistic equilibrium where all consumers initially visit flexible firms. The arguments from Section 3.1.3 apply to show that in this equilibrium the pricing strategy of flexible firms must be

$$p(c) = \begin{cases} \underline{p} + s & \text{if } p^m(c) \geq \underline{p} + s \geq c \\ p^m(c) & \text{otherwise} \end{cases}.$$

The condition for consumers to indeed prefer visiting a flexible firm first over visiting a committed firm first is given by

$$\int_0^{c^*(\underline{p})} CS(p^m(c))dG(c) + \int_{c^*(\underline{p})}^{\infty} CS(\underline{p} + s)dG(c) \geq CS(\underline{p}), \tag{9}$$

where $c^*(\underline{p}) = p^{m-1}(\underline{p} + s)$. If the left-hand side is differentiable w.r.t. $\underline{p}$ at $\underline{p}$, then the derivative is given by $-(1 - F(\underline{p} + s))(1 - G(c^*(\underline{p})))$, hence is clearly larger than the derivative of the right-hand side, which is $-(1 - F(\underline{p}))$. Since the left-hand side is monotonically decreasing without jumps, this proves the single crossing property of 9. The bounds of the threshold t w.r.t. s are given by $\underline{t} = p^m(\underline{c})$ and $\bar{t}$ solves

$$\int_0^{\infty} CS(p^m(c))dG(c) = CS(\bar{t}).$$

Appendix C

In this section, we consider an alternative model, where consumers know their valuation ex-ante and the first search is free. We show that the equilibria of Section 3.2 persist under this alternative assumption. Note that after the first search, both models are identical. Hence, the only difference lies in the search strategy of consumers before the first search. Under the model described in Section 2, consumers are ex-ante identical and base their initial search on the expected surplus of visiting a given firm. In order to participate in a market and make an initial search, s has to be sufficiently small. Under the alternative model described in this section, consumers differ even before the first search and might choose different search strategies based on their valuation. However, as the first search is free, they might participate in the market for any s.

Committed Market

The equilibrium, where all consumers visit firms displaying the lowest displayed price $\underline{p}$, still exists. However, in contrast to Section 3.1.1, it exists for any s.

Flexible Market

It is easy to see that the equilibrium described in Section 3.1.2 still exists. Firms charge the respective monopoly price to each cost type. Consumers make an initial search at a random firm, buy if their valuation is above the monopoly price and leave the market without purchase otherwise. Note that even though consumers with valuations below p_l^m do not expect to make a purchase, they visit a firm anyway, as the first search is free. In contrast to Section 3.1.2, this equilibrium exists for any s.

Partially Committed Market

The pessimistic equilibrium still exists and, in contrast to Section 3.1.3, it exists for any s.

For the optimistic equilibrium, the analysis departs from Section 3.1.3. Consider the case where consumers expect flexible firms to sometimes make better offers than $\underline{p}$. Assume $p_l < \underline{p} < p_h$, such that low-cost consumers would be better off visiting flexible firms and high-cost consumers would be better off visiting committed firms.

We find that a consumer has only two relevant search strategies. One strategy is to initially visit a flexible firm and potentially make another visit at a committed firm after receiving an offer of p_h. The consumer's expected utility of this strategy is

$$u_{\text{flex}}(v_i) := \lambda \max\{v_i - p_l, 0\} + (1-\lambda)\max\{v_i - p_h, v_i - (\underline{p} + s), 0\}.$$

Alternatively, the consumer could initially visit a committed firm. If, after the initial visit, it was optimal to go on to a flexible firm, it would be even better to visit the flexible firm first. Hence, the only other potentially optimal strategy is to initially visit a committed firm and never search on. The consumer's expected utility of this strategy is

$$u_{\text{com}}(v_i) := \max\{v_i - \underline{p}, 0\}.$$

Let $\Delta u(v) := u_{\text{flex}}(v_i) - u_{\text{com}}(v_i)$ denote the net benefit of initially visiting a flexible firm over only visiting a committed firm. Figure 3 shows $\Delta u(v)$ for two values of λ. Up

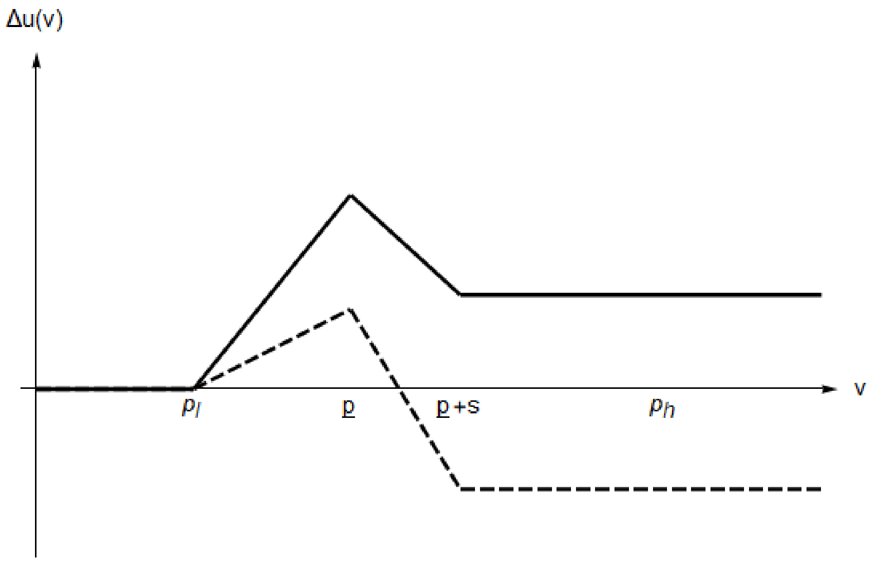

Figure 3: Net utility of visiting a flexible firm depending on v.

to p_l, $\Delta u(v)$ is constant at 0, since consumers with valuations below p_l don't expect an acceptable offer of either firm. Then $\Delta u(v)$ increases at a slope of λ because at these valuations consumers would only receive an acceptable offer from flexible firms and if they are of the low-cost type. From $\underline{p}$ to $\min\{p_h, \underline{p} + s\}$, $\Delta u(v)$ decreases at a slope of $\lambda - 1$. These consumers would always buy from a committed firm, but only from a flexible firm if they are a low-cost type. Finally, from $\min\{p_h, \underline{p} + s\}$ onward, $\Delta u(v)$ is constant as these consumers would buy at any of the three prices, and their decision only depends on which firm offers the lower price in expectation. We can distinguish two cases.

In the first case, $\Delta u(v)$ intersects the horizontal axis at

$$\tilde{v}(p_l) := \frac{\underline{p} - \lambda p_l}{1 - \lambda},$$

such that consumers with valuations above $\tilde{v}(p_l)$ initially visit a committed firm, and furthermore $\tilde{v}(p_l) < \bar{v}$, such that consumers with such valuations actually exist. Consumers with valuations below $\tilde{v}(p_l)$ are weakly better off visiting a flexible firm. This is true when

$$\tilde{v}(p_l) < \min\{p_h, \underline{p} + s, \bar{v}\} \tag{10}$$

and is depicted by the dashed line.

In the second case, (10) is violated such that either $\Delta u(v)$ does not intersect the horizontal axis or only intersects it after $\bar{v}$. Either way, all consumers are weakly better off visiting a flexible firm. This is depicted by the solid line. As we want to reproduce the results of Section 3.1.3, we will focus on the second case. Note however, that under the alternative model, more equilibrium can arise in a partially committed market, compared to the baseline model.

Assume that (10) is violated and consider the incentives of flexible firms to deviate from (p_l, p_h). Since a flexible firm is visited by consumers of all valuations, incentives are similar to a flexible market. For low-cost consumers, the search frictions make marginal deviations towards the monopoly prices p_l^m profitable and hence in equilibrium $p_l = p_l^m$. The price for high-cost consumers is also pushed up towards p_h^m, but it is bounded by $\underline{p} + s$, as otherwise consumers would buy from a committed firm. We call such an equilibrium a *pooling optimistic equilibrium* because consumers rationally expect flexible firms to make good offers, and all consumers take the same initial action, independent of their valuation. Solving (10) for $\underline{p}$ provides a threshold t for the existence of this equilibrium.

Proposition 9 (Pooling Optimistic Equilibrium)**.** In partially committed markets with

$$\underline{p} \geq t := \min\{p_l^m + \frac{1-\lambda}{\lambda}s, \lambda p_l^m + (1-\lambda)p_h^m, \lambda p_l^m + (1-\lambda)\bar{v}\}$$

there exists an equilibrium where flexible firms choose $p_l = p_l^m$ and

$$p_h = \begin{cases} \underline{p} + s & c_h \leq \underline{p} + s \leq p_h^m \\ p_h^m & \text{otherwise} \end{cases}$$

and all consumers initially visit flexible firms. In partially committed markets with $\underline{p} < t$, this equilibrium does not exist.

The pooling optimistic equilibrium resembles the optimistic equilibrium of Section 3.1.3, with the difference that the threshold t has a closed-form solution even without specifying F. The results on t partially carry over to this setting. As in Section 3.1.3, t is increasing in s and $\underline{t} = p_l^m$. Furthermore, $t \to p_l^m$ as $\lambda \to 1$ and $t \to p_h^m$ as $\lambda \to 0$. What differs is that now $\bar{t} = \min\{\lambda p_l^m + (1-\lambda)p_h^m, \lambda p_l^m + (1-\lambda)\bar{v}\}$.

Commitment Stage

All results of Section 3.2 go through, with the only difference that t might be different whenever s is not small, and hence, the monopolistic equilibrium might exist in a different region of the parameter space.

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