DO LOW PRICE GUARANTEES HURT CONSUMERS? THEORY AND EVIDENCE∗

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Abstract

The extensive literature on Low Price Guarantees (LPGs) finds that LPGs have both a competition-softening and a competition-enhancing effect. The welfare implications of LPGs depend on which effect is stronger, which is related to the market characteristics. This paper constitutes the first attempt to examine, empirically, which effect dominates. I propose a structural model where both effects are present. Depending on the market’s characteristics, LPGs can either help or hurt consumers. The structural model can be estimated using only price data. I examine a novel dataset on the tire market and I find that LPGs hurt consumers. If this policy was not allowed, prices would decrease by between four and ten percent.

JEL Classification: C51, D21, D22, L10, L40

Keywords: Low-Price Guarantees, Price-matching, Welfare analysis

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1 Introduction

A Low Price Guarantee (LPG) is a firm’s promise to reimburse its consumers if they find a lower price elsewhere. LPGs are used in a variety of markets, such as tires, consumer electronics, books, sporting goods, power tools and even flights and hotels. The extensive use of this policy raises the question of how it affects consumers. This question has important policy implications: if it turns out that LPGs are hurting consumers, by allowing firms to sustain higher prices, it would be fairly easy to forbid firms from using LPGs, hence increasing consumers’ welfare.

Even though, at first glance, it may seem that LPGs are procompetitive\textsuperscript{1}, the literature is ambiguous regarding the effects of this policy on consumers. The extensive literature on LPGs finds that they have both a competition-softening and a competition-enhancing effect.

The anti-competitive role of LPGs has been established in the literature for quite some time (e.g., Hay (1982), Salop (1986), Doyle (1988), Logan and Lutter (1989), Baye and Kovenock (1994), Chen (1995), Zhang (1995)). The argument is that, when a firm adopts an LPG, its rivals can no longer steal its consumers by undercutting its price, because the firm automatically matches the new price. Because the demand of LPG firms becomes less price sensitive, those firms have higher incentives to list higher prices.

Jain and Srivastava (2000) and Moorthy and Winter (2006) propose that, when firms are heterogeneous, they can use LPGs as a credible signal of low prices. This role of LPGs as a signaling device can benefit consumers by reducing the search costs that they incur. Even though there is some empirical evidence that the choice of offering LPGs depends on some intrinsic firm characteristics (for example, Moorthy and Zhang (2006) find that LPGs tend to be adopted by retailers with low cost or low quality), the literature is skeptical regarding this welfare improving role of LPGs (e.g. Yankelevich and Vaughan (2016)), because LPGs

\textsuperscript{1}As Edlin (1997) remarks, “On its face, a price-matching policy seems the epitome of cutthroat competition: what could be more competitive than sellers’ guaranteeing their low prices by promising to match the prices of any competitor?”.
require identical products. Since all retailers purchase the same product from the same producer, it seems reasonable to assume that they all purchase at the same price.

Another strand of the literature (Chen et al. (2001), Jiang et al. (2016)) argues that LPGs have a competition-enhancing effect, even when firms are homogeneous. The argument relies on the fact that some consumers invoke LPGs and pay the lowest price in the market when they purchase from stores that offer such policy. The fact that LPG firms sell to those consumers at the lowest market price prompts them to charge lower prices, so that they can also attract informed consumers, who shop at the lowest price firm. This imposes a cap on the price that non-LPG stores can charge. Indeed, if non-LPG stores list a very high price, high search cost consumers prefer to search another store than to purchase from them.

Empirical work on LPGs is scarce.\(^2\) Analyzing the impact of LPGs on consumers is challenging, because we do not observe the counterfactual, i.e., we never observe firms’ prices in a setting that does not allow for LPGs. Hess and Gerstner (1991) and Chen and Liu (2011) aim to identify the counterfactual by analyzing prices before and after the adoption of an LPG by a particular store. However, there were already some stores offering LPGs in the markets they analyze, so the prices observed before the adoption of the LPG policy by another store are not the counterfactual. Prices may have been very different if, in fact, firms were not allowed to offer LPGs. Whereas Hess and Gerstner (1991) find that the adoption of LPG by one more store leads to an increase in prices, Chen and Liu (2011) provide results on the opposite direction.

This paper proposes a structural model under which LPGs have both a competition-softening and a competition-enhancing effect. The relative strength of each effect depends on the composition of consumers in the market. The structural model I propose can be used to estimate the parameters of the market, using price data alone. Using those market parameters, it is possible to analyze the counterfactual, i.e., the prices we would observe if firms were not able to offer LPGs. This is the main contribution of the paper: it provides a

\(^2\)For an extensive overview of the literature, see Hviid (2010).
framework that allows the policy maker to decide whether or not to forbid firms from using LPGs, using only data on prices that are publicly available.

Section 3 introduces a rich and novel dataset that includes prices and LPG policies of tire stores located in the Chicago area. Michelin’s website lists all tire dealers that carry Michelin tires. There are a total of 396 stores in a radius of 50 miles from Chicago. The dataset was gathered by calling those stores, asking their prices for the two most popular Michelin tires (Defender and Premier) of size 215/60R16, and asking whether the stores offer a Low Price Guarantee policy.

In Section 4, I use this dataset to estimate the parameters of the model for the market of tires in the Chicago area. In Section 5, I use the estimates of the structural model to construct counterfactual prices. I conclude that, if LPGs were not allowed, prices would decrease by between four and ten percent. Even though all consumers would benefit from LPGs not being allowed, price-sensitive consumers would benefit the most. Price-sensitive consumers have a lower opportunity cost of time, so they will search all stores in the market and pay the lowest price offered. It turns out that, if LPGs were not allowed, the average price would decrease but the expected lowest price would decrease even more. It is well documented in the literature that poor consumers tend to have lower search costs (Marvel (1976), Masson and Wu (1974), Philips (1989)). This implies that not only LPGs hurt all consumers, they hurt poor consumers the most.

Even though the literature is ambiguous regarding the effect of LPGs on consumers, antitrust authorities view this policy as a tool that helps firms to extract a higher surplus from consumers. Although antitrust authorities believe that LPGs are hurting consumers, there is no empirical economic framework to back up those claims. The results presented here support antitrust authorities’ views that LPGs are hurting consumers. However, I do

\footnote{In 2013, “a federal US judge ruled that the price-matching provisions in Apple Inc.’s contracts with five major book publishers was part of a conspiracy to fix e-book prices” (Palazzolo (July 14, 2013), The Wall Street Journal). In 2014, the UK competition regulator, the Office of Fair Trading (OFT), accepted binding commitments from Expedia and Booking.com to alter the way they operated their LPGs with major hotel chain International Hotel Group. The OFT considered LPGs favored existing powerful market participants}
not claim that LPGs should never be allowed. In fact, depending on the characteristics of each market, LPGs can either help or hurt consumers. In order to analyze whether LPG policies should be forbidden in a given market, a careful analysis of that market should be carried out. This paper provides the empirical tools to analyze each market and take an informed decision on whether or not to forbid firms from using LPGs.

2 Model

Consumers

The market is composed of both consumers that favor a specific firm and consumers with no firm preference. Without loss of generality, it is assumed that consumers with no firm preference are of measure one. Figure 1 depicts the different consumer-types, for consumers with no firm preference. A fraction $\lambda$ are informed about all prices in the market.\textsuperscript{4} The remaining fraction $1 - \lambda$ are completely uninformed about both prices and LPG policies of firms (but hold rational beliefs about it), and search sequentially. In the first period, a fraction $\mu$ of these consumers have zero search cost,\textsuperscript{5} whereas the remaining consumers have a high search cost, denoted by $s_H$. Consumers that have a high search cost in the first period, will have zero search cost in the second period with probability $q$ (in the first period they do not know their second period search cost).\textsuperscript{6}

Besides the measure one of consumers described above, each firm has some loyal consumers. These consumers have a high search cost in period 1 and a probability $q$ of having zero search cost in period 2, and they start their search in the firm they are loyal to. Loyal

\textsuperscript{4}As it will be clear in the next subsection, whether informed consumers know which firms offer LPGs is not relevant, because they always purchase the good at the lowest-price store, regardless of its LPG policy.

\textsuperscript{5}As I discuss below, the results of the model do not change if I assume that zero search cost consumers know which firms offer LPGs.

\textsuperscript{6}No assumption is needed regarding the search cost in the second period of consumers that have zero search cost in the first period, as those consumers will search all stores in the first period.
consumers and high search cost consumers with no firm preference differ only in the store they start searching. Whereas loyal consumers start searching the firm they are loyal to, high search cost consumers with no firm preference search at random.

Although I name these consumers as loyal, this does not mean that they blindly purchase the product from the store they are loyal to. They visit first the store they are loyal to but, if they believe that said store’s price is high enough that they would rather search one more store, they will do so.\footnote{In equilibrium, however, loyal consumers always purchase from the store they are loyal to.}

I have assumed that loyal consumers have high search cost. As Chen et al. (2001) argue, this assumption is quite reasonable because a high search cost can cause store loyalty (Stigler and Becker (1977)) and price-insensitive consumers tend to have a higher opportunity cost of time (Narasimhan (1984)).

After firms’ decisions have been made, the game proceeds in two periods. Consumers have a valuation of $v$ in the first period, and have a zero valuation for the product in the second period. Hence, all purchasing decisions are made in the first period.\footnote{In a standard model, without LPGs, this would be a one period model in which all consumers would buy the good in the same period. I introduce the second period to allow consumers to get refunds from firms offering LPGs.}

In the first period, consumers may search as many firms as they wish. Search is with recall and the first search is for free. If, after searching $m$ stores, consumer $i$ purchases a

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7 In equilibrium, however, loyal consumers always purchase from the store they are loyal to.
8 In a standard model, without LPGs, this would be a one period model in which all consumers would buy the good in the same period. I introduce the second period to allow consumers to get refunds from firms offering LPGs.
product at price $p$ from a firm that does not offer an LPG, his payoff is $v - p - (m - 1)s_i$, where $s_i$ denotes his search cost.

If he buys from a firm that offers an LPG, he can keep searching for a lower price and, if he finds it, the firm from which he purchased will refund him the difference between the price he paid and the lowest price he was able to find. This search for a lower price, after having purchased from an LPG firm, can be done either in the first or the second period. Contrary to the first period, however, the first search in the second period is not for free.

Firms

The market is composed of $n$ firms. Firms are heterogeneous in two dimensions: the cost they face to offer an LPG\(^9\), and the number of loyal consumers they possess. I allow for firms to be heterogeneous in their number of loyal consumers, but I assume that all firms sample a number of loyal consumers from the same distribution.

Figure 2 depicts the timing of the model. First, firms privately observe their cost of offering an LPG. They then choose whether they want to offer such policy and commit to that decision. After being committed to the policy chosen, firms privately observe the number of loyal consumers to their store. Finally, firms set prices.

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\(^9\)A firm that offers LPGs needs to get the necessary software to process the refunds and to hire qualified personnel to work with said software.
Equilibrium Consumer Search Strategies

Informed consumers purchase at the firm with the lowest price. Uninformed consumers with zero search cost search all stores in the market. However, in contrast to informed consumers, they do not necessarily purchase from the firm with the lowest price. As soon as they visit a store that offers an LPG, they purchase the product. The LPG allows them to enjoy the good immediately and, at the same time, gives them the opportunity to keep searching for a lower price.\(^\text{10}\) If no firm offers an LPG, these consumers purchase at the store with the lowest price.

Whereas consumers who are informed about firms’ prices purchase directly from the store that lists the lower price, consumers that are uninformed about prices and have zero search costs purchase from an LPG store. Zero search cost consumers purchase from LPG stores for the sake of having the product sooner. Since they do not know which firm charges the lowest price, they need to search all stores to make sure they pay the lowest price. By purchasing as soon as they are offered an LPG, they can enjoy the product sooner while still searching the same number of stores. Notice that zero search cost consumers purchase at a random LPG store and pay the lowest price in the market. The results of the model do not change if we allow for these consumers to be informed about which firms offer LPGs. If that is the case, these consumers go directly to an LPG store.

The models of Jain and Srivastava (2000), Chen et al. (2001), Moorthy and Zhang (2006), and Yankelevich and Vaughan (2016) also entail some low search cost consumers purchasing from an LPG store instead of purchasing directly from the lowest price store. In those models, consumers do that because firms are vertically differentiated and some consumers have a preference for purchasing at a specific store. Hence, they use the LPG to purchase at their favorite store, and still pay the lowest market price. The model presented here is

\(^{10}\)These consumers are indifferent between purchasing the product at the first store that offers an LPG or at another store, as long as they pay the same price. I assume that consumers break ties by purchasing the product as early as possible. This way, the model is robust to modifications of the utility function that allow for discounting.
also able to encompass the vertical differentiation story, if we interpret that low search cost
consumers purchase at an LPG store not because they want to have the product sooner, but
because they prefer to purchase at that specific store.

**Proposition 1** In equilibrium, high search cost consumers purchase at the first firm they
visit. In case that firm offers an LPG, they search in the second period if and only if they
have zero search cost in that period.

Loyal consumers and high search cost consumers with no firm preference differ only in the
store they start searching. Whereas loyal consumers start searching the firm they are loyal
to, high search cost consumers with no firm preference search at random. After searching
the first firm, they face the same incentives regarding whether to purchase immediately or
to conduct one more search. The intuition for the result in Proposition 1 is as follows. High
search cost consumers always purchase at the first store they visit if it offers an LPG. The
LPG allows them to differ search to the second period, when they may have zero search
cost. Consider a firm that does not offer LPGs. If it does not sell to its loyal consumers, it
does not sell to any consumers, and it makes zero profits. This cannot be an equilibrium,
because a firm can secure positive profits by charging a price slightly higher than marginal
cost, which will ensure that it sells to high search cost consumers that visit it.

**Equilibrium Firm Strategies**

The first decision firms have to make is whether or not to offer an LPG. As there is a cost
involved in offering such policy, firms are only willing to incur that cost if the profits of LPG
firms are, on average, higher than the profits of non-LPG firms. Let $\pi_{LPG}$ and $\pi_{NO}$ denote,
respectively, the average profit of LPG and non-LPG firms. The maximum cost that a firm
is willing to incur to offer an LPG is $\pi_{LPG} - \pi_{NO}$. The first stage decision, where firms
commit to an LPG policy, takes the form of a cutoff rule.

For tractability reasons, I make the following assumption regarding the distribution from
which firms draw the number of loyal consumers, denoted by $H$.

**Assumption 1** The distribution of loyal consumers, $H$, is continuously differentiable and has full support on a convex subset of $\mathbb{R}_+$.

Because loyal consumers, in equilibrium, purchase from the store they are loyal to, a firm’s price will be increasing in the number of its loyal consumers. The intuition behind this result is simple. When a firm increases its price, it lowers the probability that it sells to informed consumers. However, by increasing its price, the firm extracts a higher surplus from its loyal consumers. The more loyal consumers the firm has, the more it is willing to increase its price. The following Proposition summarizes the equilibrium properties.

**Proposition 2** A pure strategy equilibrium exists. Firms choose their LPG policy using a cutoff rule on the cost of offering an LPG. The price firms play is increasing in the number of their loyal consumers.

Firms play pure strategies, i.e., after observing its number of loyal consumers, there is a unique price that maximizes the firm’s profits. This result is in line with what we observe in reality, as firms typically spend a considerable amount of resources in order to find the profit-maximizing price.

Let $\pi_{LPG}(p, L)$ and $\pi_{NO}(p, L)$ denote, respectively, the profit of LPG and non-LPG stores with $L$ loyal consumers when they charge price $p$. Let $F_{LPG}$ and $F_{NO}$ denote the equilibrium price distributions of LPG and non-LPG stores, and let $\alpha$ denote the probability that a firm offers an LPG. Let $F$ denote the equilibrium price distribution unconditional on firms LPG policies, i.e., $F = \alpha F_{LPG} + (1 - \alpha) F_{NO}$. Finally, let $\text{Emin}(p/k)$ denote the expected value of the lowest price in the market, given that one firm charges $p$, and at least $k$ stores do not offer LPGs.\footnote{$\text{Emin}(p/k)$ is the expected lowest price given that $k$ stores offer LPGs with probability 0, whereas the remaining $n - 1 - k$ stores offer LPGs with probability $\alpha$. Formally, $\text{Emin}(p/k) = \int_0^p \left[ (n - 1 - k)[1 - F(x)]^{n-2-k}[1 - F_{NO}(x)]^k f(x) + k[1 - F(x)]^{n-1-k}[1 - F_{NO}(x)]^{k-1} f_{NO}(x) \right] dx$.}
\[ \pi_{LPG}(p, L) = \frac{\lambda [1 - F(p)]^{n-1}}{\text{Informed}} + \sum_{k=0}^{n-1} \frac{(1 - \lambda)(1 - \mu)}{\text{High search cost}} \left( (1 - q)p + qE_{\text{min}}(p/0) - c \right) + \sum_{k=0}^{n-1} \frac{(1 - \alpha)}{\text{Zero search cost}} \left( E_{\text{min}}(p/k) - c \right) \]

\[ \pi_{NO}(p, L) = \frac{\lambda [1 - F(p)]^{n-1}}{\text{Informed}} + \sum_{k=0}^{n-1} \frac{(1 - \lambda)(1 - \mu)}{\text{High search cost}} + \sum_{k=0}^{n-1} \frac{(1 - \alpha)}{\text{Zero search cost}} \left( E_{\text{min}}(p/k) - c \right) \]

It follows from Proposition 2 that there exists a unique profit-maximizing price for each firm, which depends on both whether or not it offers an LPG and the number of loyal consumers. Let \( L^p_A \) denote the number of loyal consumers that makes it optimal for a firm with policy \( A \in \{LPG, NO\} \) to charge price \( p \). It follows from firms’ first order conditions that

\[ \frac{\partial \pi_{LPG}(x, L^p_{LPG})}{\partial x} \bigg|_{x=p} = 0 \iff L^p_{LPG} = -\frac{(1 - \lambda)(1 - \mu)}{n} + \]

\[ \lambda \left[ (n - 1)[1 - F(p)]^{n-2}f(p)(p - c) - [1 - F(p)]^{n-1} \right] - (1 - \lambda)\mu \frac{\left[ 1-F(p) \right]^{n-1}}{n} \frac{1 - \frac{1 - \alpha}{(1 - \alpha)\left[ 1 - F_{\text{NO}}(p) \right]^{n-1}}}{1 - \frac{1 - \alpha}{(1 - \alpha)\left[ 1 - F_{\text{NO}}(p) \right]^{n-1}}} \]

\[ (1) \]

\[ \frac{\partial \pi_{NO}(x, L^p_{NO})}{\partial x} \bigg|_{x=p} = 0 \iff L^p_{NO} = \lambda \left[ (n - 1)[1 - F(p)]^{n-2}f(p)(p - c) - [1 - F(p)]^{n-1} \right] - (1 - \lambda)\mu \frac{\left[ 1-F_{\text{NO}}(p) \right]^{n-1}}{n} + (1 - \lambda)\mu(1 - \alpha)^{n-1} \left[ (n - 1)[1 - F_{\text{NO}}(p)]^{n-2}f_{\text{NO}}(p)(p - c) - [1 - F_{\text{NO}}(p)]^{n-1} \right] \]

\[ (2) \]

Proposition 2 states that firm prices are increasing in their loyal consumers. Hence, a firm with policy \( A \in \{LPG, NO\} \) charges a price lower than \( p \) when the number of loyal consumers to its store is lower than \( L^p_A \). It follows that

\[ F_{LPG}(p) = H(L^p_{LPG}) \]

\[ F_{NO}(p) = H(L^p_{NO}) \]

Equations (1)-(4) characterize the equilibrium price distributions of both LPG and non-
LPG stores. Because this system of equations does not have a closed-form solution, I rely on numerical methods to derive $F_{LPG}$ and $F_{NO}$, for a given set of parameters. Appendix B presents a detailed description of the numerical methods.

2.1 Realationship between prices of LPG and non-LPG stores

Empirical evidence is inconclusive regarding the relationship between firms’ prices and their LPG policies. Although some studies (eg. Arbatskaya et al. (2006)) show that LPG firms charge higher prices, others (eg. Moorthy and Winter (2006)) find the opposite. There is even empirical evidence that finds no relation between firms’ prices and their LPG policies (Arbatskaya et al. (1999)).

The model presented here is able to encompass the diversity of empirical findings. In fact, depending on the parameters of the model, firms that offer LPGs can be either the low-price firms or the high-price firms. It can even happen that there is no relationship between LPG policies and firms’ prices. Table 1 presents, for three sets of parameters, the average price for LPG stores and non-LPG stores, as well as the probability that an LPG store has a lower price than a non-LPG store. For different sets of parameters, all the results are feasible.

<table>
<thead>
<tr>
<th>$\mu$</th>
<th>$q$</th>
<th>Average price LPG stores</th>
<th>Average price non-LPG stores</th>
<th>Probability that an LPG store has a lower price than a non-LPG store</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.80</td>
<td>0.10</td>
<td>151.16</td>
<td>125.72</td>
<td>6%</td>
</tr>
<tr>
<td>0.25</td>
<td>0.71</td>
<td>189.90</td>
<td>189.90</td>
<td>52%</td>
</tr>
<tr>
<td>0.15</td>
<td>0.90</td>
<td>182.72</td>
<td>204.64</td>
<td>95%</td>
</tr>
</tbody>
</table>

Table 1: Relationship between LPG policies and prices

Note: For the calculations in this table, I have assumed that $\lambda = 0.1$, $n = 3$, $s_H = 20$, $c = 100$, the number of loyal consumers follows the Exponential distribution with parameter 0.01 and the distribution of the cost of offering LPG is such that 40% of firms will have a cost below the cutoff and will offer an LPG.

The key parameters that determine whether LPG firms charge higher or lower prices than non-LPG firms are $q$ (the probability that a consumer that has a high search cost in
period 1 will have a low search cost in period 2) and \( \mu \) (the proportion of consumers that have a low search cost in period 1).

A high value of \( q \) means that consumers that have a high search cost in period 1 and purchase from a store that offers an LPG are very likely to come back for a refund in period 2. This implies that LPG stores are effectively selling to these consumers at the lowest price in the market. As that is the case, LPG stores prefer to list a lower price so that they also attract informed consumers, without losing revenue from high search cost consumers. Hence, the higher \( q \) the more likely an LPG store has a lower price than a non-LPG store.

A high value of \( \mu \) means that there are many consumers that search every store and purchase from the first LPG store they visit. LPG stores do not need to compete in prices to attract these consumers, as they purchase there simply because an LPG policy is offered. However, non-LPG stores can still sell to these consumers if no store offers an LPG. When that is the case, those consumers purchase from the lowest-price store. When the proportion of this type of consumers is large, non-LPG stores set lower prices so that, in the event that no store is offering an LPG, they can sell to all of these consumers. Hence, the higher \( \mu \) the less likely that an LPG store has a lower price than a non-LPG store.

### 2.2 Welfare implications

The literature on LPGs finds that they have both a competition-softening and a competition-enhancing effect. The anti-competitive role of LPGs has been established in the literature for quite some time (e.g., Hay (1982), Salop (1986), Doyle (1988), Logan and Lutter (1989), Baye and Kovenock (1994), Chen (1995), Zhang (1995)). The argument is that, when a firm adopts an LPG, its rivals can no longer steal its consumers by undercutting its price, because the firm automatically matches the new price. Because the demand of LPG firms becomes less price sensitive, those firms have higher incentives to list higher prices. In the model I propose, the competition-softening effect of LPGs is measured by \( \mu \), the share of consumers
with zero search costs - who purchase at a random LPG store and pay the lowest price in the market. The demand of LPG stores regarding these consumers does not depend on their price. In fact, consumers with zero search cost split equally between LPG firms. The larger the share of such consumers, the higher the incentives for LPG firms to list higher prices.

Another strand of the literature (Chen et al. (2001), Jiang et al. (2016)) argues that LPGs also have a competition-enhancing effect. The argument relies on the fact that some consumers invoke LPGs and pay the lowest price in the market when they purchase from stores that offer such policy. The fact that LPG firms sell to those consumers at the lowest market price prompts them to charge lower prices, so that they can also attract informed consumers, who shop at the lowest price firm. This imposes a cap on the price that non-LPG stores can charge. Indeed, if non-LPG stores list a very high price, high search cost consumers prefer to search another store than to purchase from them. Hence, the competition-enhancing effect depends on the share of consumers who search post-purchase for refunds. In the model presented here, this is measured by \( q \), the probability that consumers with high search cost in period 1 have zero search cost in period 2.

The existence of consumers with high search cost pre-purchase and zero search cost post-purchase is critical for the competition-enhancing effect of LPGs. As Jiang et al. (2016) argue, consumers under time pressure as well as consumers making an unplanned purchase, may value time before purchase more than after purchase. If a tire bursts or a TV breaks down, the cost of doing without the product while search is being conducted may be very high. In case of unplanned purchases, these sometimes happen at a moment where the consumer is very time constrained. An LPG allows consumers a grace period, typically no shorter than two weeks, in which they can search post-purchase. In order to be able to search after purchase, a consumer only needs to have some free time at some point during the grace period of the LPG. A grace period to exercise the LPG allows consumers to differ search to when their search costs are low.

Whether LPGs hurt or help consumers depends on the magnitude of these key parame-
ters, $\mu$ and $q$. Table 2 shows the change in transaction prices (i.e., prices paid after refunds have been processed) that would occur if firms were not able to offer LPGs, under two sets of parameters.\footnote{See Appendix B for the equilibrium construction of the counterfactual.} For the first set of parameters, LPGs hurt consumers and, if that policy was not allowed, prices would decrease by about 14%. In contrast, under the second set of parameters, LPGs benefit consumers and, in the absence of LPGs, prices would increase by about 10%.

<table>
<thead>
<tr>
<th>$\lambda$</th>
<th>$\mu$</th>
<th>$q$</th>
<th>$n$</th>
<th>Price change that would occur if LPGs were not allowed</th>
</tr>
</thead>
<tbody>
<tr>
<td>20%</td>
<td>60%</td>
<td>20%</td>
<td>3</td>
<td>-13.64%</td>
</tr>
<tr>
<td>50%</td>
<td>5%</td>
<td>95%</td>
<td>9</td>
<td>10.26%</td>
</tr>
</tbody>
</table>

Table 2: Price change for two sets of parameters

Note: The price change refers to the change in transaction prices, after refunds have been collected. For the calculations in this table, I have assumed that $s_h = 20$, $c = 100$, the number of loyal consumers follows the Exponential distribution with parameter 0.05 and the distribution of the cost of offering LPG is such that 40% of firms will have a cost below the cutoff and will offer an LPG.

3 Data

Michelin’s website lists all tire dealers that carry their brand of tires. I focus on a relatively narrow region, that only includes stores within 50 miles from Chicago. There are a total of 396 stores in that area. The data presented here was gathered by calling those stores, asking their price for the two most popular Michelin tires (Defender and Premier) of size 215/60R16, and asking whether the stores offer a Low Price Guarantee policy.\footnote{All calls were made between November 3, 2014 and November 6, 2014.} We were able to get price quotes and LPG policies from 350 of the 396 stores.\footnote{38 stores did not carry the tires we were asking for and 8 stores did not answer the phone. Out of the 350 stores in our data, 341 carry the Defender tire and 278 carry the Premier tire.} The main statistics of the data are summarized in tables 3 and 4.
The data presents the same feature as in Moorthy and Winter (2006) and Mañez (2006) that LPG stores have, on average, lower prices. I find an additional interesting result: prices from LPG stores have lower variance. This is a surprising result, as both the theoretical and empirical literature focus on differences on the average price of LPG and non-LPG stores, but are silent about differences on the variance of prices.

Even though the stores in the sample belong to the same metropolitan area, it is still important to understand whether we can assume that they are all part of the same market and bundle all the stores together. In Appendix C I show that there are no significant differences by location.

Chain stores account for 46% of the stores in the data. This raises the question of whether there are significant differences between chain and non-chain stores. As Table 5 shows, chain stores are much more likely to offer an LPG. This is in the same direction as findings in
The model presented in the previous section, it was assumed that firms were homogeneous in their product cost, i.e., they would buy the product at the same price. This may be a strong assumption because chain stores, that buy a much larger quantity of tires than the remaining stores, may have a higher bargaining power and may be able to purchase the tires at a lower price. As Table 6 reports, chain stores offer lower prices than non-chain stores. This holds even after conditioning on their LPG policy. This finding is in contrast with the assumption of homogeneous costs. In this light, in Section 4.4, I also estimate a model in which I allow for cost heterogeneity between chain and non-chain stores.
4 Estimation

4.1 Estimation procedure

For practical purposes, I assume that the distribution of loyal consumers belongs to a parametric family, with parameter Θ.

Given a set of parameters, the model presented in Section ?? predicts a cdf on prices for LPG and non-LPG firms. I choose the parameters that minimize the distance between the predicted cdfs and the observed cdfs from the data. More specifically, let $F_{LPG}$ and $F_{NO}$ denote the equilibrium price distributions of LPG and non-LPG firms, respectively. Let $D_{LPG}$ and $D_{NO}$ denote the observed price distributions of LPG and non-LPG firms. I choose the parameters that minimize

$$\int_0^\infty \left[ F_{LPG}(x; \lambda, \mu, q, n, s_H, c, \alpha, \Theta) - D_{LPG}(x) \right]^2 + \left[ F_{NO}(x; \lambda, \mu, q, n, s_H, c, \alpha, \Theta) - D_{NO}(x) \right]^2 \, dx$$

In the estimation of the structural model, I use a nested algorithm. The outer loop searches over different parameter values - $\lambda, \mu, q, n, s_H, c$ and $\Theta$. The inner loop constructs, for each set of parameters, the equilibrium cdfs for the two types of firms (LPG and non-LPG firms) and computes the distance between the predicted and observed cdfs.

The only search cost that the model estimates is the high search cost, as I have assumed that consumers have either a high search cost or zero search cost. This assumption is supported by empirical findings from Moraga-Gonzalez and Wildenbeest (2008) who find that ”the consumer population can be roughly split into two groups which either have quite high or quite low search costs”.

Similarly to Hong and Shum (2006), I identify the search cost using only the price distribution. As detailed in the previous sections, loyal consumers will purchase at the store

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$^{15}$I choose to minimize the distance between the equilibrium and observed price distributions instead of a maximum likelihood estimation because the former is more robust to outliers.

$^{16}$The outer loop does not search over $\alpha$, the proportion of firms offering LPG. Instead, I estimate $\alpha$ directly from the data. This substantially reduces the computation time.
they are loyal to. In particular, even if they are loyal to the highest-price store, they will purchase the good there. In equilibrium, consumers that are loyal to the highest-price store are indifferent between purchasing right away or searching one more store. This implies that the search cost is the difference between the highest price in the support of the price distribution and the expected price.

4.2 Identification

In this section, I discuss what parameters of the model are identified. There are 6 parameters to be identified - $\lambda$, $\mu$, $q$, $n$, $c$ and $s_H$ - as well as the distribution of costs of offering LPGs, denoted by $G$, and the distribution of loyal consumers, denoted by $H$.

Assumption 2 $H$ belongs to a parametric family with separable inverse, i.e., $H^{-1}(q; \Theta) = \vartheta(q)\omega(\Theta)$

The exponential distribution, the Rayleigh distribution and the uniform distribution bounded below by zero are examples of parametric families of distributions for which Assumption 2 holds.

Let $A$ be a subset of the parameters of the model, $(\lambda, \mu, q, n, c, s_H, H, G)$. Let $x$ and $y$ be two elements of $A$. Let $\mathcal{F}_{LPG}^x$ and $\mathcal{F}_{NO}^x$ denote the set of equilibrium price distributions of LPG and non-LPG firms, when the parameters of the model are $x$. $^17$ $A$ is identified if $x \neq y \implies (\mathcal{F}_{LPG}^x, \mathcal{F}_{NO}^x) \cap (\mathcal{F}_{LPG}^y, \mathcal{F}_{NO}^y) = \emptyset$.

Proposition 3 Under Assumption 2, the set $(\lambda, \mu, q, n, c, s_H, H)$ is identified

Proposition 3 states that, except for $G$, everything is identified. I will now discuss what can be learned regarding $G$.

$^17$Notice that $\mathcal{F}_{LPG}^x$ and $\mathcal{F}_{NO}^x$ are sets of price distributions. For example, suppose that $A = \{\lambda\}$ and let $x$ denote a particular value of $\lambda$. Then $\mathcal{F}_{LPG}^x$ is the set of all equilibrium price distributions (for LPG firms) that we can obtain, when we fix $\lambda = x$ and change the remaining parameters of the model.
As previously stated, firms will choose their LPG policy using a cutoff rule on the cost of offering an LPG. Let $\pi_{LPG}(L)$ be the variable profit\(^{18}\) of an LPG firm that has $L$ loyal consumers. Let $\pi_{NO}(L)$ be defined analogously for a non-LPG firm. Notice that both $\pi_{LPG}(L)$ and $\pi_{NO}(L)$ only depend on parameters that, by assumption 3, are identified. Hence, we can also identify $\pi_{LPG}(L)$ and $\pi_{NO}(L)$. A firm will offer an LPG if its cost of offering the policy is not greater than $\int_0^\infty \pi_{LPG}(L) - \pi_{NO}(L) \, dH(L)$. Let $\alpha$ be the proportion of LPG firms, in equilibrium. The following equation must hold.

$$G\left(\int_0^\infty \pi_{LPG}(L) - \pi_{NO}(L) \, dH(L)\right) = \alpha$$

Notice that we can estimate $\alpha$ directly from the data. Let $LPG_i$ be a dummy variable that takes the value 1 if firm $i$ offers an LPG and 0 otherwise. We can estimate $\alpha$ as

$$\hat{\alpha} = \frac{1}{N} \sum_{i=1}^N LPG_i.$$

We can then identify $G^{-1}(\alpha)$ as

$$G^{-1}(\alpha) = \int_0^\infty \pi_{LPG}(L) - \pi_{NO}(L) \, dH(L)$$

Without any further assumptions, this is all we can identify about $G$. We can identify the cutoff that makes firms indifferent between offering and not offering an LPG, and we can identify the fraction of firms that will have a cost of offering an LPG lower than that cutoff. It is not possible to identify anything else about $G$, because as long as the cutoff and the proportion of firms that have a cost lower than the cutoff are the same, the empirical observation will be the same, regardless of the other points of $G$.\(^{19}\)

### 4.3 Estimation results

The structural analysis is performed, separately, for the two tires - Defender and Premier. I assume that loyal consumers follow the exponential distribution. In Section 4.4, I check for

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\(^{18}\)By variable profit I mean the profit before paying the fixed cost of offering an LPG.  
\(^{19}\)If we took a parametric approach for treating $G$, we could potentially identify the entire distribution. I choose not to do that because $G$ is not needed to compute the counterfactual, i.e., what would happen if firms were not allowed to offer LPGs. The entire analysis can be carried out without any further knowledge of $G$. 

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robustness to other distributions. The results are presented in the first column of Tables 7 and 8.

I find that between 17 to 20 percent of consumers are informed and, out of the consumers that are uninformed, between 23 to 40 percent have a low search cost. I also find that consumers only consider between 2 to 3 stores. This seems reasonable as the stores are not very close to each other. It would be unlikely that a consumer would search for a tire in a store other than the 3 nearest stores to him, because that would imply incurring relatively large traveling costs. I find that the parameter $q$ - that represents the probability that a consumer with a high search cost in period 1 will have a low search cost in period 2 - is close to 1. This, however, is not surprising. LPGs typically allow consumers between two weeks and one month to find a lower price. Having a high search cost in period 1 means that, when the consumer needs the tire, his time is very costly. However, having a low search cost in period 2 simply means that, at some point during the period that he has to activate the LPG, he will have some free time to search for a lower price. In that sense, the second period is larger than the first and, having a low search cost in the second period simply means that the consumer will have a low search cost at some point in the duration of that period. It is then not surprising that $q$ is high.\footnote{The fact that $q$ is high does not imply that LPGs will be redeemed very often. As shown in Section ??, high values of $q$ imply that LPG firms have lower prices. Hence, even after searching in the second period, consumers are likely not to find a lower price.} Finally, I find the high search cost to be about $25. I find this to be reasonable, given that the MSRP for these tires is between $146 and $166. Moreover, as previously mentioned, the stores are relatively far from each other, so the traveling costs are relatively high. In addition, many tire purchases are done after a burst, which increases the urgency to get the tire.

Figure 3 plots the predicted and observed cumulative price distributions for both LPG and non-LPG stores, for the Defender tire. Table 9 presents a comparison of moments from
both the observed and predicted distributions. Figure 4 and Table 10 are analogous for the Premier tire.

[insert figures 5 and 6 about here]

[insert Tables 9 and 10 about here]

### 4.4 Robustness Checks

In this section, I analyze whether the estimates are robust to other specifications. The results of the various robustness tests are presented in Tables 7 and 8.

**Location**

As discussed in Section 3, even though the stores in the sample belong to the same metropolitan area (all stores are located within 50 miles from Chicago), it is still important to check whether there are significant differences across locations. If some region has very different prices than the remaining regions, it is likely that it constitutes a different market and, therefore, the stores in that region should not be bundled together with the remaining stores when I perform the empirical analysis.

In Appendix C, I perform a t-test analysis to check whether each region has the same proportion of stores that offer an LPG as the remaining regions, and conclude that, at a 5% significance level, only the South Cook region fails the test. South Cook has a much larger fraction of stores offering LPGs. The south of Cook county is much poorer than the remaining regions. As it is well documented in the literature (e.g., Marvel (1976); Masson and Wu (1974); Phlips (1989)), poor consumers tend to have lower search costs. The model presented in this paper implies that the more consumers with low search cost, the higher the proportion of stores that will offer LPGs. It is, then, not surprising that there are

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21 As detailed in Section ??, as the number of consumers with low search cost increases, the benefit from offering an LPG also increases. Hence, the more consumers with low search cost, the higher the cost that firms are willing to incur in order to offer an LPG. This translates into more firms offering the policy.
so many stores offering LPGs in the south of Cook county. Regarding prices, only Porter county seems to have a significantly higher price than the remaining regions.

As a robustness test, I perform an estimation in which I do not include stores in those two regions - South Cook and Porter. As reported in tables 7 and 8, the results do not change significantly.

**Distribution of Loyal consumers**

I have assumed that loyal consumers follow an exponential distribution. I test for robustness by performing the estimation assuming that loyal consumers follow the Rayleigh distribution and the uniform distribution bounded below by 0. In Appendix D, I show that all these distributions satisfy Assumption 2, so the parameters are identified. As reported in tables 7 and 8, the estimates are very similar, regardless of the functional form for the distribution of loyal consumers. The distance between the predicted and observed price distributions is also very similar, for all functional forms.

**Heterogeneity between chain and non-chain stores**

As table 5 shows, chain stores are three times more likely to offer an LPG than non-chain stores. This suggests that there may be some heterogeneity in the cost of offering the LPG policy. The estimation performed in the previous section allows for this kind of heterogeneity, as the model does not prevent firms from having different costs for offering LPGs. Moreover, the empirical observation that chain stores offer an LPG more often is consistent with the predictions of the model, as chain stores may enjoy economies of scale in advertising and acquiring the necessary software to process the refunds, so they would face a lower cost for offering LPGs.

As reported in table 6, chain stores offer, on average, lower prices. This indicates that there may be some cost heterogeneity between chain and non-chain stores. This source of
heterogeneity is not surprising, as chains buy a much larger quantity of tires than non-chain stores and, therefore, they may have a higher bargaining power which allows them to purchase the tires at a lower price. However, the estimation performed in the previous section assumed cost homogeneity across firms. In this subsection, I will estimate a model that allows for cost heterogeneity.

Another interesting feature of the data is that all stores from the same chain set the same price. This is true for all 6 chains in the data. This fact is very likely due to management restrictions that do not allow stores to set their own price. So, not only chains have different costs, they also solve a different problem than non-chain stores. Whereas non-chain stores maximize their profits after observing their share of loyal consumers, chain-stores maximize the total profit of all stores in the chain, after observing the share of loyal consumers to each store. As profits are linear in loyal consumers, a chain will use the average number of loyal consumers to its stores.\(^{22}\) Let \(k\) be the number of stores in the chain. Chain stores will choose their price after observing \(\frac{1}{k} \sum_{j=1}^{k} L_j\). As \(L_j \sim Exp(\Theta)\), it follows that \(\frac{1}{k} \sum_{j=1}^{k} L_j \sim Gamma(k, \frac{\Theta}{k})\). In the data, the average number of stores per chain is 27, so I use that number for the structural estimation.

Chain and non-chain stores will differ in two aspects: chain stores face a lower production cost and they draw many observations for the number of loyal consumers, whereas non-chain stores only draw one observation. The estimation procedure is in the same spirit as the one presented in Section 4.1. The model predicts 4 price distributions - each type of firm (chain and non-chain) will have two cdfs, one for when they offer LPGs and other for when they do not. Let \(F^t_A\) denote the predicted price distribution for a firm of type \(t \in \{c,n\}\) that chooses LPG policy \(A \in \{LPG, NO\}\) (here type \(c\) denotes a chain store and type \(n\) denotes a non-chain store). Let \(D^t_A\) be defined analogously for the observed price distribution. I

\(^{22}\)Profits can be written as: \(\pi = \phi(\lambda, \mu, q, n, c, F, p) + L(p - c)\). Let \(k\) be the number of stores in the chain. It follows that \(\arg \max_p \sum_{j=1}^{k} \left\{ \phi(\lambda, \mu, q, n, c, F, p) + L_j(p - c) \right\} = \arg \max_p \left\{ \phi(\lambda, \mu, q, n, c, F, p) + \left[ \frac{1}{k} \sum_{j=1}^{k} L_j \right] (p - c) \right\} \)
choose the parameters that minimize

$$
\int_0^\infty \sum_{t \in \{c, n\}} \left[ F_t^A(x; \lambda, \mu, q, n, s_H, c, \gamma) - D_t^A(x) \right]^2 dx
$$

As reported in table 7, regarding the estimation for the Defender tire, the parameter estimates do not change significantly when I allow for heterogeneity between chain and non-chain stores. I also find that chain stores are able to purchase the tire from Michelin for about $3 less than non-chain stores. Table 8 shows the parameter estimates for the Premier tire. I find that, when allowing for heterogeneity between chain and non-chain stores, $\mu$ - the proportion of consumers with low search cost in period 1 - decreases from around 40% to around 30%. The remaining parameter estimates do not change significantly. I also estimate that chain stores purchase the tire for around $10 less than non-chain stores.

5 Welfare Analysis

Measuring the impact that LPGs have on consumers is challenging, because we only observe firms’ behavior in a setting that allows for LPGs. In order to measure the effect of LPGs on consumer welfare, a counterfactual analysis is needed. In this section, I use the structural estimates from the previous section to construct the price distribution that we would observe in the market, if firms were not able to offer LPGs.

5.1 Counterfactual

Informed consumers would not change their behavior, in the absence of LPGs. In fact, these consumers were already not taking into account firms’ LPG policies. In the absence of LPGs, uninformed consumers with low search cost would behave as informed consumers, i.e., they would purchase the product at the lowest-price store. Uninformed consumers with high search cost and loyal consumers will still purchase the good at the first store they visit.
However, they can no longer claim refunds in period 2, if they happen to find a lower price by then. The construction of the counterfactual equilibrium is detailed in Appendix B.

5.2 Welfare implications

After constructing the counterfactual equilibrium, we are left with two cdfs on prices: one that describes the price distribution we currently observe, and another that describes the price distribution that we would observe if LPGs were not allowed. Figures 5 and 6 plot the current and counterfactual price distributions for the Defender and Premier tires, respectively. Using these price distributions, I construct three indicators to measure the impact of LPGs on consumer welfare.

The most natural indicator is the change in the average price that would occur if LPGs were not allowed. Although this indicator is an interesting predictor of how firm behavior would change, it is not the most accurate measure of the impact of LPGs on consumers. In fact, consumers pay different prices, depending on their information and search cost. The average price paid by consumers is not necessarily the average price that firms charge.

I also measure the change in the transaction price. This is a direct indicator of consumers’ welfare, as it measures the monetary savings that consumers would make if LPGs were not allowed. Figures 7 and 8 plot the current and counterfactual distributions of transaction prices for the Defender and Premier tires, respectively.

Finally, I measure the change in the expected lowest price. This indicator is of particular interest, as the lowest price in the market is the price paid by consumers that have low search costs. As it is well documented in the literature (eg. Marvel (1976); Masson and Wu (1974); Philips (1989)), consumers that have low search costs tend to be the least wealthy. Hence, this indicator is a good measure of how LPGs impact the welfare of poor consumers.

The results are reported in Tables 11 and 12. I find that LPGs hurt consumers and, in the absence of this policy, transaction prices would decrease by between 3.75% - for the
Defender tire - and 10.07% - for the Premier tire. As the tables show, this result is robust to all the different specifications discussed in Section 4.4.

[insert Tables 11 and 12 about here]

Another interesting finding is that the expected lowest price would decrease by more than the average transaction price. Consumers that have a low search cost would see prices reduced by between 4.31% - for the Defender tire - and 11.92% - for the Premier tire - if LPGs were not allowed in the market. Not only LPGs hurt consumers, they have the largest effect on price-sensitive consumers, who tend to be the poorest. This finding is also robust to the different specifications detailed in Section 4.4.

Forbidding LPGs would have no impact on the search costs incurred by consumers. Informed consumers would still purchase the good at the lowest-price store. Consumers with zero search cost would search all stores, regardless of whether or not LPGs are allowed. Uninformed consumers with high search cost will, in equilibrium, purchase the product at the first store they visit, regardless of whether LPGs are allowed. However, if LPGs are allowed, they may search more stores in the second period. But they will only do so if they happen to have zero search cost in that period. Hence, the total search cost incurred by these consumers is the same, regardless of whether or not LPGs are allowed.\footnote{If, instead of zero search cost, there was a positive search cost, the search costs incurred by consumers would be higher in the presence of LPGs.} Finally, loyal consumers will purchase the product at the first store they visit, and they will never search any other store, regardless of firms’ LPG policies.

Moreover, if LPGs were not allowed, firms would not incur costs associated with offering LPGs (advertising, software to process the refunds, qualified personnel to work with the software, etc.). By forbidding LPGs in this market, not only would we observe a welfare transfer from firms to consumers (via lower prices), but also total surplus would increase.

The findings in this paper support efforts made by antitrust authorities to stop firms from price matching. Even though LPGs may sound procompetitive and consumers may believe
that these policies are in their best interest, they are regarded by antitrust authorities as a tool that firms use to extract a higher surplus from consumers. The results presented here support antitrust authorities’ view. However, this does not imply that LPGs are always bad for consumers. As discussed in Section ??, depending on the markets characteristics, LPGs may benefit consumers. Before forbidding firms from using this policy in a given market, a careful analysis of that market should be carried out to find whether LPGs are indeed hurting consumers.

5.3 The drawbacks of reduced form analysis

Table 13 presents, for each region, the proportion of stores offering LPGs as well as average prices for both tires. It would be tempting to run a simple regression of average price on the proportion of stores that offer LPGs, in order to find whether LPGs lead to higher or lower prices. Figures 9 and 10 present a scatter plot of average price and proportion of stores that offer LPGs. I find that regions that have a higher fraction of stores offering LPGs also have lower prices. However, it would be a mistake to conclude, just based on this information, that LPGs lead to lower prices. In fact, this result is possibly due to positive correlation between the costs of offering LPGs and marginal costs.

[insert Table 13 about here]

Chain stores are three times more likely to offer an LPG than non-chain stores. Moreover, as previously discussed, chain stores tend to have lower marginal costs. Hence, it is expected that chain stores will list lower prices than the remaining stores. It is then expected that regions with higher concentration of stores offering LPGs will have lower average prices, simply because those stores tend to have lower marginal costs.

Another interesting feature of chains is that they set the same price at every store. Hence, their price decision does not depend on the number of nearby stores that offer an LPG. Rather than analyzing how the average price moves with the proportion of LPGs in
a region, it is more relevant to examine how the average price of non-chain stores responds to the proportion of stores that offer an LPG. In fact, only non-chain stores can condition their price on the proportion of nearby stores that offer LPGs.

As table 14 shows, when we only consider non-chain stores, the effect of the proportion of LPGs on prices loses significance. However, even if LPGs had no impact on prices, we would still expect that stores located in regions with higher concentration of LPG stores would offer lower prices. Because those regions have a high proportion of stores that have low marginal costs and, therefore, set lower prices, it is expected that the remaining stores will reply to this increased competition with lower prices.

[insert Table 14 about here]

There are two effects present when a store decides on its price. On one hand, the store considers the proportion of nearby stores that offer an LPG. On the other hand, the store also takes into account the price distribution in nearby stores. As stores that have low costs of offering LPGs also have low marginal costs, it is not possible to disentangle these two effects using reduced-form analysis.

6 Conclusion

Although antitrust authorities believe that LPGs hurt consumers, there is no empirical economic framework to back up those claims. Even though the results presented in this paper support antitrust authorities’ views, I do not claim that LPGs should never be allowed. In fact, depending on the characteristics of each market, LPGs can either help or hurt consumers. In order to analyze whether LPG policies should be forbidden in a given market, a careful analysis of that market should be carried out. This paper provides the empirical tools to analyze each market and take an informed decision on whether or not to forbid firms from employing LPGs.
This paper focuses on LPGs. However, as Arbatskaya et al. (2004) point out, these promises sometimes take the form of price-beating guarantees, where firms refund more than the difference between the listed price and a lower price found in another store. These guarantees can be specified in many alternative ways. The more common are a percentage of the difference (e.g. 120% of the difference) and the difference plus an absolute amount (e.g. the difference plus $10). Analyzing the coexistence of this variety of guarantees is a possible avenue for future research.

References


7 Tables
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<td>341</td>
<td>Exp Rayleigh Uniform Exp Exp Exp</td>
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<td></td>
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<td>Exp Rayleigh Uniform Exp Exp Exp</td>
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<tr>
<td></td>
<td>(0.02)</td>
<td>307</td>
<td>Exp Rayleigh Uniform Exp Exp Exp</td>
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</table>

Table 7: Parameter estimates for Defender tire

Note: Standard errors were computed using the bootstrap resampling method, with 100 resamples
<table>
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<tr>
<th></th>
<th>0.17</th>
<th>0.18</th>
<th>0.19</th>
<th>0.17</th>
<th>0.18</th>
<th>0.18</th>
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<tbody>
<tr>
<td>λ</td>
<td>(0.03)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>μ</td>
<td>0.40</td>
<td>0.38</td>
<td>0.36</td>
<td>0.39</td>
<td>0.31</td>
<td>0.32</td>
</tr>
<tr>
<td>q</td>
<td>(0.09)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.04)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
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<td>3</td>
</tr>
<tr>
<td>cL</td>
<td>96</td>
<td>92</td>
<td>92</td>
<td>96</td>
<td>81</td>
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</tr>
<tr>
<td>cH−cL</td>
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<td></td>
<td></td>
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<tr>
<td>sH</td>
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<td>25.82</td>
<td>25.86</td>
<td>24.35</td>
<td>20.59</td>
<td>21.13</td>
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<tr>
<td>Θ</td>
<td>0.013</td>
<td>0.013</td>
<td>0.0023</td>
<td>0.013</td>
<td>0.072</td>
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<td></td>
<td>(0.01)</td>
<td>(0.01)</td>
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<td></td>
<td></td>
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<td>279</td>
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<td>279</td>
<td>250</td>
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<td>Distribution of loyal consumers</td>
<td>Exp</td>
<td>Rayleigh</td>
<td>Uniform</td>
<td>Exp</td>
<td>Exp</td>
<td>Exp</td>
</tr>
<tr>
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<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Includes South Cook and Porter</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

Table 8: Parameter estimates for Premier tire

Note: Standard errors were computed using the bootstrap resampling method, with 100 resamples
### Table 9: Defender Tire - Model Fit: comparing the model’s prediction with the data

<table>
<thead>
<tr>
<th></th>
<th>LPG stores</th>
<th></th>
<th>Non-LPG stores</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model</td>
<td>Data</td>
<td>Model</td>
<td>Data</td>
</tr>
<tr>
<td>Mean</td>
<td>122.86</td>
<td>122.97</td>
<td>133.68</td>
<td>134.35</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>4.00</td>
<td>4.62</td>
<td>11.15</td>
<td>12.32</td>
</tr>
<tr>
<td>25th percentile</td>
<td>120</td>
<td>121.5</td>
<td>126.5</td>
<td>123.5</td>
</tr>
<tr>
<td>Median</td>
<td>122.5</td>
<td>121.5</td>
<td>135</td>
<td>133</td>
</tr>
<tr>
<td>75th percentile</td>
<td>125.5</td>
<td>125</td>
<td>143.5</td>
<td>147</td>
</tr>
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</table>

### Table 10: Premier Tire - Model Fit: comparing the model’s prediction with the data

<table>
<thead>
<tr>
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<th>LPG stores</th>
<th></th>
<th>Non-LPG stores</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model</td>
<td>Data</td>
<td>Model</td>
<td>Data</td>
</tr>
<tr>
<td>Mean</td>
<td>147.92</td>
<td>147.75</td>
<td>156.74</td>
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<td>Standard Deviation</td>
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<td>8.90</td>
<td>19.32</td>
<td>18.27</td>
</tr>
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<td>25th percentile</td>
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<tr>
<td>Median</td>
<td>146</td>
<td>143</td>
<td>164.5</td>
<td>160</td>
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<tr>
<td>75th percentile</td>
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<td>157</td>
<td>175</td>
<td>173</td>
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</table>

Table 9: Defender Tire - Model Fit: comparing the model’s prediction with the data

Table 10: Premier Tire - Model Fit: comparing the model’s prediction with the data
<table>
<thead>
<tr>
<th></th>
<th>Defender tire</th>
<th>Premier tire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variation in transaction price</td>
<td>-3.75% -4.84% -4.45% -3.14% -1.95% -2.69% (1.27%) (1.07%) (0.98%) (0.65%)</td>
<td>-10.07% -10.66% -10.12% -9.71% -10.86% -9.14% (2.00%) (1.77%) (2.04%) (2.13%)</td>
</tr>
<tr>
<td>Variation in average price</td>
<td>-3.76% -4.84% -4.47% -3.19% -2.25% -3.01% (1.22%) (1.03%) (0.94%) (0.72%)</td>
<td>-10.69% -11.25% -10.68% -10.31% -11.57% -9.90% (1.92%) (1.69%) (1.89%) (2.13%)</td>
</tr>
<tr>
<td>Variation in minimum price</td>
<td>-4.31% -5.46% -5.06% -3.57% -2.82% -3.47% (1.37%) (1.16%) (1.07%) (0.69%)</td>
<td>-11.92% -12.58% -11.99% -11.50% -12.53% -10.92% (2.11%) (1.83%) (2.07%) (2.22%)</td>
</tr>
<tr>
<td>Cost Heterogeneity</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Includes South Cook and Porter</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Table 11: Welfare implications for Defender tire
Note: Standard errors were computed using the bootstrap resampling method, with 100 resamples

<table>
<thead>
<tr>
<th></th>
<th>Defender tire</th>
<th>Premier tire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variation in transaction price</td>
<td>-3.75% -4.84% -4.45% -3.14% -1.95% -2.69% (1.27%) (1.07%) (0.98%) (0.65%)</td>
<td>-10.07% -10.66% -10.12% -9.71% -10.86% -9.14% (2.00%) (1.77%) (2.04%) (2.13%)</td>
</tr>
<tr>
<td>Variation in average price</td>
<td>-3.76% -4.84% -4.47% -3.19% -2.25% -3.01% (1.22%) (1.03%) (0.94%) (0.72%)</td>
<td>-10.69% -11.25% -10.68% -10.31% -11.57% -9.90% (1.92%) (1.69%) (1.89%) (2.13%)</td>
</tr>
<tr>
<td>Variation in minimum price</td>
<td>-4.31% -5.46% -5.06% -3.57% -2.82% -3.47% (1.37%) (1.16%) (1.07%) (0.69%)</td>
<td>-11.92% -12.58% -11.99% -11.50% -12.53% -10.92% (2.11%) (1.83%) (2.07%) (2.22%)</td>
</tr>
<tr>
<td>Cost Heterogeneity</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Includes South Cook and Porter</td>
<td>Yes</td>
<td>Yes</td>
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</tbody>
</table>

Table 12: Welfare implications for Premier tire
Note: Standard errors were computed using the bootstrap resampling method, with 100 resamples
<table>
<thead>
<tr>
<th>County</th>
<th>Proportion of LPG stores</th>
<th>Average Price Defender</th>
<th>Average Price Premier</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Cook</td>
<td>42%</td>
<td>124.63</td>
<td>151.41</td>
<td>19</td>
</tr>
<tr>
<td>Northwest Cook</td>
<td>27%</td>
<td>130.78</td>
<td>155.37</td>
<td>37</td>
</tr>
<tr>
<td>South Cook</td>
<td>71%</td>
<td>124.62</td>
<td>147.47</td>
<td>24</td>
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<tr>
<td>Southwest Cook</td>
<td>50%</td>
<td>126.91</td>
<td>148.42</td>
<td>22</td>
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<tr>
<td>West Cook</td>
<td>48%</td>
<td>127.01</td>
<td>150.00</td>
<td>23</td>
</tr>
<tr>
<td>Chicago</td>
<td>30%</td>
<td>129.77</td>
<td>154.66</td>
<td>20</td>
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<tr>
<td>Dupage</td>
<td>31%</td>
<td>129.84</td>
<td>150.16</td>
<td>52</td>
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<tr>
<td>Kane</td>
<td>52%</td>
<td>129.63</td>
<td>152.71</td>
<td>23</td>
</tr>
<tr>
<td>Kankakee</td>
<td>33%</td>
<td>137.16</td>
<td>140.50</td>
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<tr>
<td>Kendall</td>
<td>40%</td>
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<td>151.00</td>
<td>5</td>
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<td>La Porte</td>
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<td>153.00</td>
<td>5</td>
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<td>Lake</td>
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<td>63</td>
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<td>McHenry</td>
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<td>133.63</td>
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<td>Porter</td>
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<td>10</td>
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<td>Will</td>
<td>36%</td>
<td>131.83</td>
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Table 13: Summary statistics by region

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<th>Price_nonch</th>
<th>Price_all</th>
<th>Price_nonch</th>
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<td>Proportion_LPG</td>
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<td>-14.84*</td>
<td>1.66</td>
<td>-30.84***</td>
<td>-18.80**</td>
<td>-9.89</td>
</tr>
<tr>
<td></td>
<td>(4.35)</td>
<td>(7.08)</td>
<td>(11.79)</td>
<td>(7.20)</td>
<td>(7.05)</td>
<td>(12.18)</td>
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<td>Average_Price</td>
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<td></td>
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<td></td>
</tr>
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<td></td>
<td>(0.46)</td>
<td></td>
<td></td>
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<td>Tire Observations</td>
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<td>11</td>
<td>181</td>
<td>11</td>
<td>11</td>
<td>122</td>
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<tr>
<td>R-squared</td>
<td>0.695</td>
<td>0.328</td>
<td>0.071</td>
<td>0.671</td>
<td>0.441</td>
<td>0.068</td>
</tr>
</tbody>
</table>

Standard errors in parentheses
*** p < 0.01, ** p < 0.05, * p < 0.1

Table 14: Reduced Form Estimates
8 Figures
Figure 3: Defender Tire - Model Fit

Figure 4: Premier Tire - Model Fit
Figure 5: Price distribution - Defender Tire

Figure 6: Price distribution - Premier Tire
Figure 7: Distribution of transaction prices - Defender Tire

Figure 8: Distribution of transaction prices - Premier Tire
Figure 9: Scatter Plot of average price and proportion of LPG stores by region - Defender Tire

Figure 10: Scatter Plot of average price and proportion of LPG stores by region - Premier Tire
Appendix

A  Proofs

Proof of Proposition 2

Proof. That the choice of LPG policy follows a cutoff rule is trivial. That the choice of price is increasing in the number of loyal consumers follows from the fact that profits have strictly increasing differences in prices and loyal consumers.

After committing on their LPG policy, a firm’s type is defined by their policy and their number of Loyal consumers. Let $x_{i,A}$ be the strategy of a firm that has LPG policy $A$ and $i$ loyal consumers. Let $\alpha$ be the probability that a firm offers an LPG.

To show that an equilibrium exists, I will use the results in Reny (1999). Since the sum of the players’ profits is continuous in prices, it follows from Proposition 5.1 in Reny (1999) that the game is reciprocally upper semicontinuous.

I will now show that the game is payoff secure, as defined in Reny (1999). (See definitions ?? and ?? in the Proof of Proposition ??

I will show that each type of firm ($A \in \{LPG, NO\}$) can secure a payoff of $u_i(x) - \epsilon$ at $x$, by choosing $x_{i,A} - \epsilon$

I will start with the firms that do not offer an LPG. Let $G$ be the distribution over loyal consumers

Let $P_{i,x,A}$ denote the probability that a firm that has policy $A$ and $i$ loyal consumers will have the lowest price, given that players strategies are $x$. Let $Q(i, x)$ denote the probability that a firm that does not offer an LPG and has $i$ loyal consumers will have the lowest price and no other firm offers an LPG. Formally,

$$P_{i,A,x} = \left( \int \alpha \mathbb{1}_{\{x_{i,LPG} > x_{i,A}\}} + (1 - \alpha) \mathbb{1}_{\{x_{i,NO} > x_{i,A}\}} dG(t) \right)^{n-1}$$
\[ Q_{i,x} = \left( \int (1 - \alpha) \mathbb{1} \{ x_{t,NO} > x_{i,A} \} dG(t) \right)^{n-1} \]

We can write firm’s profits as

\[ \pi_i(x, NO) = \left[ \lambda P_{i,NO,x} + \frac{(1-\lambda)(1-\mu)}{n} + (1-\lambda)\mu Q_{i,x} \right] x_{i,NO} \]

Fix \( \epsilon > 0 \). Notice that for all \( x'_{-i} \) such that \( |x'_{-i} - x_{-i}| < \epsilon \), \( P_{i,NO,(x_{i,\epsilon},x'_{-i})} \geq P_{i,NO,x} \) and \( Q_{i,(x_{i,\epsilon},x'_{-i})} \geq Q_{i,x} \). Hence

\[
\pi_i((x_{i,\epsilon},x'_{-i}), NO) = \left[ \lambda P_{i,NO,(x_{i,\epsilon},x'_{-i})} + \frac{(1-\lambda)(1-\mu)}{n} + (1-\lambda)\mu Q_{i,x} \right] (x_{i,NO} - \epsilon)
\geq \left[ \lambda P_{i,NO,x} + \frac{(1-\lambda)(1-\mu)}{n} + (1-\lambda)\mu Q_{i,x} \right] (x_{i,NO} - \epsilon)
\]

The argument for firms that offer an LPG is similar. Profits of LPG firms are

\[
\pi_i(x, LPG) = \lambda P_{i,LPG,x} x_{i,LPG} + \frac{(1-\lambda)(1-\mu)}{n}[(1-q)x_{i,LPG} + qEmin(x_{i,LPG},x_{-i})] + (1-\lambda)\mu \sum_{j=0}^{n-1} (1-\alpha)^jEmin(x_{i,LPG},x_{-i}/j)
\]

Fix \( \epsilon > 0 \). Notice that for all \( x'_{-i} \) such that \( |x'_{-i} - x_{-i}| < \epsilon \), \( P_{i,LPG,(x_{i,\epsilon},x'_{-i})} \geq P_{i,LPG,x} \). Moreover, \( Emin(x_{i,LPG} - \epsilon, x'_{-i}) \geq Emin(x_{i,LPG}, x_{-i}) - \epsilon \). It then follows that

\[
\pi_i((x_{i,\epsilon}, x'_{-i}), LPG) > \pi_i(x, LPG) - \epsilon
\]

Since the game is both reciprocally upper semicontinuous and payoff secure, it follows from Corollary 5.2 in Reny (1999) that there exists a Nash equilibrium.

To show that the equilibrium involves pure strategies, notice that since prices are increasing in the number of loyal consumers, if a type is mixing on prices, he is the only one playing those prices. Moreover, he must be mixing on a convex set of prices. Consider a firm that offers an LPG policy \( A \in \{LPG, NO\} \). Suppose that the firm’s number of loyal consumers is such that she will play mixed prices on \((a,b)\). It follows that no other firm that chooses \( A \) and has a different number of loyal consumers is playing prices on \((a,b)\). Since the distribution of types (loyal consumers) is continuously differentiable, it follows that the cdf
of prices conditional on LPG policy $A$ is flat on $(a, b)$. So every type that mixes on prices induces a flat region on the cdf of prices conditional in $A$. The number of flat regions in any cdf is countable. To see this, consider a flat region $(a, b)$ on a cdf. Since there exists a rational number in $(a, b)$ we can construct an injection from flat regions to rational numbers. Since rational numbers are countable, so are the flat regions of the cdf. So only countably many types will play mixed strategies. The measure of countable sets is zero, so the measure of types that play pure strategies is 1.

\[ \square \]

**Proof of Proposition 3**

Let $F_{LPG}$ and $F_{NO}$ be the equilibrium price distributions of firms that offer LPGs and firms that do not, given that the parameters are $(\lambda, \mu, q, n, c, s_H, \Theta)$. Let $\alpha$ denote the probability that a firm will offer an LPG and define $F \equiv \alpha F_{LPG} + (1 - \alpha) F_{NO}$. The parameters are identified if there is no other set of parameters that generate the same equilibrium price distributions.

First notice that $\alpha$ is identified (as detailed in Section 4.2).

Let $p$ denote the upper bound of the support of $F$.

**Lemma 1** $s_H$ is identified

*Proof.* $s_H$ must be such that a loyal consumer that observes the maximum price, $p$, will be indifferent between purchasing at that price and searching one more store. Therefore

$$s_H = p - \int_0^p x dF(x)$$

\[ \square \]

**Lemma 2** $n$ is identified

*Proof.* Since $p$ is the upper bound of the support of $F$, it follows that it is also either the upper bound of the support of $F_{NO}$ or the upper bound of the support of $F_{LPG}$. We will

\[ ^{24} \text{Special thanks to Mikhail Safronov for the key insight to prove this Lemma.} \]
assume that \( \bar{\pi} \) is the upper bound of the support of \( F_{NO} \). The proof for the other case is identical.

Let \( \pi_{NO}(x, L) \) denote the profits of a firm that does not offer an LPG, charges price \( x \) and has \( L \) loyal consumers.

\[
\pi_{NO}(x, L) = \left[ \lambda[1 - F(x)]^{n-1} + (1 - \lambda)\mu(1 - \alpha)^{n-1}[1 - F_{NO}(x)]^{n-1} + \frac{(1 - \lambda)(1 - \mu)}{n} + L \right] (x - c)
\]

Let \( L_{x}^{NO} \) be the number of loyal consumers of a firm that charges \( x \) and does not offer an LPG. The FOC implies that

\[
L_{x}^{NO} = -\frac{\partial}{\partial x} \left[ \lambda[1 - F(x)]^{n-1} + (1 - \lambda)\mu(1 - \alpha)^{n-1}[1 - F_{NO}(x)]^{n-1} \right] (x - c) - \frac{(1 - \lambda)(1 - \mu)}{n}
\]

Since \( L_{x}^{NO} = H^{-1}(F_{NO}(x), \Theta) = \omega(\Theta) \partial(F_{NO}(x)) \), we have that

\[
\partial(F_{NO}(x)) = -\frac{\partial}{\partial x} \left[ \lambda[1 - F(x)]^{n-1} + (1 - \lambda)\mu(1 - \alpha)^{n-1}[1 - F_{NO}(x)]^{n-1} \right] (x - c) - \frac{(1 - \lambda)(1 - \mu)}{n}
\]

Suppose \( n \) was not identified. Then, \( \exists (\lambda', \mu', q', n', c', \Theta') \neq (\lambda, \mu, q, n, c, \Theta) \) such that

\[
\frac{1}{\omega(\Theta)} \frac{\partial}{\partial x} \left[ \lambda'[1 - F(x)]^{n'-1} + (1 - \lambda')\mu'(1 - \alpha)^{n'-1}[1 - F_{NO}(x)]^{n'-1} \right] (x - c') - \frac{1}{\omega(\Theta')} \frac{(1 - \lambda')(1 - \mu')}{n'}
\]

Equivalently,

\[
\frac{1}{\omega(\Theta')} \frac{\partial}{\partial x} \left[ \lambda'[1 - F(x)]^{n'-1} + (1 - \lambda')\mu'(1 - \alpha)^{n'-1}[1 - F_{NO}(x)]^{n'-1} \right] (x - c') - \frac{1}{\omega(\Theta')} \frac{(1 - \lambda')(1 - \mu')}{n'}
\]

The RHS does not depend on \( x \), which implies that
\[ V(x) \equiv \frac{1}{\omega(\Theta')} \left[ \lambda'[1 - F(x)]^{n' - 1} + (1 - \lambda')\mu'(1 - \alpha)^{n' - 1}[1 - F_{NO}(x)]^{n' - 1} \right] (x - c') \]
\[ \quad - \frac{1}{\omega(\Theta)} \left[ \lambda[1 - F(x)]^{n-1} + (1 - \lambda)\mu(1 - \alpha)^{n-1}[1 - F_{NO}(x)]^{n-1} \right] (x - c) \]

is linear in \( x \).

I will now show that \( V(x) \) linear \( \implies n = n' \)

Define
\[ A(x) = \frac{1}{\omega(\Theta')} \left[ \lambda'[1 - F(x)]^{n' - 1} + (1 - \lambda')\mu'(1 - \alpha)^{n' - 1}[1 - F_{NO}(x)]^{n' - 1} \right] \]
\[ R(x) = A(x)[x - c'] \]
\[ B(x) = -\frac{1}{\omega(\Theta)} \left[ \lambda[1 - F(x)]^{n-1} + (1 - \lambda)\mu(1 - \alpha)^{n-1}[1 - F_{NO}(x)]^{n-1} \right] \]
\[ S(x) = B(x)[x - c] \]

So that
\[ V(x) = R(x) - S(x) \]

Notice that
\[ \frac{\partial^k R}{\partial x^k} = \frac{\partial^k A}{\partial x^k}[x - c'] + k \frac{\partial^{k-1} A}{\partial x^{k-1}} \]

Notice that \( \frac{\partial^k A}{\partial x^k} \) and \( \frac{\partial^k B}{\partial x^k} \) can be written as
\[ \frac{\partial^k A}{\partial x^k} = \sum_{j=n'-1-k}^{n'-2} \left\{ [1 - F(x)]^j T_j + [1 - F_{NO}(x)]^j K_j \right\} \text{ where } T_j \neq 0 \forall j \]
\[ \frac{\partial^k B}{\partial x^k} = \sum_{j=n-1-k}^{n-2} \left\{ [1 - F(x)]^j T_j + [1 - F_{NO}(x)]^j K_j \right\} \text{ where } T_j \neq 0 \forall j \]

Suppose that \( n > n' \) (the proof for \( n < n' \) is analogous).
\[ \frac{\partial^{n'-1} A}{\partial x^{n'-1}} \bigg|_{x=p} \neq 0 \]
\[ \frac{\partial^{n'-1} B}{\partial x^{n'-1}} \bigg|_{x=p} = 0 \]

Hence, \( \frac{\partial^{n'-1} V}{\partial x^{n'-1}} \neq 0 \).

If \( n' > 2 \), the above is a contradiction that \( V \) is linear. If \( n' = 2 \) and \( n > 2 \), then \( \frac{\partial^2 V}{\partial x^2} \neq 0 \), which also contradicts that \( V \) is linear.

\[ \square \]

**Lemma 3** \( c \) is identified

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Proof. We will use the result from Lemma 2 that states that \( n \) is identified.

Let \( L_x^{NO} \) be the number of loyal consumers of a firm that charges \( x \) and does not offer an LPG and \( L_x^{LPG} \) be analogous for a firm that offers an LPG.

Firms’ profits are

\[
\pi_{NO}(x, L) = [\lambda(1 - F(x)]^{n-1} + (1 - \lambda)\mu(1 - \alpha)^{n-1}[1 - F_{NO}(x)]^{n-1} + \frac{(1 - \lambda)(1 - \mu)}{n} + L](x - c)
\]

\[
\pi_{LPG}(x, L) = [\lambda(1 - F(x)]^{n-1} + L](x - c) + \frac{(1 - \lambda)(1 - \mu)}{n}[qx + (1 - q)Emin(x/0) - c] + (1 - \lambda)\mu\sum_{j=0}^{n-1}(1 - \alpha)^j[Emin(x/j) - c]
\]

where

\[
Emin(x/j) = \int_{0}^{x} \{(n - 1 - j)f(y)[1 - F(y)]^{n-2-j}[1 - F_{NO}(y)]^{j} + jf_{NO}(y)[1 - F(y)]^{n-1-j}[1 - F_{NO}(y)]^{j-1}\}ydy
\]

\[+ [1 - F_{NO}(x)]^{j}[1 - F(x)]^{n-1-j}x\]

The FOC of the firm’s maximization problem implies that

\[
\left. \frac{\partial \pi_{NO}(x, L)}{\partial x} \right|_{L = L_x^{NO}} = 0 \quad \text{and} \quad \left. \frac{\partial \pi_{LPG}(x, L)}{\partial x} \right|_{L = L_x^{LPG}} = 0.
\]

Solving we get

\[
L_x^{NO} = (1 - \lambda)\mu\left[(n - 1)(1 - \alpha)^{n-1}[1 - F_{NO}(x)]^{n-2}f_{NO}(x)(x - c) - (1 - \alpha)^{n-1}[1 - F_{NO}(x)]^{n-1}\right] + \\
\lambda\left[(n - 1)[1 - F(x)]^{n-2}f(x)(x - c) - [1 - F(x)]^{n-1}\right] - \frac{(1 - \lambda)(1 - \mu)}{n}
\]

\[
L_x^{LPG} = \lambda\left[(n - 1)[1 - F(x)]^{n-2}f(x)(x - c) - [1 - F(x)]^{n-1}\right] - \frac{(1 - \lambda)(1 - \mu)}{n}\left[1 - q[1 - F(x)]^{n-1}\right] \\
-(1 - \lambda)\mu\frac{[1 - F(x)]^{n-1} - (1 - \alpha)\frac{F_{NO}(x)}{1 - F(x)}^{n-1}}{1 - (1 - \alpha)\frac{F_{NO}(x)}{1 - F(x)}}
\]

\[
L_x^{NO} - L_x^{LPG} = (1 - \lambda)\left[\mu[A_x(x - c) + B_x] - (1 - \mu)qW_x\right]
\]

where

\[
A_x = (n - 1)(1 - \alpha)^{n-1}[1 - F_{NO}(x)]^{n-2}f_{NO}(x)
\]

\[
B_x = \frac{[1 - F(x)]^{n-1} - (1 - \alpha)\frac{F_{NO}(x)}{1 - F(x)}^{n-1}}{1 - (1 - \alpha)\frac{F_{NO}(x)}{1 - F(x)}}
\]
\[ W_x = -\frac{[1-[1-F(x)]^{n-1}}{n} \]

Since \( n \) is identified, \( A_x, B_x \) and \( W_x \) are also identified.

Notice that \( L_x^{NO} = H^{-1}(F_{NO}(x), \Theta) = \omega(\Theta)\vartheta(F_{NO}(x)) \) and \( L_x^{LPG} = H^{-1}(F_{LPG}(x), \Theta) = \omega(\Theta)\vartheta(F_{LPG}(x)) \). Hence, we have that

\[ \frac{L_x^{NO} - L_x^{LPG}}{\omega(\Theta)} = \vartheta(F_{NO}(x)) - \vartheta(F_{LPG}(x)) \]

Hence,

\[ \frac{L_x^{NO} - L_y^{NO}}{L_y^{NO} - L_y^{LPG}} = \frac{\vartheta(F_{NO}(x)) - \vartheta(F_{LPG}(x))}{\vartheta(F_{NO}(y)) - \vartheta(F_{LPG}(y))} \]

Define \( \tau_{x,y} \equiv \frac{\vartheta(F_{NO}(x)) - \vartheta(F_{LPG}(x))}{\vartheta(F_{NO}(y)) - \vartheta(F_{LPG}(y))} \). We have that

\[ (1-\lambda) \left[ \mu[A_x(x-c)+B_x]-(1-\mu)qW_x \right] = \tau_{xy} \]

Equivalently,

\[ \mu = \frac{q[W_x - \tau_{x,y}W_y]}{Z_{x,y} - c[A_x - \tau_{x,y}A_y]} \quad (5) \]

where

\[ Z_{x,y} = A_x x + B_x + qW_x - \tau_{x,y}A_y + B_y + qW_y \]

Notice that (5) must hold for all \( x \) and \( y \) in the support of \( F \). Hence,

\[ \frac{q[W_x - \tau_{x,y}W_y]}{Z_{x,y} - c[A_x - \tau_{x,y}A_y]} = \frac{q[W_w - \tau_{w,z}W_z]}{Z_{w,z} - c[A_w - \tau_{w,z}A_z]} \]

Equivalently,

\[ c = \frac{Z_{x,y}[W_w - \tau_{w,z}W_z] - Z_{w,z}[W_x - \tau_{x,y}W_y]}{[W_w - \tau_{w,z}W_z][A_x - \tau_{x,y}A_y] - [W_x - \tau_{x,y}W_y][A_w - \tau_{w,z}A_z]} \]

Notice that the RHS only depends on \( n \), which is identified. Hence, \( c \) is identified. \( \square \)
**Lemma 4** \( \lambda \) and \( \mu \) are identified

**Proof.** As shown in the proof of Lemma 3,

\[
L_x^{NO} = (1 - \lambda) \mu \left( (n - 1)(1 - \alpha)^{n-1}[1 - F_{NO}(x)]^{n-2}f_{NO}(x)(x - c) - (1 - \alpha)^{n-1}[1 - F_{NO}(x)]^{n-1} + \frac{1}{n} \right) + \lambda \left( (n - 1)[1 - F(x)]^{n-2}f(x)(x - c) - [1 - F(x)]^{n-1} + \frac{1}{n} \right) - \frac{1}{n}
\]

Define

\[
P_x = (n - 1)(1 - \alpha)^{n-1}[1 - F_{NO}(x)]^{n-2}f_{NO}(x)(x - c) - (1 - \alpha)^{n-1}[1 - F_{NO}(x)]^{n-1} + \frac{1}{n}
\]

\[
Q_x = (n - 1)[1 - F(x)]^{n-2}f(x)(x - c) - [1 - F(x)]^{n-1} + \frac{1}{n}
\]

It follows that \( L_x^{NO} = (1 - \lambda) \mu P_x + \lambda Q_x - \frac{1}{n} \)

Since \( n \) and \( c \) are identified, \( P_x \) and \( Q_x \) are also identified.

Since \( L_x^{NO} = H^{-1}(F_{NO}(x), \Theta) = \omega(\Theta) \vartheta(F_{NO}(x)) \), it follows that

\[
\frac{L_x^{NO}}{L_y^{NO}} = \frac{\vartheta(F_{NO}(x))}{\vartheta(F_{NO}(y))}
\]

Define \( \eta_{x,y} \equiv \frac{\vartheta(F_{NO}(x))}{\vartheta(F_{NO}(y))} \). We have that

\[
\frac{(1 - \lambda) \mu P_x + \lambda Q_x - \frac{1}{n}}{(1 - \lambda) \mu P_y + \lambda Q_y - \frac{1}{n}} = \eta_{x,y}
\]

Equivalently,

\[
\mu = \frac{\lambda [Q_x - \eta_{x,y}Q_y] - \frac{1}{n}[1 - \eta_{x,y}]}{(1 - \lambda)[\eta_{x,y}P_y - P_x]}
\]

Notice that (6) must hold for all \( x \) and \( y \) in the support of \( F \). Hence,

\[
\frac{\lambda [Q_x - \eta_{x,y}Q_y] - \frac{1}{n}[1 - \eta_{x,y}]}{(1 - \lambda)[\eta_{x,y}P_y - P_x]} = \frac{\lambda [Q_w - \eta_{w,z}Q_z] - \frac{1}{n}[1 - \eta_{w,z}]}{(1 - \lambda)[\eta_{w,z}P_z - P_w]}
\]

Equivalently,

\[
\lambda = \frac{n^{-1} \left[ [1 - \eta_{x,y}][\eta_{w,z}P_y - P_x] - [1 - \eta_{w,z}][\eta_{x,y}P_y - P_x] \right]}{[Q_x - \eta_{x,y}Q_y][\eta_{w,z}P_y - P_x] - [Q_w - \eta_{w,z}Q_z][\eta_{x,y}P_y - P_x]}
\]

Since the RHS only depends on \( n \) and \( c \), which are identified, it follows that \( \lambda \) is also identified. We can then identify \( \mu \) using (6). \( \square \)
Lemma 5 \( q \) is identified

Proof. As shown in the proof of Lemma 3,

\[
L_{x}^{LPG} = \lambda \left[ (n-1)[1-F(x)]^{n-2}f(x)(x-c) - [1-F(x)]^{n-1} \right] - \frac{(1-\lambda)(1-\mu)}{n} \left[ 1 - q \left[ 1 - [1-F(x)]^{n-1} \right] \right] \\
\quad - (1-\lambda)\mu \left[ 1 - F(x) \right]^{n-1} \frac{1 - \left( 1-\alpha \right) \frac{1-F_{NO}(x)}{1-F(x)}^{n}}{1 - (1-\alpha) \frac{1-F_{NO}(x)}{1-F(x)}}
\]

Define

\[
T_{x} = \lambda \left[ (n-1)[1-F(x)]^{n-2}f(x)(x-c) - [1-F(x)]^{n-1} \right] - \frac{(1-\lambda)(1-\mu)}{n} \left[ 1 - \left( 1-\alpha \right) \frac{1-F_{NO}(x)}{1-F(x)}^{n} \right] \\
\quad - (1-\lambda)\mu \left[ 1 - F(x) \right]^{n-1} \frac{1 - \left( 1-\alpha \right) \frac{1-F_{NO}(x)}{1-F(x)}}{1 - (1-\alpha) \frac{1-F_{NO}(x)}{1-F(x)}}
\]

\[
U_{x} = \frac{(1-\lambda)(1-\mu)}{n} \left[ 1 - [1-F(x)]^{n-1} \right]
\]

It follows that \( L_{x}^{LPG} = T_{x} + qU_{x} \). Since \( n, c, \lambda \) and \( \mu \) are identified, it follows that \( T_{x} \) and \( U_{x} \) are also identified.

Since \( L_{x}^{LPG} = H^{-1}(F_{LPG}(x), \Theta) = \omega(\Theta)\vartheta(F_{LPG}(x)) \), it follows that

\[
\frac{\vartheta(F_{LPG}(x))}{\vartheta(F_{LPG}(y))} = \frac{L_{x}^{LPG}}{L_{y}^{LPG}} = \frac{T_{x}+qU_{x}}{T_{y}+qU_{y}}
\]

Equivalently,

\[
q = \frac{T_{x}-T_{y} \vartheta(F_{LPG}(x))}{U_{y} \vartheta(F_{LPG}(x)) - U_{x} \vartheta(F_{LPG}(y)) - U_{x}}
\]

Since the RHS only depends on \( \lambda, \mu, n \) and \( c \), which are all identified, it follows that \( q \) is identified.

Lemma 6 \( H \) is identified

Proof. Since \( (\lambda, \mu, q, n, c) \) is identified, it follows that \( L_{x}^{NO} \) is also identified. We can then identify \( H \) as follows

\[
H(L_{x}^{NO}) = F_{NO}(x)
\]
B Computation

Equilibrium Construction

In order for the problem to be suitable for numerical analysis, I discretize the set of prices that firms can choose from. Let \( \{p_1, p_2, \ldots, p_k\} \) be the set of all prices, where \( p_1 = 0 \).

I will use \( F_{LPG} \) and \( F_{NO} \) to denote the cdf of prices of firms that offer LPGs and firms that do not offer LPGs, respectively. I use \( F \) to denote the cdf of prices, unconditional on the LPG policy. Let \( \alpha \) be the proportion of firms that offer an LPG. Then, \( F(p) = \alpha F_{LPG}(p) + (1 - \alpha) F_{NO}(p) \)

At the maximum price, \( p_k \), \( F_{LPG}(p_k) = F_{NO}(p_k) = 1^{25} \)

We construct \( F_{LPG} \) and \( F_{NO} \) by backward induction, i.e., knowing \( F_{LPG}(p_i) \) and \( F_{NO}(p_i) \) allows us to get \( F_{LPG}(p_{i-1}) \) and \( F_{NO}(p_{i-1}) \). The process is described below. I use \( E_{\min}(p) \) to denote the expected value of the minimum price in the market, given that a firm is charging \( p \) and \( E_{\min}(p/m) \) to denote the expected value of the minimum price in the market, given that a firm is charging \( p \) and at least \( m \) firms are not offering LPG

LPG firms

When a firm offers an LPG and charges price \( p \), it sells to

- All informed consumers if it has the lowest price, which has probability \( [1 - F(p)]^{n-1} \)
- All consumers with high search cost that enter the store (with probability \( q \) they will have a low search cost in period 2 and will come back for a refund, effectively paying the lowest price in the market)
- Loyal consumers
- All consumers with low search cost that enter the store

\(^{25}\text{This is without loss of generality since } p_k \text{ is also a parameter that we can choose.}\)
Let $\pi_{LPG}(p, L)$ denote the profit of a firm that offers an LPGs, has $L$ loyal consumers and charges price $p$.

$$\pi_{LPG}(p_i, L) = \lambda[1 - F(p_i)]^{n-1}(p_i - c) + \frac{(1 - \lambda)(1 - \mu)}{n} \left( (1 - q)p_i + qE_{min}(p_i) - c \right) + L(p_i - c) + (1 - \lambda)\mu n \sum_{m=0}^{n-1} (1 - \alpha)^m \left( E_{min}(p_i) - E_{min}(p_i/m) - c \right)$$

Firms that offer LPGs are indifferent between $p_i$ and $p_i - 1$ when their number of loyal consumers is

$$L = \frac{\lambda[1 - F(p_i-1)]^{n-1}(p_i-1-c) - [1 - F(p_i)]^{n-1}(p_i-c) + (1 - \lambda)(1 - \mu) \left[ (1 - q)(p_i-1-p_i) + qE_{min}(p_i-1) - E_{min}(p_i) \right] + (1 - \lambda)\mu \sum_{m=0}^{n-1} (1 - \alpha)^m \left( E_{min}(p_i) - E_{min}(p_i/m) \right)}{p_i - p_i - 1}$$

(7)

Since we can reduce

$$E_{min}(p_i-1) - E_{min}(p_i) = [1 - F(p_i)]^{n-1}(p_i-1 - p_i)$$

$$E_{min}(p_i-1/m) - E_{min}(p_i/m) = [1 - F(p_i)]^{n-1-m}[1 - F_{NO}(p_i)]^m(p_i-1 - p_i)$$

we can compute $L$, as long as we know $F_{LPG}(p_i)$, $F_{NO}(p_i)$ and $F(p_i-1)$.

The result in Proposition 2, that states that firms’ prices are increasing in its loyal consumers, leads to the conclusion that LPG firms will charge prices lower or equal than $p_i - 1$ when they have less than $L$ loyal consumers, i.e.

$$F_{LPG}(p_i-1) = H(L)$$

So, if we know $F(p_i-1)$, we can compute $F_{LPG}(p_i-1)$

**Firms that do not offer LPG**

When a firm does not offer LPG and charges price $p$, it sells to

- All informed consumers if it has the lowest price, which has probability $[1 - F(p)]^{n-1}$
• All consumers with high search cost that enter the store

• Loyal consumers

• All consumers with low search cost, if it has the lowest price and no store offers an LPG

Let $\pi_{NO}(p, L)$ denote the profit of a firm that does not offer LPGs, has $L$ loyal consumers and charges price $p$.

$$\pi_{NO}(p_i, L_N) = \left[ \lambda [1 - F(p_i)]^{n-1} + \frac{(1 - \lambda)(1 - \mu)}{n} + L_N + (1 - \lambda) \mu (1 - \alpha)^{n-1} [1 - F_{NO}(p_i)]^{n-1} \right] (p_i - c)$$

Firms that do not offer LPGs are indifferent between $p_i$ and $p_i - 1$ when their number of loyal consumers is

$$L_N = \lambda \left[ (1 - F(p_{i-1}))^{n-1} (p_{i-1} - c) - (1 - F(p_i))^{n-1} (p_i - c) \right] + \frac{(1 - \lambda)(1 - \mu)(p_{i-1} - p_i) + (1 - \lambda)\mu (1 - \alpha)^{n-1} \left[ 1 - F_{NO}(p_{i-1}) \right]^{n-1} (p_{i-1} - c) - [1 - F_{NO}(p_i)]^{n-1} (p_i - c)}{p_i - p_{i-1}}$$

(8)

We can compute $L_N$ as long as we know $F(p_{i-1})$ and $F_{NO}(p_{i-1})$

Again, the result in Proposition 2, that states that firms’ prices are increasing in its loyal consumers, leads to the conclusion that firms without LPG will charge prices lower or equal than $p_{i-1}$ when they have less than $L_N$ loyal consumers, i.e.

$$F_{NO}(p_{i-1}) = H(L_N)$$

So, if we can compute $L$ and $L_N$, we can find $F_{LPG}(p_{i-1})$ and $F_{NO}(p_{i-1})$. However, in order to do that, we need to know $F(p_{i-1})$ and $F_{NO}(p_{i-1})$, which is a problem, since we do not know it. I propose an algorithm that deals with that problem.

Algorithm

Step 1: Make a guess for $F_{NO}(p_{i-1})$, call it $FNO$
Step 2: Compute $L_N$ using $L_N = H^{-1}(FNO)$

Step 3: Using the guess from step 1 and $L_N$ from step 2, we can compute $F(p_{i-1})$ using (8)

Step 4: Using $F(p_{i-1})$ from Step 3, we can compute $L$ using (7) and use it to compute $F_{LPG}(p_{i-1})$ using $H(L) = F_{LPG}(p_{i-1})$

Step 5: If $\alpha FNO + (1 - \alpha)F_{LPG}(p_{i-1}) > F(p_{i-1})$, we guess a lower value for $FNO(p_{i-1})$. Otherwise, we make a higher guess.

**Equilibrium Construction of the Counterfactual**

In order for the problem to be suitable for numerical analysis, I discretize the set of prices that firms can choose from. Let $\{p_1, p_2, ..., p_k\}$ be the set of all prices, where $p_1 = 0$.

Let $F$ denote the equilibrium cdf played by firms. I construct $F$ by backward induction, i.e., knowing $F(p_i)$ allows to compute $F(p_{i-1})$. At the maximum price, $p_k$, $F(p_k) = 1$.

Let $\pi(p, L)$ denote the profit of a firm that charges price $p$ and has $L$ loyal consumers.

$$\pi(p, L) = \left[ \lambda + (1 - \lambda)\mu \right][1 - F(p)]^{n-1} + \frac{(1 - \lambda)(1 - \mu)}{n} + L \left( p - c \right)$$

Informed consumers and consumers with low search cost.

Probability that the firm has the lowest price.

Firms with high search cost that enter the store.

Firms are indifferent between listing price $p_i$ and $p_{i-1}$ when their number of loyal consumers is

$$L = \frac{[\lambda + (1 - \lambda)\mu][1 - F(p_{i-1})]^{n-1}(p_i - c) - [1 - F(p_i)]^{n-1}(p_i - c)}{p_i - p_{i-1}} - \frac{(1 - \lambda)(1 - \mu)}{n}$$

The result in Proposition 2, that states that a firm’s price is increasing in its loyal consumers, implies that firms will charge prices lower or equal than $p_{i-1}$ when they have less than $L$ loyal consumers, i.e.,

$$F(p_{i-1}) = H(L)$$
We can then find $F(p_{i-1})$ that solves

$$H^{-1}(F(p_{i-1})) = \frac{[\lambda+(1-\lambda)\mu]\left[(1-F(p_{i-1}))^{n-1}(p_{i-1}-c) - [1-F(p_i)]^{n-1}(p_i-c)\right]}{p_i-p_{i-1}} - \frac{(1-\lambda)(1-\mu)}{n}$$

In equilibrium, consumers with high search cost are indifferent between purchasing the product at the firm with the highest possible price and searching one more store. Hence, we can calculate the search cost as

$$s_H = p_k - \sum_{j=2}^{k} \left[F(p_j) - F(p_{j-1})\right] p_j$$

Finally, if $s_H > s_H$, we make a lower guess for $p_k$, otherwise we make a higher guess.
In order to examine whether there are significant differences between locations, I group stores by county. Since 145 stores are located in Cook county, I divide that county in 6 regions. Table 13 shows, for each region, the proportion of stores that offer an LPG, as well as the average price of each of the two tires.

In order to analyze whether the proportion of stores that offer an LPG varies significantly by location, I run a t-test to check if the proportion of stores that offer an LPG in each county is the same as the proportion of stores that offer an LPG in the remaining counties. I find that, at a significance level of 5%, we can only reject that the South Cook region has the same proportion of stores that offer an LPG as the remaining regions. After removing the South Cook region, we can no longer reject, at a significance level of 5%, that any region has the same proportion of stores that offer an LPG as the remaining regions. The p-values are reported in Table C.1. Regarding prices, the only region that seems to have a much different price than the remaining regions is Porter county, that has a much higher price for the Premier tire.
<table>
<thead>
<tr>
<th>County</th>
<th>p-values (all regions)</th>
<th>p-values (excluding South Cook)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Cook</td>
<td>0.61</td>
<td>0.45</td>
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<td>Northwest Cook</td>
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<td>0.29</td>
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<tr>
<td>South Cook</td>
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<td>McHenry</td>
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<td>0.59</td>
</tr>
<tr>
<td>Porter</td>
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<td>0.09</td>
</tr>
<tr>
<td>Will</td>
<td>0.98</td>
<td>0.84</td>
</tr>
</tbody>
</table>

Table C.1: testing that each region has the same proportion of stores offering LPG has the remaining regions
D A note on distribution functions

In this appendix, I show that all the distributions used in this paper satisfy Assumption 2

Exponential distribution

\[ F(x; \gamma) = 1 - e^{-\gamma x} \]

\[ F^{-1}(q; \gamma) = \frac{-1}{\gamma} \ln(1 - q) \]

Rayleigh distribution

\[ F(x; \sigma) = 1 - e^{-\frac{x^2}{2\sigma^2}} \]

\[ F^{-1}(q; \sigma) = \sqrt{2\sigma} \sqrt{-\ln(1 - q)} \]

Uniform distribution on [0,b]

\[ F(x; b) = \frac{x}{b} \]

\[ F^{-1}(q; b) = \frac{b}{\omega(b)} q \]

\[ \theta(q) \]