Firm Heterogeneities, Click-through Fees and Pricing in Oligopoly: Theory and Evidence

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Abstract

This paper examines the impact of firm heterogeneities on equilibrium pricing behavior in an online market where an information gatekeeper charges click-through fees. As opposed to the assumption of Baye and Morgan (2001) that firms pay the gatekeeper a fixed fee regardless of the number of clicks they receive, under a click-through regime, a firm pays a listing fee only if it is clicked. This difference helps rationalize the observation that some firms that persistently charge high prices nonetheless advertise prices at comparison sites. Furthermore, the presence of sellers with very high prices distorts the "effective" number of competitors in the market, which is crucial factor in determining the equilibrium mixed strategy of actively competing firms. Data collected from a leading price comparison site reveal asymmetric pricing patterns across firms consistent with the theoretical model: some firms persistently charge high prices while other firms appear to have similar randomized pricing strategies. Based on the model, we obtain structural estimates of the "effective" number of competitors in the market, the proportion of customers who use the price comparison site, and the welfare gains the price comparison site generates for consumers.

1 Introduction

Unique to e-retailing is the prevalent engagement in price comparison by both buyers and sellers. Collecting and publicizing price information in online markets are unprecedentedly hassle-free; with several clicks at price comparison sites, not only are customers able to gather rich product

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and price information across a wide variety of retailers, but also retailers can watch prices of competitors instantaneously. This enhanced information efficiency attracts numerous shoppers to price comparison sites. According to Alexa Internet, a leading web traffic information company, 0.27% of all the global Internet users visited *Shopping.com*, the most popular price comparison site, on September 16th, 2007, with 20% of them coming from the United States. A rough calculation indicates that 633,479 Americans, or 0.21% of the population, used *Shopping.com* on that day.[1] Alexa also finds visitors of *Shopping.com* determined with respect to what they are looking for; visitors of *Shopping.com* on average only viewed 1.8 unique pages while visitors of *Yahoo.com*, the global number one site, visited 14 unique pages. The extensive use by both buyers and sellers makes shopping comparison an industry growing at an astonishing annual rate of 30 to 50%.[2] Major price comparison sites are often valued over half a billion dollars. For example, CNet acquired *MySimon.com* for $700 million in 2000, Yahoo acquired *Kelkoo.com* for €475 million in 2004, eBay acquired *Shopping.com* for $620 million in 2005, E.W. Scripps acquired *Shopzilla.com* for $525 million in 2005, and Providence Capital Partners acquired 66% of *Nextag.com* for about $863 million in 2007.

Price comparison sites successfully eliminate the geographical boundaries between firms and thus enable competition which would not be present in the traditional way of doing business. Sellers of identical product may be physically separated, but when they choose to advertise at price comparison sites, they virtually compete with sellers across the entire U.S. As price comparison has significantly changed the structure and operation of markets and as it plays an increasingly important role in the economy, it raises several questions that are of importance to industrial organization, information economics and welfare economics. How does competition adjust to price comparison? How do price comparison sites set fees? Can increased information efficiency eliminate price dispersion? How much do buyers benefit from price comparison? How much do sellers lose? Is there any need to regulate price comparison to improve social welfare? Answers to these questions are important to all players involved in the market: consumers, retailers, price comparison sites, traditional advertisers, as well as policy makers.

[1] The number of global Internet users used in the calculation is 1,173,109,925 (source: Internet World Stats), and the projected U.S. population is 302,461,000 (source: U.S. POPClock Projection by the U.S. Census Bureau).

[2] See the article on "Price Comparison Service" in Wikipedia.

The first theoretical paper that explicitly studies online price comparison is Baye and Morgan (2001). Based on the clearinghouse model of Varian (1980), Baye and Morgan (2001) characterizes competition among symmetric firms in a homogeneous product market served by a gatekeeper that informs its subscribers of all the advertised prices. The consumers' decision whether to subscribe to the gatekeeper, advertisement decision by firms, and fee setting by the gatekeeper are all endogenized. The paper finds that it is optimal for firms to mix prices when advertising, even when all the customers are "informed". The resulting price dispersion is essential to gatekeeper's profitability. Therefore, it is optimal for the gatekeeper to encourage full consumer participation by lowering subscription fees but to deliberately avoid Bertrand competition by firms.

In line with Baye and Morgan (2001), extensive empirical investigations of a wide variety of industries, including electronics, grocery products, computers, airline tickets, books, CDs, and DVDs, have found persistent price dispersion and frequent changes in the store that charges the lowest price. For example, Baye, Morgan, and Scholten (2004a) observes that the identity of the firm charging the lowest price changes significantly over time in the market for consumer electronics. In addition, the study of Baye, Morgan, and Scholten (2004b) based on over a 1000 consumer electronics products finds price dispersion to be systematically correlated with the number of advertising firms as the clearinghouse model predicts. Baye, Gatti, Kattuman, and Morgan (2006) is the first paper that empirically estimates the discontinuity of online demand; firms generate 60% more clicks when they charge the lowest price at a price comparison site. In addition, Morgan, Orzen, and Sefton (2006) finds evidence for the clearinghouse model in the lab. Baye, Morgan and Scholten (2006) provides a thorough review of theoretical and empirical works of price dispersion, while Pan, Ratchford and Shankar (2004) provides a list of how price dispersed various industries are.

Most theoretical papers on price dispersion focus on symmetric oligopolies. Studies of asymmetric oligopolies are very rare in the literature despite the wide acknowledgement among researchers that firm heterogeneity is an important feature in many markets. In a paper that does study asymmetric equilibriums, Baye, Kovenock and de Vries (1992) finds that asymmetric equilibriums may arise among symmetric sellers within a Varian (1980) type of setting, with at least two firms mixing prices whereas other firms constantly charge the monopoly price. However, a gatekeeper is not modeled in this paper. All other works on oligopoly competition in homogeneous product markets assume identical sellers and an equal amount of uninformed customers. Unfortunately, because most firms around are not homogeneous, this makes these papers less suitable for addressing empirical inquiries.

Another obstacle to the estimation of online pricing behavior comes from the evolution of information markets. While all clearinghouse models assume gatekeepers set fixed fees, click-through fees are now the most dominant advertising model for online price comparison sites. Click-through fees are claimed to be highly cost-efficient because the viewers directed to sellers are believed to be interested enough to have clicked through and thus engaged enough to make a purchase. Important as it is, unfortunately, no study has modeled click-through fees so far.

To summarize, although symmetric clearinghouse models with fixed fees are extensively studied and well accepted, little is known about the asymmetric clearinghouse model and less is known about how click-through fees have transformed the price comparison market from a theoretical perspective. This inadequacy in the literature has greatly limited researcher's capacity to analyze online price data.

This paper extends the symmetric clearinghouse model of Baye and Morgan (2001) to an asymmetric setting in which firms have heterogeneous profit functions. In addition, three modifications are made to make the model more suitable for empirically studying online markets: (*i*) a click-through fee is modeled in stead of a fixed fee, (*ii*) consumers can visit the gatekeeper's site for free, and (*iii*) a positive fraction of consumers are assumed to have no access to the gatekeeper.[3]

This paper shows that in a symmetric setting, the game being played is not fundamentally changed by having the gatekeeper charging a click-through fee: as in Baye and Morgan (2001) firms still mix their advertising decisions and advertised prices, and still charge the monopoly price when not advertising. Intuitively, the loss in margin on the firm's local market as a result of a price cut can be offset by the expected extra demand of serving the price comparing consumers at the price comparison site. Consequently, consumers in the information market

[3] Modification (*iii*) is meant to capture the fact that access to the gatekeeper is not an option for everyone. For example, price comparison sites are not available for those who do not have Internet access.

gain from comparing prices. Moreover, price dispersion is essential to the gatekeeper's profit: setting a click-through fee too high will drive firms back to their local markets, resulting in an inactive information clearinghouse.

However, in an asymmetric setting, a gatekeeper that sets click-through fees leads to remarkably different results compared to a gatekeeper that sets fixed fees. This is because the firms that enjoy monopoly price premiums do not advertise under a fixed fee regime but do advertise when the gatekeeper charges click-through fees. The reason for this is that these firms generate more profit by monopolizing their local market than by trying to compete for the price comparing consumers, and since advertising on the information clearinghouse is always costly if they have to pay a fixed fee, they will never do so. On the contrary, click-through fees effectively discriminate between competing and non-competing firms: while competing firms have to pay fees as they win the subscribers, non-competing firms pay nothing because their advertised monopoly prices are too high to be clicked by consumers.

As we will show in this paper, treating asymmetric pricing as symmetric will misinterpret the competitiveness in the market and will bias the estimation. Although the direction of the bias is ambiguous, this paper comes up with a method to efficiently recover and consistently estimate the symmetric price distribution of the firms that compete for the price comparing consumers. Since the method suggested in this paper is not restricted to the clearinghouse model only, it can be readily employed to estimate asymmetric pricing in general.

The suggested method is applied to a data set of 39 of the most popular consumer electronics products at the leading price comparison site *Shopping.com*. We find strong evidence of asymmetric pricing by firms that repeatedly charge relatively high prices. In addition, we find evidence that part of the firms mix advertised prices. By accounting for the bias resulted from asymmetric pricing on the distribution of market price, this paper consistently estimates the "effective" number of competitors in the market, the proportion of customers who use the price comparison site, and the welfare gains the price comparison site generates for consumers.

The paper is closely related to the earlier literature on advertising and consumer search behavior such as Stigler (1961), Rosenthal (1980), Reinganum (1979), Varian (1980), Burdett and Judd (1983), Narasimhan (1988), and Stahl (1989).

The structure of this paper is as follows. In the next section, we first characterize equilibrium when all firms are symmetric. Thereafter, we introduce asymmetry by allowing some firms to have different profit functions, and study the implications this has for the equilibrium. In Section 3 we compare our results with those of Baye and Morgan (2001), while we also investigate the impact of having a click-through fee in stead of a fixed fee on all players in the market. Moreover, we illustrate the relevance of our model for empirical usage. In Section 4 of this paper we discuss the data we have collected from *Shopping.com*. In Section 5 we test for mixed strategies and asymmetric pricing in the data. In Section 6 we suggest a method for handling the distortion of the distribution of market prices caused by non-competing firms. In this section we also estimate the "effective" number of competitors in the market and the proportion of consumers who use a price comparison site, and the gains the price comparison site generates for its visitors. Finally, we conclude in Section 7.

2 The Model

In this section we extend the information clearinghouse model of Baye and Morgan (2001) to allow for click-through fees, as well for asymmetric pricing. We will first derive the symmetric model, whereafter we extend the symmetric model to an asymmetric setting.

2.1 Symmetric Model

There are n retailers in the model producing a homogeneous product at a common marginal cost c. We assume the retailers to be geographically isolated from one another. There is a unit mass of consumers, each of them being local to one of the stores. The consumers are equally distributed among the local markets. Consumers can visit their local store in person for a cost of $\varepsilon > 0$. Because visiting a nonlocal store in person is assumed to be impossible due to high transaction costs, the only way to visit and buy from a nonlocal store is to use the services of a gatekeeper and buy via the Internet. We assume there is one gatekeeper active in the market. This gatekeeper is assumed to be a profit maximizing manager of an information clearinghouse that advertises prices of a subset of the firms. An example of such a gatekeeper on the Internet is a so-called price comparison site. The primary business of a price comparison site is to advertise prices. By clicking on one of these advertised prices a consumer is redirected to the web site of that particular store whereafter the consumer can buy the good, without first having to visit the store in person. The gatekeeper makes money by charging a firm a click-through fee for each consumer that is redirected from the gatekeeper's site to the web site of the firm. In this way a gatekeeper facilitates competition, even in markets where local firms would act as local monopolists otherwise. For example, although not many consumers living in Manhattan will travel to Los Angeles just to shop for one particular item, a price comparison site makes a store in Los Angeles just "a click away". This means that buying the good over the Internet from the store in Los Angeles becomes an alternative to buying the good from the local store in Manhattan.

We assume only a fraction $\mu \in (0,1)$ of consumers have access to the gatekeeper's site and there is no subscription fee for consumers, so subscribed consumers can visit the gatekeeper's site for free. However, we allow for the possibility that not all consumers who have access decide to subscribe to the gatekeeper; the share of consumers that actually subscribe is denoted $\mu_s \in [0,\mu]$. The gatekeeper's subscribers obtain all advertised prices at no cost and may buy from the firm with the lowest listed price.

A firm's profit from setting a price p is given by $\pi(p) = (p - c)D(p)$, where c is a constant marginal cost of producing, and demand function $D(p) \geq 0$ is continuous and strictly decreasing in p. We assume $\pi(p)$ to be strictly concave for all $p \geq c$.

Although each firm by definition has to serve one local market, advertising a price at the gatekeeper's site is optional. We assume a firm has to charge the same price to consumers who visit the store through the gatekeeper's site as to consumers who visit the store in person. Let $\alpha \in [0,1]$ be the probability that a firm advertises its price at the gatekeeper's site and let $F(p)$ be the cumulative distribution function of firm's advertised prices. Moreover, define $\underline{p}$ and $\overline{p}$ to be the lower and upper bound of the interval over which firms mix prices when they advertise. A gatekeeper is inactive if the probability of advertising α is equal to zero.

The game is modeled as a sequential game, where the gatekeeper sets a click-through fee first. Given this fee, firms make advertising and pricing decisions. In the last stage of this game, consumers with access to the gatekeeper's site decide whether to subscribe or not whereafter consumers purchase the good. We solve the game by backward induction.

2.1.1 Optimal Consumer Behavior

The following proposition summarizes optimal consumer behavior.

Proposition 1 *If all firms decide not to use the gatekeeper's site, the gatekeeper is inactive and all consumers visit their local firms. If the gatekeeper is active, the consumers that do not have access to the gatekeeper's site visit their local firms and buy from there, while subscribed consumers will always first visit the gatekeeper's site and buy the good at the lowest listed price. However, if no prices are listed at the gatekeeper's site, or if the lowest price at the gatekeeper's site is not as low as the sum of the (unadvertised) local price and the cost of visiting the local store, consumers will buy from their local firms.*

Proof. It is straightforward to show that the consumers with no access to the gatekeeper will buy from their local firm and that when none of the firms is using the gatekeeper all consumers will buy from their local firms. Note that the latter happens when the probability of advertising α is zero.

Two possibilities arise when a consumer visits an active gatekeeper's site: (1) her local firm is advertising, and (2) her local firm is not advertising. In case (1), by buying through the gatekeeper's site, the consumer saves at least the cost ε of visiting the local firm. In case (2), because there are no costs involved in going to the price comparison site, a consumer can always return to her local store for the same cost as when she would have visited her local store directly. Therefore, the expected surplus of visiting the gatekeeper's site first is at least as high as visiting the local firm directly. Since by definition the probability of advertising α is strictly positive when the gatekeeper is active, case (1) happens with positive probability. Therefore, for consumers with access to the gatekeeper's site, subscribing and visiting an active gatekeeper strictly dominates buying from the local firm directly. ■

2.1.2 Optimal Firm Behavior

The gatekeeper's information clearinghouse gives firms an additional channel to reach consumers. According to Proposition 1, by advertising at the information clearinghouse a firm will at least save local consumers that are subscribed to the gatekeeper the cost of a trip to the firm. Moreover, by advertising a firm has a probability of serving all visitors of the clearinghouse. This probability is decreasing in the price a firm charges, so a low price leads to more expected demand, but will also lower expected profits from the local market since firms cannot price discriminate between channels. Therefore, firms need to find a balance between extracting surplus from the local market and from the consumers that visit the store through the gatekeeper's site.

If a firm does not advertise at the gatekeeper's site, the expected profit of setting a price p stems form both its local customers that do not subscribe to the gatekeeper's site and subscribed customers that come back in case there are no prices advertised at the gatekeeper's site. Because the firm is not competing with any of the other firms it is optimal for the firm to charge the monopoly price r, where r is defined as

$$r = \arg\max_{p} \pi(p).$$

Since the probability that no prices are advertised at the gatekeeper's site is $(1-\alpha)^{n-1}$, and since each firm will have an equal share of the subscribed and non-subscribed consumers, the expected profit given that the firm does not advertise is

$$E\Pi(r|N) = (1-\alpha)^{n-1}\frac{\mu_s}{n}\pi(r) + \frac{1-\mu_s}{n}\pi(r).$$

If a firm does advertise at the gatekeeper it will first of all sell to its share of local consumers that have not subscribed to the gatekeeper. In addition, the firm sells to all visitors of the gatekeeper's site if it has the lowest price out of all firms advertising. This probability is given by $(1-\alpha F(p))^{n-1}$, so the expected profit given that the firm advertises is given by

$$E\Pi(p|A) = (1-\alpha F(p))^{n-1}\mu_s \pi(p,\phi) + \frac{1-\mu_s}{n}\pi(p), \tag{1}$$

where $\phi > 0$ is the click-through fee and $\pi(p,\phi) = (p-c-\phi)D(p)$ is the per consumer profit of selling through the gatekeeper's site.[4] We assume $\pi(p,\phi)$ to be strictly concave in p over $p \geq c+\phi$. In addition, consumer surplus at price p is defined as $S(p) = \int_p^\infty D(t)dt$. We assume ε to be sufficiently small such that $S(r) > \varepsilon$.

[4] For simplicity, the conversion rate is assumed to be 1 for each firm. However, the all results are still valid as long as conversion rates are the same across firms and public information.

First note when the gatekeeper is active, there exists no pure strategy equilibrium. By Proposition 1, because consumers with access to the gatekeeper's site can subscribe at no cost, an active gatekeeper implies that they all will subscribe, i.e., $\mu_s = \mu$. Since the share of consumers with access to the gatekeeper μ is by assumption strictly positive, there will be a positive fraction of consumers comparing prices at the gatekeeper's site, i.e., $\mu_s > 0$. If a firm would have a pure strategy in pricing, the positive share of price comparing consumers at the gatekeeper's clearinghouse makes undercutting profitable. As a result, no pure strategy exists.[5]

The price distribution $F(p)$ in equation (1) can only be part of a symmetric Nash equilibrium if the expected profits are the same for all prices in the support of $F(p)$. Moreover, as we will show below, for click-trough fees low enough there does not exist a symmetric equilibrium in which all firms do not advertise, so in equilibrium the expected profits from not advertising should be equal to the expected profits from advertising. Given α, a firm that advertises and charges a price equal to the upper bound $\overline{p}$ of $F(p)$ has an expected profit of

$$E\Pi(\overline{p}|A) = (1-\alpha)^{n-1}\mu\pi(\overline{p},\phi) + \frac{1-\mu}{n}\pi(\overline{p}). \tag{2}$$

Because both $\pi(p,\phi)$ and $\pi(p)$ are strictly concave, $E\Pi(\overline{p}|A)$ will be strictly concave as well. This means there is a price $\hat{\overline{p}}$ for which equation (2) is maximized. Note that neither prices below $\hat{\overline{p}}$ nor prices above $\hat{\overline{p}}$ can be equilibrium upper bound. And it can never be optimal for a firm to set an advertised price that is higher than $m = S^{-1}(S(r) - \varepsilon$, because in that case consumers will buy from their local firms. Therefore, the upper bound of $F(p)$ is given by $\overline{p} = \min\{\hat{\overline{p}}, m\}$. Also equilibrium α must solve $E\Pi(r|N) = E\Pi(\overline{p}|A)$, implying

$$\alpha^* = 1 - \left[\frac{(1-\mu)\left[\pi(r) - \pi(\overline{p})\right]}{n\mu\pi(\overline{p},\phi) - \mu\pi(r)}\right]^{\frac{1}{n-1}}. \tag{3}$$

Notice that for $\phi \geq \frac{[(n-1)\mu+1]\pi(\overline{p})-\pi(r)}{n\mu D(\overline{p})}$, $\alpha(\phi) = 0$.[6] Intuitively, what this means is that for high click-through fees it is too costly for firms to advertise, so in that case firms will only be active

[5] See Stahl (1989) for a formal proof.

[6] To see this, $\alpha \in (0,1)$ whenever $0 < \phi < \frac{[(n-1)\mu+1]\pi(\overline{p})-\pi(r)}{n\mu D(\overline{p})}$. This means that if $\phi \geq \frac{[(n-1)\mu+1]\pi(\overline{p})-\pi(r)}{n\mu D(\overline{p})}$ profits when advertising are smaller than when not advertising, i.e.,

$$(1-\alpha)^{n-1}\mu\pi(\overline{p},\phi) + \frac{1-\mu}{n}\pi(\overline{p}) < (1-\alpha)^{n-1}\frac{\mu}{n}\pi(r) + \frac{1-\mu}{n}\pi(r).$$

in their local markets.

Plugging the optimal probability of advertising α^* into equation (1) and solving for $F(p)$ gives

$$F(p) = \frac{1}{\alpha^*(\phi)} - \frac{1}{\alpha^*(\phi)} \left[\frac{\left[(1-\alpha^*(\phi))^{n-1} + \frac{1-\mu}{\mu}\right]\pi(r) - \frac{1-\mu}{\mu}\pi(p)}{n\pi(p,\phi)} \right]^{\frac{1}{(n-1)}}. \tag{4}$$

The lower bound of $F(p)$ can be found by setting $F(\underline{p}) = 0$ and solving for $\underline{p}$, i.e., $\underline{p}$ solves $\mu n\pi(p,\phi) + (1-\mu)\pi(p) = (1-\alpha^*(\phi))^{n-1}\mu\pi(r) + (1-\mu)\pi(r)$.

The following proposition summarizes optimal firm behavior.

Proposition 2 *Suppose the gatekeeper sets a fee ϕ and firms optimally determine their pricing and advertising decisions. Then in a symmetric Nash equilibrium:*

(i) Each firm advertises its price at the gatekeeper with probability

$$\alpha^* = \max\left\{0, 1 - \left[\frac{(1-\mu)\left[\pi(r) - \pi(\overline{p})\right]}{n\mu\pi(\overline{p},\phi) - \mu\pi(r)}\right]^{\frac{1}{n-1}}\right\}.$$

(ii) When advertising, the firm draws its price from the price distribution

$$F(p) = \frac{1}{\alpha^*(\phi)} - \frac{1}{\alpha^*(\phi)} \left[\frac{\left[(1-\alpha^*(\phi))^{n-1} + \frac{1-\mu}{\mu}\right]\pi(r) - \frac{1-\mu}{\mu}\pi(p)}{n\pi(p,\phi)} \right]^{\frac{1}{(n-1)}},$$

with lower bound $\underline{p}$ that solves $\mu n\pi(p,\phi) + (1-\mu)\pi(p) = (1-\alpha^*(\phi))^{n-1}\mu\pi(r) + (1-\mu)\pi(r)$ and upper bound $\overline{p} = \min\{\hat{\overline{p}}, m\}$.

(iii) When not advertising, the firm sets a price equal to the monopoly price r.

Proposition 2 implies firms are mixing advertised prices. Since these prices are randomly drawn from the equilibrium price distribution, firms cannot successfully anticipate rivals' prices, and each firm has a positive probability to win the consumers that are searching for the lowest price at the gatekeeper's site. Prices will be lower than when the firm would only focus on its local market, but this is offset by the higher expected demand as a result of being active at the clearinghouse.

Consumers that have subscribed to the gatekeeper have a higher consumer surplus than the consumers that cannot subscribe. Since advertised prices generate consumer surplus no less than that of the local monopoly price, subscribers always benefit from searching for the lowest price at the gatekeeper's site.

Notice that the gatekeeper cannot set its click-through fee too high. If it overcharges advertising firms, the firms will find it more profitable to monopolize their individual local markets and, hence, stay away from the gatekeeper, resulting in an inactive gatekeeper. By setting a click-through fee low enough there is positive probability that firms will advertise and that it can collect fees from the firms.

2.1.3 Optimal Gatekeeper Behavior

In Baye and Morgan (2001) the gatekeeper charges advertising firms a fixed fee. However, most gatekeepers on the Internet, like for example price comparison sites, set click-through fees. In our model we explicitly allow for click-through fees instead of a fixed fee. A profit maximizing gatekeeper faces a trade-off between the number of clicks it generates from subscribers and the level of the click-through fee. Since we assume that each click-through also leads to a unit being sold, the amount of clicks equals the demand of subscribers. Demand is determined by the number of subscribers and the lowest price in the market. As shown above, as long as the click-through fee is low enough, firms will advertise on the information clearinghouse and the gatekeeper will attract all μ consumers. Therefore, the lowest advertised price is critical for the gatekeeper's profit. Notice that the distribution of the lowest price depends on the probability of advertising α and the price distribution $F(p)$. The effects of an increase in the click-through fee ϕ on $F(p)$ is nontrivial; the proposition below summarizes the negative relationship between ϕ and α.

Proposition 3 *An increase in click-through fee will decrease firm participation in the equilibrium.*

Proof. In equilibrium $E\Pi(r|N) = E\Pi(\overline{p}|A)$. Taking the derivative of $E\Pi(r|N)$ with respect to α gives

$$\frac{\partial E\Pi(r|N)}{\partial \alpha} = -(n-1)(1-\alpha)^{n-2}\frac{\mu}{n}\pi(r) < 0,$$

which shows that the expected profits from not advertising are decreasing in the participation rate. The derivative of $E\Pi(\overline{p}|A)$ with respect to α gives

$$\frac{\partial E\Pi(\overline{p}|A)}{\partial \alpha} = -(n-1)(1-\alpha)^{n-2}\mu\pi(\overline{p},\phi) + \frac{\partial E\Pi(\overline{p}|A)}{\partial \overline{p}}\frac{\partial \overline{p}}{\partial \alpha} = -(n-1)(1-\alpha)^{n-2}\mu\pi(\overline{p},\phi) < 0,$$

since $\frac{\partial E\Pi(\overline{p}|A))}{\partial \overline{p}} = 0$. Both $E\Pi(\overline{p}|A)$ and $E\Pi(r|N)$ are strictly decreasing in α. Furthermore, because $\mu\pi(\overline{p},\phi) > \frac{\mu}{n}\pi(r)$ it is straightforward that $\frac{\partial E\Pi(r|N)}{\partial \alpha} > \frac{\partial E\Pi(\overline{p}|A)}{\partial \alpha}$. This implies that if there is an equilibrium α^*, $E\Pi(\overline{p}|A)$ crosses $E\Pi(r|N)$ from above. This is also illustrated in Figure 1. An increase in ϕ decreases $E\Pi(\overline{p}|A)$ for any given α, which shifts $E\Pi(\overline{p}|A)$ down and results in a smaller equilibrium α^*.

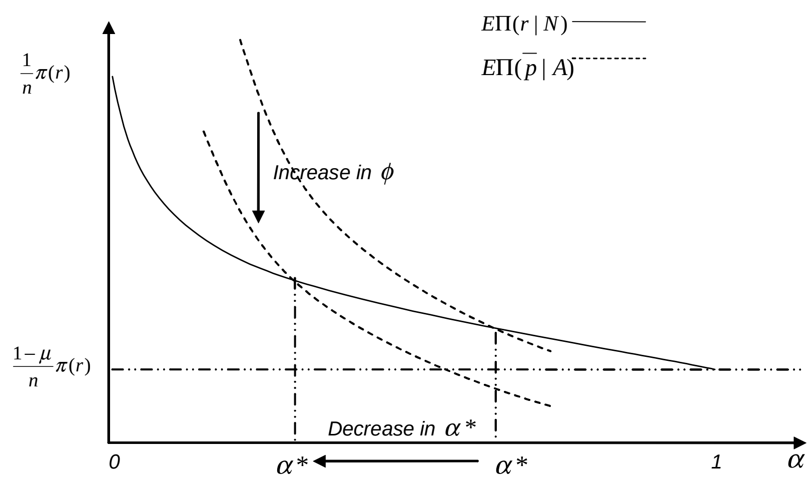


Figure 1: Change in α^* as a result of change in click-through fee

Intuitively, a higher click-through fee makes it more costly for firms to advertise, which discourages the firms from participating at the information clearinghouse. Since advertised prices will be higher as a result of a lower participation rate of the firms, this in turn makes it less attractive for subscribers of the gatekeeper to actually click on the prices listed. The gatekeeper's problem is to find the right trade-off and find the level of click-through fee that maximizes its profit. Since it can never be optimal for the gatekeeper to have an inactive information clearinghouse, the gatekeeper will only consider click-through fees in the range

$\left(0, \frac{[(n-1)\mu+1]\pi(\overline{p})-\pi(r)}{n\mu D(\overline{p})}\right)$. Within this range the expected profit of the gatekeeper is given by

$$E\Pi_G(\phi) = \mu\phi \sum_{j=1}^{n} B_j^{\alpha^*}(\phi) \int_{\underline{p}}^{\overline{p}} D(p) h_j(p;\phi) dp.$$

Hence, the click-through fee ϕ that maximizes $E\Pi_G(\phi)$ is given by

$$\phi^* = \underset{\phi \in \left(0, \frac{[(n-1)\mu+1]\pi(\overline{p})-\pi(r)}{n\mu D(\overline{p})}\right)}{\arg\max} \mu\phi \sum_{j=1}^{n} B_j^{\alpha^*}(\phi) \int_{\underline{p}}^{\overline{p}} D(p) h_j(p;\phi) dp,$$

where $B_j^{\alpha^*}(\phi) = \binom{n}{j} (\alpha^*(\phi))^j (1-\alpha^*(\phi))^{n-j}$ and $h_j(p|\phi)$ is the density function of the lowest price in j draws from $F(p|\phi)$. ■

This suggests that in equilibrium the gatekeeper will set a click-through fee reasonably low to induce firms to advertise their prices. As a result, firms will advertise their price with positive probability. When not advertising, firms will charge the monopoly price and will sell only to consumers on their local markets. When advertising, prices will be cut so that there is reasonable chance to win all the price comparing consumers. The lower margin when advertising is compensated by a higher demand if the price is indeed the lowest listed. Consumers can attain higher consumer surplus at the information clearinghouse, so all consumers with access to the gatekeeper's site will choose to subscribe.

2.2 Asymmetric Model

So far we have assumed firms to be homogeneous, which led to the characterization of a symmetric equilibrium. An interesting question is what would happen to the symmetric equilibrium if we introduce asymmetry in the model. As a first illustration, suppose that at the same price, some firms generate more sales than other firms. It turns out that as long as the ratio of the quantity demanded at firm i to the quantity demand at firm j is constant for all prices p, that is, $D_i(p) = \omega_{ij} D_j(p)$, where ω_{ij} is a constant, the equilibrium is characterized by the same symmetric equilibrium discussed above. Such an asymmetry in demand curves would for example occur if the product has the same constant elasticity of demand for all firms but the firms have different sizes, i.e., if $\ln D_i(p) = s_i + e \ln p$ then $\omega_{ij} = \frac{s_i}{s_j}$. Demand for each firm i can then be written as the demand for firm 1 multiplied by ω_{i1}, i.e., $D_i(p) = \omega_{i1} D_1(p)$. Moreover, the constant elasticity of demand assumption implies the monopoly price r is the same for all firms. Writing down the equilibrium condition $E\Pi_i(r|N) = E\Pi_i(p|A)$ gives

$$\omega_{i1}\left[(1-\alpha)^{n-1}\frac{\mu_s}{n}\pi_1(r) + \frac{1-\mu_s}{n}\pi_1(r)\right] = \omega_{i1}\left[(1-\alpha F(p))^{n-1}\mu_s\pi_1(p,\phi) + \frac{1-\mu_s}{n}\pi_1(p)\right].$$

Obviously, we can get rid of ω_{i1} by dividing both sides by ω_{i1}, so the equilibrium price distribution $F(p)$ is not affected by this particular form of asymmetry in the demand curves. Intuitively, as long as the asymmetric effects affect the non-subscribing and subscribing consumers in the same way the equilibrium will not be changed by introducing heterogeneity. This finding helps to justify the use of a symmetric model in some asymmetric settings.

Although the assumption that all firms face the same constant elasticity of demand might be appealing in some settings, in many markets firm heterogeneities stem from heterogeneity in elasticities across firms. Some firms may face more elastic demand than others, and some firms may generate more demand at the same price. In the remainder of this subsection we consider two specific forms of firm heterogeneities: (1) all firms have constant elastic demand, but with different elasticities; (2) all firms have strictly decreasing and non-convex demand functions, which are similar up to a constant d_i.[7] Notice that firms can be ordered by elasticity in the first case and by the constant d_i in the second case. Furthermore, assume that every firm has at least one other firm that has either the same elasticity of demand or the same constant d_i.

Notice that both cases result in heterogeneity in monopoly prices. In the first case firms with more inelastic demand will have a higher optimal monopoly price, while in the second case the monopoly price is increasing in d_i. This allows us to order and group firms by the height of their monopoly price. Suppose a total of N firms in the market are grouped into G groups of similar monopoly price. This means in group g there are $n_g > 1$ symmetric firms with common monopoly profit $\pi_g(r_g)$, where r_g is the common monopoly price. Without loss of generality, assume $r_g < r_{g+1}$ and that there are L firms with monopoly prices higher than m.

Suppose we start from a situation where there is a group of $n_1 < N$ symmetric firms with

[7] Note that a linear demand function falls into this type.

similar monopoly profit $\pi_1(r_1)$ that set prices as in the symmetric equilibrium, i.e.,

$$F(p|\phi^*) = \frac{1}{\alpha^*}\left\{1 - \left[\frac{\left[(1-\alpha^*)^{n_1-1} + \frac{1-\mu}{\mu}\right]\pi_1(r_1) - \frac{1-\mu}{\mu}\pi_1(p)}{N\pi_1(p,\phi^*)}\right]^{\frac{1}{n_1-1}}\right\},$$

where

$$\alpha^* = 1 - \left[\frac{(1-\mu)\left[\pi_1(r_1) - \pi_1(\overline{p}_1^*)\right]}{N\mu\pi_1(\overline{p}_1^*,\phi^*) - \mu\pi_1(r_1)}\right]^{\frac{1}{n_1-1}} \in (0,1)\,.$$

Furthermore, assume all consumers in the market with access to the gatekeeper's site are relatively price sensitive with demand equal to that in π_1 and their consumer surplus equals zero at price m. Then if

$$\frac{1-\mu}{N}\pi_g(r_g) > \left[1 - \alpha^* F(p|\phi^*)\right]^{n_1}\mu\pi_1(p,\phi^*) + \frac{1-\mu}{N}\pi_g(p) \quad \forall \quad p \leq m,$$

these L firms will be indifferent between advertising at the gatekeeper's site or not. The intuition for this is that even though actively competing for the price comparing consumers by setting a price lower than m is not profitable, since no subscribed consumer has an incentive to click on a price which is higher than m, advertising a price $p > m$ does not cost the firm any money.

Firms with a monopoly price higher than r_1 but lower than m will not advertise their price at the gatekeeper's site if

$$\left[(1-\alpha^*)^{n_1}\frac{\mu}{N} + \frac{1-\mu}{N}\right]\pi_g(r_g) > \left[1 - \alpha^* F(p|\phi^*)\right]^{n_1}\mu\pi_1(p,\phi^*) + \frac{1-\mu}{N}\pi_g(p) \quad \forall \quad p \leq r_g.$$

For these firms it is more profitable to monopolize the local market, and advertising at the gatekeeper would actually result in lower profits. Notice that the presence of firms with a monopoly price higher than the monopoly price of the first symmetric group of firms does not have any impact on the behavior on the behavior of the firms in the first group, the consumers, and the gatekeeper all follow the same strategy as in the symmetric game.

The asymmetric firms can be seen as firms with very loyal consumers that have a very high willingness to pay. Thus by setting a price which is higher than the market price, these firms generate more profit from monopolizing their local consumers than from advertising at the information clearinghouse and competing for the price comparing consumers. However, the firms with very high monopoly prices can still advertise their monopoly prices at the gatekeeper, since the price does not generate any clicks. With a fixed fee this would not have been possible.

Although the analysis so far only implies that asymmetric pricing may happen under certain conditions, the following two propositions show that such equilibrium will arise for sure when the market is competitive enough.

Proposition 4 *As $\mu \to 1$, or as $\varepsilon \to 0$, or $n_1 \to \infty$, firms in the first group advertise with probability converging to* 1*, and all other firms may advertise their monopoly prices at the gatekeeper.*

Proof. First, note that irrespective of the assumption on the elasticities

$$\frac{1-\mu}{N}\pi_1(r_1) - \frac{1-\mu}{N}\pi_1(p) < \frac{1-\mu}{N}\pi_g(r_1) - \frac{1-\mu}{N}\pi_g(p) \quad \forall \quad p \leq r_1.$$

To see this, first consider the case where the firms in group g have constant elastic demand function $D_g(p) = p^{-\epsilon_g}$, where $\epsilon_g > 1$ and $\epsilon_g > \epsilon_{g+1}$. In this case $r_g = \frac{\epsilon_g}{\epsilon_g - 1} \cdot c$. For $g \neq 1$

$$\frac{\partial\left[\pi_g(p) - \pi_1(p)\right]}{\partial p} = p^{-\epsilon_g}\left[1 - \epsilon_g\left(1 - \frac{c}{p}\right)\right] - p^{-\epsilon_1}\left[1 - \epsilon_1\left(1 - \frac{c}{p}\right)\right]$$

is positive for $p \leq r_1$. Therefore, $\frac{1-\mu}{N}\pi_g(p) - \frac{1-\mu}{N}\pi_1(p) < \frac{1-\mu}{N}\pi_g(r_1) - \frac{1-\mu}{N}\pi_1(r_1)$. In the second case, firms in group g have demand function $D_g(p) = D_1(p - d_g)$, where $d_g > 0$ is a constant, $d_g < d_{g+1}$ and $d_1 = 0$. Again, it can be shown that for $g \neq 1$,

$$\frac{\partial\left[\pi_g(p) - \pi_1(p)\right]}{\partial p} = D_1(p - d_g) - D_1(p) + (p - c)\left[D_1'(p - d_g) - D_1'(p)\right] > 0,$$

which leads to the same result.

Second, it can be seen from equation (3) that $\alpha^* \to 1$ as $\mu \to 1$ or $n_1 \to \infty$. Similarly, the upper bound $\overline{p} = m \to r_1$ as $\varepsilon \to 0$, so by equation (3) $\alpha^* \to 1$. Therefore, in all cases the firms in group g have expected profit of $\frac{1-\mu}{N}\pi_g(r_g)$ in the limit equilibrium. Moreover it implies $(1 - F(p|\phi^*))^{n_1 - 1}\mu\pi_1(\phi^*, p) = \frac{1-\mu}{N}\pi_1(r_1) - \frac{1-\mu}{N}\pi_1(p)$.

If a firm from group $g \neq 1$ advertises, its expected profit $E_g\Pi(p|A)$ is

$$(1 - F(p|\phi^*))^{n_1}\mu\pi_1(\phi, p) + \frac{1-\mu}{N}\pi_g(p) < \frac{1-\mu}{N}\pi_1(r_1) - \frac{1-\mu}{N}\pi_1(p) + \frac{1-\mu}{N}\pi_g(p).$$

Recall that in both cases,

$$\frac{1-\mu}{N}\pi_1(r_1) - \frac{1-\mu}{N}\pi_1(p) < \frac{1-\mu}{N}\pi_g(r_1) - \frac{1-\mu}{N}\pi_g(p),$$

so that

$$(1-F(p))^{n_1}\mu\pi_1(\phi, p) + \frac{1-\mu}{N}\pi_g(p) < \frac{1-\mu}{N}\pi_g(r_g),$$

implying it is optimal for the firm not to compete for subscribers by lowering its price. However, since firms in the first group price below the firm's monopoly price with probability 1, no consumer will click on the price of the firm, so the firm can advertise at no cost. ■

Proposition 5 *For small ε, as $N \to \infty$, firms in the first group advertise with probability converging to* 1*, and all other firms may advertise their monopoly prices at the gatekeeper.*

Proof. It can be shown that the optimal upper bound $\overline{p}$ increases in N and converges to r_ϕ as $N \to \infty$. If ε is small, $m < r_\phi$, and thus $\overline{p}$ has corner solution m as $N \to \infty$. It then follows from equation (3) that $\alpha^* \to 1$. The remainder of the proof is as in proof of Proposition 4. ■

Contrary to the common belief that aggressive pricing leads to the noncompetitive firms leaving the market, according to Proposition 4 and 5 more non-competing firms may advertise as the advertised prices become more competitive. The aggressive advertising by the firms that do compete for the price comparing consumers virtually eliminates the likelihood that local subscribers do not find a satisfying price at the gatekeeper. In addition, the aggressive pricing also eliminates the likelihood that the high prices of the non-competing firms are clicked.

3 Results

3.1 Click-through Fee versus Fixed Fee

Although charging click-through fees is now the dominant advertising model used by for example price comparison sites, the theoretical implications have not been carefully studied yet. Results are likely to be of significance to all players in the market: consumers, gatekeepers, retailers, as well as traditional advertiser. In this section, the results from this paper are compared with predictions derived from Baye and Morgan (2001) to determine the impact the advertising model – fixed fee or click through fee – has on market outcomes.

First consider the symmetric model. Despite that the distribution of advertised prices is different, and although the upper bound of the advertised price distribution goes up as a result of having click-through fees in stead of a fixed fee, the nature of competition is not fundamentally changed. In both models firms advertise their prices on the gatekeeper's site with positive probability and in both models firms use mixed strategies to avoid Bertrand competition for the price comparing consumers.

Once asymmetry is introduced in the model the models start behaving differently. The most significant difference is the advertising decision of the non-competing L firms. In both this paper and Baye and Morgan (2001), the symmetric firms are willing to advertise because they can recover either the click-through fee or the fixed fee from the extra surplus they generate from the price comparing consumers. However, the L firms are only willing to advertise if the gatekeeper is paid by click-through fees. Remember that the L firms only advertise if it is costless to do so. A fixed fee is by definition costly, so will not be considered by the L firms. However, because the high price of the L firms guarantees that nobody is willing to buy from them via the gatekeeper's site, advertising at a gatekeeper charging click-through fees is for free. Notice that although the L firms advertise at the gatekeeper in this case, they do not contribute to market competitiveness since no price comparing consumer is prepared to buy the product at their advertised prices.

Unfortunately, both the equilibrium fixed fee in Baye and Morgan (2001) and the equilibrium click-through fee in this paper do not have a closed-form solution. This prevents us from doing a theoretical analysis of the advantages for the gatekeeper to charge click-through fees in stead of fixed fees. From a more intuitive point of view, because a click-through fee also attracts the firms with high prices, a click-through fee allows the gatekeeper to attract more advertising firms than a fixed fee would. Although the firms charging the high monopoly prices do not generate any click-through fees, it might still be beneficial for the gatekeeper to have these firms listed, since having many firms listed is often considered by consumers as an attractive feature of a gatekeeper's site. On the other hand, even though the asymmetric firms do not directly benefit from being listed on the gatekeeper's site, they are not hurt by advertising and might simply use the gatekeeper's site as a cheap way to place a banner.

3.2 Implications for Empirical Estimation

Efficient recovery of the symmetric price distribution is critical to accurate evaluation of the increased information efficiency brought by price comparison sites. However, the presence of asymmetric firms makes that care should be taken when interpreting prices listed on a gatekeeper's site. Recall that price comparing consumers will never purchase from the non-competing firms. Therefore, prices by non-competing firms should be excluded from the calculation of the efficiency gain brought by price comparison sites. If we would not correct for the asymmetric pricing of the non-competing firms, the recovery of the symmetric price distribution will be biased in two ways: firstly, because symmetric pricing is first order stochastically dominated by asymmetric pricing, the observed market prices underestimate the competitiveness in the market; and secondly, the observed number of firms overstates the number of firms that are competing. The overall effect is ambiguous.

If the empirical economist has knowledge on how asymmetric pricing changes the price distribution of advertised prices, observed prices might be corrected for the impact of non-competing firms. In that way, the parameters of interest can be estimated in a consistent way. Figure 2 illustrates how the presence of non-competing firms at the gatekeeper's site might change the advertised price distribution. Suppose there are four non-competing firms advertising their monopoly prices r_1, r_2, r_3, and r_4. Suppose these firms are responsible for half of the advertised prices. Let $F(p)$ be the advertised price CDF of the competing firms, and let $G(p)$ be the overall price distribution. As illustrated in Figure 2, for prices lower than $\overline{p}$ the overall price distribution $G(p)$ equals $F(p)$ multiplied by the total share of prices by non-competing firms at the gatekeeper. This means that if we would know the proportion of prices charged by competing firms we can divide the overall price distribution $G(p)$ by this proportion to recover the price distribution of competing firms $F(p)$.

4 Data

The data studied in this paper is collected from *Shopping.com*, the leading price comparison site in United States. It was ranked by Hitwise as the price comparison site with the biggest market share in the US (18.38%) in the week ending November 19th, 2005. According to

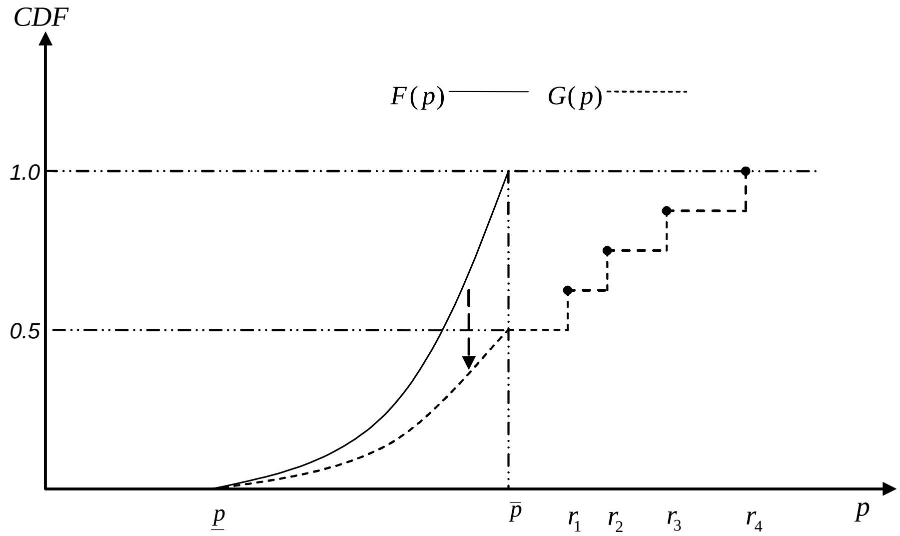


Figure 2: Overall price CDF (G(p)) and price CDF of competing firms (F(p))

Nielsen/NetRatings, *Shopping.com* was the second among the top 5 companies ranked by sponsored link impressions in the week ending August 21, 2005 and only outrun by eBay. On December 13th, 2006, according to *Alexa.com*, it ranked 354th of all the web sites and generated 2,900 reaches per million users.

The consumer electronics market is considered as one of the most developed online retail markets. All Dealerscope's Top 50 Consumer Electronics Retailers have online outlets. A joint study by Yahoo! and the Consumer Electronics Association in June 2006 found that 77% of consumer spending on electronics was affected by the Internet. They also identified 47% of buyers as "searchers".[8] Because of these characteristics, we collected prices of 39 different computer or electronic products. We did this twenty times in the period from from October 21st, 2006 to January 7th, 2007. From October 21st, 2006 to December 17th, 2006, the prices were collected twice a week, and from December 17th, 2006 to January 7th, 2007, prices were collected once a week.

The 39 products are from 6 different categories: 7 flash memory sticks, 7 printers, 4 monitors,

[8] No distinction was made between the online and off-line market.

7 digital camcorders, 9 digital cameras, and 5 media players. Detailed product information can be found in Table 1 in the Appendix. We randomly picked several brands from the top 10 most popular brands. Next, for each brand chosen, we randomly picked at most three products from the top 5 most popular products. Besides being random, an advantage of this particular way of sampling is that it is not related to the retailers. Moreover, the collected prices are for popular products which ensures more dynamic markets. We have chosen to focus on a variety of brands and products to avoid complications related to manufacturers dominating certain product categories or retailers having a close relationship with specific manufacturers. Although popular products do not literally represent the whole market, they do generate a lot more clicks and have much more economic and managerial impact.

In total we have collected 10,755 prices, set by 127 different firms. Although the default way of listing advertised price on *Shopping.com* is not based on price ranking, visitors of the price comparison site could easily sort the prices from low to high by clicking the "Sort by Price (Low to High)" button. Products that were refurbished or out of stock were kept out of the analysis. We included shipping cost and taxes to capture the actual cost to buyers.[9]

The price data cover a total period of two and half months, so we do not expect significant changes in unit cost. As illustrated in Figure 3, the traffic at *Shopping.com* did fluctuate noticeably during the period. However, there was no trend and the theoretical model allows for changes in the size of the population visiting the gatekeeper, as long as the same changes occur in the local market as well.

4.1 Test Asymmetric Pricing

Before we move on to present a statistical test how to correct the price data for asymmetric pricing, Figure 4 gives an example of a typical pricing pattern at *Shopping.com*. Figure 4 gives the prices charged for the 2GB Apple iPod Nano by 12 shops advertising their prices at *Shopping.com* between October 21 and November 23 in 2006. Within this period, 5 out of 12 sellers at some point in time had the lowest price in the market. Moreover, 11 out of 12 sellers either changed their advertising decision or changed their advertised price. Notice that *6ave.com* and *DirectDeals.com* repeated their high advertised prices during the period of

[9] Shipping and tax are calculated using Zip Code IN 47403.

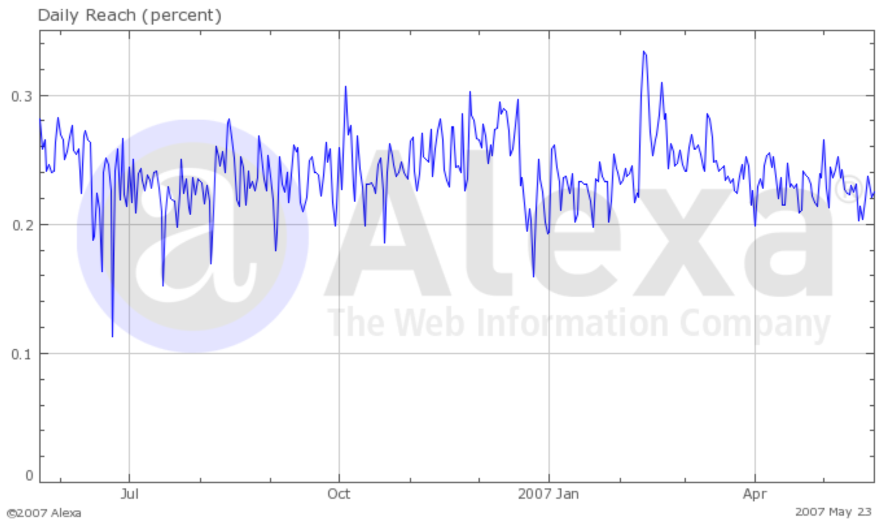


Figure 3: Prices at *Shopping.com* for the 2GB Apple iPod Nano

observation, which suggests these store are asymmetric firms, while other firms seem to have a pricing strategy which is more in line with the symmetric mixed strategy equilibrium.[10]

4.2 Mixed Pricing and Advertising

To test if sellers are using mixed advertising and pricing strategy we proceed as follows. First, we pool all prices in our sample. We ignore the fact that most sellers are selling several products and treat different products by the same seller as if those products were sold by different sellers. Out of the 989 product-retailer pairs formed in this way, for 84.4% of the pairs we observed at least one change in the decision whether to advertise or not, and for 64.5% of the pairs we observed changes in the advertised prices.[11] Only 3.5% of the product-retailer pairs never changed their advertising decision or their advertised prices.

Table 1 shows that on average retailers advertised 54.3% of the time and set on average three different prices during the period. Given that we have twenty price observations over time this means a typical seller tends to advertise eleven times, while setting three different prices over time.

[10] *IbuyDigital.com* also posted a high price, but since we have only one price observation for this firm we cannot infer whether this firm would classify as an asymmetric firm or not.

[11] For 8.8% of the pairs priced we observed only one price observation.

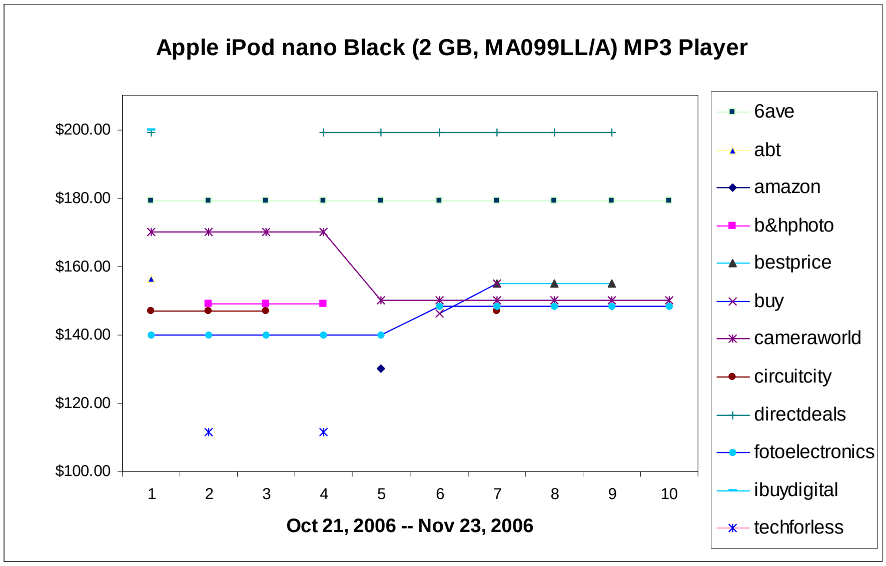


Figure 4: Sellers mix both advertising decision and prices advertised. Also, the non-competing sellers repeatedly charge their higher-than-market local monopoly prices.

Variable	Obs	Mean	Std. Dev.
Percentage of advertising times	989	0.54373	0.32964
Different advertised prices by same product-seller	989	2.99596	2.52357
Different advertised prices among sellers with multiple prices	902	3.18847	2.56155

Table 1: Statistics mixed pricing and advertising

4.3 Store Characteristics

One could argue that even though the products are homogenous, the stores selling the products are not. For example, it might be that the stores are heterogeneous in observed characteristics other than price, like consumer ratings, the number of reviews, and whether they are classified as "trusted" firms at *Shopping.com*.[12] If consumers are willing to pay a premium for more favorable store characteristics, part of the variation in prices might be due to quality difference between stores. To test whether these observable store characteristics can explain price differences across

[12] A store gets a "trusted" logo assigned at *Shopping.com* if they meet the following requirements: "Consistently receive positive customer ratings and reviews. Provide accurate price, shipping, and availability information. Provide basic store information including store address. Must note when products are used or refurbished. Must be listed on *Shopping.com* for at least one year. Honor prices listed on their site without excuses. Resolve customer service complaints quickly and fairly." —*Shopping.com*

firms, we ran linear regressions of prices on the rating, logarithm of the number of reviews, and a "trusted" dummy. The results of these regressions can be found in Table 2 of the Appendix. According to these results, between 0.7% and 71.9% of the variation in prices can be explained by observed firm heterogeneities, while the average adjusted R^2 is 21.4%. Moreover, around 36% of the products have adjusted R^2 less than 0.10 and 77% of the products have an adjusted R^2 less than 0.26. So for most products, observed firm heterogeneities explain the variation in prices quite poorly.

4.4 Asymmetric Pricing

The next step is to test for the presence of asymmetric firms in the data. A glance at the data reveals that of all 10,755 prices, only 2,963 prices are unique prices which are for different products, or by different sellers, or for the same product by the same seller but of different levels. This suggests that a considerable amount of prices are repeated prices and some firms do not mix advertised prices.

Of the 989 product-seller combinations, 87 product-seller pairs advertised their price only once and are left out of the analysis. Of the 902 remaining product-seller pairs, 264 pairs did not change advertised prices. Although this indicates that a substantial share of the firms do not seem to be mixing, in order to qualify as an asymmetric firm the advertised prices of these 264 product-seller combinations should be relatively high. One way to test this is by looking at the the correlation between the level of advertised prices and price variability. If firms price asymmetrically, they will set a high price without changing it over time, so there should be a negative correlation between the price level and price variability. To be able to compare results for different products, for each price of a product-seller pair we calculate the empirical price CDF value and take the average over time, and for each product-seller pair we calculate the coefficent of variation (CV). Next we calculate the correlation between the two measures. We find the correlation to be -0.19, and significantly different from zero at a 1% level. In addition, sorting the product-seller pairs by average empirical CDF value, we find that the 25% product-seller pairs with the lowest average empirical price CDF values to have an average CV of 0.0421, while the 25% product-seller pairs with the highest average empirical price CDF have an average CV of 0.0179. This suggests that retailers who change price more often have relatively lower prices than those who do not.

Another way to identify asymmetric pricing is to examine in more detail the pricing strategies of those who repeatedly set higher prices. For example, of the 61 product-seller pairs who never priced below the 90th percentile of the empirical price CDF, 43 had a CV equal to zero, while the largest CV among these 61 pairs was 0.082. Similarly, of the 129 product-seller pairs who never priced below the 80th percentile of the empirical price CDF, 84 pairs had a CV of zero. This is strong evidence that some of the firms advertising their prices on *Shipping.com* can be considered as non-competing, asymmetric firms. As argued above, to get meaningful estimates of the parameters of the model, one should correct for the presence of these firms. This will be the focus of the next section.

5 Estimation

5.1 Asymmetric Pricing

Since different products have different marginal costs, proportions of price comparing consumers, and number of competitors, we estimate the model separately for each product. First consider the pricing strategy of the n symmetric firms. Remember that these firms draw their price from the equilibrium price distribution given by equation (4). For simplicity we assume unit demand, which implies the equilibrium price distribution is

$$F(p|c', \mu, n) = \frac{1}{\alpha}\left\{1 - \left(\frac{(1-\alpha)^{n-1}(\overline{p} - c') + \frac{1-\mu}{N\mu}(\overline{p} - p)}{(p - c')}\right)^{\frac{1}{n-1}}\right\},$$

where $c' = c + \phi$, since c and ϕ cannot be identified separately.

Because of the presence of asymmetric, non-competing firms, the observed price CDF $G(p)$ will be different from the symmetric price CDF $F(p|c', \mu, n)$. However, since the non-competing firms never price below $\overline{p}$ we can recover $F(p|c', \mu, n)$ by multiplying $G(p)$ by $\frac{n\alpha + \sum_{l=1}^{L} \alpha_l}{n\alpha}$. If in addition we assume $\alpha_l = \alpha \ \forall \ l = 1, 2, 3, \ldots, L$ and let $N = n + L$, then the $F(p|n)$ is given by

$$F(p|n) = \begin{cases} \frac{N}{n} G(p) & p \in \left(0, F^{-1}\left(\frac{100n}{N}\right)\right) \\ 1 & p \in \left[F^{-1}\left(\frac{100n}{N}\right), \infty\right) \end{cases}$$

The total number of firms that set prices during the data collection period is used as an estimate for N. Because we assume α to be the same for each firm we can estimate it from the data by maximum likelihood. This allows us to treat N and $\widehat{\alpha}$ as known and non-stochastic. Using a similar approach as Baye and Morgan (2004), we find estimates $\widehat{c}'$, $\widehat{\mu}$, and $\widehat{n}$ that minimize the mean of the sum of squared errors between the recovered empirical cumulative distribution function given $\widehat{n}$, $\widetilde{F}(p|\widehat{n})$, and the predicted cumulative distribution function $\widehat{F}(p|\widehat{c}', \widehat{\mu}, \widehat{n})$. The estimates are reported in Table 3 in the Appendix. We also graph the recovered $\widetilde{F}(p|\widehat{n})$, predicted $\widehat{F}(p|\widehat{c}', \widehat{\mu}, \widehat{n})$, and empirical $\widetilde{G}(p)$ in the Appendix.

5.2 Fit of the Asymmetric Pricing Model

Proposition 4 and 5 suggest that products for which the estimated probability of advertising at the gatekeeper $\widehat{\alpha}$ is high should have higher share of non-competing firms as well. To test this prediction we regress the proportion of competing firms $\widehat{n}/N$ on $\widehat{\alpha}$. The resulting estimate of the coefficient is significantly negative at the 1% level. Next, since price comparing consumers will only click on prices of non-competing firms if there are no competing firms active at the gatekeeper's site, the probability that no competing firm is present gives an indication of how 'risky' it is for non-competing firms to advertise at the price comparison site. Based on our estimates, the average probability of the 39 products turns out to be 0.78%, and the median probability is 0.34%. Moreover, for only two products this probability is higher than 2%. Therefore we can conclude that the non-competing firms are not at risk of being clicked by consumers on the price comparison site.

Although the estimates of the parameters of the symmetric price distribution are consistent under regularity conditions of the nonlinear least square estimator, one may have worries about the overall consistency of the above estimation. Note that this particular estimator is a two-step estimator or estimator based on estimated dependent variable (EDV). According to Achen (2005), the second stage is consistent as long as first stage sample size is much larger than the second-stage sample size. This holds even when none of the stages is a conventional linear regression. Since the first stage sample sizes are on average seven times as large as the sample sizes in the second stage, the estimated parameters in the second stage should be consistent.

As can be seen in the figures in the Appendix, the predicted $\widehat{F}(p|\widehat{c}', \widehat{\mu}, \widehat{n})$ closely matches the recovered $\widetilde{F}(p|\widehat{n})$ for all products. To formally test how good the fit is we use the Kolmogorov-

Smirnov test. Since the parameters are obtained by pooling prices for the same product over time, prices collected at different moments in time are tested separately against the predicted CDF to make sure that fluctuations in the underlying market structure do not interfere with the test results. Because the parameters of the predicted price CDF are estimated, the standard critical region of the Kolmogorov-Smirnov test is no longer valid. Therefore, we determine the critical region by simulating the statistic 10,000 times.

The predicted $\widehat{F}(p|\widehat{c}', \widehat{\mu}, \widehat{n})$ is tested against the recovered $\widetilde{F}(p|\widehat{n})$ for each of the 731 product-day pairs using the Kolmogorov-Smirnov Goodness-of-Fit Test. The test results show that 85.8% of the product-day pairs pass the test at the 20% level, 89.6% pass at the 15% level, 93.6% at the 10% level, and 96.3% at the 5% level. Only 10 product-day pairs (1.4%) do not pass the test at the 1% level. This reassures us that the asymmetric model generates a very good fit and it also suggests that there is no significant structural change in the market during the period.

5.3 How many customers are comparing prices and how many firms are competing?

Given the estimated μ in the 39 product markets, the average μ can be considered as the proportion of consumers comparing prices in the whole market. Ideally, the adjusted $\widehat{\mu}$'s should be weighted by the clicks each product gets. However, although *Shopping.com* reports the popularity of products, firstly, the calculation method is not published and secondly, products from different categories are calculated separately. Nevertheless, since all the products were picked from the most popular items, their relative weights should not vary dramatically. Assuming all the products receive the same number of clicks, the average proportion comparing prices at the gatekeeper is 20.6%. This estimate is noticably larger than those from other studies based on symmetric models because we have addressed the underestimation of market competitiveness resulted from asymmetric pricing.

Since price comparing consumers only buy from the firm with the lowest advertised price on the price comparison site, focusing on the price comparing consumers might not be optimal for every firm. According to the estimates, only 32.9% of the 989 product-seller pairs are competing sellers. This estimate is consistent with the finding that only 27.6% of the prices are unique prices.

5.4 Gains from comparing prices

The answer to the question how much consumers actually gain from comparing prices at the price comparison site has significant implications for information economics and social welfare. Since we assume unit demand during the estimation of the model, the difference between the expected price paid by the price comparing consumers and the consumers who do not compare price is a good measure of how information promotes efficiency. As argued above, since the overall observed price distribution might be misleading, we use the number of competing firms estimated above to recover the empirical price distribution of competing firms. That is, the recovered empirical CDF is given by

$$\widetilde{F}(p) = \begin{cases} \frac{N}{\widehat{n}}\widetilde{G}(p) & \text{if } \frac{N}{n}\widetilde{G}(p) < 1; \\ 1 & \text{if } \frac{N}{n}\widetilde{G}(p) \geq 1. \end{cases}$$

Then, the expected price paid by consumers comparing prices is

$$E\left(P|C\right) = \sum_{j}^{\widehat{n}} \left\{ \binom{\widehat{n}}{j} \widehat{\alpha}^{j} \left(1-\widehat{\alpha}\right)^{n-j} \left[\sum_{p} pj \left(1-\widetilde{F}(p)\right)^{j-1} \widetilde{\Pr}(p) \right] \right\} + \left(1-\widehat{\alpha}\right)^{\widehat{n}} r,$$

where $\widetilde{\Pr}(p)$ is the probability density function for $\widetilde{F}(p)$. The expected price paid by consumers who do not compare prices is given by

$$E\left(P|C\right) = \widehat{\alpha} \sum_{p} p \Pr(p) + \left(1-\widehat{\alpha}\right) r.$$

Although the local monopoly price r cannot be observed at the gatekeeper's site, it is possible to find bounds for it. Since the cost for visiting a local firm may range from driving to the firm to a phone call or a word of mouth promotion, we set the cost for visiting a local firm to \$1. Note that $\overline{p}$ can be deduced from $\widetilde{F}(p)$, and that under the unit demand assumption $m = r + \varepsilon$, so $r \geq \overline{p} - \varepsilon$. Also recall that $r < \overline{p}$, so $\overline{p} - \varepsilon$ and $\overline{p}$ should be the lower and upper bounds of the monopoly price r.

The result are reported in Table 3. Saving 1 is the percentage saving of subscribers relative to the inferred local monopoly price. Saving 2 is the percentage saving of subscribers relative to non-subscribers. Note that since we use bound estimates for the local monopoly prices, we also get bound estimates for the two saving percentages. Also note that these savings are for the subscribers local to the n symmetric firms; subscribers local to the non-competing firms save even more.

Across products, subscribers will pay 5% to 42% less than the monopoly price with an average saving of 16%. Subscribers also pay 4% to 36% less than non-subscribers with an average saving of 13%. Ideally, consumer savings from subscribing to the gatekeeper should be weighted by the relative numbers of different products sold through the gatekeeper's site. Unfortunately, this information cannot be obtained. Instead, we construct a hypothetical customer who buys each of the 39 products. If such a consumer subscribes to the gatekeeper, she will pay 17.2% to 17.4% less than if she would have bought at the monopoly prices, and she will pay 13.6% to 13.7% less than if she would not have been subscribed to the gatekeeper.

6 Conclusion

In this paper we have studied the implications of a gatekeeper charging click-through fees in stead of fixed fees in a information clearinghouse model. Moreover, to make the theoretical model more suitable for empirical applications, we allow for asymmetry in profit functions across firms. We find that although having a gatekeeper charging firms for each click-through does not have any major impact on the nature of competition in a symmetric setting, once we introduce heterogeneity in firm types, the asymmetric equilibrium with click-through fees is fundamentally different from the asymmetric model with fixed fees. Although we show that firms with relatively high monopoly prices will not compete for price comparing consumers if the gatekeeper charges click-through fees, they might still advertise at the gatekeeper since nobody will click on them. With a fixed fee this would not be optimal, since advertising will always be costly, irrespective of whether the firm gets clicked or not.

Since in most empirical settings firms are heterogeneous, we show that if we do not correct for the presence of non-competing firms at the gatekeeper, estimates of the model will be biased. In addition we show how one can effectively estimate the symmetric mixed strategy equilibrium of the firms that do compete at the gatekeeper from the observed price distribution at the gatekeeper. We apply our estimation method to a large date set of electronics prices collected from *Shopping.com*, a large price comparison site. Estimates indicate that the average proportion of consumers comparing prices is 20.6% and only 32.9% of the sellers are competing for the price comparing consumers. Moreover, the estimates show that subscribed customers save 17.2% to 17.4% off the monopoly prices and pay 13.6% to 13.7% less than non-subscribers.

7 Appendix

Table 1. Detailed Product Information

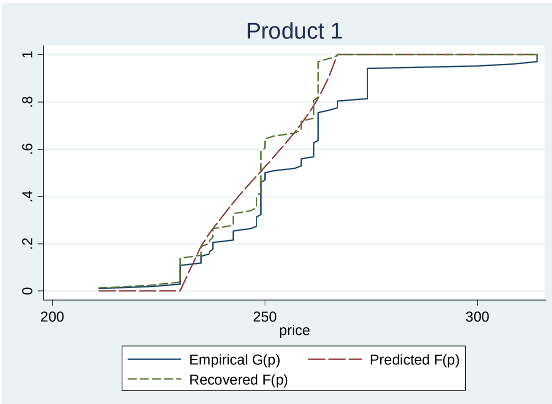
ID	Product	Manufacturer	Category	Section
1	Apple iPod (30G, MA146LL/A)	Apple	Media Player	Electronics
2	Apple iPod (1G, MA352LL/A)	Apple	Media Player	Electronics
3	Apple iPod (2G, MA099LL/A)	Apple	Media Player	Electronics
4	Multi-Function Center MFC-7820N	Brother	Printer	Computers
5	DC100 DVD Camcorder	Canon	Camcorder	Electronics
6	PIXMA MP830 All-In-One InkJet Printer	Canon	Printer	Computers
7	PowerShot S3 IS Digital Camera	Canon	Digital Camera	Electronics
8	EXILIM EX-Z1000 Digital Camera	Casio	Digital Camera	Electronics
9	ZEN Vision:M (30G)	Creative Tech.	Media Player	Electronics
10	Stylus R1800 InkJet Photo Printer	Epson	Printer	Computers
11	FinePix S5200 / S5600 Digital Camera	Fuji	Digital Camera	Electronics
12	Officejet 5610 All-In-One Inkjet	HP	Printer	Computers
13	F2105 21 inch LCD monitor	HP	Monitor	Computers
14	DZBX35A DVD Camcorder	Hitachi	Camcorder	Electronics
15	GR-D370 Mini DV Digital Camcorder	JVC	Camcorder	Electronics
16	DataTraveler I 1G USB2.0	Kingston	Flash Memory	Computers
17	2G 40x SD Card (SD2GB231)	Lexar	Flash Memory	Computers
18	X2350 All-In-One InkJet Printer	Lexmark	Printer	Computers
19	D80 with 18-200mm Lens	Nikon	Digital Camera	Electronics
20	C5800Ldn Led Printer	OKI	Printer	Computers
21	EVOLT E-500 (Body Only) Digital	Olympus	Digital Camera	Electronics
22	Attache 2G USB 2.0 Flash Drive	PNY	Flash Memory	Computers
23	Lumix DMC-TZ1 Digital Camera	Panasonic	Digital Camera	Electronics
24	PV-GS300 Mini DV Digital Camcorder	Panasonic	Camcorder	Electronics
25	Optio A10 Digital Camera	Pentax	Digital Camera	Electronics
26	PL2010M 20 inch LCD Monitor	Planar	Monitor	Computers
27	Digimax S500 Digital Camera	Samsung	Digital Camera	Electronics
28	ML-2510 Laser Printer	Samsung	Printer	Computers
29	SC-D363 Mini DV Digital Camcorder	Samsung	Camcorder	Electronics
30	SyncMaster 215TW 21 inch LCD	Samsung	Monitor	Computers
31	2G SD Card (SDSDB2048A10)	SanDisk	Flash Memory	Computers
32	Cruzer Micro 2G USB2.0	SanDisk	Flash Memory	Computers
33	Sansa e260 (4G) MP3 Player	SanDisk	Media Player	Electronics
34	Xacti VPC HD1A Camcorder	Sanyo	Camcorder	Electronics
35	Cyber-shot DSC-H5 Digital Camera	Sony	Digital Camera	Electronics
36	Handycam DCR-SR100 Camcorder	Sony	Camcorder	Electronics
37	MSX-M1GS Memory Stick Duo Pro	Sony	Flash Memory	Computers
38	4G 150x SD Card	Transcend	Flash Memory	Computers
39	VX2025wm 20.1 inch LCD	ViewSonic	Monitor	Computers

Table 2. Results of OLS estimation of individual product.

Product	Obs	Mean	Median	Std. Dev.	C. V.	Min	Max	Adjusted R^2
1	102	256.104	250.995	19.714	0.077	210.90	313.95	0.099
2	43	131.177	124.920	15.976	0.122	99.99	158.13	0.251
3	91	179.582	178.960	36.227	0.202	111.51	262.49	0.084
4	327	302.926	308.960	43.187	0.143	208.08	378.66	0.471
5	425	387.597	375.000	56.233	0.145	271.13	524.99	0.059
6	443	304.340	301.480	33.676	0.111	215.07	408.40	0.010
7	416	392.254	381.180	44.930	0.115	293.00	629.99	0.007
8	387	311.546	299.990	38.631	0.124	244.00	425.49	0.233
9	285	238.439	236.940	23.892	0.100	195.29	399.99	0.030
10	473	551.209	549.000	51.715	0.094	448.00	709.03	0.197
11	380	272.423	267.990	35.866	0.132	223.99	408.44	0.355
12	432	150.079	149.655	22.617	0.151	95.61	202.41	0.034
13	88	501.361	493.490	104.368	0.208	352.98	654.69	0.719
14	111	263.438	368.000	25.549	0.070	276.00	419.99	0.263
15	305	288.171	283.490	31.083	0.108	209.22	377.30	0.246
16	299	37.672	33.410	17.121	0.454	15.75	94.98	0.348
17	150	73.568	70.380	11.883	0.162	51.19	105.99	0.660
18	236	66.186	63.980	18.900	0.286	35.60	173.48	0.099
19	60	1279.041	1299.990	258.367	0.202	859.00	1904.00	0.257
20	274	788.896	797.950	46.995	0.060	680.99	963.19	0.410
21	275	604.913	550.710	138.964	0.230	484.00	1074.94	0.054
22	135	48.132	46.980	11.537	0.240	30.42	83.99	0.153
23	481	264.947	253.920	36.115	0.136	202.00	374.49	0.119
24	456	524.278	507.840	58.768	0.112	424.00	699.95	0.175
25	339	264.254	261.100	39.113	0.148	197.00	379.98	0.221
26	236	415.645	392.965	63.922	0.154	324.42	613.90	0.179
27	203	135.394	136.490	11.560	0.085	110.24	162.99	0.137
28	212	138.349	139.980	15.238	0.110	88.07	156.65	0.401
29	178	245.823	229.940	41.951	0.171	184.90	354.98	0.143
30	208	502.570	502.700	21.158	0.042	434.93	583.14	0.066
31	448	70.809	71.100	19.114	0.270	27.29	121.79	0.253
32	402	72.036	72.400	17.217	0.239	31.50	110.88	0.061
33	367	168.883	160.940	26.134	0.155	126.94	271.40	0.067
34	137	611.453	609.000	64.367	0.105	480.00	746.36	0.453
35	425	416.464	413.920	34.919	0.084	359.96	503.99	0.173
36	302	821.387	799.990	86.389	0.105	684.99	1038.88	0.076
37	331	59.966	53.740	19.330	0.322	31.94	163.16	0.035
38	186	99.906	97.450	17.228	0.172	77.98	175.00	0.245
39	105	361.935	349.940	29.732	0.082	306.87	490.59	0.511

Table 3. Results of structural estimation

Product	$\widehat{\alpha}$	N	$\widehat{n}$	$\widehat{\mu}$	$\widehat{c}'$	$(1-\widehat{\alpha})^{\widehat{n}}$	Saving1 (%)	Saving2 (%)
1	0.283	18	14	0.26	223.4	0.95%	(12.8, 13.2)	(11.2, 11.4)
2	0.195	11	11	0.24	81.7	9.20%	(20.6, 21.0)	(17.9, 18.2)
3	0.253	18	14	0.27	122.6	1.68%	(26.9, 27.2)	(23.5, 23.8)
4	0.654	25	8	0.21	189.0	0.02%	(25.9, 26.1)	(19.6, 19.7)
5	0.483	44	8	0.05	298.2	0.51%	(6.8, 7.0)	(5.7, 5.8)
6	0.582	38	8	0.11	232.0	0.09%	(13.5, 13.8)	(10.6, 10.7)
7	0.392	53	11	0.05	319.9	0.42%	(8.9, 9.2)	(7.8, 7.9)
8	0.667	29	5	0.02	213.3	0.41%	(6.3, 6.6)	(4.7, 4.8)
9	0.527	27	9	0.13	188.1	0.12%	(12.0, 12.4)	(9.5, 9.7)
10	0.622	38	6	0.07	438.8	0.29%	(8.1, 8.2)	(5.9, 5.9)
11	0.452	42	12	0.49	231.0	0.07%	(7.7, 8.1)	(6.3, 6.5)
12	0.600	36	4	0.02	74.6	2.56%	(10.9, 11.6)	(7.0, 7.3)
13	0.629	7	7	0.54	306.5	0.10%	(40.0, 40.1)	(29.5, 29.6)
14	0.427	13	9	0.06	226.8	0.67%	(12.1, 12.3)	(10.0, 10.1)
15	0.610	25	7	0.02	168.7	0.14%	(12.3, 12.6)	(10.1, 10.2)
16	0.623	24	8	0.13	15.2	0.04%	(29.1, 31.5)	(24.0, 25.0)
17	0.469	16	7	0.04	46.9	1.19%	(13.5, 14.7)	(11.3, 12.0)
18	0.561	21	4	0.10	19.2	3.71%	(28.3, 29.5)	(18.4, 19.1)
19	0.250	12	12	0.65	887.5	3.17%	(41.4, 41.5)	(36.1, 36.1)
20	0.721	19	4	0.02	505.8	0.61%	(6.5, 6.6)	(4.4, 4.4)
21	0.550	25	11	0.75	506.1	0.02%	(8.3, 8.5)	(6.4, 6.5)
22	0.519	13	6	0.12	19.2	1.24%	(24.8, 26.3)	(18.9, 19.8)
23	0.601	40	7	0.09	209.1	0.16%	(8.5, 8.9)	(6.8, 7.0)
24	0.556	41	6	0.01	350.4	0.77%	(5.2, 5.4)	(4.2, 4.3)
25	0.565	30	6	0.04	213.9	0.68%	(5.0, 5.4)	(4.1, 4.3)
26	0.694	17	8	0.17	356.8	0.01%	(8.0, 8.2)	(6.6, 6.7)
27	0.539	19	12	0.59	121.2	0.01%	(13.3, 13.9)	(10.8, 11.1)
28	0.758	14	7	0.11	63.5	0.00%	(23.4, 24.0)	(18.4, 18.6)
29	0.468	19	9	0.14	184.4	0.34%	(13.9, 14.3)	(11.5, 11.7)
30	0.520	20	11	0.37	473.2	0.03%	(7.9, 8.1)	(6.7, 6.8)
31	0.622	36	5	0.11	25.9	0.77%	(29.7, 31.1)	(20.9, 21.5)
32	0.648	31	9	0.36	34.6	0.01%	(41.0, 41.9)	(32.0, 32.5)
33	0.524	35	6	0.05	106.1	1.16%	(13.9, 14.4)	(10.1, 10.4)
34	0.685	10	5	0.04	139.1	0.31%	(15.2, 15.4)	(10.9, 11.0)
35	0.559	38	6	0.02	336.7	0.74%	(5.0, 5.3)	(4.2, 4.4)
36	0.559	27	11	0.56	712.0	0.01%	(11.3, 11.4)	(8.9, 9.0)
37	0.552	30	11	0.23	35.1	0.01%	(21.8, 23.3)	(17.7, 18.5)
38	0.715	13	6	0.34	74.5	0.05%	(16.7, 17.5)	(11.2, 11.5)
39	0.350	15	9	0.09	288.2	2.07%	(7.3, 7.6)	(5.9, 6.1)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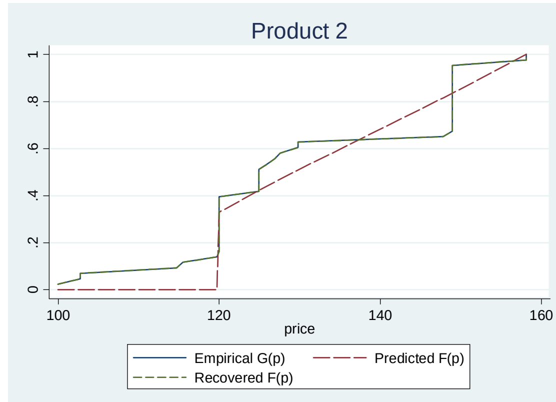
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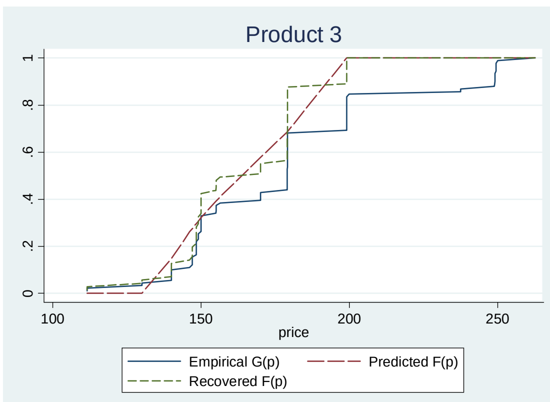
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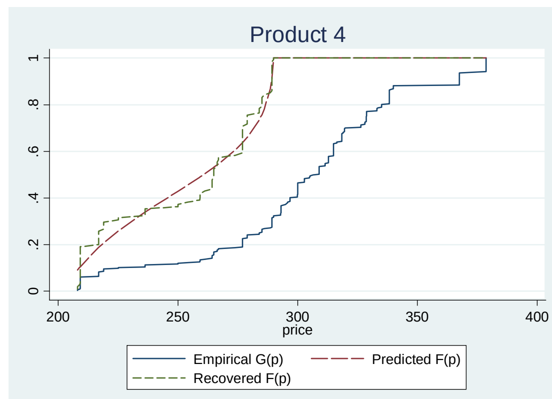
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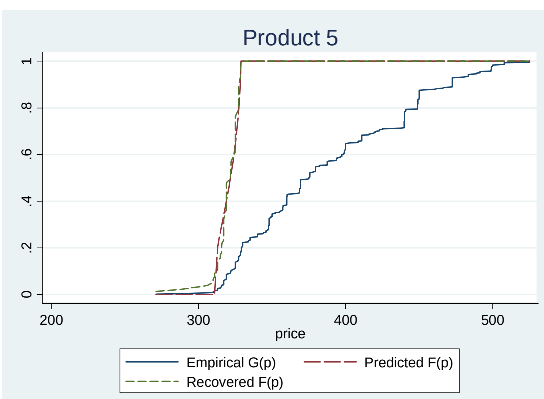
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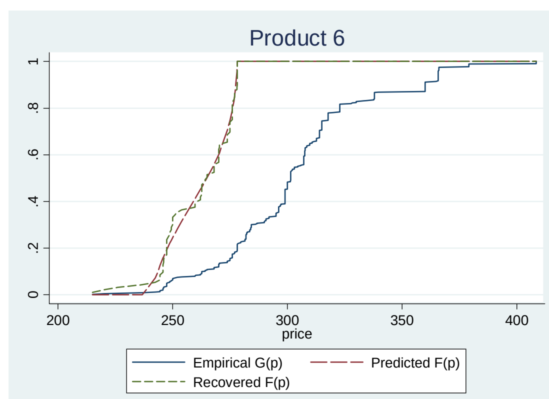
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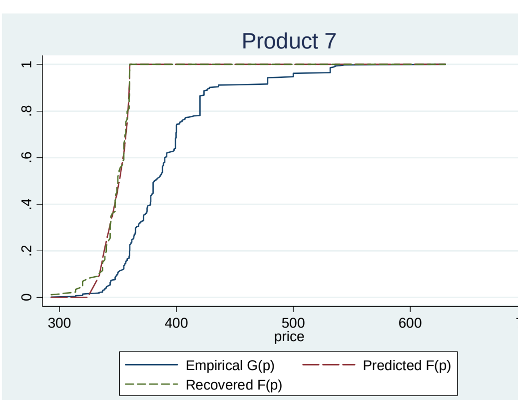
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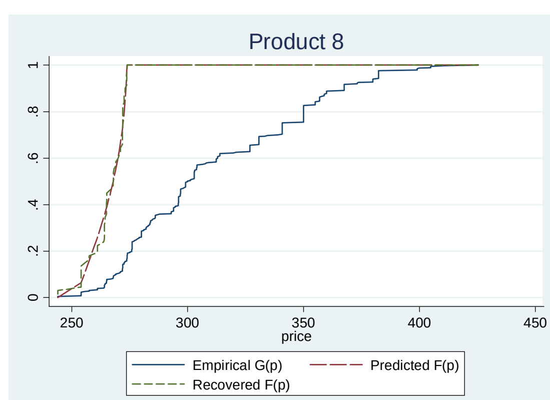
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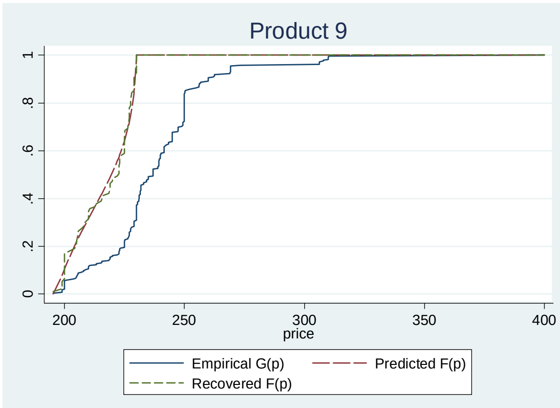
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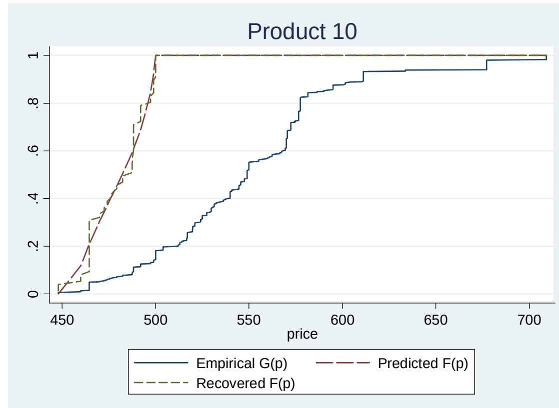
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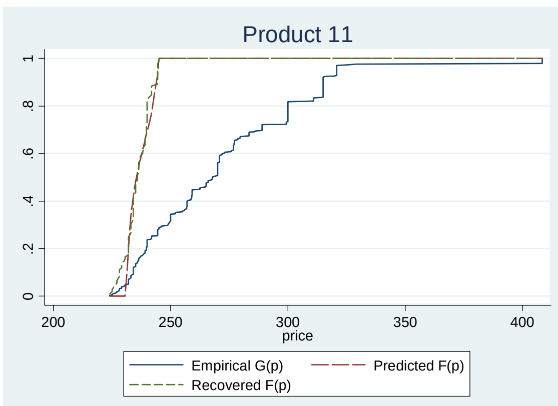
Recovered F(p)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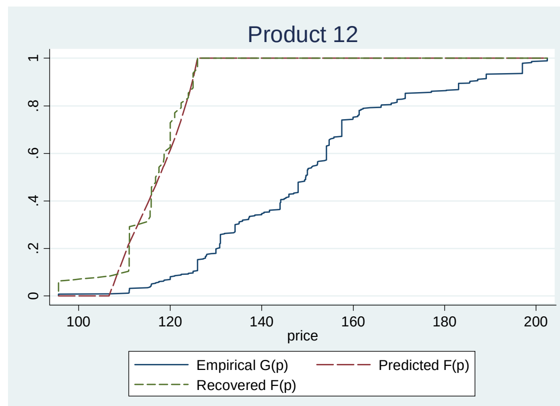
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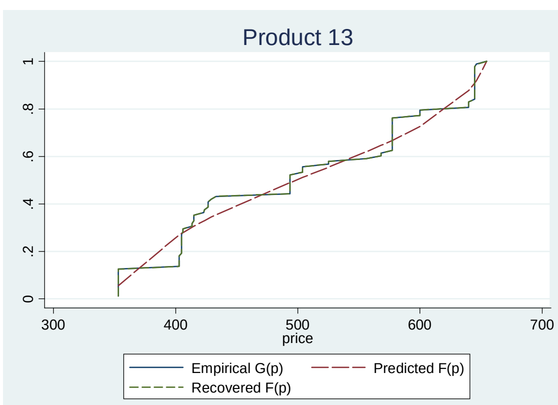
Recovered F(p)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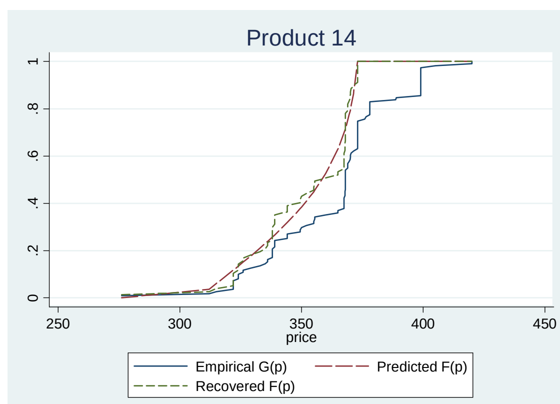
Recovered F(p)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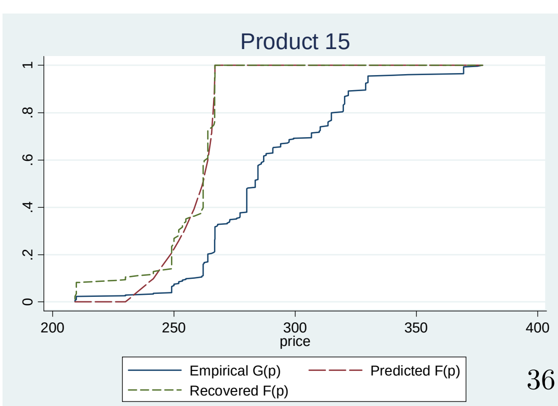
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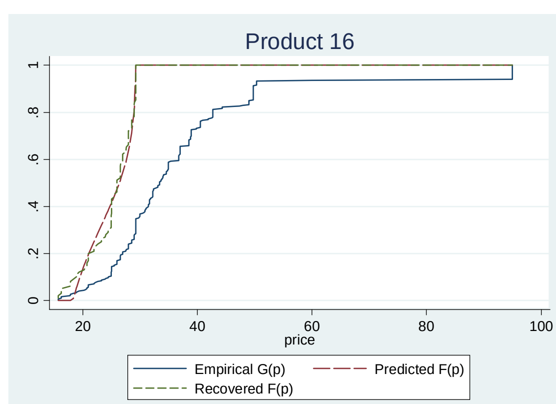
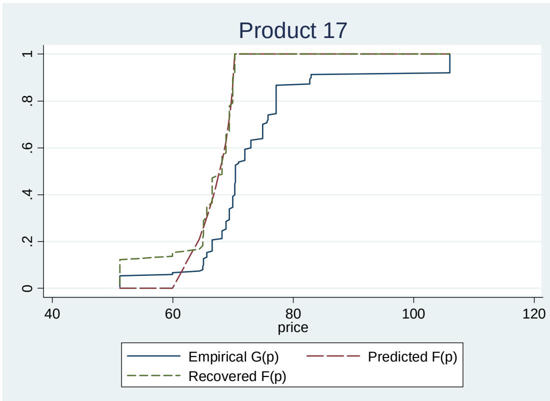
Predicted F(p)
Recovered F(p)


Product 16
0
.2
.4
.6
.8
1
20
40
60
80
100
price
Empirical G(p)
Predicted F(p)
Recovered F(p)


Product 17
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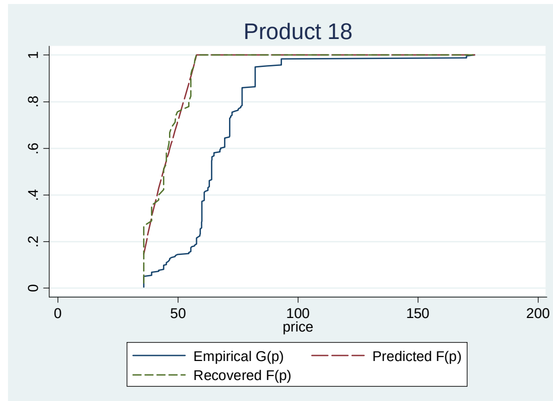
40 60 80 100 120
price
Empirical G(p)
Predicted F(p)
Recovered F(p)


Product 18
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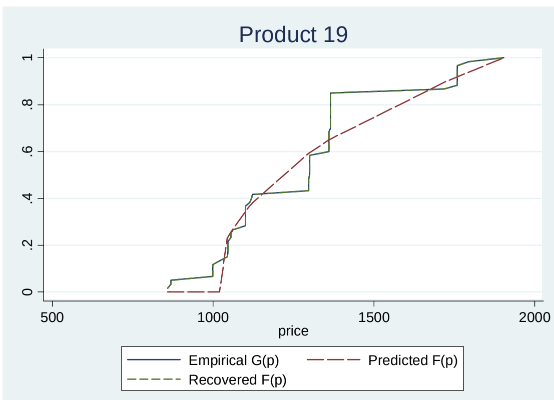
price
Empirical G(p)
Predicted F(p)
Recovered F(p)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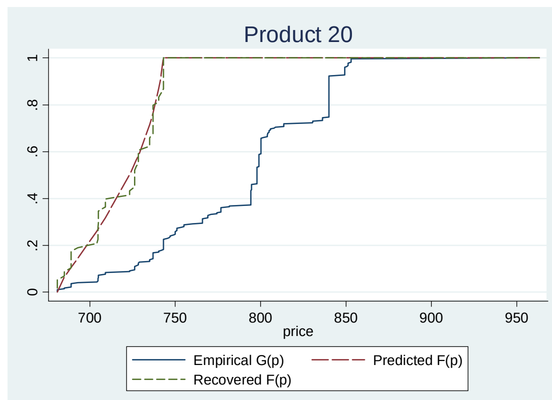
price
Empirical G(p)
Predicted F(p)
Recovered F(p)


Product 20
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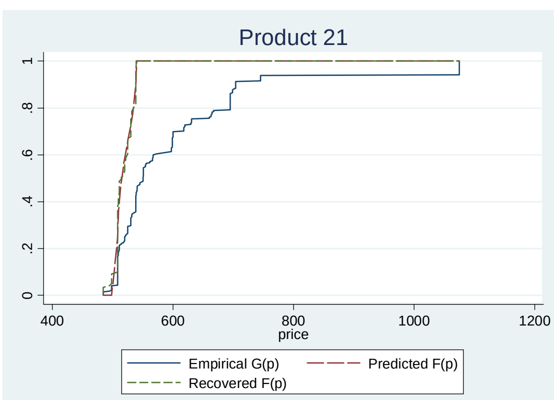
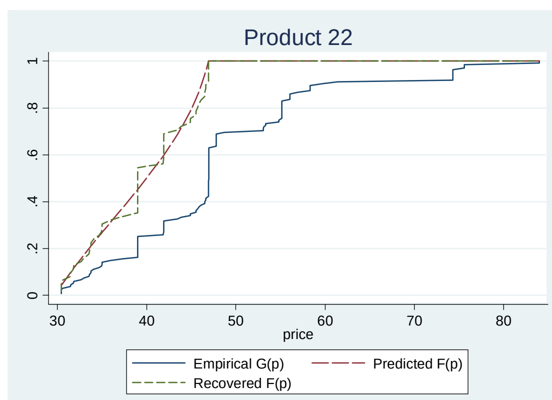
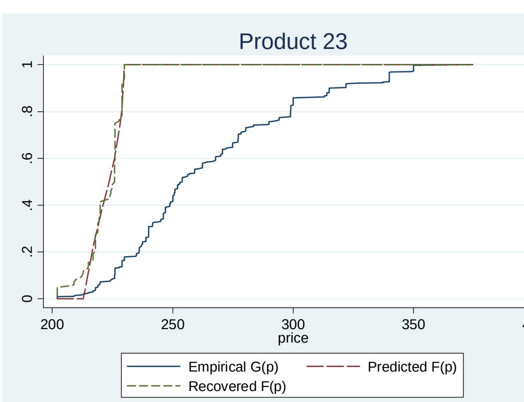
price
Empirical G(p)
Predicted F(p)
Recovered F(p)


Product 21
0 .2 .4 .6 .8 1
400 600 800 1000 1200
price
Empirical G(p)
Predicted F(p)
Recovered F(p)


Product 22
0 .2 .4 .6 .8 1
30 40 50 60 70 80
price
Empirical G(p)
Predicted F(p)
Recovered F(p)


Product 23
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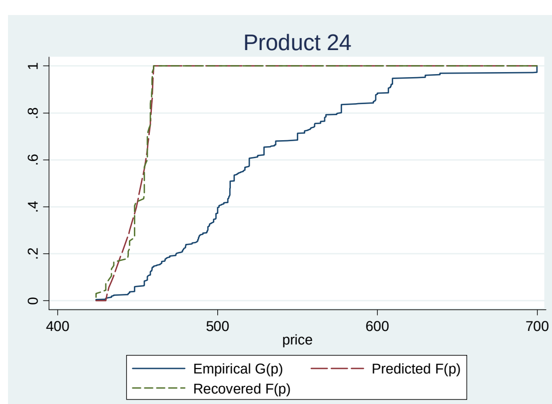
200 250 300 350 400
price
Empirical G(p)
Predicted F(p)
Recovered F(p)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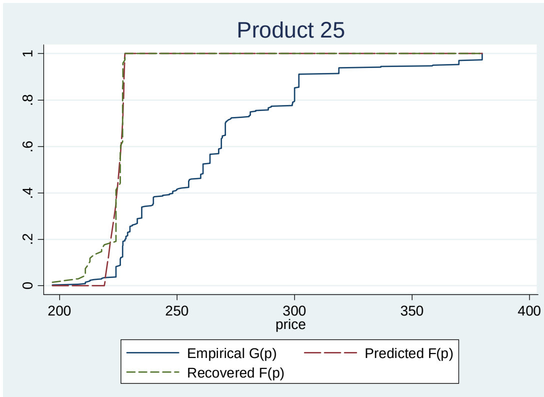
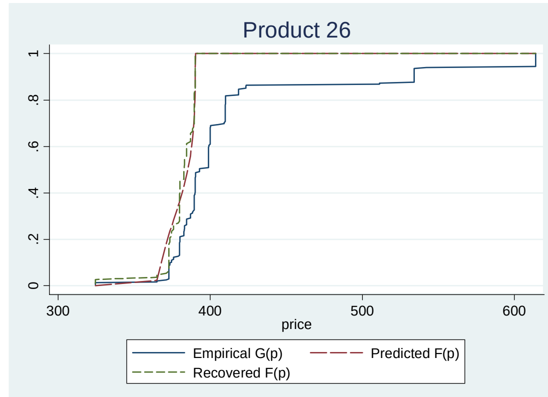
price
Empirical G(p)
Predicted F(p)
Recovered F(p)


Product 25
0
.2
.4
.6
.8
1
200
250
300
350
400
price
Empirical G(p)
Predicted F(p)
Recovered F(p)


Product 26
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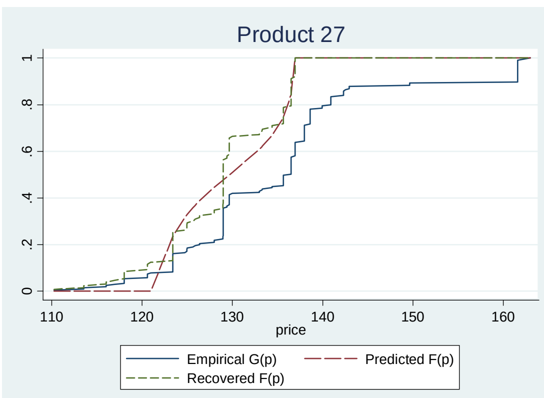
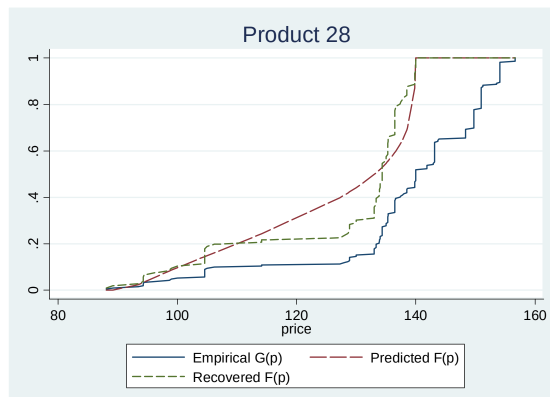
.6
.8
1
300
400
500
600
price
Empirical G(p)
Predicted F(p)
Recovered F(p)


Product 27
0
.2
.4
.6
.8
1
110
120
130
140
150
160
price
Empirical G(p)
Predicted F(p)
Recovered F(p)


Product 28
0
.2
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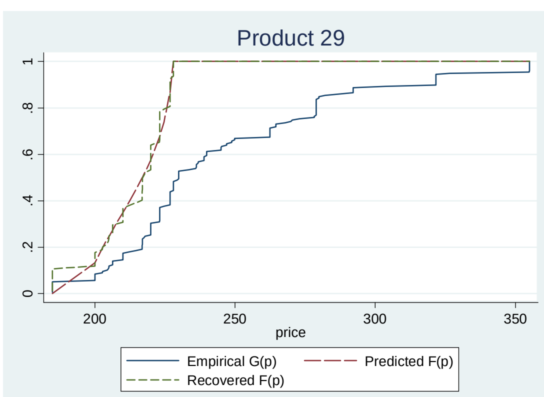
.6
.8
1
80
100
120
140
160
price
Empirical G(p)
Predicted F(p)
Recovered F(p)


Product 29
0
.2
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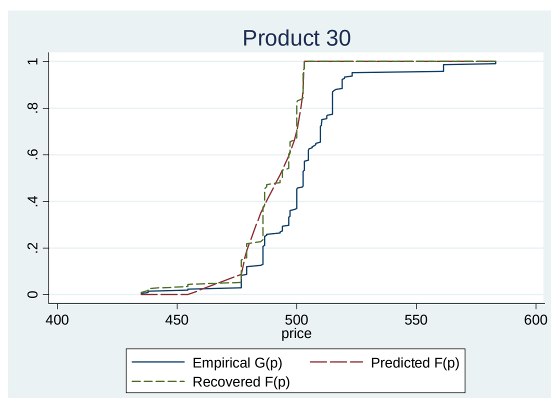
.6
.8
1
200
250
300
350
price
Empirical G(p)
Predicted F(p)
Recovered F(p)


Product 30
0
.2
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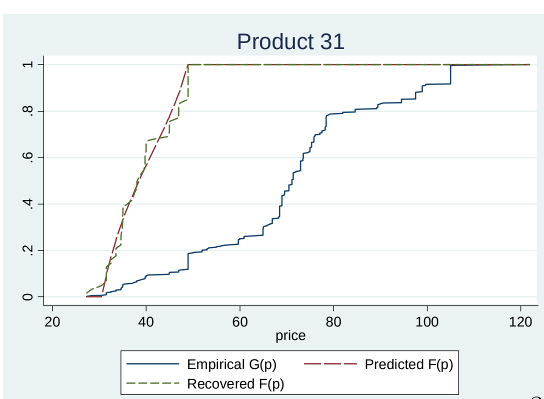
.6
.8
1
400
450
500
550
600
price
Empirical G(p)
Predicted F(p)
Recovered F(p)


Product 31
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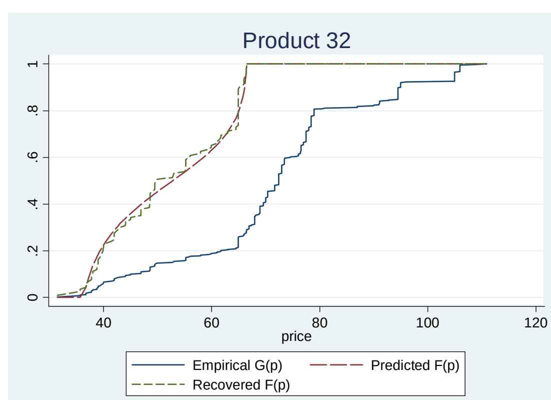
.6
.8
1
20
40
60
80
100
120
price
Empirical G(p)
Predicted F(p)
Recovered F(p)


Product 32
0
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.6
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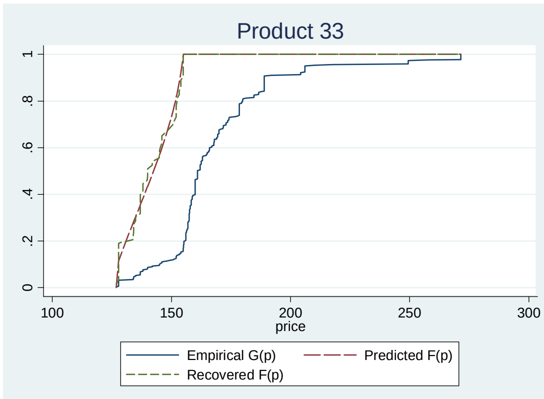
1
40
60
80
100
120
price
Empirical G(p)
Predicted F(p)
Recovered F(p)


Product 33
0
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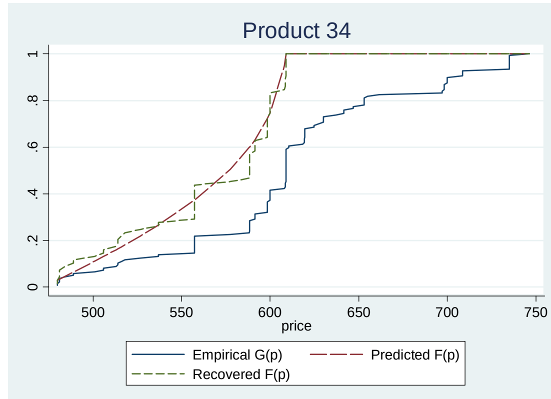
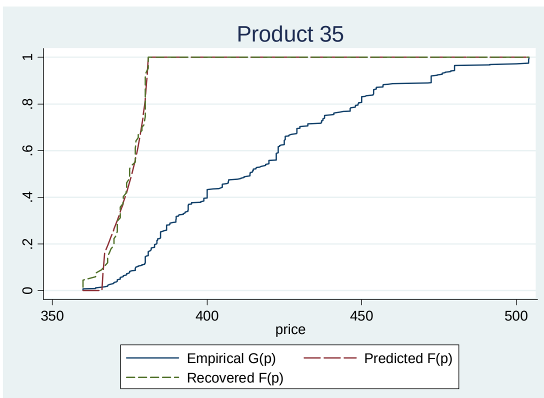
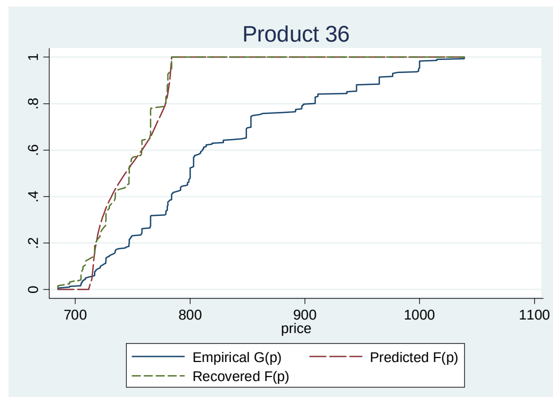
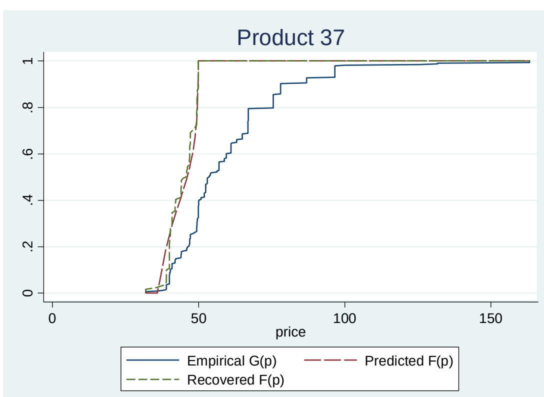
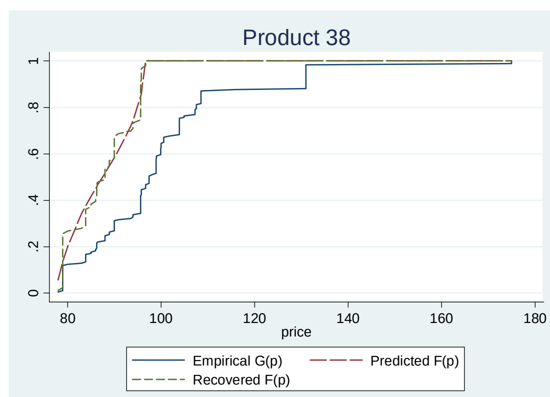
.4
.6
.8
1
100
150
200
250
300
price
Empirical G(p)
Predicted F(p)
Recovered F(p)


Product 34
0
.2
.4
.6
.8
1
500
550
600
650
700
750
price
Empirical G(p)
Predicted F(p)
Recovered F(p)


Product 35
0
.2
.4
.6
.8
1
350
400
450
500
price
Empirical G(p)
Predicted F(p)
Recovered F(p)


Product 36
0
.2
.4
.6
.8
1
700
800
900
1000
1100
price
Empirical G(p)
Predicted F(p)
Recovered F(p)


Product 37
0
.2
.4
.6
.8
1
0
50
100
150
price
Empirical G(p)
Predicted F(p)
Recovered F(p)


Product 38
0
.2
.4
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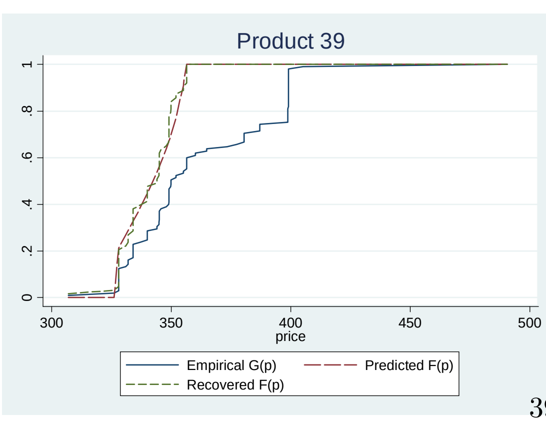
.8
1
80
100
120
140
160
180
price
Empirical G(p)
Predicted F(p)
Recovered F(p)


Product 39
0
.2
.4
.6
.8
1
300
350
400
450
500
price
Empirical G(p)
Predicted F(p)
Recovered F(p)

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