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Master's Thesis

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Transparency and the Price Setting Behavior of Firms

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Preface

During our years as students of economics, we have been introduced to theoretical literature considering incomplete information among firms, and especially how information can affect firms' ability to engage in tacit collusion. It occurred to us that the basic setup in many of these models is peculiar; firms lack information about each other's prices, but yet it is assumed that consumers can costlessly observe these.

We were first introduced to the concept of uninformed consumers in the fall of 2005, when we had the pleasure of taking the class "Advanced Industrial Economics" at the University of Copenhagen. Here, Professor Christian Schultz introduced us to Hal R. Varian's article "A model of sales" (1980), which considered the effect of uninformed consumers on equilibrium prices. Varian taught us that 'the law of one price' fails to apply in a competitive market where some consumers are uninformed about prices, and thus prepared the ground for our interest in firms' price setting behavior and the effects of changes in consumer side information on competition.

Discussing the existence of uninformed consumers with our fellow students, two questions came into our minds: Was the conventional wisdom of consumer side information improving competition always true? And could the public opinion of uniform prices being a signal of collusive behavior be formalized? These questions became the seed of our thesis.

We thank Professor Christian Schultz for excellent advice during the past months. We would like to thank Peder Kongsted and Frederik Silbye from the Danish Competition Authorities for helpful comments and especially for bringing our attention to the existence of the Federation of Danish Motorists (FDM) gasoline price portal. We also thank FDM for providing us with data. Furthermore, we thank Jens Nielsen for giving us insight into the gasoline business through several conversations, and Birgitta Spiteri for proof-reading and keen advice on English grammar. We are grateful to Peter Rasmussen and Claus Bjørn Jørgensen for commenting a final draft of this thesis. All errors are ours.

To comply with existing rules, we have chosen to divide the thesis, in the way that Jonas is responsible for chapter 1 and sections 2.1, 2.3, 3.1, 3.3, 4.2, 5.2, 5.4, 6.2, 6.3, and 6.5, while Casper is responsible for sections 2.2, 2.4, 3.2, 4.1, 4.3, 5.1, 5.3, 5.5, 6.1, and 6.4, and chapter 7.

Copenhagen, September 2006

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Chapter 1

Introduction

The rapid growth in e-commerce and the widespread use of information gathering on the internet have brought the policy implications of promoting transparency into focus. Price comparison websites, buyer agents and shop bots have significantly reduced the cost and time required to discover the lowest price on these markets. The increased availability of price information has not only affected online markets, but also numerous price portals aim at informing consumers about the quality and prices of products in ”real-life” markets. In Denmark examples of such price portals are teleprisguide.dk, benzinpriser.dk and, most recently, pengepriser.dk.

1.1 Competition policy

In the public opinion and among consumer councils, the traditional view has been that increased transparency promotes competition, since more informed consumers make it more attractive for firms to set low prices. Economists and competition authorities, however, have been concerned that increased transparency not only helps consumers in their search for the lowest price, but also provides a foundation for information sharing between firms, making collusion easier to sustain. The idea that access to information about competitors' prices can promote anti-competitive behavior originates from Stigler (1964), who argues that increased information on the producer side may serve as an instrument for firms to detect ”undercutters”, thus facilitating cartels. Over the years this conception has developed into a profound knowledge of how information affects firms' ability to collude. The general learning from the vast number of articles on this topic is that more transparency on the producer side is usually anti-competitive, e.g. Kühn & Vives (1995).

Hence, the traditional policy recommendations on transparency issues have balanced the perceived positive effects of increased price information among consumers against the negative effects of more information among firms. This trade-off is reflected in the Series Roundtables on Competition Policy, OECD (2001) p. 9: "*As a general rule, increased price transparency will benefit buyers unless it results in considerably increased risks of collusion among sellers.*" Moreover, OECD states that "*measures extending to consumer transparency which already exist among businesses should generally be pro-competitive.*" This illustrates clearly that the perceived downside to more transparency is usually more information among firms. The validity of such statements is the key topic in this thesis. As the effects of increased producer side information are well understood, we will assume that firms are perfectly informed. While this is obviously a simplification of reality, it enables us to distinguish how changes in transparency on the consumer side alter competition.

While there seems to be general agreement that more information among consumers will lower prices and make the single shot market outcome more competitive, the story is less clear-cut if repeated competition is taken into consideration. More informed consumers do not only increase firms' incentive to undercut competitors - they also enhance firms' ability to punish a potential undercutter. A priori, it is not possible to determine which of these two countervailing effects is dominating. Hence, the policy implications concerning transparency are mixed, even if producer side information is unaffected.

1.2 Framework

Although transparency is an often-used term in the policy debate, the definition of the term may sometimes be unclear. In this thesis we use the term transparency to describe the degree of consumer side information in the market. More precisely, we use the term in two slightly different ways. First, as a measure of how easily consumers can become informed about prices. The lower the cost in time and money required to discover prices, the more transparent is the market.[1] However, in a large part of the literature, search is not modeled explicitly, and hence, we also interpret transparency as the share of consumers who are informed about prices. As will be clear later, there is no conflict between these two definitions of transparency in this thesis.

1.2.1 Transparency and competition in static games

An obvious requirement when studying the effects of changes in transparency is a setup where some consumers are imperfectly informed about prices. Traditional workhorse models, such as the Bertrand model, are not directly suited for this purpose, since they implicitly assume that all consumers are informed about prices. A few modifications may however turn the Bertrand model into a satisfactory starting point for studying how competition is affected by changes in transparency. This is exactly the procedure followed in Salop & Stiglitz (1977) and Varian (1980). Here firms compete in prices in a market where some consumers are informed and some are uninformed about the prices offered by firms. Informed consumers shop at the store offering the lowest price, while the uninformed consumers choose a store at random. Since firms are not able to price discriminate, they face the following problem: By pricing low, firms can hope to win the informed consumers, but by doing so, they forgo the possibility of charging a high price and exploit the uninformed consumers. There are two effects in play. If all firms charge a high price, a firm can reduce the price slightly and win all informed consumers, with only a marginal loss on existing customers. This puts a downward pressure on prices similarly to traditional price competition. However, since firms can always charge the monopoly price and serve their share of the uninformed consumers, there is a limit to how low firms are willing to price. Instead of tying at this low price, a firm is better off abandoning informed consumers and charging a high price to exploit uninformed consumers. This simple argument reveals that no single price can be the market outcome when there are both informed and uninformed consumers. In Varian (1980), firms avoid this catch 22 by setting unpredictable prices. Instead of offering a fixed price, firms randomize prices, making it impossible for competitors to systematically offer a slightly lower price.

A natural extension to this stylized model is to endogenize consumers' decision to become

[1]This is the definition of transparency used by OECD, see OECD (2001)

informed. This is done in Burdett & Judd (1983) among others. Rather than assuming differences in consumer information *ex ante*, they use the idea that consumers' willingness to search is determined by the expected gain from being informed about prices. The main finding is that differences in consumer information *ex post* can arise even if all consumers are alike.

The general findings in static game models with imperfectly informed consumers are that differences in information usually generate market outcomes where prices are dispersed. The learnings from this literature seems to be that more transparency promotes competition.

1.2.2 Consumer side information in dynamic games

The research on how consumer side information affects firms' ability to collude in repeated games is more limited. This topic has primarily received attention from Scandinavian researchers; perhaps because Scandinavian competition authorities have been some of the strongest advocates for promoting transparency, see Nilsson (1999). Nilsson (1999) considers firms' ability to collude in the Burdett & Judd (1983) framework. He finds that collusion may be easier to sustain when search costs are lower and more consumers are informed. Schultz (2005) analyzes how product differentiation affects collusion when some consumers are imperfectly informed about prices. He finds that when products are differentiated, collusion becomes harder to sustain when more consumers are informed. Møllgaard & Overgaard (2000) interpret the degree of product differentiation as transparency and reuse the results from the literature on collusion with heterogeneous products. They find that full transparency is not optimal. To summarize, the literature does not give any conclusive policy recommendations if there is a potential risk that firms are able to collude.

1.3 Our approach

This thesis reviews and extends the existing literature to shed light on the following questions:

- How do changes in transparency affect competition?
- How do differences in firms' costs affect policy recommendation regarding transparency?
- Is the predicted price-setting behavior of firms supported by data from the Danish gasoline market?

The thesis proceeds as follows: Chapters 2-4 survey the existing literature on transparency and competition to clarify circumstances under which transparency is likely to promote competition. In chapter 5 we extend the existing literature on transparency and competition by studying how the presence of asymmetric costs affects competition under imperfect transparency. More specifically, we consider a duopoly version of Varian (1980), where firms face a downward sloping demand curve and differ with respect to marginal costs. We show that the mixed strategy equilibrium suggested by Varian is quite robust to this change, although an asymmetric pure strategy equilibrium emerges when there are only few informed consumers. Moreover we study how the presence of asymmetric costs affects firms' ability to collude when transparency is less than perfect. The result is surprisingly clear in this particular setup: When firms have different costs, more transparency unambiguously makes it easier for firms to sustain collusion. Finally, in chapter 6 we study firms' price-setting behavior in the Danish gasoline market to see whether the theoretical predictions from chapter 2 - 5 are supported by empirical data. We find that significant price dispersion exists when stations compete, and that this dispersion is temporal rather than spatial. Moreover, we find that prices in Helsingør are higher and less dispersed during the tourist season when there are many uninformed consumers. This phenomenon can be explained by the pure strategy equilibrium in our model but is inconsistent with the predictions on transparency and collusion.

Chapter 2

Incomplete Consumer Information

A natural starting point when analyzing the influence of transparency on competition is to assume that some consumers lack information about prices, while others are perfectly informed. One interpretation of such differences in consumer information is that stores advertise their prices in a weekly newspaper, so that informed consumers are those who buy the newspaper and are able to compare prices, whereas uninformed consumers do not read the paper. A more modern interpretation is the "digital divide". Some people have access to the internet, where they can easily search for products and compare prices, while others do not have this option or choose not to make use of it. The implications of such heterogeneous consumer information is the topic presented in this chapter. Our primary focus will be on Salop & Stiglitz (1977)[1] and Varian (1980). These classical papers are some of the earliest attempts to study competition and consumer side information. Their approaches have built the foundation for the majority of more recent research, although the main purpose of Varian's and Salop & Stiglitz' articles were not to analyze transparency, but rather to explain the existence of equilibrium price dispersion.

This chapter proceeds by explaining the main idea in Salop & Stiglitz (1977) where the presence of uninformed consumers results in a pure strategy equilibrium, where some firms offer high prices while other set low prices. Next, we study Varian (1980) who finds that differences in consumers information leads to a mixed strategy equilibrium, where firms randomize their prices. Finally, we look at how differentiated goods affect firms' price

[1]Salop & Stiglitz (1977) do not assume differences in consumer information but rather differences in consumers' search cost. We consider searching in more details in chapter 3.

setting behavior. The main result in this chapter is that more informed consumers makes it more profitable for firms to set a low price, thereby promoting competition.

2.1 Spatial price dispersion

Salop & Stiglitz (1977) show that the presence of some uninformed consumers may lead to persistent differences in the prices offered by firms. They show that if the market consists of both informed and uninformed consumers, the equilibrium outcome may be that some firms persistently serve only uninformed consumers at a high price, while other firms persistently offer a low price to attract the informed consumers. They characterize this market outcome as *spatial price dispersion*.

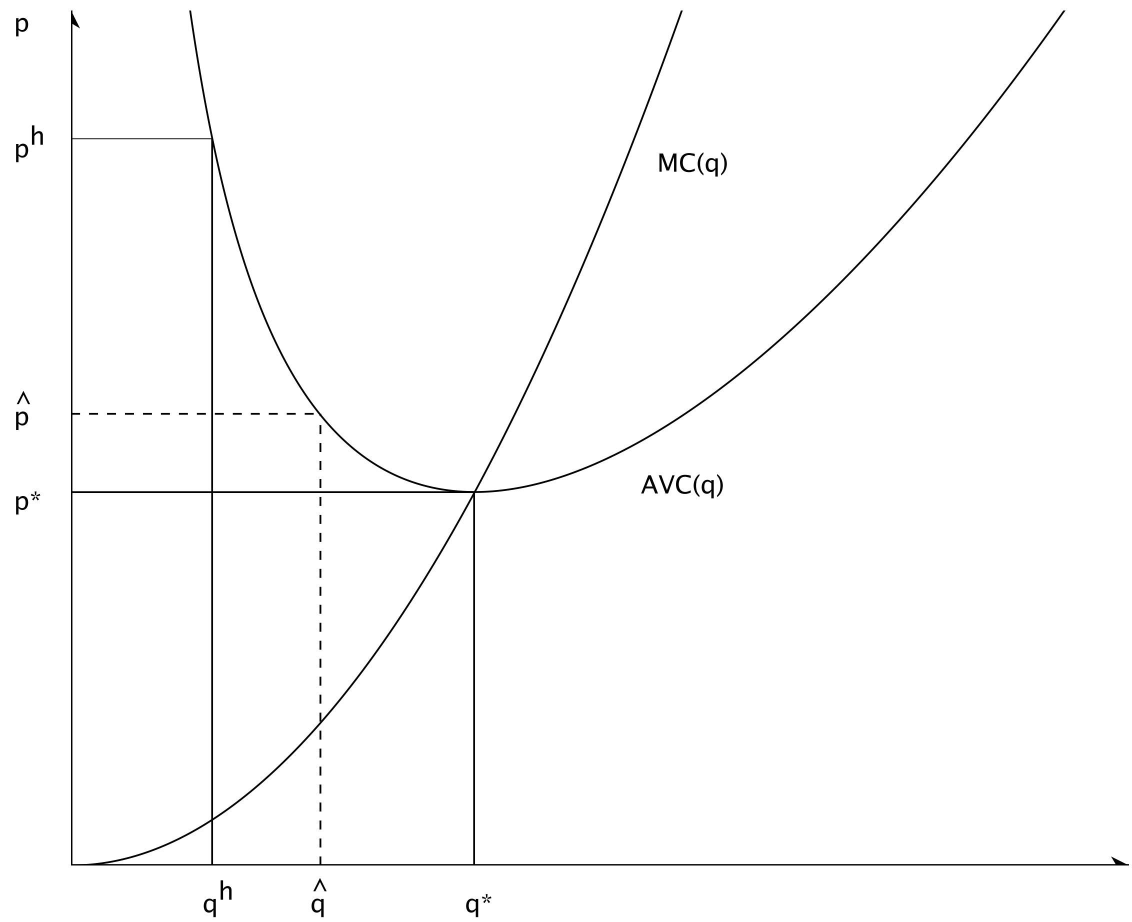
Salop & Stiglitz (1977) set up a model where consumers with either high (type 1) or low (type 2) search costs can become completely informed about prices through costly information-gathering. An informed consumer shops at the lowest price on the market, while an uninformed consumer shops at a random store if the price is below his reservation price. A consumer chooses to search when the cost of searching is lower than the value of information. This means that a consumer searches if the difference between the expected price an uninformed consumer has to pay and the lowest price on the market is greater than the cost of searching. Salop & Stiglitz (1977) make a crucial assumption about the consumers' information: Consumers know the distribution of prices in the market, but not at which store each price is charged.

Under these assumptions, Salop & Stiglitz (1977) show that three types of equilibria in pure strategies exist; a Single-Price Equilibrium (SPE) where all consumers are informed and all firms set the competitive price denoted p^*. A SPE where all consumers are uninformed and all firms set the monopoly price, u, identical to the consumers' reservation price. And finally, a Two-Price Equilibrium (TPE) where only consumers with low search costs are informed. Here, some firms set the competitive price, p^*, and some a higher price, p_h. It is easy to understand the intuition behind the two SPEs. When all consumers are informed, we are back to the classical Bertrand model. On the other hand, each firm acts as a monopolist on each share of the market when all consumers are uninformed. In the following we focus on the TPE where both informed and uninformed consumers coexist, since this is the relevant case when studying transparency.

2.1.1 Two-price equilibria

A necessary condition for a TPE to exist is that there are both informed and uninformed consumers in equilibrium. Hence, type 1 consumers must find it beneficial to become informed, while type 2 consumers must choose to stay uninformed.

Figure 2.1: Two-price equilibrium with U-shaped average costs



Price range

From Figure 2.1 it can be concluded that low price firms will charge p^* in equilibrium: To see this suppose the lowest price charged is $\hat{p} > p^*$. Then a single firm can lower the price slightly and reap all informed consumers, making a positive profit. Also, since the average cost curve is U-shaped, no firm will set a price below p^*, since it would make a negative profit. Thus, p^* is the only possible price charged by low price firms in equilibrium.

High price firms charge a price p_h. Two scenarios may occur: If type 2's search costs are low, p_h is equal to the price that makes type 2 consumers indifferent between searching and staying uninformed. If searching is sufficiently costly to type 2 consumers, high price firms can charge the monopoly price without inducing type 2 consumers to search.

No deviation conditions

In the TPE no firm setting p^* will choose to raise its price, as it would lose all type 1 consumers, since some firms would still be charging the competitive price. Since lowering the price yields negative profits, deviating is unprofitable for a low price firm.

For a high price firm it may be possible to lower its price such that the average price decreases enough to make type 1 consumers unwilling to search. In this case, all consumers - now being uninformed - would buy randomly, increasing the deviant's sale. This deviation is unprofitable if the new price is not sufficiently high to cover the deviant's average cost at the new quantity, or if the decrease in average cost is not sufficiently large. Moreover, if the number of firms is large, a deviant may be unable to affect the average price enough to affect the consumers' search behavior, and a TPE may exist.

Note that the TPE never exists when there are only two firms. To see this, first notice that the high price firm, h, can never make a higher profit than the low price firm, l, since l can always mimic firm h. Next, notice that if l's profit is larger than h's, h will undercut l's price slightly, reaping l's profit. If l and h make the same profit, the demand for l's goods is $\frac{1+\alpha}{2}$ and $\pi_l = \frac{1+\alpha}{2}p^l = \bar{\pi}$ while h sells to $\frac{1-\alpha}{2}$ consumers, making $\pi_h = \frac{1-\alpha}{2}p^h = \bar{\pi}$, where α is the share of type 1 consumers. In this case, it is always profitable for firm l to raise the price marginally, since it would still be the cheaper firm and hence still be serving the informed consumers. But then l will make a higher profit than h which was rejected above. Hence, a TPE cannot exist when there are only two firms.

To summarize, there exists a TPE where some firms charge the competitive price while other firms charge a higher price, when there are many firms, type 1 consumers are informed, and type 2 consumers are uninformed.

Spatial price dispersion as described by Salop & Stiglitz (1977) entails that identical product are sold at different prices at the same time. While this may be the outcome in a market where consumers buy the product once, it is questionable if this kind of persistent price difference can prevail in markets where consumers are able to learn from experience.

In the next section we will turn to Varian (1980), who assumes that average cost curves are strictly declining, ensuring that firms will always be tempted to undercut the competitors. Consequently there exists no PNE in this case.

2.2 Temporal price dispersion

Rather than considering *spatial* price dispersion Varian (1980) analyzes a market where the existence of uninformed consumers implies that firms have randomly sales, so that the market is characterized by a *temporal* price dispersion. Since the lowest price is charged by different firms at different times, temporal price dispersion seems more resistant to consumers learning and is therefore more likely to persist for longer periods of time.

Varian (1980) considers a market with n symmetric firms, all incurring a fixed cost, k, such that average cost curves are strictly declining. It is assumed that entry occurs until the profit in equilibrium is zero. There are a large number of consumers with unit-demand and the reservation price r. M of the consumers are uninformed about prices while I consumers are informed. Uninformed consumers choose a store at random and buy the product if the price is lower than their reservation price. Informed consumers know the distribution of prices and shop at the cheapest store at all times. For later reference, we define the number of uninformed consumers per store as $U = \frac{M}{n}$. The firm which has the lowest price succeeds in its sale, and sells to $I + U$. In contrast, firms who fail to have the lowest price only sell to U consumers.

2.2.1 Equilibrium behavior

In equilibrium each firm sets prices according to some density function $f(p)$, which indicates the probability of different prices. Firms' objective is to choose the density function in order to maximize expected profit, taking the strategy of their competitors as given. Before we derive the equilibrium density function, we will examine some characteristics of firms' price-setting behavior.

First, note that no consumers are willing to buy at a price above their reservation price, thus prices higher than r will result in negative profits. A firm can never get more consumers than $I + U$. When this happens, the average cost is $p^* = \frac{c(I+U)}{I+U}$. Since setting a price below average cost is certain to yield negative profit, no firm will set a price lower than p^*. Hence, firms will never charge prices below p^* or above r.

Second, there is no symmetric equilibrium where all stores charge the same price. To see this, suppose that the stores charged a price p higher than p^* and lower than or equal to r. In this case a firm could increase profits by reducing their price marginally and serve all informed consumers. If all firms charged p^*, each would get an equal share of the market and make negative profits. This argument suggests that in equilibrium, firms must play a mixed strategy. Note that this is the key difference compared to Salop & Stiglitz (1977). Here the average cost curve is U-shaped and firms are willing to tie at the competitive price, since undercutting and attracting all informed consumers would yield a negative profit.

Third, Varian (1980) argues that no equilibrium prices can be set with positive probability, since this would imply the possibility of a tie at that price. Instead firms could increase expected profits by setting a marginally lower price with the same probability. Hence, there are no point masses, and thus firms will never set the same price. The firm which sets the lowest price *succeeds* in its sale and sells to all informed consumers. Profits will then be $\pi_s(p) = p(U + I) - c(U + I)$. All other firms *fail* to have the lowest price and gain $\pi_f = pU - c(U)$.

Equilibrium density function

We now turn to the optimal density function. Since no price is set with positive probability in equilibrium the cumulative distribution function is continuous in the relevant interval. Firms choose $f(p)$ in order to maximize expected profits. For each store the expected profit is

$$E(p) = \int_{p^*}^{r} \left[\pi_s(p) \underbrace{(1-F(p))^{n-1}}_{\text{prob of having the lowest price}} + \pi_f(p) \underbrace{\left(1-(1-F(p))^{n-1}\right)}_{\text{prob of not having the lowest price}} \right] f(p)dp \tag{2.1}$$

The expression in the square brackets is the expected profit when setting a specific price, p. The first part is the profit when succeeding multiplied by the probability of having the lowest price. To see this, note that since $F(p)$ is the probability that a firm sets a price lower than p, $1 - F(p)$ is the probability that a firm sets a price higher than p. A firm has $n - 1$ competitors, thus $(1 - F(p))^{n-1}$ is the probability of all other firms having a higher price than p. The second term is the profit when failing to have the lowest price multiplied by the probability of this event. Since the density function assigns probability mass to all price intervals, the expression is multiplied by $f(p)$ and integrated from p^* to r to get the expected profit when playing according to $f(p)$.

In equilibrium all prices must yield the same expected profit. Otherwise firms could increase the density on the more profitable price and lower density on the less profitable price, thus increasing expected profit. Since Varian assumes free entry, the expected return must be equal to zero. Thus, when maximizing (2.1) we only have to consider a single price. Hence, the symmetric equilibrium condition is

$$\pi_s(p)(1-F(p))^{n-1} + \pi_f(p)(1-(1-F(p))^{n-1}) = 0 \tag{2.2}$$

By rearranging this expression, the cumulative distribution function $F(p)$ can be found as

$$1 - F(p) = \left(\frac{\pi_f(p)}{\pi_f(p) - \pi_s(p)}\right)^{\frac{1}{n-1}} \tag{2.3}$$

Since the denominator is always negative for prices between p^* and r, the nominator must be negative. This means that firms make negative profits when they fail to win the informed consumers. Hence, in equilibrium firms lose money when they do not succeed, but make positive profits when they do. On average they earn just enough money to be willing to stay in the market.

Since (2.3) is only valid for prices charged with positive density, it is relevant to find these prices. Prices close to p^* must be charged with positive density; otherwise firms could charge a price very close to p^*, win all consumers, and make a positive profit. Furthermore, prices close to r must also be charged with positive density. If not, some price, $\hat{p}$, would be the highest price ever charged. In this case, a firm charging $\hat{p}$ would never win the informed consumers, since an other firm would certainly set a lower price. In equilibrium the expected profit from charging $\hat{p}$ must be zero, but then firms could reap a positive profit by charging r. Hence prices close to r must be charged with positive density.

Finally, there is no gap in the density function where $f(p) = 0$. To see this, assume that there exist an interval $[p_1, p_2]$ where $f(p) = 0$. Then, a firm charging p_1 could change its price to $\hat{p}$ where $p_1 < \hat{p} < p_2$, and succeed in having the lowest price in exactly the same instances as if it had offered p_1. Similarly, a firm setting $\hat{p}$ would fail to have the lowest price if a competitor sets a price below p_1 - just as would have been the case if it had offered p_1. But since $\hat{p} > p_1$, it would be more profitable to offer $\hat{p}$ than p_1. Since a firm setting p_1 must make zero profit, charging $\hat{p}$ with certainty will result in positive profits. This contradicts the assumption of free entry. Hence, there can be no gap in the density function. To summarize, the argument above imply that the density function $f(p)$ is strictly positive for all $p \in [p^*, r]$.

An example with free entry

As an example, Varian (1980) assumes that firms incur a fixed cost k and have zero marginal costs. By doing so, the model can be solved to find the number of firms in the market, n, and the minimum price, p^*. A firm charging r can never win the informed consumers and profits must therefore be zero at this price. The same is true when a firm charges p^* and wins all consumers for sure. This can be used to determine the number of firms, n, and the minimal price, p^*. Instead of reproducing the example here, we consider a duopoly case which is comparable to the extension developed in chapter 5. Before doing so, we will however briefly explain the result in Varian's free entry example.

The minimal price firms are willing to set, p^*, is lower when there are more informed consumers, as the succeeding firm will serve more consumers. Similarly, the profit when setting r is larger when there are more uninformed consumers. Since the expected profit in equilibrium is equal to serving the uninformed consumers at the monopoly price, more uninformed consumers leave room for more firms when there is free entry. If there are enough uninformed consumers, so that the number of firms is sufficiently large, Varian (1980) shows that the equilibrium density function is U-shaped, and firms tend to set prices close to p^* and r with a high probability. Intermediate prices, however, are charged more seldom. If a firm sets a low price but fails to win the informed consumers, this is costly, since it sells to few consumers at a low price. Thus, instead of offering intermediate prices, firms set very low prices to increase the chance of winning or charge very high prices to exploit uninformed consumers.

The randomizing behavior of firms implies that at any point in time, equilibrium prices will be dispersed, even though firms are identical and use the same pricing strategy. To see how competition is affected by information in this setup, Varian (1980) considers the average price offered by firms. Informed consumers affect the expected price in two ways. First, more informed consumers make it more tempting to set relatively low prices, and second it lowers p^*. Hence, information always reduces the average prices set by firms. In contrast, more uninformed consumers have an ambiguous effect on prices. The reason is the following: An increase in the number of uninformed consumers makes it more attractive to set a high price, which tends to increase average prices. However, it also increases the number of firms in equilibrium. Higher average prices hurt uninformed consumers, but since there are more firms, the lowest price set by firms tends to decrease. This benefits informed consumers. Hence, when there is free entry, uninformed consumers confer a positive externality on informed consumers.

In order to compare Varian's model with the model developed in chapter 5, we will now analyze a situation where the number of firms in the market is fixed.

2.2.2 Example with two firms

We consider a duopoly where firms have zero marginal costs and a fixed cost, k. In Varian's model, informed and uninformed consumers are defined in absolute terms. Hence increasing the number of informed consumers affects the size of the market and the share of informed consumers. In order to eliminate the demand effect and be able to analyze the effect of changes in the level of transparency, we define the share of informed consumers as

$$\alpha = \frac{I}{I+U} \tag{2.4}$$

Note that, since both I and U are assumed to be strictly positive, α is greater than 0 and below 1. Implementing these changes, profits when succeeding and failing are reduced to

$$\pi_s(p) = p\left(\frac{1+\alpha}{2}\right) - k \tag{2.5}$$

$$\pi_f(p) = p\left(\frac{1-\alpha}{2}\right) - k \tag{2.6}$$

When there are only two firms and no possibility of entry, the expected profit increases from zero to $\pi_f(r)$, since a firm can always charge r and serve the uninformed consumers. Note that $\pi_f(r) \geq k$ is a necessary condition for firms to be willing to stay in the market. Moreover, since there is profit to be made in the market, no firm is willing to price at average cost p^*. Instead the lower boundary for prices, $\underline{p}$, is where firms are indifferent between offering $\underline{p}$ and winning the informed consumers and setting r and exploiting the uninformed consumers. Thus,

$$\begin{aligned}
\pi_f(r) &= \pi_s(\underline{p}) \quad \Leftrightarrow \\
(1-\alpha)r &= (1+\alpha)\underline{p} \quad \Leftrightarrow \\
\underline{p} &= \frac{1-\alpha}{1+\alpha}r
\end{aligned}$$

The equilibrium condition from (2.2) now becomes

$$\pi_s(p)(1-F(p))^{n-1} + \pi_f(p)(1-(1-F(p))^{n-1}) = \pi_f(r)$$

and the cumulative distribution function reduces to

$$F(p) = \frac{\pi_s(p) - \pi_f(r)}{\pi_s(p) - \pi_f(p)}$$

Inserting the profits from (2.5) and (2.6) gives

$$\begin{aligned} F(p) &= \frac{p\left(\frac{1+\alpha}{2}\right) - r\left(\frac{1-\alpha}{2}\right)}{\alpha p} \\ &= \frac{1+\alpha}{2\alpha} - \frac{1-\alpha}{2\alpha}\left(\frac{r}{p}\right) \\ &= 1 - \frac{1-\alpha}{2\alpha}\left(\frac{r}{p} - 1\right) \end{aligned}$$

Differentiating with respect to p gives the density function

$$f(p) = \frac{1-\alpha}{2\alpha}\frac{r}{p^2} \tag{2.7}$$

Contrary to the equilibrium density function in the free entry case with many firms described above, this density function is not U-shaped. Instead $f(p)$ is downward sloping, implying that firms are more likely to set lower prices. From (2.7) it is clear that lower prices are set more often when the share of informed consumers increases. Since $\underline{p}$ is also decreasing in α, more transparency unambiguously leads to lower prices in this setup. The reason is that a larger share of informed consumers makes it more profitable to set the lowest price and win the competition, and less profitable to set a high price and exploit uninformed consumers.

Throughout this thesis, this two firm example will be expanded to include consumers search, collusion and finally firms with asymmetric costs. This simple setup enables us to study and illustrate the effects of transparency in different market environments.

2.3 Product differentiation

In the homogenous goods market considered above, a firm can reap all the informed consumers by setting a price marginally below its competitors', because informed consumers always buy from the cheaper firm. This is not the case when products are differentiated and consumers pay a transportation cost. Schultz (2005) extends Varian's model to include heterogeneous goods by considering the effect of transparency in a Hotelling market. He shows that, besides the mixed strategy equilibrium seen in the homogeneous market, there may also exist an equilibrium in pure strategies when goods are differentiated. Rather than analyzing transparency in a static setup, Schultz' purpose is to study transparency and collusion in differentiated goods market. We will return to the dynamic part of the model in section 4.2.

In Schultz' model two firms with zero marginal costs located at 0 and 1 charge p_0 and p_1 respectively. Consumers face the transportation cost, t, and consumer x obtains utility $u-p_0-tx$ when buying one unit from firm 0 and $u-p_0-t(1-x)$ when buying from firm 1, where $x \in (0,1)$. A share ϕ of the consumers are *informed* about both prices, while the remaining $1-\phi$ consumers are *uninformed* but have (correct and rational) expectations about prices. A consumer located at $x(p_0,p_1)$ is indifferent between buying from 0 and 1 if

$$x(p_0,p_1) = \frac{p_1 - p_0 + t}{2t} \tag{2.8}$$

Pure strategy Nash equilibria

Schultz (2005) shows that a pure strategy Nash equilibrium (PNE) exists when goods are sufficiently differentiated. The intuition is that consumers are reluctant to buy the product from a firm very different from their preferred one. Thus, a firm may charge a higher price than its competitor still serving consumers located close to the firm. If the profit made when serving closely located consumers is larger than the profit made when undercutting the competitor, a PNE exists.

More interestingly Schultz (2005) shows that if the share of informed consumers is either close to zero or close to one, a PNE may exist, even when product differentiation is relatively low. When goods are homogeneous, as in Varian (1980), firms can reap the uninformed market by setting a price marginally below the competitor's. On the contrary, when goods are differentiated, a firm can only attract all informed consumers at the competitors "home turf" by setting a price significantly below the competitor's price. When the share of informed consumers is close to zero, a price cutting firm loses significantly on many existing uninformed consumers, while only gaining from a few informed consumers. Thus, charging a high price from the uninformed is optimal. On the other hand, when the market is very transparent and the share of informed consumers is close to one, the profit from serving the few uninformed is low, and the profit made when competing for the informed consumers may be more attractive. Again, we can point out the differences compared to Varian (1980). When goods are homogeneous, competing in a fully transparent market is very unattractive since the profit is zero. On the contrary, the profit is positive when goods are differentiated, and firms may prefer to always compete for the informed consumers rather than serving a few uninformed consumers at a high price.

In a pure strategy Nash equilibrium (PNE) firm 0 sets p_0 in order to maximize

$$\pi_0 = p_0\Big(\phi\left(\frac{p_1 - p_0 + t}{2t}\right) + \frac{1-\phi}{2}\Big)$$

The first order condition is

$$\phi\left(\frac{p_1 - p_0 + t}{2t}\right) + \frac{1-\phi}{2} - p_0\left(\frac{\phi}{2t}\right) = 0$$

which can be reduced to

$$p_0 = \frac{1}{2}\left(p_1 + \frac{t}{\phi}\right) \tag{2.9}$$

which is firm 0's response function. Since firms are symmetric, they set the same price, $p_1 = p_0$, and we can solve 2.9 to find the price and profit in equilibrium.

$$p^N(\phi) = \frac{t}{\phi} \quad , \qquad \pi^N = \frac{t}{2\phi} \tag{2.10}$$

The equilibrium price and profit increase with transportation cost and decrease with transparency. Moreover, a percent decrease in transportation costs has the same effect on the equilibrium price as a percent increase in transparency. Hence, introducing market transparency corresponds to a reparametrization of product substitutability. This suggests that the impact of transparency can be analyzed using the existing framework developed for heterogeneous goods.[2] However, below we will see that such a reparametrization of

[2]Møllgaard & Overgaard (2000) use this approach to analyze the effect of transparency on competition in a differentiated duopoly model. They assume that products are in fact homogeneous but that consumers do not realize this due to limited transparency.

the substitutability is only valid in the static game when the Nash equilibrium is in pure strategies. In section 4.2 we will realize that this simplification is never adequate when we consider collusion in the dynamic game.

Mixed strategy Nash equilibria

When product differentiation is low or the share of informed consumers is intermediate the only potential equilibrium is in mixed strategies. The intuition is similar to the one given by Varian and described in section 2.2.1. On the one hand, firms are tempted to undercut the competitor in order to get the informed consumers. However, when the price becomes too low, they prefer to serve the uninformed consumers at the monopoly price $p^m = u - \frac{t}{2}$.

In the mixed strategy Nash equilibrium, firms set prices according to some distribution function $F_t(p)$. If firm 0 charges the price, p_0, the expected profit is given by

$$E(\pi_0) = \left[\left((1 - F_t(p_0 + t)) + \int_{p_0-t}^{p_0+t} \left(\frac{p_1 - p_0 + t}{2t} f_t(p_1)dp_1\right)\right)\phi + \frac{1-\phi}{2}\right] p_0 \qquad (2.11)$$

The term inside the square brackets is the expected total demand, which is divided into the demand from informed and uninformed consumers. If firm 1 sets $p_1 \geq p_0 + t$, firm 0 wins all the informed consumers. This happens with probability $(1 - F_t(p_0 + t))$. If firm 1 sets prices in the range $p_0 - t$ to $p_0 + t$, firm 0 only gets the share $\frac{p_1 - p_0 + t}{2t}$ of the informed consumers.[3] Firm 1 sets every given price $p_1 \in (p - t, p + t)$ with probability $f_t(p_1)$. The total expected demand in these cases is given by the second term in (2.11). Finally, if $p_0 > p_1 + t$, firm 0 only serves uninformed consumers. In addition to the informed consumers, firm 0 always gets half of the uninformed consumers regardless of p_1. This is the last term inside the square brackets. Varian (1980) finds that when goods are homogeneous, the expected profit in equilibrium is identical to serving half of the uninformed consumers at the monopoly price. Maximizing $E(\pi_0)$ with respect to p_0 in (2.11), Schultz (2005) finds that this is also approximately true when goods are *almost* homogeneous. He finds that the profit approaches $\frac{1-\phi}{2}u$ when $t \rightarrow 0$.

Schultz (2005) finds that the often seen result that increased transparency leads to lower

[3]This can easily be derived from equation (2.8)

prices in a static game also holds when goods are differentiated.

Moreover, there is an interesting difference between firms' profits in pure strategies and in mixed strategies. In the pure strategy equilibrium market, transparency and product differentiation are substitutes, since an increase in transparency monotonically corresponds to a decrease in product differentiation. This is not the case in mixed strategies. In particular, when $t \to 0$, the effect on firms' profits following an increase in transparency is independent of the degree of product substitutability.

We will return to the dynamic part of Schultz (2005) in chapter 4.

Endogenous choice of product differentiation

In his paper from 2004, Schultz considers a Hotelling market with endogenous choice of product differentiation, where some consumers are uninformed about both prices and locations of the firms. For given locations, more informed consumers will increase the effective elasticity of demand, thus reducing prices. However, when firms choose product characteristics, increasing transparency has two contrary effects: First, since more informed consumers will decrease prices, firms want to move apart to mitigate competition. On the other hand, since uncertainty about product characteristics is also reduced, it is easier to steal business from competitors. This tends to reduce product differentiation. Schultz (2004) shows that the latter effect dominates, implying that product variety, and thus transportation costs, is reduced when transparency is increased. Since transportation costs and prices decrease when more consumers are informed, transparency always benefits consumers.

2.4 Concluding remarks

The models studied in this chapter all share the assumption that consumers have different information about prices. We conclude this chapter with the following remarks:

- In the presence of uninformed consumers, equilibrium prices are likely to be dispersed. This dispersion can be spatial, so that some firms persistently offers low prices while others charge high prices, or it can be temporal, so that firms randomize prices.

- More transparency increases the effective elasticity of demand, promoting competition and lowering prices. This is true regardless of whether products are homogeneous or differentiated.

Chapter 3

Becoming Informed

Most of the papers described in chapter 2 assume that consumer information is exogenously given. However, information about prices is usually a result of actions taken by either consumers or firms. There are at least two ways in which consumers can become informed about prices: Either they can *actively* engage in a search by visiting stores, reading newspapers etc., or they *passively* hope to obtain price information through advertisements. How this affects competition is the topic analyzed in this chapter.

We begin this chapter with an extensive review of Burdett & Judd (1983), who analyze consumers' incentives to search. The result is that price dispersion can arise even when consumers and firms are identical. To focus on the effects of increased transparency we study Nilsson (1999)'s two firm example of Burdett & Judd's search model. The main finding here, is that the share of informed consumers depends negatively on the search cost. In the last part of the chapter we use Bester & Petrakis (1995) to study firms' incentives to inform consumers about prices through the use of advertisements.

3.1 Search

When modeling search behavior, it is natural to assume that more consumers search if prices are dispersed, and the gain from searching is large. In the literature this is incorporated by assuming that rational consumers infer the expected gain from searching by anticipating firms' price-setting behavior and compare this to the search cost. However, if a single firm chooses to change its price, it is not obvious whether this would change consumers' search behavior. On one hand it seems unrealistic that a priori uninformed consumers are aware of a change in prices, but on the other hand it may also be unappealing that firms are able to change prices significantly without affecting consumers' search behavior. The literature has not proposed a fully satisfying solution to this issue yet, but deals with it in various ways. The articles analyzed below all assumes that consumers know the distribution of prices on the market, but lack information about which price is set by which firm. In the model by Salop & Stiglitz (1977) analyzed in section 2.1, the authors assume that consumers observe changes in prices and react upon them, whereas in Burdett & Judd (1983) analyzed below, changes in prices *ex post* do not affect consumer's search. When search is considered in a multi period model, as done by Nilsson (1999), the problem becomes even more tangible, since it is unclear how information about changes in competition will be transmitted to uninformed consumers. We will return to this issue in chapter 4.

3.1.1 Sequential and non-sequential search

Price dispersion often arises from ex ante heterogeneity in production costs, willingness to pay, or search costs. Burdett & Judd (1983) show that *ex post* differences in consumers information are crucial for the existence of dispersed prices in equilibrium and that such an equilibrium may exist, even when all firms and consumers are identical *ex ante*. They consider a model where consumers search to minimize total costs, consisting of search cost and price. All agents have rational expectations, so that firms know consumers' search strategy and consumers have correct expectations of the distribution of prices. Consumers must search at least once to obtain a price and purchase the good.

Two similar frameworks are investigated: Non-sequential search, where consumers choose how many prices to observe before search is initiated, and sequential search, where consumers decide after each search whether to observe more prices or whether to buy at the lowest price observed to date. To distinguish the two search types, think of a consumer who wants to buy a durable good. Sequential search is when he writes to a store to ask about its price, waits for the reply, and then decides whether to write to another store or buy at the lowest price observed. The search is non-sequential if he decides how many stores to write and mails the letters at once. Burdett & Judd (1983) do not consider standard sequential search, but rather what they call noisy sequential search. If a consumer searches for one price, there is a chance he will observe more prices.

Model framework

There are N firms and L consumers in the market, so that there are $\mu = \frac{L}{N}$ consumers per firm in total. Each firm selects its own price and $F(p)$ describes the distribution of prices in the market, so that $F(p)$ is the proportion of firms that charge a price no higher than p. As in Salop & Stiglitz (1977), consumers know the distribution of prices but not the location of the firm charging a specific price, however, this information can be obtained through costly search. All consumers have the reservation price $\tilde{p}$ and all firms have the same marginal cost r. Hence, no firm will ever set a price lower than the marginal cost r or higher than $\tilde{p}$, thus $F(\tilde{p}) = 1$ and $F(r - \epsilon) = 0$, $\epsilon > 0$.

Firm equilibrium

Contrary to Salop & Stiglitz (1977), firms in Burdett and Judd's model cannot affect consumers' incentive to search but instead take consumers' search strategy as given. Consumers observe k prices and purchase at the lowest price observed, if this price is lower than the reservation price $\tilde{p}$. If the lowest price is higher than $\tilde{p}$ they search again. A consumer's search strategy is described by $(\langle q_k \rangle_{k=1}^{\infty}, \tilde{p})$, where q_k is the probability that a given consumer searches k times.

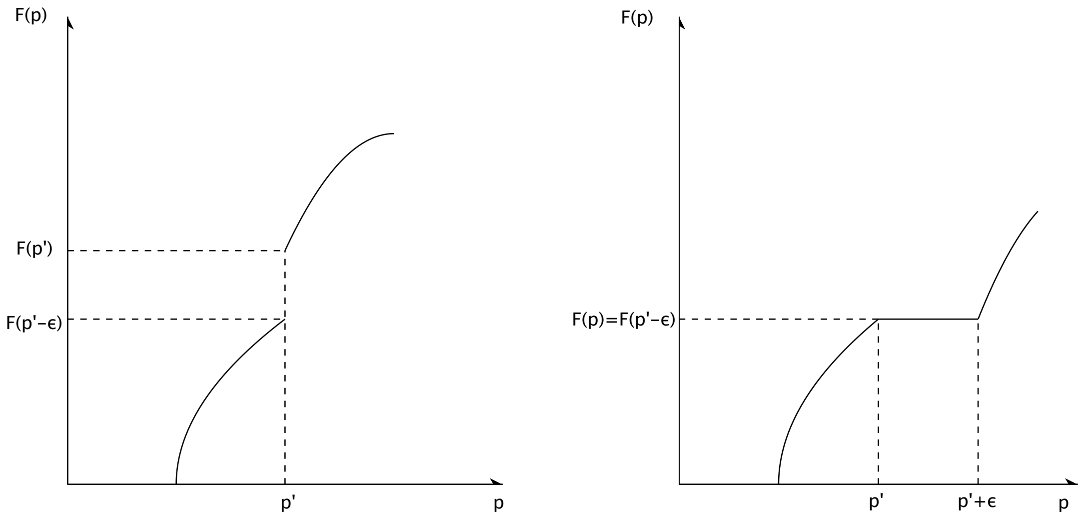
In the *firm equilibrium* denoted $(F(\cdot), \pi)$, all firms must earn the same expected profit $\pi(p) = \pi$ and, as in Varian (1980), $F(p)$ must be well behaved if $0 < q_1 < 1$, i.e. continuous and increasing in r to $\tilde{p}$. Clearly, no firm will set $p > \tilde{p}$ in equilibrium. To see that $F(p)$ must have the above characteristics when $0 < q_1 < 1$, first suppose that $F(p)$ has a discontinuity at some p' in equilibrium. Then, a deviant can set its price infinitesimally below p' and increase expected sales, since the probability that a rival firm is cheaper decreases significantly (see figure 3.1(a)). Now, suppose $F(p)$ is non-increasing in a non-empty range after p' (figure 3.1(b)). A deviating firm can increase its profit by setting the price $p' + \epsilon$, as it does not affect the probability that a competitor is cheaper. Hence, $F(p)$ must be well behaved when $0 < q_1 < 1$.

If $q_1 = 1$ such that all consumers observe exactly one price, all firms will set the monopoly price $\tilde{p}$ and sell to the share μ of the consumers who visit each firm.[1] If $q_1 = 0$ all consumers observe at least two prices and all firms set the competitive price $p = r$ as in the Bertrand outcome. Given the above specification of the firm equilibrium the expected profit of firm i charging p_i can written as

$$\pi(p_i) = (p_i - r)\mu \sum_{k=1}^{\infty} q_k k(1 - F(p_i))^{k-1} \qquad \text{, if } r \leq p_i \leq \tilde{p} \tag{3.1}$$

Clearly, $\pi(p_i) = 0$ if $\tilde{p} = r$. A few comments may help to understand equation (3.1).

Figure 3.1: Non-existing F(p)



(a) Discontinuity (b) Non-increasing

Obviously, $p_i - r$ is the mark-up on each good sold, and $\mu \sum_{k=1}^{\infty} q_k k(1 - F(p_i))^{k-1}$ is the demand for firm i's good at price p_i. Intuitively, consumers who only search once, i.e. $k = 1$, will buy at firm i. Hence, the demand firm i faces from uninformed type 1 consumers is μq_1. Likewise, there are μq_2 consumers per firm but since they search two times $2\mu q_2$ consumers visit firm i and buy with probability $(1 - F(p_i))$, i.e. the

[1] This is the main difference in the results arising from the different assumptions about consumers information in Burdett & Judd (1983) and Salop & Stiglitz (1977). In the latter, firms can induce consumers to search by lowering their price, which makes the restrictions on consumers' search cost stricter compared to the former, where search costs just have to be positive.

probability that firm i is cheaper than the other firms the consumer visits. Hence, the expected demand from type 2 consumers is $2\mu q_2(1 - F(p_i))$, and similar for other k.

Since all prices must yield the same expected payoff in equilibrium and firms can always set $\tilde{p}$ serving only type 1 consumers, the expected payoff must be $\pi = \pi(\tilde{p}) = (\tilde{p} - r)\mu q_1$ in equilibrium.[2] No firm will ever charge $p = r$ since it could raise its price slightly and make a positive profit. Thus, the minimum price a firm will ever charge, $\underline{p}$, is defined by

$$\pi(\underline{p}) = (\underline{p} - r)\mu \sum_{k=1}^{\infty} q_k k = \pi(\tilde{p}) \tag{3.2}$$

That is, $\underline{p}$ is the price where a firm is indifferent between winning the price competition against the k other firms the consumer visits, and serving the uninformed type 1 consumers at the monopoly price.

Similar to Salop & Stiglitz (1977), three possible firm equilibria exist: (*i*) A monopoly price equilibrium if $q_1 = 1$, where all consumers are *uninformed* if we follow the terminology used in chapter 2. (*ii*) A competitive equilibrium where all consumers observe at least two prices ($q_1 = 0$) and firms engage in Bertrand competition.[3] And finally, (*iii*) a Price-Dispersion Equilibrium where $q_1 \in]0, 1[$, so that some consumers are *uninformed* while others are (partly) *informed*. Due to constant marginal costs, the Price-Dispersion Equilibrium is not a Two-Price Equilibrium as seen in Salop & Stiglitz (1977), but rather a mixed strategy equilibrium similar to the one seen in Varian (1980), see section 2.2.

The intuition behind the two Single-Price Equilibria is very similar to the one given in section 2.1. If all consumers are uninformed the firms behave as monopolists on their share of the market. If all consumers know at least two prices, firms compete on prices and end up in a Bertrand equilibrium. The intuition behind the Price-Dispersion Equilibrium is similar to the one in Varian (1980). If all firms set the same price, a deviant could lower its price slightly, capturing all visiting consumers who know at least two prices, and loosing only marginally on existing consumers. Hence, the only possible symmetric equilibrium is a mixed strategy equilibrium similar to Varian's. Thus, we do not need consumers to

[2] To see that firms will indeed set $\tilde{p}$, suppose $p' < \tilde{p}$ was the highest price in the market. Then, a firm setting p' would have the highest price for sure. But then it could increase its profit by setting $\tilde{p}$.

[3] Contrary to consumers in chapter 2, *informed* consumers in this model do not know all prices in the market. However, knowing just two prices is sufficient to put a downward pressure on firms' prices because of the price competition.

be informed about all prices in order to arrive at an equilibrium similar to the one in Varian (1980). Partly informed consumers in combination with uninformed consumers is sufficient.

Market equilibrium with non-sequential search

As mentioned above, consumers search to minimize the expected cost of purchasing the good. Burdett & Judd (1983) also consider non-sequential search, where consumers pay c for each price sample. The expected total cost of a good after n searches can then be written as[4]

$$cn + \int_0^\infty np(1 - F(p))^{n-1} f(p)dp \qquad (3.3)$$

The intuition behind equation (3.3) is as follows. The consumer visits a firm which sets a given price, p, with probability $f(p)$. Since $F(p)$ is the proportion of firms that charge a price no higher than p, $(1 - F(p))^{n-1}$ is the probability that p is the lowest price the consumer will observe. For instance, if the consumer decides to search just once, his expected price will be $\int_0^\infty pf(p)dp$ which is just the average price on the market.

Note that the consumer's expected cost function from (3.3) is U-shaped, as the second term decreases in n and thus has a unique minimum. Hence, either all consumers observe the same number of prices, or they are indifferent between searching n or $n + 1$ times. As mentioned above firms will set the competitive price if all consumers search twice or more, but then consumers would wish to search only once, since there is no gain from searching twice. Hence, there will always be some consumers who only observe one price, i.e. $q_1 > 0$. If $q_1 < 1$ we know that $q_1 + q_2 = 1$ in equilibrium, since consumers must be indifferent between observing one or two prices.

Using equation (3.1) and the equal profit condition we can now establish the firm equilibrium

$$(\tilde{p} - r)\mu q = (p - r)\mu \left[q + 2(1 - q)(1 - F^q(p))\right] \qquad (3.4)$$

where $q \equiv q_1$ and $q_2 = 1-q$. The left hand side is the profit when serving uninformed type 1 consumers at the monopoly price, where $F^q(\tilde{p}) = 1$. The right hand side is the expected

[4]Burdett & Judd (1983) write equation (3.3) as $cn+\int_0^\infty np(1-F(p))^{n-1}dF(p)$. However, as $f(p)dp = dF(p)$ since $f(p) = \frac{dF(p)}{dp}$ we have chosen to use notations similar to those in previous sections.

profit when following $F^q(p)$. Equation (3.4) describes how all prices must yield the same expected profit in equilibrium. We can find the distribution of prices in equilibrium by solving for $F^q(p)$. This yields

$$F^q(p) = 1 - \frac{\tilde{p} - p}{p - r}\frac{q}{2(1-q)} \qquad , \underline{p}(q) \leq p < \tilde{p} \tag{3.5}$$

The lowest price ever charged, $\underline{p}$, can be found using equation (3.4), setting $p = \tilde{p}$ and noting that $F^q(\underline{p}) = 0$

$$(\tilde{p} - r)\mu q = (p - r)\mu\left[q + 2(1-q)\right]$$

giving

$$\underline{p}(q) = (\tilde{p} - r)\frac{q}{2-q} + r \tag{3.6}$$

Since $0 < q \leq 1$, $\underline{p}$ increases in marginal cost r, except in the special case where no consumers observe more than one price ($q = 1$). In this case, no firms set prices below the monopoly price.

Consumers search to minimize the expected cost of the good, i.e. the sum of the total search costs plus the expected price. Given the distribution of prices $F^q(p)$, the expected price paid by a consumer who observes one price is $\int_0^{\tilde{p}} p dF^q(p)$, while the expected price of a consumer searching two times is $2\int_0^{\tilde{p}} p(1 - F^q(p))dF^q(p)$, see (3.3). Thus, the expected gain from observing two prices instead of one is given by

$$V = \int_0^{\tilde{p}} pf^q(p)dp - 2\int_0^{\tilde{p}} p(1 - F^q(p))f^q(p)dp$$

which can be reduced to

$$V = -\int_0^{\tilde{p}} pf^q(p)dp + 2\int_0^{\tilde{p}} pF^q(p)f^q(p)dp \tag{3.7}$$

It is helpful to note that

$$\begin{aligned}\int_0^{\tilde{p}} pF^q(p)f^q(p)dp &= \left[pF^q(p)^2\right]_0^{\tilde{p}} - \int_0^{\tilde{p}} (F^q(p) + pf^q(p))F^q(p)dp \\ &= \left[pF^q(p)^2\right]_0^{\tilde{p}} - \int_0^{\tilde{p}} F^q(p)^2 dp - \int_0^{\tilde{p}} pF^q(p)f^q(p)dp\end{aligned}$$

by integrating by parts, such that

$$2\int_0^{\tilde{p}} pF^q(p)f^q(p)dp = \left[pF^q(p)^2\right]_0^{\tilde{p}} - \int_0^{\tilde{p}} F^q(p)^2 dp \tag{3.8}$$

Using (3.8) in (3.7) and integrating by parts we get

$$\begin{aligned} V(q) &= -\left[pF(p)\right]_0^{\tilde{p}} + \int_0^{\tilde{p}} F(p)dp + \left[pF(p)^2\right]_0^{\tilde{p}} - \int_0^{\tilde{p}} F(p)^2 dp \\ &= \int_0^{\tilde{p}} F(p)dp - \int_0^{\tilde{p}} F(p)^2 dp \end{aligned}$$

as $[pF(p)]_0^{\tilde{p}} = [pF(p)^2]_0^{\tilde{p}}$ since $F(0) = 0$ and $F(\tilde{p}) = 1$.

A consumer will choose to search twice if $V(q) > c$, and will be indifferent between observing one or two prices only if $V(q) = c$. As argued earlier, no equilibrium exists where all consumers search twice, and thus prices will be distributed such that $V(q) = c$ in equilibrium.

Market equilibrium with noisy sequential search

Sequential search is when a consumer pays c to observe a price, after which he decides whether to shop at the lowest price observed to date, or whether to search again. When the search is noisy, the consumer observes an unknown number of prices each time he searches. Although the consumer does not know how many prices he will observe when searching, he knows that k prices are observed with probability Q_k, $k = 1, 2, ...$, and $\sum_{k=1}^{\infty} Q_k = 1$. That is, Q_k is the probability of observing k prices when the consumer searches once.

A consumer will observe more prices as long as the cost from searching is lower than the expected gain from searching another time. Let z be the price where the consumer is indifferent between searching again and accepting the current lowest price. If the lowest price a consumer has observed is higher than z, the consumer will search again.[5] That is, z becomes the effective reservation price. Hence, no firm will set prices higher than z in equilibrium, since there will be no sale here. As a consequence, no consumer will search more than once, since he will always find his reservation price, and hence a share, Q_1, of

[5]Naturally, $z \leq \tilde{p}$ before any market can exist

the consumers will know only one price. If $Q_1 = 1$ the monopoly price equilibrium is the only possible equilibrium, since all consumers will be uninformed. As all firms charge the reservation price, z, no consumer is tempted to engage in a second search. If $Q_1 = 0$ all consumers know at least two prices, and the only possible equilibrium is the competitive equilibrium. Note that, since Q_1 is a parameter and not generated endogenously when search is sequential, a firm can not raise its price without losing all customers.[6] For $0 < Q_1 < 1$ a dispersed price equilibrium exists, since Q_1 consumers will be uninformed about prices, while the rest of the consumers will know two or more prices. The intuition is similar to the one described earlier in section 3.1.1.

To summarize, Burdett & Judd (1983) show that a price dispersion equilibrium may exist even when there is no a priori heterogeneity in the market and agents are fully rational. However, ex post heterogeneity in consumers' information is a necessary condition for the existence of a dispersed price equilibrium. Specifically, a share of the consumers must be *uninformed* observing only one price, while others must observe at least two prices.

Issues when modeling search

There is a caveat by the consumers' search costs, since no consumer will search if the expected price is equal to the consumer's reservation price, $\tilde{p}$. Burdett & Judd (1983) note this and state that if we interpret $\tilde{p}$ as the monopoly price of some downward sloping demand curve, there will still be some consumer surplus to cover the search cost, i.e. $\tilde{p}$ is simply the monopoly price on the demand curve after search cost is subtracted. However, there seems to be a commitment problem. Let p' be a consumer's true reservation price, so that $\tilde{p} = p' - c$, and suppose that all firms charge $\tilde{p}$ in the monopoly price equilibrium. Now, if a consumer pays c to observe a firm's price, the firm has no incentive to keep the price at $\tilde{p}$, since the consumer's search cost is sunk and he will buy as long as $p \leq p'$. Expecting this, the consumer will not search in the first place and the market fails to exist. This is known as the Diamond Paradox, see Diamond (1971).

As noted earlier, contrary to Salop & Stiglitz (1977), Burdett & Judd do not allow firms

[6]With non-sequential search we saw that consumers would only search once, if all firms charged the competitive price. This made it profitable to firms to increase the price slightly to make a positive profit, and hence, the competitive price equilibrium could not exist.

to affect consumers' search strategy, but take consumers' strategy as given. This seems plausible when the number of firms is large, as a single firm cannot affect the distribution of prices. However, if the number of firms is small, each firm is likely to be able to affect the distribution of prices, and hence affect consumers' search strategy. In fact, this is exactly the case in Salop & Stiglitz (1977), where the focus is on an oligopolistic market. Janssen & Moraga-González (2004) provide an oligopolistic version of the Burdett and Judd model. Here, three equilibria characterized by low, moderate, and high search intensity exist. They show that more firms lead to increased price dispersion and reduced welfare in the low search equilibria. When consumers search with high intensity, the welfare effects of more firms depend on the initial number of firms.

3.1.2 The two firm example

Burdett & Judd (1983) show that equilibrium prices can be dispersed even when consumers have identical search cost. However they do not devote much time to analyzing the effect of policies which aim at reducing search costs. This is done in Nilsson (1999). He extends the two firm example examined in section 2.2.2, so that the decision to become informed is endogenized. By doing so it becomes possible to consider the effects of changes in the cost of searching.[7]

There are two identical firms, and costs have been normalized to zero. Consumers have unit demand and identical reservation prices, r. Unlike Burdett & Judd (1983), Nilsson considers a market where a share of the consumers, α, have zero search costs and search even if the gain from doing so is zero. These consumers are called 'shoppers'. The remaining consumers, $(1-\alpha)$, have a positive search cost, s, and maximize expected utility by comparing the expected gain from searching with the search cost. In equilibrium, a fraction $\beta \in [\alpha, 1]$ of the consumers becomes informed and buys from the cheapest store. The rest are uninformed and shop at random, like in Varian (1980). By endogenizing the decision to become informed, Nilsson (1999) is more in line with Burdett & Judd (1983) than with Varian (1980). The price-setting behavior of firms in all three articles is, however, the same when a duopoly is considered. From (3.5) we know that firms in

[7]Nilsson (1999) develops the model in order to analyze firms ability to collude in markets without full transparency. We will return to the article to consider this in section 4.1.

Burdett & Judd (1983) randomize prices according to

$$F^q(p) = 1 - \frac{\tilde{p} - p}{p - r}\frac{q}{2(1-q)} \qquad , \underline{p}(q) \leq p < \tilde{p}$$

When there are only two firms in the market the share of informed consumers corresponds to those who search twice, while uninformed are those consumers who only search once, q. In Nilsson (1999) the share of informed consumers is denoted β while $(1-\beta)$ is uninformed consumers. Since firms have zero costs and the reservation price is denoted r, the distribution function becomes

$$F(p_i) = 1 - \frac{1-\beta}{2\beta}\left(\frac{r}{p_i} - 1\right) \qquad \text{if } p^* < p_i < r \tag{3.9}$$

which is identical to the distribution function in the duopoly example of Varian, see equation (2.7) on page 17).

It is assumed that both the share of 'shoppers', α, and the share of β are negatively correlated with the search cost s. The 'non-shoppers' $(1-\alpha)$ compare the expected gain from searching, v, with the search cost, s. Informed consumers pay the expected minimum price, $\bar{p}_{min}$, whereas uninformed pay the expected price, $\bar{p}$. Hence, the non-shoppers search if $v = \bar{p} - \bar{p}_{min} > s$.

For later reference note that the probability that both firms set a price higher than p is $(1-F(p))^2$. Hence, with probability $1-(1-F(p))^2$ the lowest price charged is p. Thus,

$$F(p_{min}) = 1 - (1 - F(p_{min}))^2 = 1 - \frac{(1-\beta)^2}{4\beta^2}\left(\frac{r}{p_{min}} - 1\right)^2$$

Differentiation with respect to p_{min} yields

$$f(p_{min}) = \frac{(1-\beta)^2}{2\beta^2}\frac{r}{p_{min}^2}\left(\frac{r}{p_{min}} - 1\right) \tag{3.10}$$

The gain from searching then becomes

$$\begin{aligned} v &= \bar{p} - \bar{p_{min}} \\ &= \int_{p^*}^{r} pf(p)dp - \int_{p^*}^{r} p_{min}f(p_{min})dp_{min} \end{aligned}$$

Inserting (3.10) this reduces to

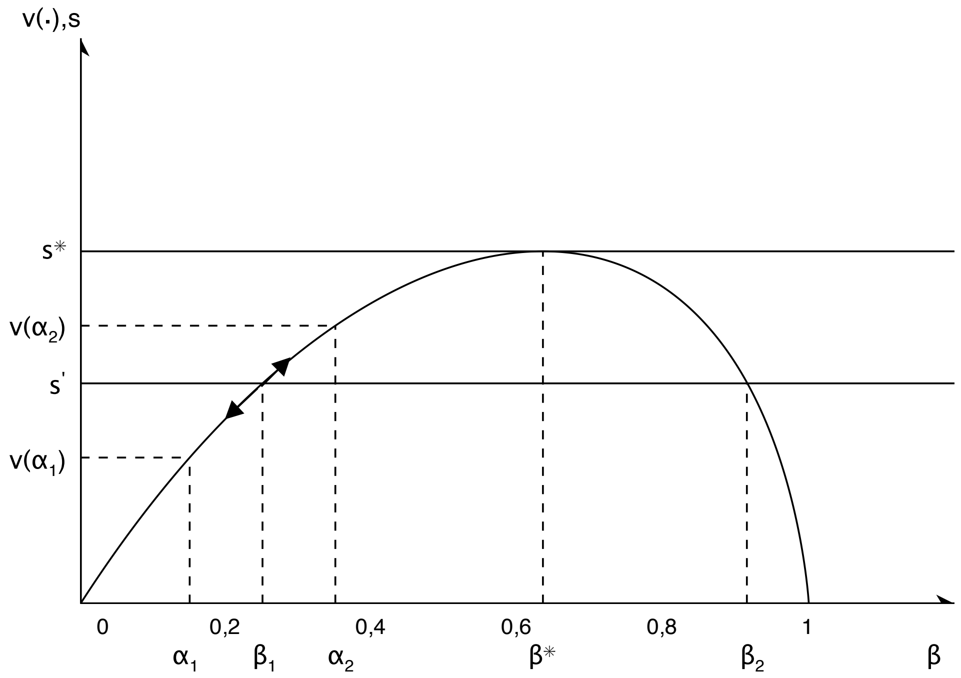
$$\begin{aligned}
v &= \int_{p^*}^{r} p\frac{1-\beta}{2\beta}\frac{r}{p^2}dp - \int_{p^*}^{r} p_{min}\frac{(1-\beta)^2}{2\beta^2}\frac{r}{p_{min}^2}\left(\frac{r}{p_{min}}-1\right)dp_{min} \\
&= \frac{(1-\beta)r}{2\beta}\int_{p^*}^{r}\frac{1}{p}dp - \frac{(1-\beta)^2 r}{2\beta^2}\int_{p^*}^{r}\frac{1}{p_{min}}\left(\frac{r}{p_{min}}-1\right)dp_{min} \\
&= r\frac{1-\beta}{2\beta}\left[ln(p)\right]_{p^*}^{r} + r\frac{(1-\beta)^2}{2\beta^2}\left[\frac{r}{p_{min}}+ln(p_{min})\right]_{p^*}^{r} \\
&= r\frac{1-\beta}{2\beta}ln\left(\frac{r}{p^*}\right) + r\frac{(1-\beta)^2}{2\beta^2}\left(1+ln\left(\frac{r}{p^*}\right)-\frac{r}{p^*}\right)
\end{aligned}$$

Inserting $p^* = \frac{1-\beta}{1+\beta}r$ this yields

$$\begin{aligned}
v &= r\frac{1-\beta}{2\beta}\left(ln\left(\frac{1+\beta}{1-\beta}\right)+\frac{1-\beta}{\beta}\left(ln\left(\frac{1+\beta}{1-\beta}\right)+1-\frac{1+\beta}{1-\beta}\right)\right) \\
&= r\frac{1-\beta}{2\beta}\left(ln\left(\frac{1+\beta}{1-\beta}\right)+\frac{1-\beta}{\beta}ln\left(\frac{1+\beta}{1-\beta}\right)-2\right) \\
&= r\frac{1-\beta}{2\beta}\left(\frac{1}{\beta}ln\left(\frac{1+\beta}{1-\beta}\right)-2\right) \qquad (3.11)
\end{aligned}$$

In figure 3.2 the gain from searching v is depicted as a function of β.

Figure 3.2: The expected gain from from searching, $v(\beta, r)$



First note that the gain from searching increases in the share of informed consumers when $\beta < \beta^*$, and decreases when $\beta^* < \beta$, so that $v(r, \beta)$ has a unique maximum in $\beta = \beta^*$. The intuition is that more informed consumers put downward pressure on prices, increasing the difference between buying at random and buying at the lowest price. However, when the share of informed consumers increases beyond β^*, both firms set low prices so often that the expected gain from being informed about both prices starts to decrease.

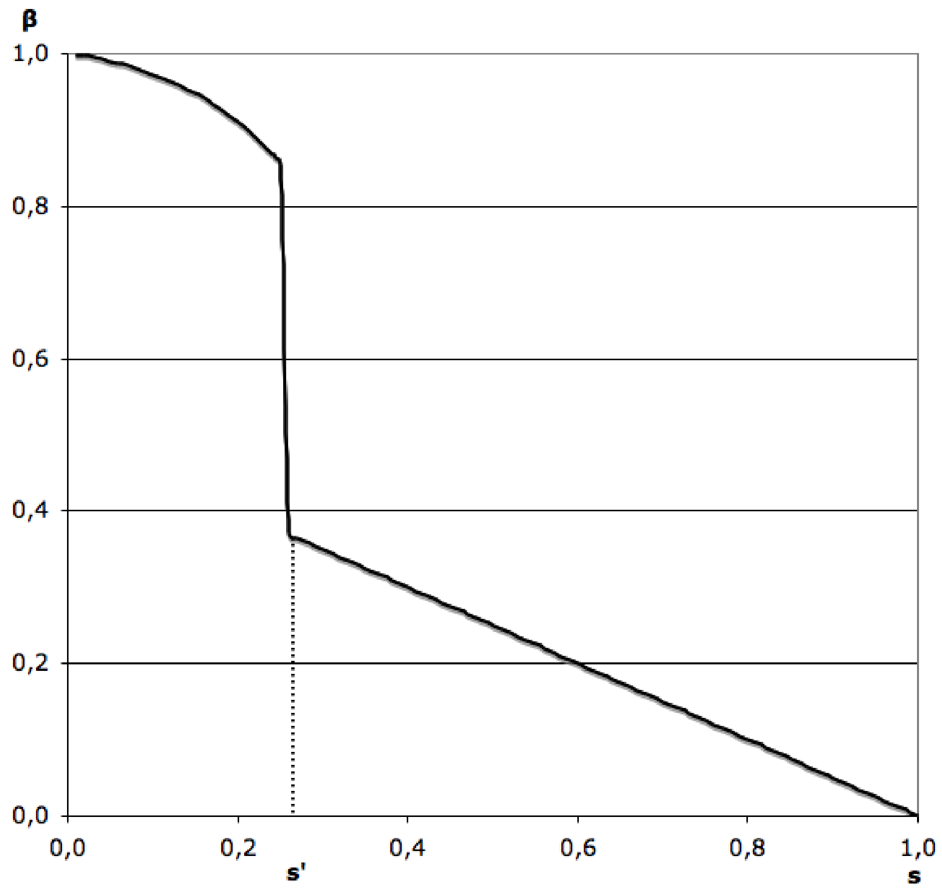
In equilibrium the gain from searching is equal to the search cost. Several equilibria may exist. First, if $s > v(\beta^*) = s^*$, it is never optimal for consumers with positive search costs to search, and only shoppers will be informed. Second, if $s = s^*$, a share, β^*, of the consumers will search. Finally, if $s' < s^*$, there are two equilibria, β_1 and β_2, where the gain from searching exactly equals the search cost. The equilibrium where $\beta = \beta_1$ is, however, not stable, since for values of β slightly *larger* than β_1, the gain from searching is higher than the search cost, which induces more consumers to start searching. Similarly, when β is slightly *smaller* than β_1, the gain from searching is lower than the search cost implying that β decreases down to α_1. In contrast, the equilibrium where $\beta = \beta_2$ is stable. We will focus on this equilibrium for the remaining part of the analysis.

Consider a case where we are in a stable equilibrium. If policy makers could reduce the search cost, s, this would definitely increase the share of informed consumers, since $v(\beta)$ is downward sloping for $\beta \in (\beta^*, 1)$. However, if $s > s^*$, only the shoppers will search, and a reduction in the search cost will not induce any new 'non-shoppers' to search, unless s is reduced to a level below s^*.

Similarly, if $v(\alpha_2) < s < s^*$, but there a very few shoppers, so that $\alpha = \alpha_1$, reducing the search cost to s' will not make any 'non-shoppers' search, since there are too few informed consumers for searching to be beneficial. However, if there are more shoppers, $\alpha = \alpha_2$, reducing the search cost to s' will make more consumers search and push the equilibrium to β_2.

It is not possible to solve (3.11) for β. Hence, in order to get the share of informed consumers, β, as a function of the search cost, we have solved the model numerically. Nilsson (1999) does not model the relationship between α and s. We assume that half of the consumers are predisposed to become shoppers. Among these consumers, the pleasure of shopping is uniformly distributed between zero and one, hence $\alpha = 0,5(1-s)$. In section 4.1 the implications of this assumption will be investigated in more detail. For values of s, where $v(\alpha) > s$, the share of consumers who search, β_2, is calculated numerically.[8] When $s > v(\alpha)$, only shoppers search, i.e. $\beta = \alpha$. The result is depicted in figure 3.3.

Figure 3.3: β as a function of s



Source: Own calculation based on Nilsson (1999)

Figure 3.3 illustrates that two scenarios may arise; either almost everybody is informed about the prices, or only shoppers are informed. Hence, the model does not support markets with intermediate levels of information.

Furthermore, since consumers who search exert a positive externality on non-seaching consumer, consumer surplus is not maximized in equilibrium. The reason is that when consumers compare the expected gain from searching with the search cost, they do not take into account that searching puts additional downward pressure on the average price. The

[8]The calculations are made using a macro based on the Excel Solver function.

existence of this positive externality implies that too few consumers search.[9] However, a social planner concerned with consumers' surplus should not make every consumer search. To see this, consider the case where almost all consumers search. Firms approximately compete in a Bertrand market and there are hardly any differences between the price paid by an informed and an uninformed consumer. Hence, if the last consumers pay the search cost consumer surplus is reduced.[10]

One way policy makers could affect the search cost is by publishing websites where prices are easily compared. Price portals can have two potential effects in this model. First, by lowering the s, the share of non-shoppers who search increases. Second, since price comparison is now very easy for those with access to the internet, more consumers will become shoppers. This increases the chance that the reduction in search cost will induce a jump to β_2. This is an argument in favor of the policy the Danish Consumer Counsel has carried out in the last decade; initiating several price portals such as www.pengepriser.dk.

3.2 Advertising

Consumer search, as described above, is only one way that consumers may become informed about prices. Another is advertising. In this section we consider how competition is altered if firms can affect consumer side transparency.

3.2.1 Price competition and advertising in oligopoly

Bester & Petrakis (1995) study price advertising in a duopoly where consumers are perfectly informed about product characteristics, availability and the price offered by the nearest store but lack information about the price available at stores further away. By advertising, firms can inform distant consumers about their price. Thus, this model is relevant in markets where consumers are aware of the existence of the product offered at different stores, but unaware of the current prices. This differs from other papers on in-

[9] In this particular setup consumers have unit demand and always buy in equilibrium. Hence, total welfare is maximized if no resources are wasted on searching.

[10] Especially note that for the last consumer, there is no externality, since he is the only one who is not informed about both prices.

formative advertising, such as Butters (1977), who considers advertising of new products that consumers are unaware of.

There are two locations, A and B, and one firm at each location. Both firms produce a homogeneous good at zero costs. A unit mass of consumers lives in the neighborhood of each firm. All consumers have the reservation utility v, but must pay a transportation cost to visit a store. A consumer of type s has to pay αs to visit the neighborhood store and s to visit the distant store. It is always cheaper to visit the neighborhood store, i.e. $0 < \alpha < 1$. It is assumed that s is uniformly distributed in the interval $s \in [0, \bar{s}]$ in each location.[11] By advertising, firms can provide price information to distant consumers. The cost of advertising is k and the advertisement decision, λ_i, is simplified to being a matter of advertising or not advertising. If $\lambda_i = 1$, firm i advertises and informs *all* distant consumers about its price. If $\lambda_i = 0$ the firm chooses not to advertise and only local consumers know its price.

The model can also be interpreted in a non-geographical way: A and B are two different brands. All consumers have a preferred brand whose price they are informed about. Consumers differ in their absolute valuations of the products, but they have the same *relative* assessment. Thus, for consumers with small s, the two brands are considered to be very close to ideal, whereas consumers with high s think of the two products as being far from perfect. If α is close to one, consumers agree that the two products are close substitutes, whereas a low α implies that A and B are perceived to be differentiated.

Demand

A consumer who has not received an ad will expect the distant firm j to set a higher price than the local store, i.e. $p_j > p_i$. Hence, he will buy the good from his home location $i \in \{A, B\}$ if the utility from doing so exceeds his reservation utility, i.e. when

[11] It is not explicitly stated if s is the transportation cost of a specific consumer or if s is the distance a consumer has to travel to visit the distant store. If s is interpreted as the transportation cost, it implies that all consumers live in the exact same location but incur a different cost of traveling. Since s is distributed in the interval $[0, \bar{s}]$, this interpretation implies that some consumers can travel at no cost. If s is the distance (and all consumers have the same transportation costs), consumers must be located in an oval ring around each store, so that the distance is always αs to the neighborhood store and s to the distant store. This is however not consistent with s being distributed in the interval $[0, \bar{s}]$, since $s = 0$ would imply that stores must have the same location. Thus, it seems most reasonable to interpret s as a combination of consumers' transportation costs and location.

$p_i + \alpha s \leq v$. This expectation will turn out to be correct in equilibrium and the behavior of the uninformed consumers is rational.

A consumer who is informed about both prices will buy the good from his neighborhood store if $p_i + \alpha s \leq p_j + s$ and $p_i + \alpha s \leq v$. He will choose to buy from the distant store if $p_j + s < p_i + \alpha s$ and $p_j + s \leq v$. The demand for firm i's product $D_i(p, \lambda)$ depends on both prices and the information available to consumers. Since s is uniformly distributed on $[0, \bar{s}]$, firm i faces the demand

$$D_i(p, \lambda) = min\left[\frac{v - p_i}{\alpha \bar{s}}, 1\right] - \lambda_j min\left[\frac{p_i - p_j}{(1-\alpha)\bar{s}}, \frac{v - p_i}{\alpha \bar{s}}, 1\right] \text{if } p_i \geq p_j \tag{3.12}$$

The first part of (3.12) is firm i's potential demand on its home turf without advertising. When firm i sets $p_i \geq p_j$, it can at most sell to all (i.e. 1) local consumers. If $p_i + \alpha s < v$ for some consumers, only those with $s > \frac{v - p_i}{\alpha}$ will choose to buy. Since s is uniformly distributed on $[0, \bar{s}]$, firm i's demand on its home turf without advertising is $\frac{v-p_i}{\alpha \bar{s}}$. The second part of (3.12), is the consumers, firm j steals from firm i when advertising a lower price. If p_j is sufficiently small (and $\bar{s}$ is not too large), firm j is able to attract all i's local customers, that is $min\left[\frac{v-p_i}{\alpha \bar{s}}, 1\right]$. Otherwise, firm B is able to attract these consumers with sufficiently low transportation costs, such that $v - p_j - s > v - p_i - \alpha s$, i.e. where $s < \frac{p_i - p_j}{(1-\alpha)}$.

If $p_i < p_j$, local demand is equal to the first part of (3.12), but now firm i is able to attract distant consumers by advertising the price. Hence firm i's demand is

$$D_i(p, \lambda) = min\left[\frac{v - p_i}{\alpha \bar{s}}, 1\right] + \lambda_i min\left[\frac{p_j - p_i}{(1-\alpha)\bar{s}}, \frac{v - p_i}{\bar{s}}, 1\right] \text{if } p_i \leq p_j \tag{3.13}$$

From (3.12) and (3.13) we see that a firm with a higher price than the competitor will never choose to advertise, since no distant consumers will find it worthwhile to visit the firm. Thus, choosing to advertise only affects demand when a firm has the lowest price.

Pure strategy equilibrium

Bester & Petrakis (1995) show that a symmetric pure strategy equilibrium *without adver-*

tisement exists when advertising costs are sufficiently large. This result seems intuitively appealing: Without advertising firms act as monopolists on their shares of the market, where they exploit local consumers. If the cost of advertising is sufficiently large, firms are not tempted to advertise, and reduce the price to attract distant consumers. The minimal advertising cost for which there exists a 'no advertising' equilibrium increases in v, since a higher reservation price makes it more tempting to undercut and advertise. When $\bar{s}$ is high the no advertising equilibrium is more likely to exist, since a high transportation cost makes consumers more immobile, which makes it less profitable to undercut the rival's price. A higher α implies that products are perceived as being closer substitutes and it becomes easier to steal the distant consumers. This makes it more tempting to undercut and advertise.

As described above firm i can only profit from advertising if $p_i < p_j$. Thus, for both firms to be willing to advertise it would require that $p_i < p_j$ and $p_i > p_j$, which of course is impossible. Hence, a pure strategy equilibrium cannot exist where $\lambda_i = \lambda_j = 1$. Moreover, the symmetric structure of the model entails that an asymmetric pure equilibrium cannot exist where only one firm advertises.

Mixing strategy equilibrium

When the cost of advertising, k, is not too large, the pure strategy equilibrium fails to exist and the only potential equilibrium must involve randomizing behavior. A priori, one could imagine many different randomizing strategies. Bester & Petrakis (1995) consider strategies where firms choose prices and marketing strategies in the following way: With probability q, firm i sets a low price, p^l and advertises $\lambda_i = 1$; otherwise firm i charges a high price p^h without spending resources on advertising. Bester & Petrakis (1995) do not discuss deriving the equilibrium strategy much. To facilitate understanding, we will explain the derivation of the randomizing equilibrium in more detail.

Assume that firm j adopts the strategy described above. If both firms playing this strategy is to constitute an equilibrium, firm i must maximize its profit by using the same strategy.

Taking p_j^h and p_j^l as given, the expected profit when advertising and setting p_i is

$$\psi^l(p_i, p_j, \lambda_i, \lambda_j) = q\pi_i(p_i^l, p_j^l, 1, 1) + (1-q)\pi_i(p_i^l, p_j^h, 1, 0)$$

Inserting (3.13) and recalling the assumption $\frac{v}{\bar{s}} < \alpha \leq \frac{1}{2}$ this yields

$$\psi^l(p_i, p_j, \lambda_i, \lambda_j) = qp_i\left(\frac{v-p_i}{\alpha\bar{s}} + \frac{p_j^l - p_i}{(1-\alpha)\bar{s}}\right) + (1-q)p_i\left(\frac{v-p_i}{\alpha\bar{s}} + \frac{p_j^h - p_i}{(1-\alpha)\bar{s}}\right)$$

Note that the second part of the first bracket becomes negative if $p_i > p_j^l$. Maximizing by choice of p_i, the first order condition becomes

$$\frac{q(p_j^l - 2p_i)}{1-\alpha} + \frac{v-2p_i}{\alpha} + \frac{p_j^h - 2p_i}{1-\alpha} + \frac{q(p_j^h - 2p_i)}{1-\alpha} = 0$$

Since firms are symmetric, $p_i = p_j^l = p^l$ and $p_j^h = p^h$ in equilibrium. Thus, the first order condition reduces to

$$p^l(2-\alpha q) - (1-\alpha)v = \alpha p^h(1-q) \tag{3.14}$$

Similarly, we define the expected profit when firm i sets a p_i and chooses not to advertise as

$$\begin{aligned}\psi^h(p_i, p_j, \lambda_i, \lambda_j) &= q\pi_i(p_i, p_j^l, 0, 1) + (1-q)\pi_i(p_i, p_j^h, 0, 0) \\ &= qp_i^h\left(\tfrac{v-p_j^l}{\alpha\bar{s}} - \tfrac{p_i - p_j^l}{(1-\alpha)\bar{s}}\right) + (1-q)p_i\left(\tfrac{v-p_i}{\alpha\bar{s}}\right)\end{aligned}$$

Maximizing by choice of p_i, using the symmetry argument and reducing gives

$$\alpha q p^l + (1-\alpha)v = 2p^h(1-\alpha(1-q)) \tag{3.15}$$

The two first order conditions (3.14) and (3.15) are two equations with two unknown variables, which can be solved to yield

$$p^h(q) = \frac{2v(1-\alpha)}{\alpha^2 q(1-q) - 2\alpha(2-q) + 4} \tag{3.16}$$

and

$$p^l(q) = \frac{v(2-\alpha(1-q))(1-\alpha)}{\alpha^2 q(1-q) - 2\alpha(2-q) + 4} \tag{3.17}$$

In equilibrium, the profit when setting p^l and spending resources, k, on advertisement must equal profit when setting p^h without advertising. Hence, in equilibrium $\psi^l(p^l) - k = \psi^h(p^h)$. Define $\varphi(q) \equiv \psi^l(p^l) - \psi^h(p^h)$. Reducing this comprehensive expression $\varphi(q)$ becomes

$$\varphi(q) = \frac{\alpha v^2(1-q)^2(1-\alpha)}{\bar{s}(\alpha^2 q(1-q) - 2\alpha(2-q) + 4)^2} \tag{3.18}$$

The equilibrium probability that firms set a low price and advertise, q^*, is determined uniquely by solving $\varphi(q^*) = k$. Both $p^h(q), p^l(q)$ and $\varphi(q)$ are continuous and decreases in q. Further, $p^h(1) = p^l(1) = \frac{(1-\alpha)v}{2-\alpha}$ Thus, in this model there exists an equilibrium where the price distribution function contains only two prices and firms randomize their advertising decision.

The expected profit in equilibrium becomes

$$\psi^h(p^h(q^*))) = \frac{4v^2(1-\alpha)(1-\alpha(1-q^*))}{\alpha\bar{s}(2\alpha(2-q^*) - \alpha^2 q^*(1-q^*) - 4)^2} \tag{3.19}$$

which is decreasing in q^*.

Note that in this equilibrium prices are set with positive probaility. This contrasts Varian (1980), where no single price is set with positive probability. The difference stems from the characteristics of the demand functions. In Varian (1980), demand is discontinuous, since firms can capture all informed consumer by cutting prices marginally. In contrast, for a given marketing decision, profit in this model is a strictly concave function of the price that a firm sets. The reason is that consumers do not have the same effective valuation of the two goods because of differences in transportation costs. This means that firms are not able to capture all consumers by cutting the price marginally.

We will now examine a number of comparative statistics of the randomizing equilibrium. As it becomes more expensive to advertise (i.e. when k increases), firms set a low price more seldom (q^* decreases). Since this reduces the risk of a competitor stealing customers, both $p^l(q)$, $p^h(q)$, and profit increase, reducing the price competition to the benefit of firms. The intuition is straightforward: With low advertising costs, firms are caught in a "prisoners' dilemma" situation where profits would be maximized if they refrained from advertising. However, this is not possible, since firms cannot commit to abstain from advertising. Increasing the cost of advertising reduces the temptation to advertise, thereby mitigating the "prisoners' dilemma" situation. By (3.18) an increase in transportation cost, $\bar{s}$, reduces q^*. The intutuition is that a higher transportation cost makes it more costly for consumers to switch firms, and hence less profitable to set a low price and advertise. Since a higher q^* increases both p^l and p^h, prices increase with transportation costs. The degree of substitutability, α, works in the other direction; higher α (closer substitutes) makes advertising more effective since it becomes easier to steal market shares. Hence, q^* increases and prices decrease in α.

Since firms make their advertising decisions independently, there is a risk that both firms choose to advertise. This happens with probability $(q^*)^2$. When this occurs, advertising is inefficient, since it induces no consumers to switch stores, and sellers will regret having wasted resources k on marketing. With probability $(1 - q^*)^2$, both firms set a high price and refrain from advertising. When this happens firms will ex post regret not having advertised a low price.

Welfare implications

Obviously, firms advertise more, when the cost of doing so is low, i.e. a decrease in k increases q. As described above, both $p^h(q^*)$ and $p^l(q^*)$ decrease in q^*, and since the low price is set more often for high q^*, consumers are definitely better off when the cost of advertising decreases. Thus, if the aim is to maximize consumer surplus, policy makers should try to reduce k and thereby promote price competition. Interestingly, this implies that a tax on advertising would benefit firms and harm consumers, since the increase in advertising cost mitigates the "prisoners dilemma" situation.

It is worthwhile to note that all consumers are informed about prices in equilibrium, since a consumer who does not receive an ad knows that the distant firm is setting the price p^h. Hence, there are no incentives for consumers to search in this model. The fact that all consumers are informed about prices in equilibrium, makes the interpretation of transparency as the share of informed consumers useless. This conclusion would however change, if firms where only able to inform some of the distant consumers by advertising. Then, a consumer who had not received an ad, would be uncertain whether the distant seller where setting a high or a low price. This would leave room for consumer search and make the interpretation of transparency more clear-cut.

Advertising creates two kinds of inefficiencies when total welfare is considered. First, marketing is in itself unproductive and lowers welfare by the amount spent on advertising. Second, in the randomizing equilibrium some consumers travel to the distant store with positive probability, and thus pay a larger transportation cost. This tends to reduce total welfare. Hence, advertising is a trade-off between increasing production and the waste of resources from more traveling and higher advertising costs. Whether advertising improves or reduces welfare depends on the specific values of the parameters. Consider the case where $\frac{v}{s} \leq \alpha < \frac{1}{2}$, so that demand is always elastic and k is close to zero. Here a decrease in k will result in q^* approaching one and a decrease in both prices, such that $p^h(q*)$ approaches $p^l(q^*)$. This increases demand and welfare. Moreover, when prices charged by the two firms are identical, consumers always buy from the local store, transportation costs are minimized and, since k is close to zero, hardly any resources are wasted on advertising. Hence, when k is sufficiently small and demand is elastic advertising increases social welfare. This conclusion does, however, hinge on demand being sufficiently elastic. Consider instead a situation where v is sufficiently high such that each firm will serve the entire local market in the case without advertising, and the two goods are not close substitutes (low α), so that the cost of switching suppliers is relatively high. Since the entire market is covered, advertising cannot increase production, and only serves to steal business from the competitor. This reduces welfare, since more resources are wasted on transportation and advertising. To summarize, a necessary condition for advertising to be beneficial to society is that demand is sufficiently elastic, which is more likely when consumers perceive products as being close substitutes.

3.2.2 Information clearing houses

A different way to think of advertising is when firms decide whether to post their prices in a newspaper or on an internet site. By doing so, consumers who have access to this 'information clearing house' become able to compare prices charged by different firms. This is analyzed in Baye & Morgan (2001). Their model is an extended version of Varian's with a fixed number of firms. In Baye & Morgan (2001), informed consumers are those with access to the clearing house, whereas uninformed consumers are not able to see the listed prices. The key difference to Varian's model is that the owner of the clearing house can charge a fee to make firms' prices publicly available, and a fee from consumers for getting access to the website. Since the market outside the clearing house only consists of uninformed consumers, firms which decide not to list their prices, will certainly charge the reservation price. In contrast, firms which access the clearing house compete for both informed and uninformed consumers. Baye & Morgan (2001) shows that in equilibrium firms join the clearing house with some probability and randomize their prices. Otherwise, they do not publish their price and charge the reservation price to exploit 'offline' consumers. Contrary to Varian (1980), price dispersion in this model does not arise from differences in search costs, but from the positive advertising fee. For a more comprehensive review of studies on information clearing houses, see Baye, Morgan & Scholten (2004*a*).

3.3 Concluding remarks

Rather than assuming differences in consumer information, the search literature endogenizes the decision to become informed. The literature on informative advertising sheds light on firms' incentive to inform consumers. The key findings in the chapter are summarized below.

- Differences in consumers information, as assumed in the models in chapter 2, are likely to arise even when search is endogenized.
- Equilibrium price dispersion can arise even when consumers and firms are identical *ex ante*.
- Lower search costs increase the share of informed consumers and promote competition. Moreover, a small decrease in the search cost may induce a large increase in the share of informed consumers and vice versa.
- The feasibility of price advertising promotes competition and increases consumer surplus. The reason is that firms are caught in a "prisoners' dilemma" situation when deciding whether to advertise: Total profit is maximized if no firms advertise,

but if the cost of advertising is not too high, all firms have incentives to advertise. The lower the cost of advertising, the more tempted firms are to advertise. Hence, the feasibility of price advertising promotes competition and increases consumer surplus. The effect on total welfare is, however, ambiguous.

Chapter 4

Collusion

The literature reviewed in chapters 2 and 3 generally supports that increasing transparency on the consumer side leads to more competitive markets with lower prices. This seems intuitively appealing since more informed consumers increase the effective elasticity of demand which makes it more profitable to lower prices. If firms are able to collude on prices, this positive effect may change, however. Increasing transparency makes it more tempting to disregard a collusive agreement and undercut prices, but it also intensifies the harshness of the punishment phase. A priori it is not possible to determine which of the two effects dominates.

The following simple example serves as a benchmark for considering collusion in a market with imperfect consumer information. Assume that firms try to collude in an infinitely, repeated game using the following trigger strategy: Each firm charges the monopoly price, p^m in period 0. Moreover, it charges p^m in period t if both firms have charged p^m in all previous periods. Otherwise, it sets a low price (this price may be the result of a randomizing strategy) in all remaining periods. Denote each firm's profit π^c in a collusive period, π^d, in a period when it deviates, and π^p in a punishment period. Firms are able to sustain collusion if the discounting factor δ is high enough to satisfy

$$\frac{1}{1-\delta}\pi^c \geq \pi^d + \frac{\delta}{1-\delta}\pi^p \tag{4.1}$$

where the left side of the inequality is the present value of collusion and the right hand side is the present value of deviating followed by infinite punishment. Solving for δ equation

(4.1) yields

$$\delta \geq \frac{\pi^d - \pi^c}{\pi^d - \pi^p} \equiv \delta^* \tag{4.2}$$

Now consider the duopoly version of Varian (1980), analyzed in section 2.2.2, where the share of uninformed consumers is exogenously determined. In periods of collusion, firms serve half of the entire market and earn $\pi^c = \frac{\pi_I + \pi_U}{2}$, where π_I and π_U are the profit from serving the informed and uninformed consumers at the monopoly price respectively. The optimal deviation is to cut the price marginally and serve all informed consumers and half of the uninformed, hence $\pi^d = \pi_I + \frac{\pi_U}{2}$. Finally, firms revert to the single stage Nash equilibrium in the punishment phase, where they randomize and earn an expected profit equivalent to serving half of the uninformed consumers at the monopoly price. Hence, $\pi^p = \frac{\pi_U}{2}$. Inserting this in (4.2) the discount factor has to satisfy

$$\delta \geq \delta^* = \frac{\pi_I + \frac{\pi_U}{2} - \frac{\pi_I + \pi_U}{2}}{\pi_I + \frac{\pi_U}{2} - \frac{\pi_U}{2}} = \frac{1}{2} \tag{4.3}$$

Interestingly, the share of informed consumers does not enter the restriction, and firms' ability to collude is exactly the same as if all consumers were informed. The reason is that, since firms' profits are as if they reap the monopoly profit from half of the uninformed consumers, firms only collude on the informed consumers de facto. Put differently, some imperfectly informed consumers make deviation less attractive, but this is exactly counterbalanced by a less competitive punishment phase, where firms can exploit the uninformed consumers. Hence, transparency does not affect firms' ability to collude. This result does not hold in general. In the following, we will study models on tacit collusion and transparency, where transparency has an impact on firms' ability to collude.

- In Nilsson (1999) transparency affects collusion, since more consumers search in a punishment phase compared to a collusion phase. In equation (4.3) this implies that the profit from serving the uninformed does not cancel out in the denominator. This model is analyzed in section 4.1.

- Schultz (2005) avoids the benchmark result by considering differentiated products. When goods are heterogeneous, firms cannot undercut the monopoly price slightly and serve all informed consumers. As we will see in section 4.2, this means that transparency affect the sustainability of collusion.

- In Chapter 5 we extend Varian's model by introducing different costs. When costs are asymmetric, the expected profit in the punishment phase is not identical to serving the uninformed consumers at the monopoly price, and the denominator of (4.3) does not reduce to π_I.

4.1 Homogenous goods and consumer search

The effects of transparency on tacit collusion are considered in Nilsson (1999). Since we have already analyzed the one-shot game of this model, see section 3.1.2, we will only consider the dynamic game here.

In periods when firms collude, there is no price dispersion and the expected gain from searching is zero. Hence, only the α shoppers search in these periods.[1] In the punishment phase, however, firms compete by mixing prices according to the distribution function in equation (3.9) on page 33, and a larger share of the consumers, β, finds it profitable to search.

One potential hurdle is that consumers must be able to identify a shift from a collusive period to a period of punishment in order to know the expected gain from searching. Nilsson argues that consumers can infer this from the demand of the store they visit; if demand is higher, or lower, than usual, one of the firms must have deviated and the next period will be a punishment period. One could also imagine that shoppers who always know the nature of the following period are able to transmit this information to those who do not search. The ad hoc assumption of shoppers transmitting price information to non-shoppers is crucial for the results of the model and arguably is a considerable limitation of this model.

4.1.1 Trigger strategies

When the Bertrand game is repeated, firms seek to maximize the present value of their profits. Consider a case with an infinite time horizon where firms play symmetric trigger

[1] Recall that shoppers have zero search costs and always search.

strategies. Firms start by playing the monopoly price, r, and continue to do so as long as the competitor plays r. Otherwise, they mix for the rest of the periods according to the cumulative distribution function described on page 33. The one period profit when sticking to the collusive agreement is $\pi^c = \frac{r}{2}$. The optimal deviation is to undercut the collusive price by ϵ serving half of the uninformed consumers and all the shoppers in the following period, thus reaping a profit of $\pi^c = \frac{1+\alpha}{2}r$. This triggers the punishment phase, and for the remaining periods, firms randomize and get an expected profit equivalent to serving half of the uninformed consumers at the monopoly price, i.e. $\pi^p = \frac{1-\beta}{2}r$. Inserting this in (4.2) yields

$$\delta \geq \delta^* = \frac{\frac{1+\alpha}{2}r - \frac{r}{2}}{\frac{1+\alpha}{2}r - \frac{1-\beta}{2}r} = \frac{\alpha}{\alpha + \beta} \tag{4.4}$$

When all consumers are perfectly informed about prices, $\alpha = \beta$, and the discount factor has to be greater than one half to sustain collusion. When the cost of searching is not too large, some of the 'non-shoppers' find it profitable to search and $\beta > \alpha$. In this case it is easier to sustain collusion compared to a completely transparent market. The reason is that only shoppers can be attracted when deviating, whereas competition in the punishment phase is made tougher since some of the non-shoppers search. If, however, the cost of searching is sufficiently high (greater than $v(\alpha)$ in figure 3.3 on page 36) only shoppers search and again $\alpha = \beta$, yielding the same restriction on the discount factor as when the market is fully transparent. The reason is that the gain of deviating is perfectly neutralized by the weaker competition in the punishment phase.

4.1.2 Optimal punishment

In the above analysis it is assumed that firms use trigger strategies. Trigger strategies are convenient since they are simple, easy to calculate, and do not involve negative prices. Firms may, however, use other strategies which are more effective in sustaining collusion. Nilsson (1999) considers how transparency affects the ability to collude if firms play according to optimal punishment strategies. We will not explore this in detail, but will briefly explain the idea and how it alter the policy implications.

Under optimal punishment, a deviation from the collusive agreement is not punished with the Nash equilibrium for all future periods. Instead the opponent sets a price equal to marginal cost in the following period, and reverts to the collusive price only if the deviator sets a price even lower (since marginal cost is zero this implies negative prices).

In order for this to be an equilibrium, the penal code must be sustainable and credible, see Abreu (1986) and Abreu (1988). Sustainability requires that firms find the immediate gain from deviating less attractive than the discounted value of staying in the collusive arrangement, where the latter depends on the harshness of the punishment phase. The punishment phase is, however, only credible if the *punisher* is willing to set a price equal to marginal cost and the *deviator* accepts playing negative prices. The deviator is only willing to do so as long as the current negative profit combined with the gain from reverting to the collusive arrangement in future periods dominates playing best response, i.e. setting $p = r$ and serving the uninformed consumers. Collusion is easier to sustain, and the punishment is optimal, if the present value of the punishment is minimized subject to the constraint that the equilibrium is sustainable and credible. Under optimal punishment, collusion is sustainable for

$$\delta_{opt} \geq \frac{\alpha}{\alpha + \beta_0} \tag{4.5}$$

where β_0 is the share of consumers who search in the punishment phase. The gain from searching does not depend on other consumers' search behavior, since the punisher sets the price to zero and the deviator sets a fixed negative price. Hence, as long as the search cost is below the fixed gain from searching, all consumers search and $\beta_0 = 1$, otherwise only shoppers search.[2] Hence, as long as the search cost is not too large, collusion is always easier to sustain with optimal punishment than with trigger strategies.

Normally, when firms are not able to collude on the monopoly price, they can agree to collude on a lower price, since this makes it less tempting to deviate. However, this is not possible in this model. The reason is that since only a fraction of the consumers is informed, the temptation to deviate is reduced less than the value of collusion when the collusive price is lowered. Hence, if firms collude, they do it on the monopoly price. We do not reproduce Nilsson's proof of this here. Instead we use a similar procedure in the proof of proposition 8 in chapter 5.

[2]Nilsson shows that this threshold value for s is $\delta r/4(1-\delta)$. Substituting δ with $\delta = \alpha/(\alpha+1)$, this becomes $s = r\alpha/4$.

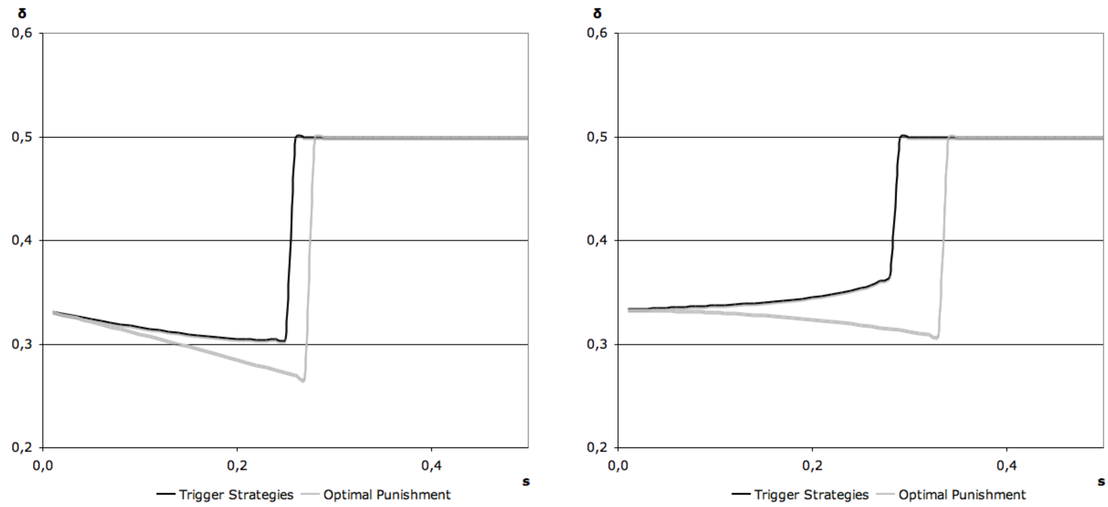
4.1.3 Policy implications

As described in section (3.1.2), price publications lower the search costs which increases both the share of shoppers, and the share of consumers who search in equilibrium. From (4.4) it is clear that this has an ambiguous effect on the discount factor when firms use trigger strategies, since

$$\begin{aligned}\frac{\partial\delta_{trig}}{\partial\alpha} &= \frac{\beta}{(\alpha+\beta)^2} > 0\\ \frac{\partial\delta_{trig}}{\partial\beta} &= -\frac{\alpha}{(\alpha+\beta)^2} < 0\end{aligned}$$

The intuition is that higher α increases the gain from deviating, which makes it harder to sustain collusion. This may, however, be dominated by the fear of entering a tougher punishment phase with a higher β. In contrast, when firms use optimal punishment and s is low, such that $\beta_0 = 1$, collusion is always easier to sustain for higher search costs. Figures 4.1(a) and 4.1(b) may shed light on the different effects. In figure 4.1(a) the

Figure 4.1: Collusion and search costs



(a) Discount factor, $\alpha(s) = 0.5(1-s)$ (b) Discount factor, $\alpha(s) = 0.5(1-s^2)$

Source: Own numerical calculations based on Nilsson (1999).

restriction on the discount factor under trigger strategies and under optimal punishment is drawn using the numerical values for α and β calculated in section 3.1.2. Recall that $\alpha(s) = 0.5(1-s)$. In figure 4.1(b) a marginal reduction in s is assumed to increase α less when s is initially low, i.e. $\alpha(s) = 0.5(1-s^2)$.

Before we turn to the difference between the two figures, note that when the search cost is sufficiently high, a discount factor of one half is necessary for firms to sustain collusion. In this case only shoppers search, and a small decrease in the search cost will have no effect on firms' ability to collude. When firms use trigger strategies, lowering the search cost to a level below the expected gain from search will induce a jump in the share of informed consumers, since non-shoppers begin to search. This will make the punishment phase significantly tougher, thereby making it easier to sustain collusion. Similarly, when firms play according to optimal punishment strategies reducing s below $r\alpha/4$ will make all consumers search in the punishment phase and make collusion easier to sustain. This contradicts proposition 3.1 in Nilsson (1999), where he argues that improving price information will never facilitate collusion under optimal punishment. From figure 4.1(a) and 4.1(b) we clearly see that his argument is only valid for small values of s. Hence, if search costs are initially high, this model suggests that policy makers should be very careful to implement changes which aim at reducing the search cost significantly.

If the search cost is below the threshold value so that some non-shoppers search, the effect of improving transparency depends on whether firms collude by using trigger strategies or optimal punishment. Reducing search costs when firms use optimal punishment will increase the temptation to undercut, but has no effect on the punishment phase, since all consumers search during this phase. Hence, in this case, transparency unambiguously promotes competition under optimal punishment. If, however, firms use trigger strategies, the effect of reducing s will depend on the exact relationship between α and s. In figure 4.1(a) the share of shoppers depends linearly on the search cost. When s is reduced, the temptation to deviate increases relatively much, and this effect dominates the more severe punishment, hence making collusion harder to sustain. If, however, the share of shoppers is a concave function of the search cost, reducing s can facilitate collusion. This is illustrated in figure 4.1(a), where $\alpha(s) = 0.5(1-s^2)$. The intuition is that since only very few extra consumers become shoppers, the effect of an increased temptation to undercut is dominated by the tougher punishment.[3] Hence, if the search cost is low initially and firms use trigger strategies, improving transparency can facilitate collusion if it fails to generate enough new shoppers. If firms use optimal punishment, and the search cost is low, transparency will always mitigate collusion.

[3] Since $s < 1$ the share of shoppers is less sensitive to changes in s when the function is concave.

4.1.4 Perceiving product differentiation as transparency

Before we turn to studying collusion and transparency in differentiated goods market, we will briefly consider the results of Møllgaard & Overgaard (2000). In their oligopoly model, products are in fact homogenous, but if the market is less than fully transparent, consumers perceive the products as being differentiated. Hence, they interpret product differentiation as transparency. By doing so, they are able to derive advantage from the results on product differentiation and tacit collusion, see Deneckere (1983). In this literature firms face an inverse demand function of the form

$$p_i = \alpha - \beta q_i - \gamma q_j \tag{4.6}$$

where $\beta > \gamma \geq 0$ reflects that products are not homogenous. Møllgaard & Overgaard (2000) assume that $\beta \equiv \frac{1}{1+t}$, $\gamma \equiv \frac{t}{1+t}$ and finally that $\alpha = 1$. Inverting the demand function gives the following direct demand

$$q_i = 1 - \frac{1}{1-t}p_i + \frac{t}{1-t}p_j \tag{4.7}$$

When the market is transparent (t close to one), consumers perceive the two goods as being close substitutes and demand is very sensitive to changes in the price. In contrast, if the market is intransparent (t equal to zero), firms act as monopolists on their share of the market. Møllgaard and Overgaard state that interpreting t as the degree of transparency *is a natural and simple way to model what commentators have in mind when they argue that lack of transparency creates "artificial" product differentiation and dampens price competition.*, Møllgaard & Overgaard (2000) p. 10. Reusing the results from the literature on tacit collusion and product differentiation, they find that the effect of transparency on competition is ambiguous. For low values of t, regulators should seek to increase transparency, and for high values of t they should aim at reducing it. To what extent this interpretation of transparency is valid will be discussed in more details in the following section, where collusion is studied in a Hotelling model with some uninformed consumers.

4.2 Tacit collusion with differentiated goods

In section 2.3 we analyzed the stage game of Schultz (2005). In the dynamic part, Schultz studies the effect of transparency when firms compete in a differentiated goods market. In line with previously described dynamic game literature, Schultz assumes that firms follow a trigger-strategy where both firms set a collusive price p^c initially, and revert to the stage game equilibrium price if the rival deviates.

Consider a case where consumers' utility is high, so that the market is covered, and products are reasonably close substitutes, so that firms cannot sustain monopoly prices in the stage game. Here, if firms collude, they split the market and earn $\pi^c = \frac{p^c}{2}$. The optimal deviation is the profit maximizing price in the one-period game. This can be written as

$$p^d = \begin{cases} \frac{1}{2}\left(p^c + \frac{t}{\phi}\right) & \text{if } p^c \leq 2t + \frac{t}{\phi}, \\ p^c - t & \text{if } p^c > 2t + \frac{t}{\phi}. \end{cases}$$

If product differentiation is low, it is optimal to deviate to a price low enough to attract all informed consumers (the second part of p^d). If products differ substantially, a deviating firm is not willing to set a price low enough to attract all informed consumers (the first part of p^d). In this case the optimal deviation price is lower when a larger share of consumers is informed. The reason is than in a more transparent market, a deviating firm is able to serve a larger share of the market. Notice that when products are differentiated, a firm cannot capture all informed consumers by setting a price marginally lower than the competitor. This is key reason why the results of this model differ from the benchmark example analyzed earlier. A deviating firm earns the profit

$$\pi^d(p) = \begin{cases} \frac{1}{8}\frac{(\phi p^c + t)^2}{\phi t} & \text{if } p^c \leq 2t + \frac{t}{\phi}, \\ (p^c - t)\frac{1+\phi}{2} & \text{if } p^c > 2t + \frac{t}{\phi}. \end{cases}$$

As in other models studying collusion and transparency, the temptation to deviate is larger when more consumers are informed about prices. Finally, the profit in a punishment phase π^d depends on the equilibrium in the stage game.

Schultz (2005) shows that when goods are almost homogeneous, the scope for collusion is hardly affected by changes in market transparency. Moreover collusion on the monopoly price is easier than collusion on any other price. Hence, when goods are not too differentiated, Schultz obtains results almost identical to the benchmark example for homogeneous goods described in the beginning of chapter 4. Further, interesting results arise when products are relatively differentiated, and thus, we will focus on this case here.

With relatively high product differentiation, the stage game equilibrium is in pure strategies and profit in the punishment phase given by $\pi^p = \frac{t}{2\phi}$. Assume that firms collude on the monopoly price, $p^m = u - \frac{t}{2}$ and that this price is not too high, so that a deviating firm does not serve all informed consumers. The discount factor required to sustain collusion is found by inserting π^c, π^d and π^p in equation (4.2). This yields

$$\delta \geq \delta^* = \frac{\frac{1}{8}\frac{(\phi p^m + t)^2}{\phi t} - \frac{p^m}{2}}{\frac{1}{8}\frac{(\phi p^m + t)^2}{\phi t} - \frac{t}{2\phi}} = \frac{p^m - t/\phi}{p^m + 3(t/\phi)} = \frac{(u + t/2) - t/\phi}{(u + t/2) + 3(t/\phi)} \tag{4.8}$$

The required discount factor δ^* increases with transparency. Hence, if firms are able to collude on the monopoly price, it is more difficult to collude in a more transparent market. As noted in section 2.3, introducing uninformed consumers corresponds to a reparametrization of product substitutability in the static game, and thus, perceiving changes in product differentiation as changes in transparency may be attractive. From (4.8) we see that this only suffices for a *given* monopoly price. However, as the monopoly price is not affected by changes in transparency, whereas changes in product differentiation *do* alter the monopoly price, one must be careful when interpreting transportation costs as transparency in the dynamic game.

If the monopoly price is sufficiently high, so that $p^d = p^m - t$ and $\pi^d = (p^m - t)\frac{1+\phi}{2}$, the required discount factor becomes

$$\delta^* = \phi \frac{(2u - 3t) - 2(t/\phi)}{(2u - 3t)(1 + \phi) - 2(t/\phi)}$$

which also increases in ϕ.

Finally, Schultz shows that if firms cannot collude on the monopoly price, they are either unable to collude or the sustainable price decreases in transparency.

To summarize, when products are differentiated, this model indicates that more transparency destabilizes cartels and unambiguously promotes competition.

4.3 Concluding remarks

First of all, the articles considered in this chapter illustrate that if firms have the possibility to engage in tacit collusion, changes in transparency are likely to affect the sustainability of such agreements - even when producer side information is left unchanged. Whether transparency promotes or mitigates collusion is a more complicated question. On the one hand, more informed consumers make it more tempting to deviate, but on the other hand, the punishment phase is tougher when more consumers are informed, and this facilitates collusion. Which of the two countervailing effects dominates depends on the specific market characteristics. Hence, it seems fair to say that the literature on collusion and consumer side information does not support the OECD recommendation; that if information already exists among firms, more transparency will be pro-competitive. Besides cautioning against potentially harmful effects of consumer side transparency, the literature is scarce on precise policy implications concerning collusion and transparency. This chapter has shown that slight modifications in the model setup result in qualitatively different policy implications. Hence, competition authorities should be cautious using the results summarized below as a specific guideline for their policy.

- If products are homogenous, firms are identical, and the share of informed consumers is the same in the collusion, deviation and punishment phase, then transparency has no impact on firms' ability to collude.
- If products are differentiated, transparency is likely to make it more difficult for firms to collude.
- Entering a punishment phase is likely to induce search, since the gain from searching is larger when prices are dispersed. The implication of this may be that transparency can facilitate collusion.
- The competitive outcome in markets with incomplete consumer information is usually not compatible with identical prices. Hence, a single market price is likely to be an indication of weak competition.

Chapter 5

A Model of Sales with Asymmetric Firms

In this section we analyze Varian (1980) in a more general setup where firms face a downward sloping demand curve and have different marginal costs. We show that when few consumers are informed, there exists a pure strategy Nash equilibrium where firms set their monopoly prices. When the share of informed consumers is sufficiently high, firms are tempted to lower prices to capture the informed consumers, and end up in a mixed strategy equilibrium similar to the one seen in Varian (1980). However, contrary to Varian (1980), they set their monopoly price with positive probability and randomize in a continuum of prices otherwise. Firms set lower average prices as more consumers are informed, leading the high-cost firm's profit to decrease, whereas the effect on the low-cost firm's profit is ambiguous. If the cost difference is large, the low cost firm's profit increases, but when the cost difference is small and competition from the high-cost firm is tough, profit decreases along with more informed consumers. Finally, we consider how transparency affects firms' ability to collude in the presence of asymmetric costs. We show that collusion is easier to sustain when prices are more transparent. Hence, more consumer information is not always pro-competitive.

5.1 The setup

The setup in the model is as follows. Two firms, A and B, with different marginal costs compete in a homogenous goods market, where firms set prices. Without loss of generality firm A's marginal cost is normalized to zero. Hence, firm B's marginal cost c can be interpreted as the firm's cost disadvantage. We only consider cases where $0 < c < \frac{1}{2}$, that is where the high cost firm B is able to sell at a price lower than A's monopoly price.

The number of consumers is normalized to one and consumers' reservation price is uniformly distributed between 0 and 1. A share α of the consumers is informed about prices and buy at the lowest price while $1-\alpha$ uninformed consumers choose randomly between firms and buy if the price is below their reservation price. Moreover, consumers do not know which firm is the low cost firm. When treating α as an exogenous parameter we follow Varian (1980). A more comprehensive model would allow consumers to choose whether to search or not, as seen in Burdett & Judd (1983) and Nilsson (1999). They show that differences in information ex post can arise even when consumers have identical search costs. Hence, instead of complicating the analysis by modelling search, we simply assume that there are differences in consumer information.

Given firm j's price firm i faces the following demand

$$D_i(p_i, p_j, \alpha) = \begin{cases} \frac{1+\alpha}{2}(1-p_i) & \text{if } p_i < p_j < 1 \\ \frac{1}{2}(1-p_i) & \text{if } p_i = p_j < 1 \\ \frac{1-\alpha}{2}(1-p_i) & \text{if } p_j < p_i < 1 \end{cases} \quad i = A, B,\ i \neq j$$

One is easily convinced that when all consumers are informed, $\alpha = 1$, firms will engage in Bertrand competition and set $p_A = p_B = c$ in equilibrium. With $\alpha = 0$ market shares are not affected by prices and firms split the market and act as a monopoly on their share. Hence, firm A sets its monopoly price $p_A^M = \frac{1}{2}$ and makes the profit $\pi_A = \frac{1}{8}$ and B sets $p_B^M = \frac{1+c}{2}$ and reaps $\pi_B = \frac{1}{2}\left(\frac{1-c}{2}\right)^2$.

With intermediate transparency $(0 < \alpha < 1)$ there exists no equilibrium where both firms set the same price. If both firms set p they have an incentive to make a marginal price cut, since they gain $\alpha(1-p)$ informed consumers and only lose a marginal revenue on existing customers. Hence, both firms will lower their price until the high cost firm, B, is better off serving half of the uninformed consumers at its monopoly price. Thus, there exists no pure strategy equilibrium where both firms set the same price when there are both informed and uninformed consumers.

Given that firms charge different prices, the only potential pure strategy Nash equilibrium (PNE) is where A sets $p_A = p_A^M$ and B sets $p_B = p_B^M > p_A^M$. To see this, consider a case where α is very small. Here, firm B is not tempted to undercut A, since the loss on existing uninformed consumers is greater than the gain from serving the few informed consumers. As $p_A^M < p_B^M$ firm A serves all informed consumers at its monopoly price and has no incentive to change its price. However, when the share of informed consumers is sufficiently high, B has an incentive to undercut A in order to gain the informed consumers. In this case the pure strategy equilibrium fails to exist, and firms play a mixed strategy somewhat similar to what is seen in Varian (1980). We now turn to a detailed description of the different equilibria.

5.2 Static game

5.2.1 Pure strategy nash equilibrium

Following Varian (1980) we use π_i^s to denote the profit when firm i sets the lowest price and *succeeds* in getting the informed consumers. Likewise, we use π_i^f when firm i *fails* to set the lowest price.

If both firms set their monopoly price, firm B will never deviate when the profit from charging its monopoly price, $\pi_B^f(p_B^M) = \frac{1-\alpha}{2}\left(\frac{1-c}{2}\right)^2$ is higher than the profit from slightly undercutting firm A and gaining all the informed consumers, earning $\pi_B^s(p_A^M) = \frac{1+\alpha}{2}(1 - p_A^M)(p_A^M - c)$. Thus, a PNE exists when $\pi_B^f(p_B^M) > \pi_B^s(p_A^M)$, i.e. when

$$\frac{1-\alpha}{2}\left(\frac{1-c}{2}\right)^2 > \frac{1+\alpha}{2}(1 - p_A^M)(p_A^M - c) \tag{5.1}$$

which, given $p_A^M = \frac{1}{2}$ can be rearranged to

$$c^2 > [2(1-c)^2 - c^2]\alpha \tag{5.2}$$

As $c < \frac{1}{2}$ and $\alpha > 0$ the right hand side is always positive. Hence, a PNE exists when

$$\alpha < \frac{c^2}{c^2 - 4c + 2} \equiv \alpha^* \tag{5.3}$$

Notice that $c > 0$ is a necessary condition for the existence of a pure strategy Nash equilibrium. If both firms have the same marginal cost they have the same monopoly price too, and firm B can gain all informed consumers by lowering the price marginally. In contrast, B must lower the price significantly to gain informed consumers when $c > 0$. This also means that a downward sloping demand curve is necessary for a PNE to exist, since the firms' monopoly prices are identical, despite differences in marginal costs, if all consumers have the same reservation price.

A PNE exists for larger shares of uninformed consumers if the cost difference is large. To see this we differentiate (5.3) with respect to c. This yields

$$\frac{\partial \alpha^*}{\partial c} = \frac{2c}{c^2 - 4c + 2} - \frac{c^2(2c-4)}{(c^2 - 4c + 2)^2} = \frac{4c(1-c)}{(c^2 - 4c + 2)} \geq 0 \tag{5.4}$$

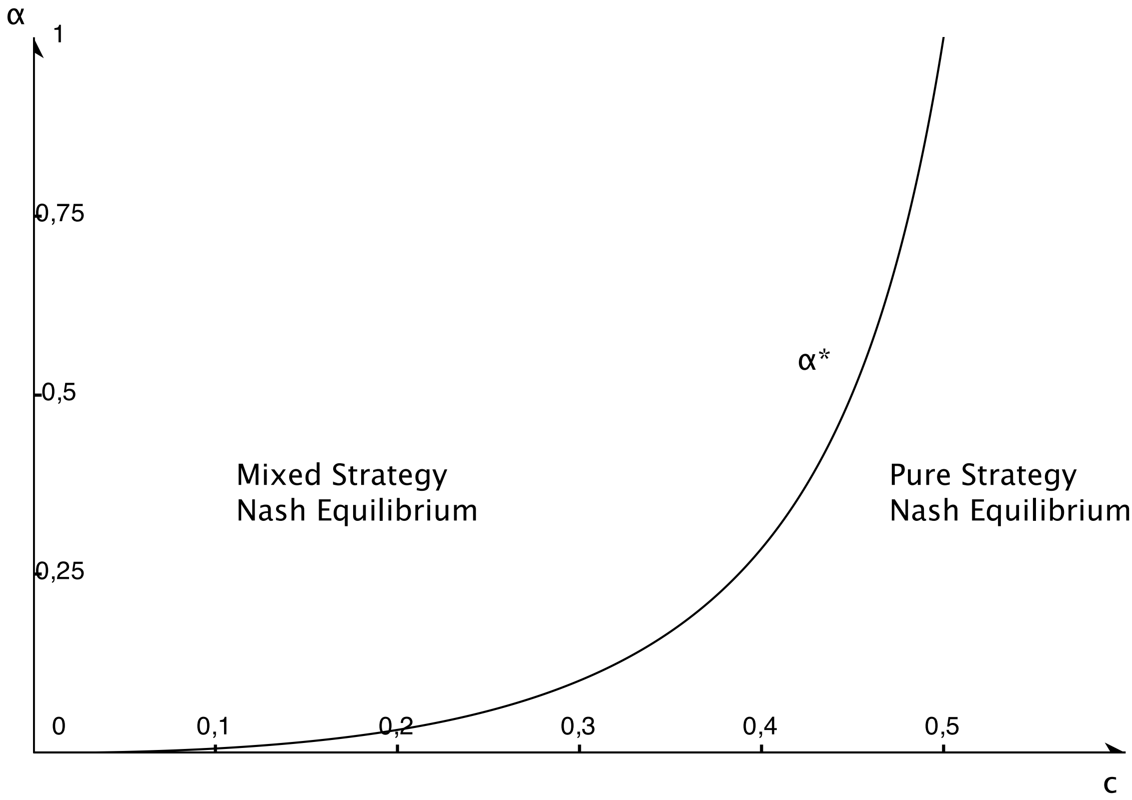
which is greater than or equal to zero for c between 0 and $\frac{1}{2}$.

Figure 5.1 shows α^* as a function of c. When B's costs are high it becomes less attractive to undercut A, since B suffers a higher loss on existing consumers. Hence, firms will set their monopoly price for higher shares of informed consumers when costs differ substantially.

5.2.2 Mixed strategy nash equilibrium

When the share of informed consumers is larger than α^*, no pure strategy equilibrium exists. In this section we suggest a mixed strategy equilibrium where firms set their monopoly price with positive probability and randomly set prices lower than the monopoly price otherwise. We continue by showing that this is indeed a Nash equilibrium and derive the distribution functions in the interval where firms randomize over a continuum of prices.

Figure 5.1: The existence of a pure strategy Nash equilibrium



Note: The figure displays α^* as a function of c. For α's lower than α^* a pure strategy nash equilibrium exists.

To our knowledge, this hybrid of temporal and spatial price dispersion is new.

Consider a mixed strategy profile where firms set their monopoly price with probability $0 < \rho_i < 1$ and set prices according to $\tilde{F}(p)$ in the interval $p \in [p^*; p_A^M[$ otherwise. $\tilde{F}(p)$ is a continuous function, so that there is positive density but zero probability at all prices. The complete distribution function, $F_i(p)$, can be written as

$$F_i(p) = \begin{cases} \tilde{F}_i(p) & \text{for } p \in [p^*; p_A^M[\\ 1 & \text{for } p = p_i^M \end{cases}, i = A, B \tag{5.5}$$

where the probability by which firms set their monopoly price is $\rho_i = 1 - \tilde{F}_i(p_A^M)$.

In the following we show that the proposed strategy profile is a Nash equilibrium. We start by showing that it can never be profitable for a firm to set prices other than those included in the strategy profile. Next we establish the conditions under which all prices set with positive density yield the same expected payoff, by finding the distribution function for each firm that makes its opponent indifferent between setting each of *its* prices. This is sufficient for the proposed equilibrium to exist, (see Mas-Colell, Whinston & Green (1995), Proposition 8.D.1). Finally, we derive $F_i(p)$, i.e. ρ_i and $\tilde{F}_i(p)$.

Price interval

We now focus on the range where firms will set prices. Firm B can always choose to set its monopoly price and make the profit $\pi_B^f(p_B^M)$. Hence, it is never willing to compete for the informed consumers if the profit when succeeding is lower than $\pi_B^f(p_B^M)$. Define p^* as the minimal price B is willing to set, i.e. where

$$\pi_B^f(p_B^M) = \pi_B^s(p^*) \tag{5.6}$$

Inserting the profits this yields

$$\begin{aligned}
\frac{1-\alpha}{2}\left(\frac{1-c}{2}\right)^2 &= \frac{1+\alpha}{2}(1-p^*)(p^*-c) \quad \Leftrightarrow \\
0 &= (p^*)^2 - (1+c)p^* + c + \frac{1-\alpha}{1+\alpha}\left(\frac{1-c}{2}\right)^2
\end{aligned}$$

where the only relevant solution is

$$p^* = 1 - \frac{1}{2}\left(1 + \sqrt{\frac{2\alpha}{1+\alpha}}\right)(1-c) \tag{5.7}$$

Notice that $p^* = p_B^M$ for $\alpha = 0$ and $p^* = c$ for $\alpha = 1$ as argued in section 5.1. Since firm B will never set prices below p^* neither will A.[1]

Now consider the upper end of the interval. Clearly, no firm will set a price above its monopoly price. Moreover, B will never set prices between p_A^M and p_B^M since the chance of winning in this interval is equal to the chance of winning when setting p_B^M where the profit is higher. This leads us to the following proposition:

Proposition 1 *Firms always set prices, $p \in [p^*, p_i^M]$. Firm B never sets prices where $p \in [p_A^M, p_B^M[$.*

[1] In the suggested equilibrium no prices except the monopoly price is set with positive probability, hence we can neglect the possibility of a tie at p^*.

Proof: This is concluded above. ■

Equilibrium conditions

As stated earlier, all prices set with positive density must yield the same expected profit in equilibrium. Firms are always able to capture the informed consumers by setting p^*. Hence the expected profit in equilibrium must be $\pi_i^s(p^*)$.

In equilibrium each firm must choose a strategy which makes the other firm indifferent over *its* possibilities. That is, we need to ensure that all prices set with positive density yield the same expected payoff to a firm, given the other firm's strategy. If firm A sets p_A^M, two events may occur: Either p_A^M is the lowest price, and the firm succeeds in attracting the informed consumers. This happens with probability ρ_B, i.e. when B sets p_B^M. Otherwise, p_A^M is not the lowest price and only uninformed consumers buy. This happens with probability $1-\rho_B$. Hence, in order for A to be willing to randomize, B must set ρ_B such that A's expected profit from setting p_A^M is equal to the profit when setting p^* and win for sure. Now look at firm B. If it sets $p_A^M - \epsilon$ it succeeds with probability ρ_A and fails with probability $1-\rho_A$. Since all prices must yield the same expected profit in equilibrium, A must set ρ_A such that B is indifferent between setting p^* and $p_A^M - \epsilon$. Hence, firm i must choose ρ_i such that

$$\pi_j^s(p^*) = \rho_i \pi_j^s(p_A^M) + (1-\rho_i)\pi_j^f(p_A^M) \tag{5.8}$$

Rearranging (5.8) gives the following expression for ρ_i

$$\rho_i = \frac{\pi_j^s(p^*) - \pi_j^f(p_A^M)}{\pi_j^s(p_A^M) - \pi_j^f(p_A^M)} \tag{5.9}$$

Inserting the relevant profits this reduces to

$$\rho_i = \frac{\frac{1+\alpha}{2}(1-p^*)(p^*-c_j) - \frac{1-\alpha}{2}(1-p_A^M)(p_A^M-c_j)}{\frac{1+\alpha}{2}(1-p_A^M)(p_A^M-c_j) - \frac{1-\alpha}{2}(1-p_A^M)(p_A^M-c_j)} \tag{5.10}$$

where c_j is zero for A and c for B. Since A has zero cost $p_A^M = \frac{1}{2}$ and (5.10) reduces to

$$\rho_i = \frac{2(1+\alpha)}{\alpha}\frac{(1-p^*)(p^*-c_j)}{1-2c_j} - \frac{1-\alpha}{2\alpha} \tag{5.11}$$

Now consider a case where firm j sets a price p which is lower than p_A^M. At p firm j succeeds with probability $\tilde{F}_i(p)$ and fails with probability $1-\tilde{F}_i(p)$. Hence, in equilibrium $\tilde{F}_j(p)$ must be chosen such that

$$\pi_j^s(p^*) = (1-\tilde{F}_i(p))\pi_j^s(p) + \tilde{F}_j(p)\pi_j^f(p) \text{ for all } p \in [p^*, p_A^M[\tag{5.12}$$

To find an expression for $\tilde{F}_i(p)$ we rearrange (5.12) to get

$$\tilde{F}_i(p) = \frac{\pi_j^s(p) - \pi_j^s(p^*)}{\pi_j^s(p) - \pi_j^f(p)} \tag{5.13}$$

Inserting the profits this yields

$$\tilde{F}_i(p) = \frac{\frac{1+\alpha}{2}((1-p)(p-c_j) - (1-p^*)(p^*-c_j))}{\frac{1+\alpha}{2}(1-p)(p-c_j) - \frac{1-\alpha}{2}(1-p)(p-c_j)} \tag{5.14}$$

which can be reduced to

$$\tilde{F}_i(p) = \frac{1+\alpha}{2}\left(1 - \frac{(1-p^*)(p^*-c_j)}{(1-p)(p-c_j)}\right) \tag{5.15}$$

Proposition 2 *There exists an equilibrium where firms set their monopoly price with probability* $0 < \rho_i < 1$ *and otherwise set prices according to* $\tilde{F}_i(p)$ *in the interval* $p \in [p^*; p_A^M[$, $i = A, B$, *such that*

$$\begin{aligned} \rho_i &= \frac{2(1+\alpha)}{\alpha}\frac{(1-p^*)(p^*-c_j)}{1-2c_j} - \frac{1-\alpha}{2\alpha} \\ \tilde{F}_i(p) &= \frac{1+\alpha}{2}\left(1 - \frac{(1-p^*)(p^*-c_j)}{(1-p)(p-c_j)}\right) \end{aligned}$$

Proof: The argumentation above proves the proposition.■

Before we turn to a thorough description of the equilibrium we must check whether $F_i(p)$ is a legitimate cumulative distribution function. First, $\tilde{F}_i(p)$ has to be increasing in p.

From Proposition 2 we see that p only enters the denominator in the second term of $\tilde{F}_i(p)$. Since the denominator is identical to the monopolist's problem, it is increasing in p for $c < p < \frac{1+c_j}{2}$. Thus, $\tilde{F}_i(p)$ increases in p. Second, the total probability has to sum to one. This is true if $\tilde{F}_i(p^*) = 0$ and $1 - \tilde{F}_i(p_A^M) = \rho_i$.

$$\tilde{F}_i(p^*) = \frac{1+\alpha}{2\alpha}\left(1 - \frac{(1-p^*)(p^*-c_j)}{(1-p^*)(p^*-c_j)}\right) = 0$$

and from (5.13) we have

$$\begin{aligned}
1 - \tilde{F}_i(p_A^M) &= 1 - \frac{\pi_j^s(p_A^M) - \pi_j^s(p^*)}{\pi_j^s(p_A^M) - \pi_j^f(p_A^M)} \\
&= \frac{\pi_j^s(p_A^M) - \pi_j^s(p^*) - \pi_j^s(p_A^M) + \pi_j^f(p_j^M)}{\pi_j^s(p_A^M) - \pi_j^f(p_A^M)} \\
&= \frac{\pi_j^s(p^*) - \pi_j^f(p_A^M)}{\pi_j^s(p_A^M) - \pi_j^f(p_A^M)} = \rho_i
\end{aligned}$$

Hence, $F_i(p)$ fulfils the usual requirements of a cumulative distribution function.

Equilibrium characteristics

Having derived the mixed strategy equilibrium we will now investigate its characteristics. Since firms either set their monopoly price or randomize in a lower price interval, one way to interpret the equilibrium described in proposition 2 is that, when costs are asymmetric, firms use a strategy similar to Varian's, with probability $1 - \rho_i$ and set the monopoly price otherwise. The equilibrium behavior of firms is somewhat similar to Baye & Morgan (2001) where firms with positive probability advertise low prices in an information clearing house and otherwise set the monopoly price. While their result stems from a positive advertising fee, our result is due to differences in costs, see section 3.2.2. A closer look at $\tilde{F}_i(p)$ and ρ_i may shed some light over how asymmetric costs affect price competition in this model.

The Randomizing Interval

With probability $1 - \rho_i$ firm i does not set the monopoly price. When this happens both firms randomly choose a price according to $\tilde{F}_i(p)$.

Proposition 3 *There are no point masses in the interval* $[p^*, p_A^M[$

Proof: Suppose firm i sets a price, $p_i \in [p^*, p_A^M[$, with positive probability and firm j plays according to some arbitrary strategy. In this case firm j can set $p_j = p_i - \epsilon$ with positive probability and increase profits. In mathematical terms, no point masses correspond to $\tilde{F}_i(p)$ being continuous in the interval $[p^*, p_A^M[$. Since $\frac{1}{2} > p > c > 0$ it is easily seen from Proposition 2 that this is indeed the case. ■

Hence, similar to Varian (1980), no prices are set with positive probability in this interval. Both firms' cumulative distribution functions are illustrated in figure 5.2.[2] For later reference we calculate the density function that corresponds to the cumulative distribution functions, $\tilde{F}_i(p)$. The density function is found by differentiating $\tilde{F}_i(p)$:

$$\tilde{f}_i(p) = \frac{1+\alpha}{2\alpha}\frac{-(1-p^*)p^*(-(p-c_j)+(1-p))}{((1-p)(p-c_j)^2} \tag{5.16}$$

$$= \frac{1+\alpha}{2\alpha}\frac{(1-p^*)(p^*-c_j)(1+c_j-2p)}{((1-p)(p-c_j)^2} \tag{5.17}$$

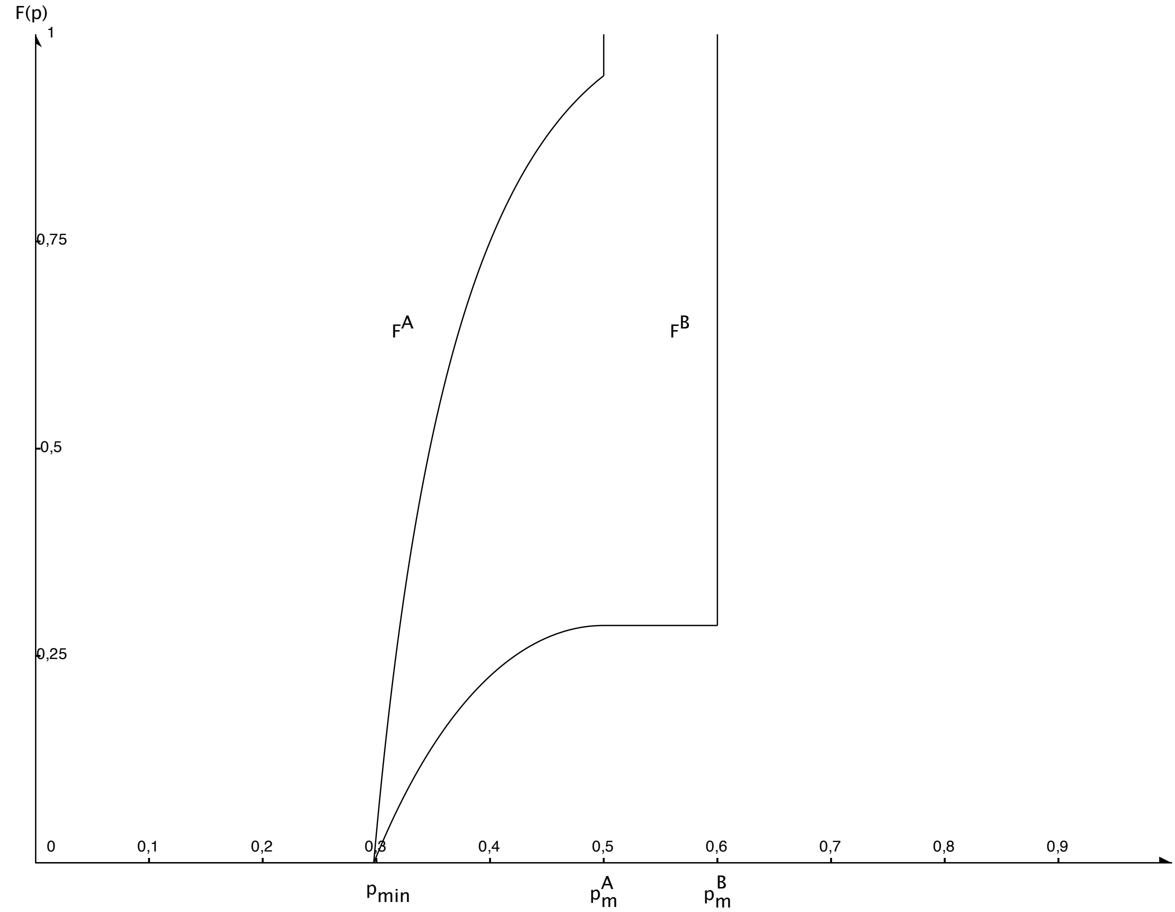
Since the numerator of (5.17) decreases along with p and the denominator increases along with p, the density function is downward sloping. Hence, when firms do not set the monopoly price they set lower prices with higher probability. The intuition seems clear; either firms charge the monopoly price to exploit uninformed consumers or they set very low prices to increase the chance of winning the informed consumers.

The Probability that Firms Set their Monopoly Price

When firms have asymmetric costs the monopoly price is set with positive probability in equilibrium. To see this, consider a case where A sets the monopoly price with positive probability. Since monopoly prices differ, B cannot hope to win the informed consumers if he reduces the price marginally. Instead it must undercut A's monopoly price, thereby winning when A sets its monopoly price. But reducing the price significantly is costly, since

[2]Unless otherwise noted, all figures in this chapter are displayed for $\alpha = 0.4$ and $c = 0.2$ if they do not display functions of α and/or c. This is done in order to make figures comparable. Other values yield qualitatively identical figures.

Figure 5.2: Firms' price distribution functions



Note: The price distribution functions are displayed for $\alpha = 0.4$ and $c = 0.2$.

it incurs an infra-marginal loss on the uninformed consumers. Hence, as long as A sets its monopoly price seldom enough to make B indifferent between serving the uninformed consumers at *its* monopoly price and trying to win the informed consumers at a low price, both firms set the monopoly price with positive probability.

In contrast, when firms have identical costs, monopoly prices cannot be set with positive probability. To see this, note that for $c = 0$ the lowest price firms are willing to set reduces to

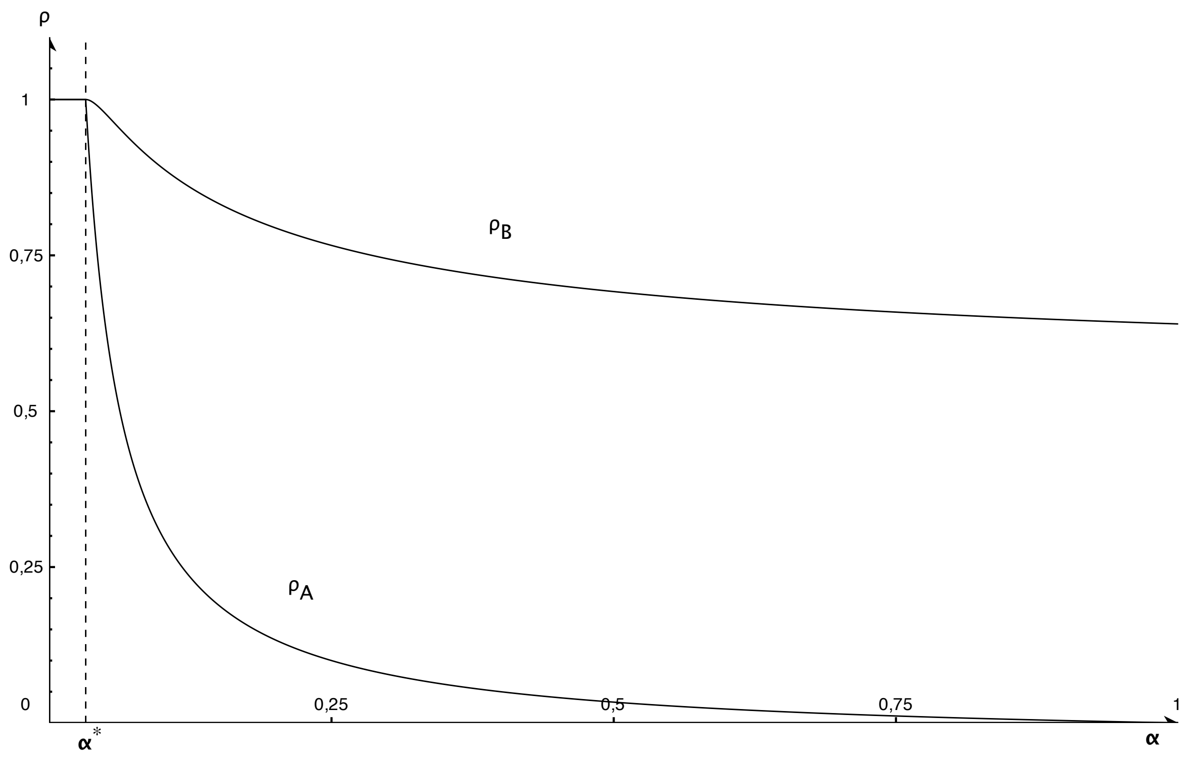
$$p^* = \frac{1 - \sqrt{\frac{2\alpha}{1+\alpha}}}{2} \tag{5.18}$$

Hence, the probability that firms set the monopoly price reduces to

$$\begin{aligned}\rho_i &= \frac{2(1+\alpha)}{\alpha}\frac{1}{4}\left(1+\sqrt{\frac{2\alpha}{1+\alpha}}\right)\left(1-\sqrt{\frac{2\alpha}{1+\alpha}}\right)-\frac{1-\alpha}{2\alpha} \\ &= \frac{1+\alpha}{2\alpha}\left(1-\frac{2\alpha}{1+\alpha}\right)-\frac{1-\alpha}{2\alpha}=\frac{1+\alpha}{2\alpha}\left(\frac{1-\alpha}{1+\alpha}\right)-\frac{1-\alpha}{2\alpha}=0\end{aligned}$$

This shows that when firms have identical costs, the equilibrium in our extension reduces to an equilibrium similar to Varian (1980).[3] The reason is that when there is no cost difference the monopoly prices are coincident. Thus, if a firm sets the monopoly price with positive probability, the opponent can charge a marginally lower price and gain all informed consumers without losing on existing costumers. Figure 5.3 shows the probability

Figure 5.3: Probability of firms setting their monopoly price



Note: The figure displays ρ_i as a function of α when $c = 0,2$.

with which firms set their monopoly prices, i.e. ρ_A and ρ_B, as a function of the share of informed consumers. The figure shows that firm A responds vigorously to the competition from firm B, since ρ_A is heavily declining after the point where α increases above α^*. The figure also indicates that firm B will set its monopoly price often, even for very high shares

[3]The equilibria are not identical since there is still an effect from the downward sloping demand curves in our extension

of informed consumers.

5.2.3 Average prices

To measure how changes in transparency affect competition in this model, we will now analyze how average prices depend on the share of informed consumers. We show that more informed consumers lead to lower prices on average. The average price each firm charges is equal to

$$\bar{p}_i(\alpha) = \int_{p^*}^{p_A^M} p\tilde{f}_i(p)dp + \rho_i p_i^M, i = A, B \tag{5.19}$$

where the first part is the firms' probability weighted average price when they randomize and the second part is the weighted average price when they charge their monopoly price. Integrating by parts yields

$$\bar{p}_i(\alpha) = \left[p\tilde{F}_i(p)\right]_{p^*}^{p_A^M} - \int_{p^*}^{p_A^M} \tilde{F}_i(p)dp + \rho_i p_i^M \tag{5.20}$$

Note that $\left[p\tilde{F}_i(p)\right]_{p^*}^{p_A^M} = \frac{1-\rho_i}{2}$ since $p_A^M = \frac{1}{2}$, $\tilde{F}_i(p^*) = 0$, and $\tilde{F}_i(p_A^M) = 1 - \rho_i$. Hence,

$$\bar{p}_i(\alpha) = \frac{1 + c_i\rho_i}{2} - \int_{p^*}^{\frac{1}{2}} \tilde{F}_i(p)dp \tag{5.21}$$

To find i's average price we insert $\tilde{F}_i(p)$ in (5.21)

$$\begin{aligned}
\bar{p}_i(\alpha) &= \frac{1 + c_i\rho_i}{2} - \int_{p^*}^{\frac{1}{2}} \frac{1+\alpha}{2\alpha}\left(1 - \frac{(1-p^*)(p^*-c_j)}{(1-p)(p-c_j)}\right) dp \\
&= \frac{1 + c_i\rho_i}{2} - \frac{1+\alpha}{2\alpha}\left([p]_{p^*}^{\frac{1}{2}} - (1-p^*)(p^*-c_j)\left[ln\left(\left|\frac{p-1}{p-c_j}\right|\right)\right]_{p^*}^{\frac{1}{2}}\right) \\
&= \frac{1 + c_i\rho_i}{2} - \frac{1+\alpha}{2\alpha}\left(\frac{1}{2} - p^* - (1-p^*)(p^*-c_j)\left(ln\left(\frac{\frac{1}{2}}{\frac{1}{2}-c_j}\right) - ln\left(\frac{1-p^*}{p^*-c_j}\right)\right)\right)
\end{aligned}$$

which can be rearranged to

$$\bar{p}_i(\alpha) = \frac{1 + c_i\rho_i}{2} - \frac{1+\alpha}{2\alpha}\left(\frac{1}{2} - p^* - (1-p^*)(p^*-c_j)ln\left(\frac{p^*-c_j}{2\left(\frac{1}{2}-c_j\right)(1-p^*)}\right)\right) \tag{5.22}$$

Proposition 4 *The high cost firm sets higher prices on average than the low cost firm,* *i.e.* $\bar{p}_B > \bar{p}_A$.

Proof: Refer to (5.21). The first term is definitely larger for B than for A. Hence, it suffices to show that

$$\int_{p^*}^{\frac{1}{2}} \tilde{F}_A(p)dp \geq \int_{p^*}^{\frac{1}{2}} \tilde{F}_B(p)dp \quad \Leftrightarrow$$

$$\tilde{F}_A(p) \geq \tilde{F}_B(p) \quad \Leftrightarrow$$

$$\frac{1+\alpha}{2\alpha}\left(1-\frac{(1-p^*)(p^*-c)}{(1-p)(p-c)}\right) \geq \frac{1+\alpha}{2\alpha}\left(1-\frac{(1-p^*)p^*}{(1-p)p}\right) \quad \Leftrightarrow$$

$$\frac{(1-p^*)p^*}{(1-p)p} \geq \frac{(1-p^*)(p^*-c)}{(1-p)(p-c)} \quad \Leftrightarrow$$

$$p \geq p^* \quad \blacksquare$$

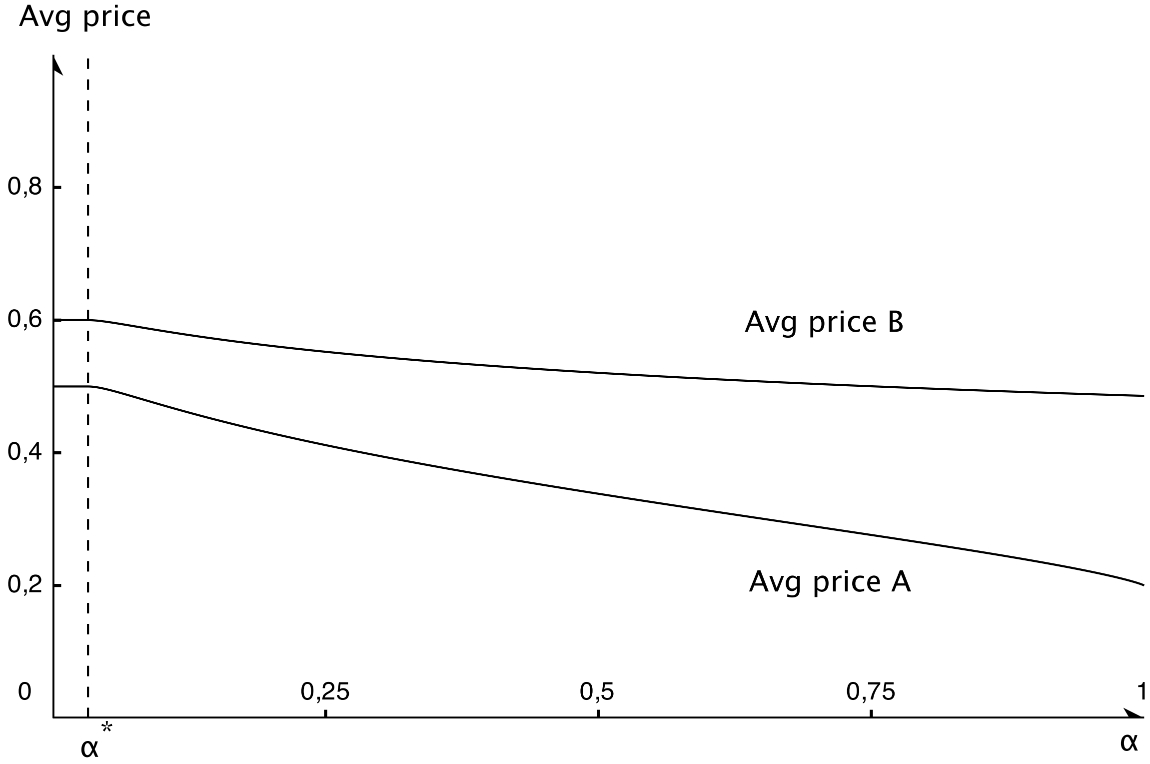
which holds since $p \in [p^*; p_A^M]$.

How average prices are affected by transparency is shown in figure 5.4. As long as α is below α^*, more information has no impact on firms' price setting behavior. When the share of informed consumers rises above α^*, both firms' average prices start to decrease. For firm A the average price continues down to firm B's marginal cost. In contrast, the average price of B is above marginal cost, even when all consumers are informed. This stems from the fact that firm B earns zero profit, and hence is indifferent between setting all prices. Since average prices are drawn for specific cost levels, the figure is not enough to prove a negative relationship between prices and information. The most obvious way to prove this would be to differentiate (5.22) with respect to α. But since p^* and the average price depends of α in quite a complicated way, we are not able to determine the sign of this derivative. The proposition below uses a different approach.

Proposition 5 *More transparency leads to lower average prices, i.e.* $\frac{\partial \bar{p}_i}{\partial \alpha} < 0$.

Proof: Following Corollary 2.3. in Nilsson (1999), it is sufficient to show that $i)$ p^* is

Figure 5.4: Average prices



Note: The figure displays firm's average prices as a function of α when $c = 0.2$

decreasing in α, ii) the density function $\tilde{f}_i(p_i)$ is decreasing in α and finally that iii) the probability, ρ_i, that firm i sets its monopoly price is non-increasing in α.[4]

i) Recall from (5.7) that $p^* = 1 - \frac{1}{2}(1 + \sqrt{\frac{2\alpha}{1+\alpha}})(1 - c)$. Differentiating with respect to α yields

$$\frac{\partial p^*}{\partial \alpha} = -\frac{1}{2}(1-c)\frac{\sqrt{1+\alpha}}{\sqrt{2\alpha}(1+\alpha)^2} < 0 \tag{5.23}$$

ii) Now refer to $\tilde{f}_i(p)$. Differentiating with respect to α equals

$$\begin{aligned}
\frac{\partial \tilde{f}_i(p)}{\partial \alpha} &= \frac{1+c_j-2p}{2((1-p)(p-c))^2}\left[\left(\frac{2\alpha - 2(1+\alpha)}{(2\alpha)^2}\right)(1-p^*)(p^*-c_j)\right. \\
&\quad \left. + \frac{1+\alpha}{2\alpha}\left(-2p^*\frac{\partial p^*}{\partial \alpha} + (1+c_j)\frac{\partial p^*}{\partial \alpha}\right)\right] \\
&= \underbrace{\frac{1+c_j-2p}{2((1-p)(p-c_j)^2}}_{>0}\left(\underbrace{\frac{-1}{4\alpha^2}(1-p^*)(p^*-c_j)}_{<0} + \underbrace{(1+c_j-2p^*)\frac{\partial p^*}{\partial \alpha}}_{<0}\right) < 0
\end{aligned}$$

iii) To show that ρ_i is decreasing in α requires more effort. This is done in appendix A

[4]Since $\rho_i = 0$ in Nilsson (1999), he does not consider iii).

where we find that $\frac{\partial \rho_i}{\partial \alpha} < 0$ for $i = A, B$. This proves the proposition. ■

Increases in transparency will unambiguously make competition tougher and will lower the average prices of both firms. This result is consistent with most of the static games considering transparency and competition. The intuition is that when more consumers are informed, firms are more willing to risk setting a low price since the profit when succeeding is higher and the gain from serving the uninformed is lower.

5.2.4 The value of information

Similar to the Varian (1980) our extension takes the share of informed and uninformed consumers as exogenously given. However, as described in Burdett & Judd (1983) and related literature, consumers are usually able to search to become informed, see chapter 3. An indication of the scope for search can be found by comparing the average price paid by informed and uninformed consumers.

As an uninformed consumer buys at a random firm, his expected price will be the average of firm A and B's prices.

$$\bar{p}_U(\alpha) = \frac{1}{2}\bar{p}_B + \frac{1}{2}\bar{p}_A \tag{5.24}$$

Note that this calculation is only valid for consumers with a reservation price above p_B^M: Uninformed consumers with low reservation values turn down price offers above their reservation value, and hence their actual average price is lower than (5.24) suggests. Hence, the calculated average prices only apply to consumers with reservation values above p_B^M.

The informed consumer buys at the store with the cheaper price. His expected price can be calculated as

$$\bar{p}_I(\alpha) = E(min(p_A, p_B)) = \int_{p^*}^{p_A^M} \int_{p_A}^{p_A^M} min(p_A, p_B)\tilde{f}(p_A, p_B)dp_A dp_B + \rho_A \rho_B p_A^M \tag{5.25}$$

where p_A is the price firm A charges and p_B is the price firm B charges.[5] The last part is the probability that both firms set their monopoly price where the informed consumers

[5] The expected value of a function of (X, Y) can be calculated as $E[g(X,Y)] = \int\int g(x,y)f(x,y)dxdy$. See Berry & Lindgren (1990), Chapter 5.6 for a more thorough explanation.

will buy at p_A^M, as firms set prices independently, $\tilde{f}(p_A, p_B) = \tilde{f}_A(p_A)\tilde{f}_B(p_B)$. Moreover, the minimum function allows us to split the integral into two parts. One where $p_A < p_B$ and one where $p_B < p_A$. Hence, (5.26) can be written as

$$\bar{p}_I(\alpha) = \underbrace{\int_{p^*}^{p_A^M}\int_{p_A}^{p_A^M} p_A \tilde{f}_A(p_A)\tilde{f}_B(p_B)dp_A dp_B}_{p_A<p_B} + \underbrace{\int_{p^*}^{p_A^M}\int_{p_B}^{p_A^M} p_B \tilde{f}_A(p_A)\tilde{f}_B(p_B)dp_A dp_B}_{p_B<p_A} + \rho_A\rho_B p_A^M \tag{5.26}$$

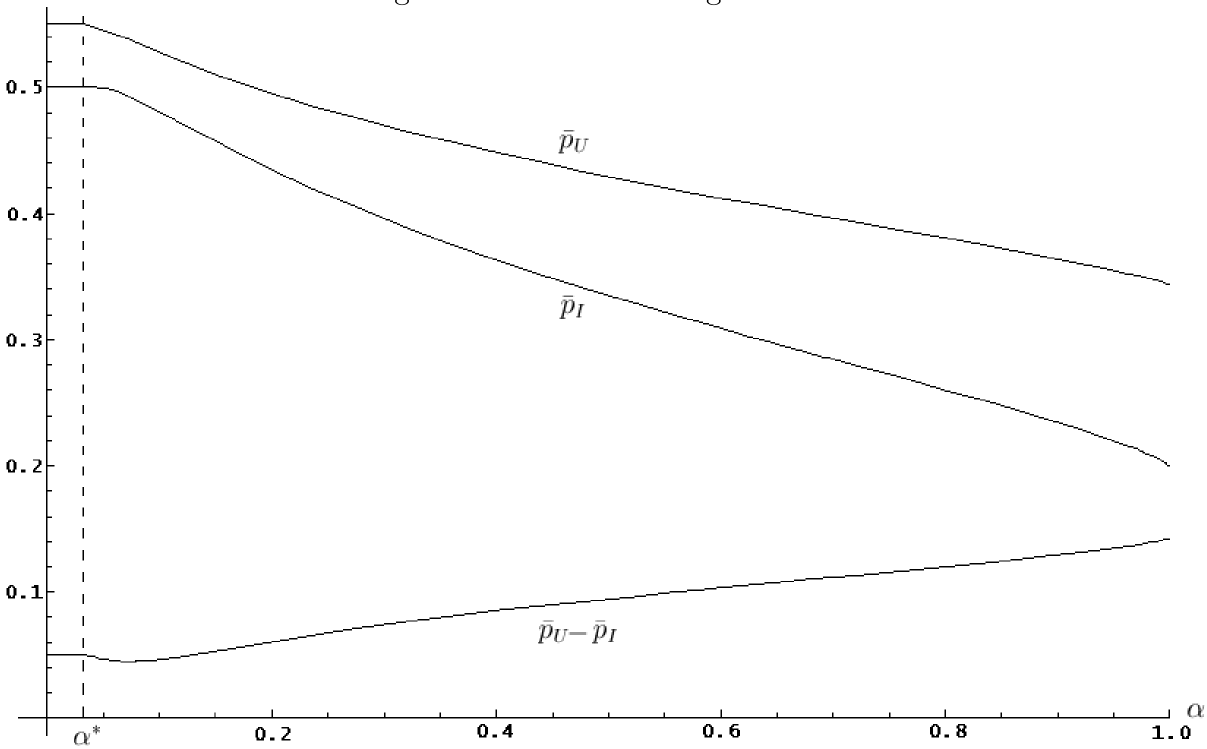
Unfortunately we have not been able to solve (5.26) explicitly. Instead we have calculated $\bar{p}_U$ and $\bar{p}_I$ numerically in Matematica to illustrate the value of being informed as a function of α. For $c = 0.2$ the result is shown in figure 5.5. For sufficiently large α the value of being informed increases with the share of informed consumers, since transparency reduces A's average price more than it reduces the average price of firm B. However, the value of becoming informed does contain an interesting feature as it is increasing for α's slightly above α^*. The intuition is clear. When B starts to randomize $\bar{p}_B$ reduces significantly since prices between p_A^M and p_B^M are never set. In contrast, $\bar{p}_A$ does only decrease marginally since p^* is very close to p_A^m. Since informed consumers almost always buy from A, when α is close to α^*, changes in B's average price have little impact on $\bar{p}_I(\alpha)$. In contrast, uninformed consumers buy from B half of the time and changes in B's average price have greater impact on $\bar{p}_U(\alpha)$. This means that the value of being informed decrease for α close to α^*.

5.2.5 Profits

In Varian (1980) firms are identical and more transparency hurts profit, as firms are forced to lower their prices. In our extension, however, firm A has lower costs and more informed consumers, enabling it to utilize this advantage.

As described in section 5.2.1 and 5.2.2, firms' expected profits as a function of α can be

Figure 5.5: Value of being informed



Note: The figure displays the average price payed by uninformed consumers, $\bar{p}_U$, informed consumers, $\bar{p}_I$ and the value of being informed, i.e. $\bar{p}_I - \bar{p}_U$. The functions are displayed for $c = 0.2$.

described by

$$\pi_A = \begin{cases} \pi_A^s(p_A^M) & = & \frac{1+\alpha}{8} & \text{if } \alpha < \alpha^* \\ \pi_A^s(p^*) & = & \frac{1+\alpha}{2}(1-p^*(\alpha))p^*(\alpha) & \text{if } \alpha > \alpha^* \end{cases} \tag{5.27}$$

and from (5.6) we have

$$\pi_B = \pi_B^s(p^*) = \pi_B^f(p_B^M) = \frac{1-\alpha}{8}(1-c)^2 \tag{5.28}$$

Proposition 6 *Firm B's profit is decreasing in the share of informed consumers.*

Proof: This follows directly from (5.28). ■

How the profit of firm A responds to more informed consumers is less clear-cut. For small shares of informed consumers, i.e. $\alpha < \alpha^*$, an increase in α leads to an increase in profits, since firm A serves a larger share of the market. We call this the demand effect. When α increases above α^* a price effect comes into play. Firm B is now willing to undercut

A, who must lower its prices. Thus, when firms randomize, a higher α implies that firm A on average sells to more consumers but at a lower price. Differentiating $\pi_A^s(p^*)$ with respect to α gives the following expression

$$\frac{\partial \pi_A^s(p^*)}{\partial \alpha} = \underbrace{\frac{1}{2}(1-p^*)p^*}_{\text{Demand effect}>0} + \underbrace{\frac{1+\alpha}{2}(1-2p^*)\frac{\partial p^*}{\partial \alpha}}_{\text{Price effect}<0} \tag{5.29}$$

Define α^{**} as the α which maximizes A's expected profit, i.e. where $\frac{\partial p^*}{\partial \alpha} = 0$. It is not possible to solve (5.29) to find α^{**} explicitly, however the solution has the following characteristics:

Proposition 7 *The share of informed consumers that maximizes firm A's profit, α^{**}, is always larger than α^*.*

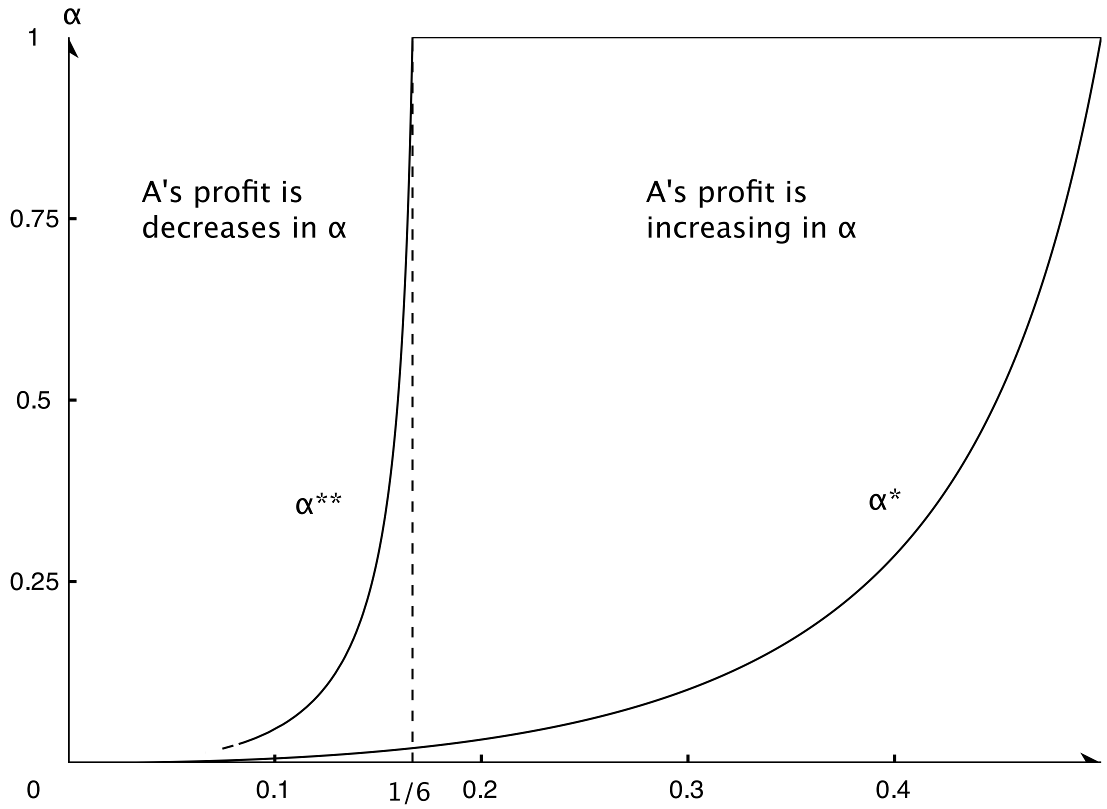
Proof: At $\alpha = \alpha^*$ we know that $p^* = p_A^M = \frac{1}{2}$ since this is where B is indifferent between setting p_B^M and p_A^M per definition. From (5.29) we see that the price effect is close to zero, and the demand effect is strictly positive when p^* is close to $\frac{1}{2}$. Hence, the positive demand effect dominates the negative price effect when α is not too large. Thus, $\frac{\partial \pi_A^s(p^*)}{\partial \alpha} > 0$ for α slightly above α^*. This concludes the proposition. ■

Figure 5.6 shows α^{**} as a function of c. α^{**} is an interior solution when $c < \frac{1}{6}$, implying that A is interested in some — but not full — transparency.[6] The reason is that when c is low, the competition from B becomes fierce at relatively low α's, so that the negative price effect dominates the positive demand effect for firm A. When $c > \frac{1}{6}$ full transparency is optimal for A — i.e. $\alpha^{**} = 1$ — since more informed consumers enable A to make use of its large competitive advantage.

This analysis suggests that if firms are able to affect the level of transparency, it is to be expected that low cost firms are willing to contribute to increasing transparency, whereas high cost firms supposedly are more reluctant to inform consumers. This is relevant when considering internet price portals such as www.pengepriser.dk. Here we would expect low cost internet banks such as Basis Bank and Skandia Banken to be supporting the

[6] $c < \frac{1}{6}$ is found by solving $\frac{\partial \pi_A^s(p^*)}{\partial \alpha} = 0$ when $\alpha = 1$. Recall that $p^* = c$ for $\alpha = 1$. Hence, $\frac{\partial \pi_A^s(p^*)}{\partial \alpha} = \frac{1}{2}(1-c)c + (1-2c)(-\frac{1}{2})(1-c)\frac{1}{4} = 0 \Leftrightarrow c = \frac{1}{6}$.

Figure 5.6: The share of informed consumers which maximizes firm A's profit



Note: The figure displays α^{**} as a function of c. α^{**} is the share of informed consumers which maximizes firm A's profit. For $\alpha < \alpha^{**}$ Firm A's profit is increasing in the share of informed consumers. For $c > \frac{1}{6}$ Firm A prefers full transparency in order to fully utilize its cost advantage. As α^{**} is always above α^{*}, firm A's profit is always increasing when α is close to α^{*}

portal. In contrast, traditional banks with branches such as Nordea and Danske Bank, have higher costs and are probably less interested in a price portal.

5.3 Collusion

In this section we analyze how differences in costs affect firms' ability to collude in a market with imperfect transparency.

5.3.1 The collusive price

If firms have the same costs it is natural to assume that they collude on the monopoly price, since this is identical for all firms. In contrast, when asymmetric costs are introduced there is no longer a focal price on which to coordinate. Also, in a more comprehensive search model, it is likely that firms collude on different prices. The essence of such an agreement is that the low cost firm is less tempted to deviate, since it serves the informed consumers, and the high cost firm is willing to accept this as long as the price spread is sufficiently narrow to not induce too much search. We will not investigate this further, but will continue by assuming that firms collude by setting the same price, p^c. Moreover, we will only consider cases where firms collude by using trigger strategies. Naturally, we will focus on cases where $\alpha > \alpha^*$, since firms would have no incentives to collude otherwise.

In a collusive period each firm serves half of the entire market such that

$$\pi_i^C = \frac{1}{2}(1 - p^c)(p^c - c_i) \tag{5.30}$$

For both firms the optimal deviation is to set a price marginally lower than p^c. Here we ignore cases where $p^c > \frac{1}{2}$. Below it will become apparent that these are not relevant. Hence, when deviating firm i reaps

$$\pi_i^D = \frac{1+\alpha}{2}(1 - p^c)(p^c - c_i). \tag{5.31}$$

In the punishment phase firms randomize according to proposition 2. Here A and B earn

$$\pi_i^P = \frac{1+\alpha}{2}(1 - p^*)(p^* - c_i) \tag{5.32}$$

Note that we assume that the share of informed consumers α is identical in all phases of competition. This is a natural starting point when search is not incorporated. However, the assumption may be questionable, since more consumers are likely to search in the punishment phase when prices are more dispersed. By treating α as exogenous, we also avoid the question presented in Nilsson (1999) of how uninformed consumers gain information about shifts from one phase of competition to another. One way to think of this simplification is a market in a holiday resort. Each period a new group of tourists arrives who acts as uninformed consumers while the locals are informed.

Recall from (4.2) on page 48 that the minimal discount factor required to sustain collusion is given by

$$\delta^* = \frac{\pi^D - \pi^C}{\pi^D - \pi^P}$$

Inserting the relevant profits firm i does not wish to deviate if $\delta_i > \delta_i^*$ where

$$\begin{aligned}
\delta_i^* &= \frac{\frac{1+\alpha}{2}(1-p^c)(p^c-c_i) - \frac{1}{2}(1-p^c)(p^c-c_i}{\frac{1+\alpha}{2}(1-p^c)(p^c-c_i) - \frac{1+\alpha}{2}(1-p^*)(p^*-c_i)} \\
&= \frac{\alpha(1-p^c)(p^c-c_i)}{(1+\alpha(1-p^c)(p^c-c_i) - (1-p^*)(p^*-c_i))} \\
&= \frac{\alpha}{(1+\alpha)\left(1-\frac{(1-p^*)(p^*-c_i)}{(1-p^c)(p^c-c_i)}\right)}
\end{aligned} \tag{5.33}$$

Proposition 8 *i) Collusion is easiest to sustain for firm i when $p^c = \frac{1+c_i}{2}$, i.e. δ_i^* is minimized when $p^c = \frac{1+c_i}{2}$. ii) For all choices of p^c, firm A is always more tempted to deviate from collusion than firm B, i.e $\delta_A^*(p^c) > \delta_B^*(p^c)$ for all p^c.*

Proof: *i)* Minimizing $\delta_i^*(p^c)$ with respect to p^c is equivalent to solving the monopolist problem:

$$\arg\max_{p^c}(1-p^c)(p^c-c_i) = \frac{1+c_i}{2} \tag{5.34}$$

ii) Collusion is easier to sustain for B than A if

$$\begin{aligned}
\frac{\alpha}{(1+\alpha)\left(1-\frac{(1-p^*)p^*}{(1-p^c)p^c}\right)} &> \frac{\alpha}{(1+\alpha)\left(1-\frac{(1-p^*)(p^*-c)}{(1-p^c)(p^c-c)}\right)} \Leftrightarrow \\
\frac{(1-p^*)p^*}{(1-p^c)p^c} &> \frac{(1-p^*)(p^*-c)}{(1-p^c)(p^c-c)} \Leftrightarrow \\
p^c &> p^*
\end{aligned}$$

Since the collusive price is always greater than p^* this proves the proposition. ■

The intuition behind proposition 8 seems clear. Since A has the lowest cost, it has the most attractive alternative compared to collusion. Hence, the easiest sustainable agreement is the one most attractive to A. Since A is always more tempted to deviate, we solely focus on δ_A^*. Note, that more sophisticated strategies may make it even easier to sustain collusion. Suppose firm B set a price higher than p_A^M, say, every third period and charge p_A^M otherwise, if A has not triggered the punishment phase. In this case firm A would be less tempted to deviate since it sometimes serve all informed consumers alone, instead of having to split the market with firm B. Another possibility is that firms use optimal punishment as described in section 4.1. However, in the following we will only consider simple trigger strategies.

Usually firms can lower the collusive price if collusion is not sustainable. However, $i)$ proves that in this setup this is not possible. This is in line with the rest of the literature on collusion and consumer side transparency. The intuition is that by lowering the collusive price, firms forgo the inframarginal rent made on uninformed consumers from whom they can always charge their monopoly price. Hence, collusion on a price lower than the monopoly price is always less attractive. We continue this section with $p^c = p_A^M = \frac{1}{2}$.

When $p^c = \frac{1}{2}$ (5.33) reduces to

$$\begin{aligned} \delta_A^* &= \frac{\alpha}{4(1+\alpha)\left(p^* - \frac{1}{2}\right)^2} \\ &= \frac{\alpha}{(1+\alpha)(1-4(1-p^*)p^*)} \\ &= \frac{\alpha}{4(1+\alpha)\left(p^* - \frac{1}{2}\right)^2} \end{aligned} \tag{5.35}$$

Inserting p^* from (5.7), this can be reduced to

$$\begin{aligned} \delta_A^* &= \frac{\alpha}{(1+\alpha)\left(1-(1-c)-(1-c)\sqrt{\frac{2\alpha}{1+\alpha}}\right)^2} \\ &= \frac{1}{\left(c\sqrt{\frac{1+\alpha}{\alpha}}-(1-c)\sqrt{2}\right)^2} \end{aligned} \tag{5.36}$$

From (5.36) it is seen that if $c = 0$ the discount factor required for firms to be able to collude simplifies to one half, as in the benchmark example on page 48.

5.3.2 The effect of increasing transparency

Firms' ability to collude is affected by changes in transparency in two ways: First, more informed consumers make it more tempting to deviate, since the effective elasticity of demand is increased. Second, the punishment phase is intensified since the expected profits in equilibrium are lower in the stage game when there are more informed consumers. In most of the literature considering tacit collusion with imperfectly informed consumers these two countervailing effects result in ambiguous predictions, see chapter 4. We will show that when firms have different costs, more transparency unambiguously makes it easier for firms to collude. To our knowledge this result is new.

Proposition 9 *When firms have different costs, an increase in transparency always makes it easier to sustain collusion. More formally,* $\frac{\partial \delta_A^*}{\partial \alpha} < 0$.

Proof: Differentiating (5.36) with respect to α yields

$$\frac{\partial \delta_A^*}{\partial \alpha} = -2\left(c\sqrt{\frac{1+\alpha}{\alpha}} - (1-c)\sqrt{2}\right)\left(-\frac{c}{2\sqrt{\frac{1+\alpha}{\alpha}}}\left(-\frac{1}{\alpha^2}\right)\right) \quad < \quad 0 \quad \Leftrightarrow$$

which is equivalent to

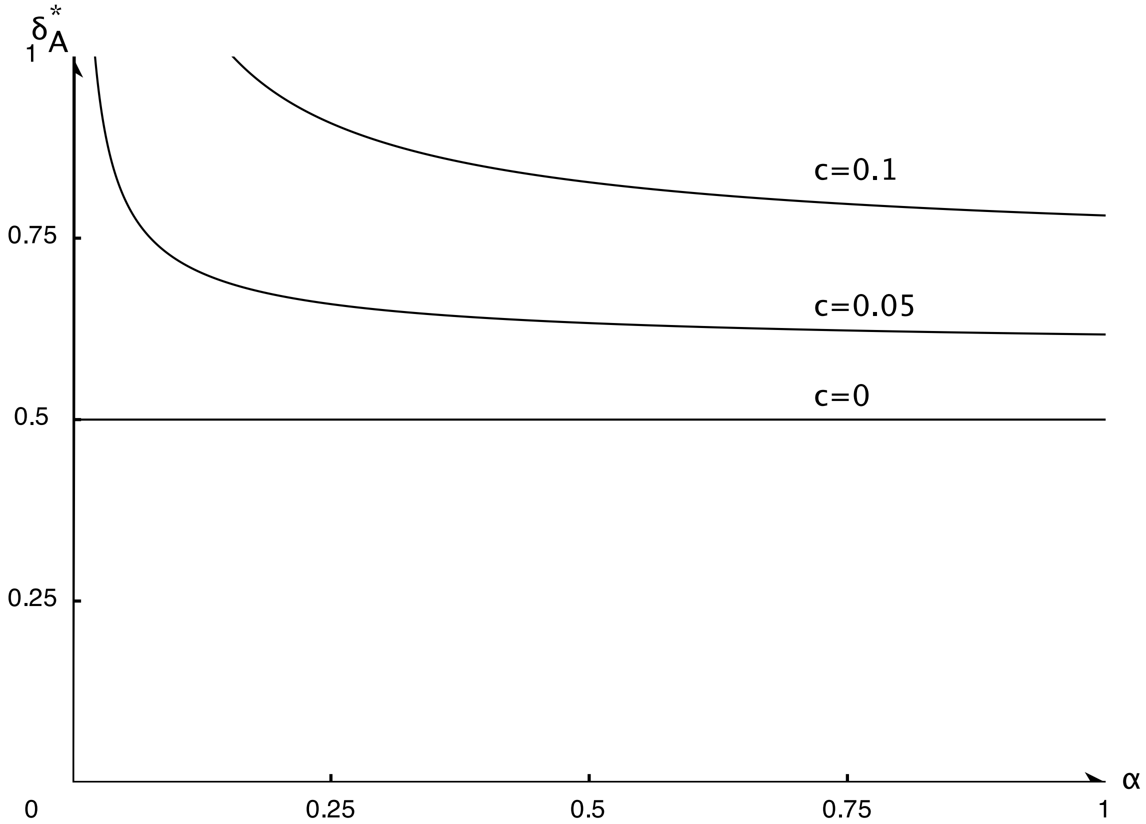
$$\begin{aligned} c\sqrt{\frac{1+\alpha}{\alpha}} - (1-c)\sqrt{2} \quad &> \quad 0 \quad \Leftrightarrow \\ \sqrt{\frac{1+\alpha}{\alpha}} \quad &> \quad \frac{(1-c)\sqrt{2}}{c} \quad \Leftrightarrow \\ \frac{1}{\alpha} \quad &> \quad \frac{2(1-c)^2 - c^2}{c^2} \quad \Leftrightarrow \\ \alpha \quad &> \quad \frac{c^2}{c^2 - 4c + 2} = \alpha^* \end{aligned}$$

Since, $c > 0$ and $\alpha > \alpha^*$ in the relevant interval, this proves the proposition. ■

The reason for this counterintuitive result is that in the presence of cost differences more informed consumers have a greater impact on the profit in the punishment phase than on the temptation to deviate. In figure 5.7 we show δ_A^* as a function of α for different levels of c. As shown in proposition 9, the figure illustrates that collusion is easier for firms to sustain when there are many informed consumers. Moreover, note from the figure that when marginal costs differ, collusion is always more difficult to sustain than in the benchmark case, where $\delta^* = \frac{1}{2}$. The reason is that A's cost advantage makes the punishment phase soft for A, since B is not a very tough competitor.

The presence of asymmetric costs imply that for some combinations of c and α, the punishment phase is more attractive than the collusive phase. Hence, a $\delta_i^* < 1$ does

Figure 5.7: The effect of transparency on firms ability to collude



Note: The figure displays the minimal discount factor required to sustain collusion, δ^*, for different values of c. Only δ_A^* is displayed, as this is always above δ_B^*

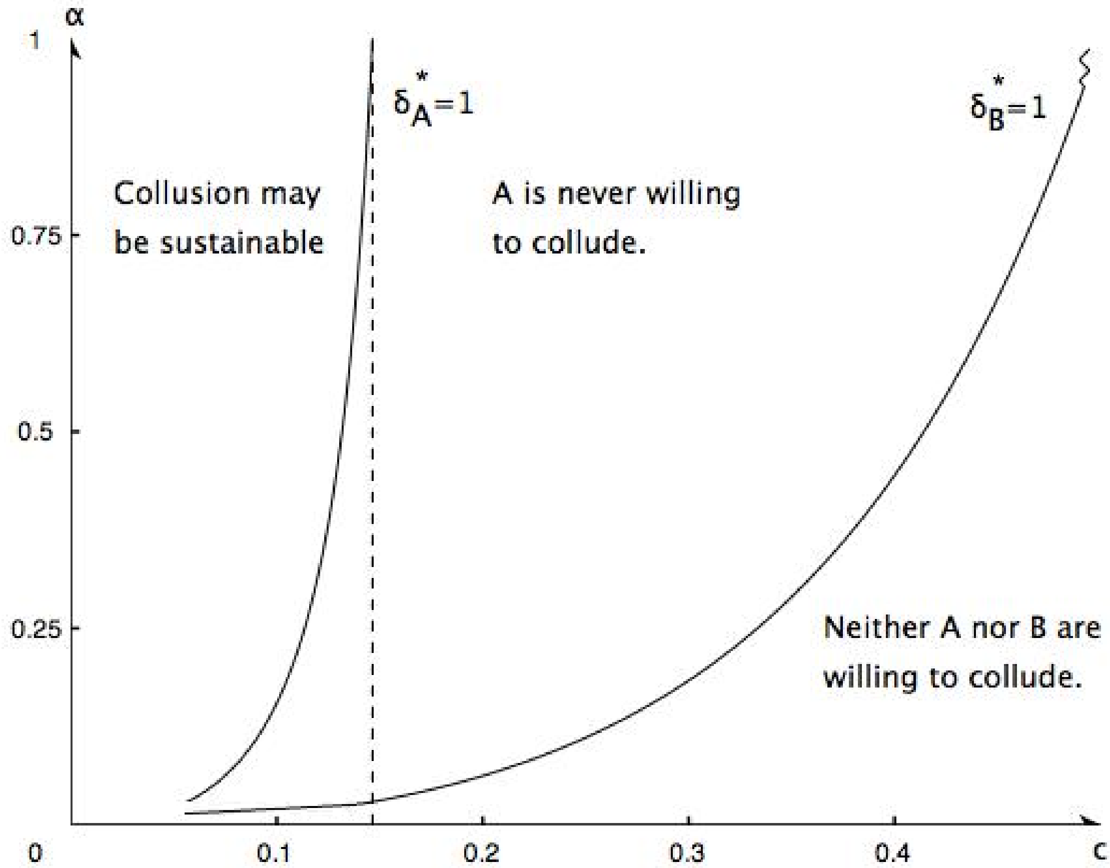
not always exist. Figure 5.8 depicts combinations of α and c for which there exists δ_i's fulfilling $0 < \delta_i < 1$ such that A and B can gain from collusion. The figure shows that there is a potential gain from collusion for both firms, as long as the cost difference is not too large and the share of informed consumers is not too small. Moreover, when $c > c^* = \frac{1}{2} - \frac{1}{2\sqrt{2}} \approx 0.146$ firms are never able to collude.[7]

5.4 Policy Implications

From a policy perspective it is relevant to know when transparency promotes competition. The predictions of this model are illustrated in figure 5.9. When few consumers are informed and firms do not find it worthwhile to compete, a pure strategy equilibrium where firms charge their monopoly price exists. When the level of transparency becomes greater

[7]The maximal cost difference c^* is found by solving $\pi_A^c = \pi_A^p$ for c when $\alpha = 1$. Recall that $p^* = c$ for $\alpha = 1$, such that $\pi_A^p = c(1-c)$, and that $\pi_A^c = \frac{1}{8}$. Hence, there is a potential for collusion when $\frac{1}{8} > c(1-c)$. The relevant solution to this equality is $c^* < \frac{1}{2} - \frac{1}{2\sqrt{2}} \approx 0.146$.

Figure 5.8: Cases where firms may be able to collude



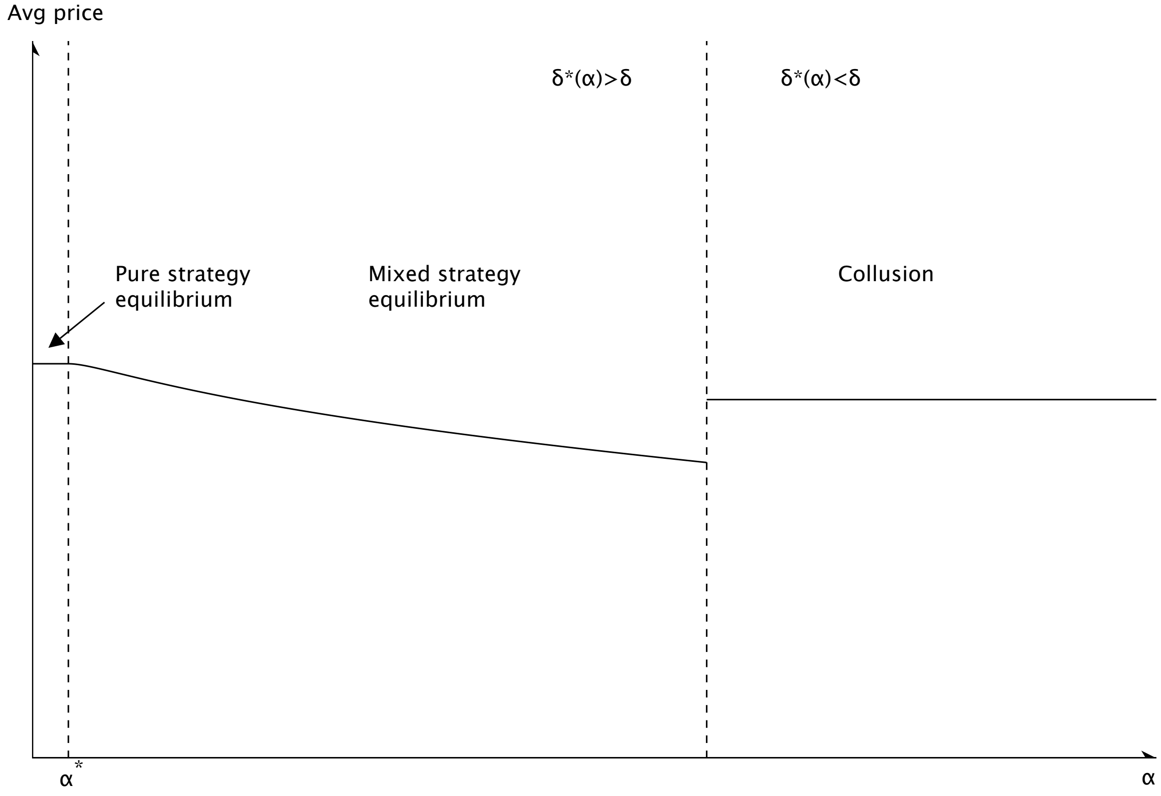
Note: The figure displays combination of α and c where collusion is sustainable if δ_i is sufficiently large. B is willing to collude for lower values of δ relative to A.

than α^*, the pure strategy equilibrium fails to exist and firms begin to randomize, which decreases average prices. However, when the market becomes sufficiently transparent the firms may be able to sustain collusion on A's monopoly price. Hence, the model predicts that an intermediate level of transparency is optimal if firms can possibly collude, and that high levels of transparency are preferred to very low levels. A similar result is found by Møllgaard & Overgaard (2000), who find that intermediate levels of transparency is optimal.

5.4.1 The n-firm market

Our extension to Varian (1980) in chapter 5 considers a duopoly, but the idea could presumably be generalized to a market with n firms. Intuitively we expect our results to be robust to this extension. With e.g. three firms, A, B, and C, with different cost,

Figure 5.9: Medium transparency is optimal



$c_A < c_B < c_C$, it is not difficult to see that the results from the duopoly case persist. When the market is very intransparent each firms sets its monopoly price since competing for the few informed consumers is not worthwhile for the two firms with highest costs. As more consumers become informed, firm B will sooner or later be tempted to undercut firm A. If there are not too many informed consumers, firm C will still charge its monopoly price, and firm A and firm B will end up in a mixed strategy comparable to the one seen in the duopoly case.

As even more consumers are informed it becomes less profitable for firm C to serve his share of the uninformed, and hence firm C is tempted to engage in price competition with A and B. On the other hand more informed consumers intensify competition among A and B and this reduces C's incentives to compete for informed consumers. Which effect dominates is difficult to say a priori.

5.5 Concluding remarks

In this chapter we have extended Varian (1980) to include asymmetric firms. Contrary to Varian's model, a pure strategy equilibrium exists when few consumers are informed, where firms charge their monopoly price and the high cost firm do not find it worthwhile to compete for the informed consumers. Hence, when markets are non-transparent, the model predicts spatial price dispersion, when prices are constant but each firm charges a different price. This is similar to Salop & Stiglitz (1977), see section 2.1. There is, however, one major difference between the two models. In Salop & Stiglitz (1977), some firms charge the competitive price, whereas others set the monopoly price. In the pure strategy equilibrium in our extension, both firms charge their monopoly prices and competition is non-existent.

However, for larger shares of informed consumers, firms end up in a mixed strategy equilibrium where firms sometimes play a strategy similar to the one described in Varian (1980) and set their monopoly price otherwise. In this equilibrium average prices are lower when more consumers are informed. Hence, the one period model supports the traditional view that consumer information is pro-competitive.

If firms are able to affect transparency, our analysis suggests that the high cost firm will seek to hamper initiatives aiming at promoting transparency, whereas the low cost firm's incentives are ambiguous. On one hand, more transparency enables the low cost firm to capitalize on its cost advantage but on the other hand competition from the high cost firm is tougher when there are more informed consumers. The relative extent of these effect depends on the cost difference between the two firms and the share of informed consumers.

If the game is repeated, transparency affects firms' ability to collude in two ways. First, an increase in transparency makes it more attractive for a firm to deviate, since it can reap a larger share of the market. This tends to undermine collusion. Second, since the stage game equilibrium is more competitive, the punishment phase is intensified when prices are more transparent. This tends to facilitate collusion. We show that when firms have asymmetric costs, the latter effect always dominates. Hence, more consumer information increases firms' ability to collude when they have different marginal costs. It should however be underlined that this result may be specific to our assumptions, and may change in a more general setup.

To summarize, our extension to Varian (1980) give us the following new insights:

- If there are not too few informed consumers, firms randomize prices in equilibrium, even when firms have asymmetric costs. Else, they set their monopoly price.
- Increased transparency unambiguously facilitates collusion when firms' marginal cost differ.

Chapter 6

An Illustrative Case

In this chapter we investigate whether the predictions delivered by the literature on competition under imperfect consumer information are supported by data from the Danish gasoline market.

As with all other empirical studies, there are omitted variables in the analysis conducted in this thesis. It is likely that there are factors that distort the results, which we have not been able to account for. Thus, the empirical analysis in this chapter should be taken as an illustrative case rather than an econometric analysis.

The different models analyzing this topic generally agree that the 'law of one price' does not apply in markets where informed and uninformed consumers coexist, and they all predict persistent price dispersion. There is, however, less consensus on how this price dispersion can be characterized. Salop & Stiglitz (1977) predict *spatial* price dispersion where some firms consistently set high prices, while others offer low prices. This view is challenged by Varian (1980) who argues that firms must set unpredictable prices to avoid being systematically exploited by their competitors. Hence firms use unpredictable 'hit and run' sales to attract informed consumers and set high prices to exploit uninformed consumers. Since different firms are cheapest at different times, this is known as *temporal* price dispersion. One way of analyzing which kind of price dispersion prevails is to rank firms by their prices. With spatial price dispersion we would expect the same firm to offer the lowest – or the highest – price over time. On the contrary, temporal price dispersion predicts significant changes in ranking over time. If firms have different costs, our extension to Varian (1980) supports temporal price dispersion, but with low cost firms offering lower prices on average.

Our data from the Danish gasoline market clearly indicates that prices are dispersed, and supports that this dispersion is temporal rather than spatial. But although the identity of the cheapest firm varies greatly over time, unstaffed stations, which presumably have lower costs, are cheaper more often than staffed stations, and their average prices are significantly lower. This is in line with the predictions in our extension, but can also be a result of differences in services.

In order to be able to measure the effect of changes in transparency we need a variable that measures the level of consumer information. The data does not include such a variable. Instead we study a ”natural experiment” in Helsingør where there is an abrupt change in the share of uninformed consumers. We find that during the tourist season – when there are more uninformed consumers – prices are generally higher and less dispersed. One explanation offered by our extension is that firms do not find it worthwhile to compete for the informed consumers but prefer to set a high price to exploit tourists. Another explanation is that firms are able to collude during the summer, since the temptation to deviate is lower. The literature on collusion and consumer side transparency is for the most part ambiguous, but this ”case study” indicates that increased transparency can make it more difficult for firms to sustain collusion. This story, however, is not in line with our prediction concerning collusion, but can be explained by the pure strategy equilibrium of our extension to Varian (1980).

6.1 Existing empirical literature

Before we turn to the Danish gasoline market, we briefly summarize the existing empirical studies on price dispersion.

Baye, Morgan & Scholten (2004*b*) analyze price dispersion in online markets for consumer electronics products sold at Shoppers.com. They find evidence consistent with temporal price dispersion, since there is considerable turnover in the identity of the firm offering the lowest price in the market over time. The explanation offered in this study is that firms either offer a low price to attract 'shoppers' who search intensively on the internet before purchasing a product, or set a high price to exploit 'loyals' who do not use the price listing service or have a strong brand preference for an existing firm. Baye et al. (2004*b*) argue that *strategic unpredictability in prices – through the use of hit and run sales – is a widely used and effective weapon for avoiding all-out price competition in online market.*

Baylis & Perloff (2002) find support for spatial price dispersion in the online market for a specific digital camera and a flatbed scanner. Unlike Baye et al. (2004*b*) they find that low price firms remain low priced and high price firms remain high priced over longer periods of time. This persistent price dispersion could be explained by service premium models where some retailers are able to charge a higher price as they provide a better service. However, Baylis & Perloff (2002) find that high price firms often use consumer unfriendly practices, such as no information about whether products are in stock. Hence, they reject the premium service hypothesis.

6.2 The Danish gasoline market

We focus on the market for 95 octane unleaded gasoline which made up 78 percent of the gasoline market in Denmark in 2005.[1] There are several reasons why the gasoline market is a useful foundation for our purpose. First of all, since gasoline is traded at the New York Mercantile Exchange (NYMEX) and gas stations make prices easily available to consumers and competitors via boards next to the road, it is not unreasonable to assume that gasoline companies have almost complete information about competitors' prices and marginal costs, allowing us to ignore effects caused by increased firm side information. Moreover, gasoline is a very homogeneous good, and so we avoid disturbance from differences in consumers' brand preferences.

Also, it is likely that there are differences in consumer side information. For instance commuters are likely to be better informed about prices, compared to people who use their car less often, since they presumably observe more gasoline prices and also have a larger gain from information as they use more gasoline. Moreover, some motorists obtain discounts through their workplace, which is likely to make them behave as uninformed

[1] Source: www.oil-forum.dk

Table 6.1: Market characteristics

Company	No. of staffed stations	No. of unstaffed stations	Market* share	Share of obs. in data
Shell	227	0	19.5	18.5
Metax	0	70		4.5
Statoil	245	1	16.6	19.7
1-2-3	0	58		0.3
Q8	217	4	13.5	17.7
F24	0	23		2.8
Hydro Texaco	147	0	17.1	10.2
Uno X	0	223		5.8
DK-Benzin	147	23	26.1	4.4
OK	0	556		9.2
Jet	0	69	7.2	6.7
Other	1	23	0	0.2
Total	984	1050	100.0	100.0

Source: www.oil-forum.dk

* In recent years traditional companies have either opened or acquired a discount company. We have only been able to find market shares on group level. Therefore, combined market shares are reported for Shell & Metax, Statoil & 1-2-3, Q8 & F24, Hydro Texaco & Uno X, and DK-Benzin & OK

consumers, as they tend to refuel at the same company regardless of the price.[2] Finally it should be noted that although gas stations announce prices and search costs may seem low, some consumers may not find it worth the effort to turn around the car and go back to a cheaper station spotted earlier, while others are less reluctant to do so.

In general the gasoline market in Denmark consists of two different types of companies; the *traditional companies* which are typically combined with a staffed shop, and the *discount companies* which are unstaffed. In recent years all the traditional companies have either opened or acquired a discount company, and today the market is dominated by 6 large players, of which only JET is a pure discount company (see Table 6.2). Since 1997 the share of unstaffed stations has risen from less than 30 percent to more than 50 percent while the total number of gas stations has decreased by approximately 20 percent.

All companies operate with a national list price which is the company's official price. In 2000 the Danish Competition Authorities (DCA) published the report "Analyse af danske benzin- og oliepriser".[3]. DCA noted that with the exception of a few local price wars, the prices at gas stations in Denmark typically reflected the list prices of the companies.

[2]In the theoretical models this could be incorporated by allowing the share of informed consumers to be divided unevenly between firms.

[3]Analysis of Danish gasoline and oil prices.

One way to understand this behavior is to perceive the list price as a reference price on which local gas stations collude if possible.[4] When collusion is not possible, the local managers undercut prices and price wars are observed. Consequently, we should expect that stations often set the list price in markets where there is a high degree of collusion. We use this idea to validate the identification of competitive markets in section 6.3.4.

Konkurrencestyrelsen (2000) also found that most gasoline in Denmark was sold with some kind of discount on the list price. Discounts were typically used by the traditional companies, while the discount companies typically had a lower list price.[5] Since then, things have changed dramatically, and today only Statoil offers discounts to ordinary consumers.[6] Still, we observe persistent differences in the list prices, with the list price of the traditional companies being about 7 øre higher than discount companies' on average. One explanation of this price difference is that staffed and unstaffed stations do not sell exactly the same good. For instance, when buying gasoline from a staffed station consumers also buy the possibility to shop basic groceries, inflate their tires etc. We will keep this in mind when we analyze the data.

6.3 Data

We have assembled a data set with information on gasoline prices in the period January 1st 2005 to April 30th 2006.[7] The data set includes price observations from most local gas stations in Northern Zealand as well as the national gasoline companies' list prices. Moreover, it contains an estimate of firms' gasoline cost prices based on the NYMEX closure spot price on regular gasoline for delivery in Rotterdam.

[4]This assumption is not unrealistic although we observe differences in list prices. First, the gasoline companies may collude on the 'service effective' price, i.e. the price where consumers are indifferent between buying at a low price or buying at a high price with more service. Second, firms may collude on a price which does not induce consumer search as noted in section 5.3.

[5]According to DCA up to 80 percent of gasoline from companies giving rebates were sold with some form of rebate. Together, these companies had a market share of 83 percent.

[6]Statoil's rebate is 7 øre per liter and includes a monthly service charge of 5.50 DKK. In addition to this many oil companies, including Statoil, offer rebates to consumers via firm deals, where a firm's employees are offered a special rebate. A manager of a Statoil station at Frederiksberg guessed that approximately 20 percent of the gasoline was sold with some kind of rebate. We have not been able to find recent data to support this guess. However, we feel confident that the share of people using rebate cards is significantly lower today than in 2000.

[7]The data process is carried out using Stata/SE 8.0 for Windows. The 26 pages of code written for this thesis is available from the authors upon request.

This following sub sections describe the data set in more details. We first describe the construction of the data set. Then, we discuss the data quality and describes the characteristics of the data. Finally, we categorize the local markets according to the degree of competition.

6.3.1 Sources

The analysis in this chapter is based on three main data sets; the list price, the local price, and the cost price data set.[8] The list- and local price data are collected from the Federation of Danish Motorists (FDM), while the closure spot prices from NYMEX were gathered by the U.S. Energy Information Administration (EIA).

The local price data set (FDM) FDM runs the price portal www.benzinpriser.dk (gasolineprices.dk). They collect information about list prices from the gasoline companies' homepages while local prices are reported by the price portal's users via a cell phone or the internet. Both consumers registered at Benzinpriser.dk and unregistered consumers can report prices. Historical data is not available for downloading at the price portal, but after contacting FDM they generously allocated resources to extract the data used in this thesis.

The local price data set from Benzinpriser.dk contains 11,299 observations of prices from 123 different gas stations from 13 gasoline companies. There are no obvious extreme observations, as all observations are within a reasonable price range. The lowest price observed is DKK 6.54 and the highest price is DKK 11.27.

The list price data set (FDM) The list price data set contains 5,513 observations over 320 days. As list prices are collected manually by FDM, there is no price information for Saturdays and Sundays. The data covers 12 gasoline companies. We have left out 118 of the observations as they are identical[9] with other observations. Moreover, three of the companies report list prices for both staffed and unstaffed stations; Q8, Statoil and DK

[8] Hereinafter, we will use the term 'local price' for prices from local gas stations, while the term 'list price' refers to the gasoline companies' list price.

[9] That is, same date, time, company, and price.

Benzin. As seen in Table 6.2 these companies only have staffed stations and we therefore assume that stations from these companies are all staffed. This reduces the data set by 1,051 observations of list prices for unstaffed stations from these companies. This leaves us with 4,344 list price observations.

The cost price data set (EIA) The EIA supplies historical data on the NYMEX closure spot price of conventional, regular gasoline for delivery in any port city along the refining centers of Amsterdam-Rotterdam-Antwerp. The data is readily available for downloading from their homepage www.eia.doe.gov.

The cost price data set was estimated using the 366 spot price observations from NYMEX. Naturally, we do not have cost price estimates from weekends and holidays. The Danish central bank only provides currency exchange rates for 359 of these days, and thus 7 observations are dropped. Gasoline in Denmark is taxed with a DKK 0.22 CO_2 tax and a DKK 3.81 energy tax totalling DKK 4.03 per liter plus a 25 percent VAT.[10] Hence, we estimate the companies' cost prices as

$$\textit{cost price} = (\textit{spot price} + 4.03\ DKK) \cdot 1.25$$

Merging the data sets The three data sets are merged, so that if possible we have a list price and a cost price for each local observation. We assume that when a local price is reported, the list price at that moment is the latest observed list price, given that it has been observed within the past day.

Since we do not have list prices nor the NYMEX spot prices on weekends, we have left out 2.782 local price observations from Saturdays, and Sundays leaving us with 8,517 observations of local prices from 34 postal code areas, with 123 different gas stations from 13 gasoline companies. We have left out 880 observations for which we do not have both the local price, list price and cost price. 831 of these observations were deleted because we do not have the list price, while 49 were left out due to missing information about cost price. In order to reduce the influence of erroneous observations on the results, we only include cities where at least 100 local prices have been reported. This reduces the data

[10]Source: www.oil-forum.dk

set by 402 observations. The final data set thus contains 7,235 observations, covering 17 cities, with 79 different gas stations from 10 different oil companies.

One obstacle when comparing theory with the data is that prices fluctuate simply due to changes in oil prices. In order to be able to compare prices collected on different days, we clean prices for these fluctuations by subtracting the cost price from the local price in order to obtain a net price.[11] The net price is estimated as

$$\textit{net price} = \textit{local price} - \textit{cost price}$$

6.3.2 Data quality

The local price data set: Benzinpriser.dk's registered users earn points which are used to rank them on a ninelevel list ranging from *Prisindberetter* (Price reporter) to *Guld prispilot* (Gold price pilot), offering them a non-monetary incentive to report prices.[12] Had the homepage offered a prize incentive scheme, it is likely that consumers would have reported more price observations. However, a monetary incentive scheme also increases consumers' incentive to report random prices, i.e. prices they have not actually observed, in order to earn points and win prizes. In the lack of monetary incentives at Benzinpriser.dk, we assume that the prices reported by motorists are trustworthy. Table 6.2 indicates that our sample is representative as the share of observations in our data set reflects the companies market share satisfactorily. Still, there are a few caveats to note.

First, we have heard of one incidence where a station manager reported a faulty low price in order to attract customers.[13] Whether this mendacious behavior is widespread is difficult to say. Investigating the data, we found that prices below the estimated cost price were observed significantly more often for a few stations, with the most conspicuous having 12.2 percent of 82 observations below cost price, compared to a data average of 1.3 percent. We note this potential problem, but since it only concerns a few stations we do not investigate this further. Second, it is possible that consumers may be more

[11] The analyses in this chapter have also been carried out using an estimated mark up defined as $\frac{\textit{local price} - \textit{cost price}}{\textit{cost price}}$ rather than estimated net prices. This yielded similar results. However, as may be seen from Figure 6.2, net prices are more stable, and thus we choose this estimate for our main analysis.

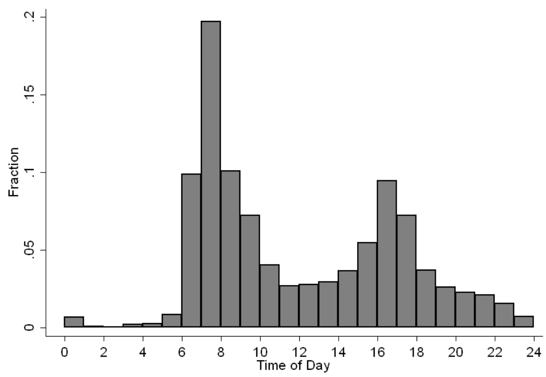
[12] GasBuddy.com (a similar price portal in the U.S.) offers its users lottery tickets for frequent reporting.

[13] The above-mentioned station is not in our data set.

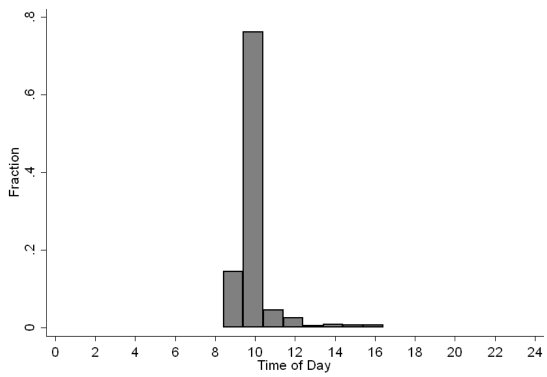
likely to report prices they find useful to others, e.g. prices that are very low or very high compared to the average price in the market. In this case, our data would be biased towards dispersed prices.

The list price data set: As seen in Figure 6.3.2 FDM usually collects list prices in the morning, while local price observations are spread out over the day with the most being reported during the rush hours. According to the person responsible for the collection of list prices, the prices are collected between 9.00 and 10.00 AM as a result of work routines rather than oil companies' price setting behavior. Hence, the time of changes in list prices are not correctly reported, and thus not always comparable to local prices. However, this error is unlikely to bias our results significantly, as the reported list price will be highly correlated with the true list price.

Figure 6.1: Time of observation



(a) Distribution of local price observations



(b) Distribution of list price observations

Source: Federation of Danish Motorists and the Energy Information Administration.
Note: The figure shows the distribution of the time of the day when observations were reported. Local prices are primarily reported during the rush hour, while FDM has mostly gathered list prices between 9.00 and 10.00 AM.

The cost price data set: Clearly, the closure spot price of gasoline at NYMEX plus taxes is not the true cost price for Danish gasoline companies. First of all, the stations' true cost price includes much more than the price of the gasoline, e.g. transportation, wear-and-tear and the like. Secondly, the data from NYMEX covers prices of regular gasoline which is not exactly the same as 95 octane unleaded gasoline, although prices should be highly correlated. Moreover, it could be argued that gasoline companies buy gasoline on long term contracts and therefore have costs different from the spot price.

However, a company could potentially sell or buy its gasoline at the spot price, which can therefore be viewed as the company's opportunity cost. Since we are concerned about changes in prices rather than the level of prices, we note these problems but do not expect them to alter our results.

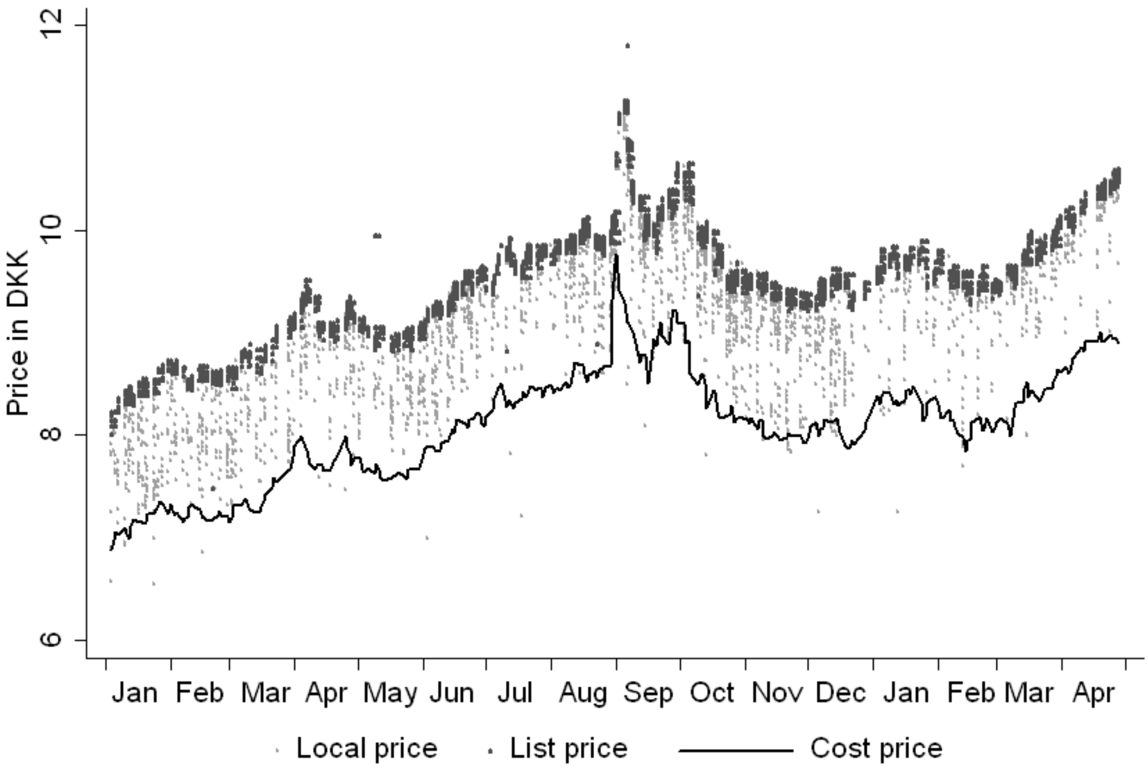
Based on the above data assessment, we conclude that the quality of the data is adequate for our analysis. The main issue is a possible dispersion bias in the reported prices.

6.3.3 Data description

Figure 6.2 shows the fluctuations in gross gasoline prices from January 1$^{\text{st}}$ 2005 to April 30$^{\text{th}}$ 2006. As expected, local prices are usually between the cost price and the list price. Cost prices vary greatly over time and are largely followed by changes in list prices. In average the oil companies set a list price of DKK 1.38 above the estimated cost price and 90 percent of the prices are within $\pm$ DKK 0.20 of this level.

Table 6.2 summarizes the data set. On average we have 26.2 observations of local prices per day equal to each station having its price observed every three days on average. Although there are sizable differences between stations and cities, and some stations are observed several times a day, the relatively few observations should make us heedful when comparing prices between stations.

Figure 6.2: Gross gasoline prices



Source: Federation of Danish Motorists and the Energy Information Administration.
Note: The figure displays observations of list, local and cost prices included in the data set. The upward price movement in August/September 2005 was caused by the hurricane Katrina.

Table 6.2: Data Description

Markets		Stations			Local Prices					Net Price		
City	Postal code	Number of stations	Number of oil companies	Share of staffed stations	Number of obs.	Obs. per station	Minimum obs. per station	Number of days with price obs.	Obs. per day	Mean	Median	Std. dev.
Tough Competition												
Hillerød	3400	13	9	0.44	556	42.8	6	211	2.01	0.93	1.04	0.27
Holte	2840	1	1	1.00	120	120.0	120	94	0.43	1.00	1.08	0.22
Lynge	3540	2	2	0.50	121	60.5	35	83	0.44	1.03	1.22	0.20
Allerød	3450	5	4	1.00	778	155.6	87	252	2.82	1.05	1.22	0.20
Birkerød	3460	5	5	0.80	544	108.8	53	213	1.97	1.08	1.21	0.22
Helsingør	3000	8	8	0.63	725	90.6	31	208	2.63	1.10	1.25	0.17
Medium Competition												
Hørsholm	2970	6	4	1.00	804	134.0	48	263	2.91	1.14	1.28	0.15
Slangerup	3550	4	3	0.67	137	34.3	17	67	0.50	1.14	1.25	0.15
Værløse	3500	3	3	1.00	460	153.3	24	189	1.67	1.15	1.22	0.11
Frederikssund	3600	6	6	0.67	549	91.5	15	176	1.99	1.15	1.26	0.12
Søsum	3670	2	2	0.50	228	114.0	28	148	0.83	1.16	1.29	0.13
Weak Competition												
Stenløse	3660	2	2	1.00	227	113.5	29	148	0.82	1.18	1.32	0.16
Nivå	2990	2	2	0.50	109	54.5	50	87	0.39	1.20	1.30	0.15
Farum	3520	5	5	0.60	737	147.4	41	210	2.67	1.24	1.29	0.10
Frederiksværk	3300	6	5	0.60	339	56.5	36	81	1.23	1.25	1.33	0.13
Ølstykke	3650	5	3	0.67	352	70.4	11	175	1.28	1.30	1.38	0.11
Humlebæk	3050	4	4	0.75	449	112.3	72	164	1.63	1.32	1.36	0.07
Total		79	10	0.68	7235	91.6	6	332	26.2	1.14	1.27	0.28

Source: Federation of Danish Motorists and the Energy Information Administration.

Note: Net prices are calculated as local price minus estimated cost price.

6.3.4 Categorizing markets by competition

Some of the theory investigated in chapter 2 only applies in a static setting. OECD (2001) notes that *Highly concentrated retail gasoline markets could be almost textbook examples of markets where price co-ordination is particularly easy and attractive* (p. 13). Hence, in order to analyze whether the theory is supported by data from the Danish gasoline market, we have to separate markets with competition from those characterized by collusion, as relatively competitive markets fit the static game to a higher degree. Defining the width and depth of a market is a difficult task and beyond our needs.[14] Instead, we conceive each postal code as a separate market. Although this assumption is likely to blur the general picture, Table 6.2 illustrates the significant differences in net prices between different geographical areas.

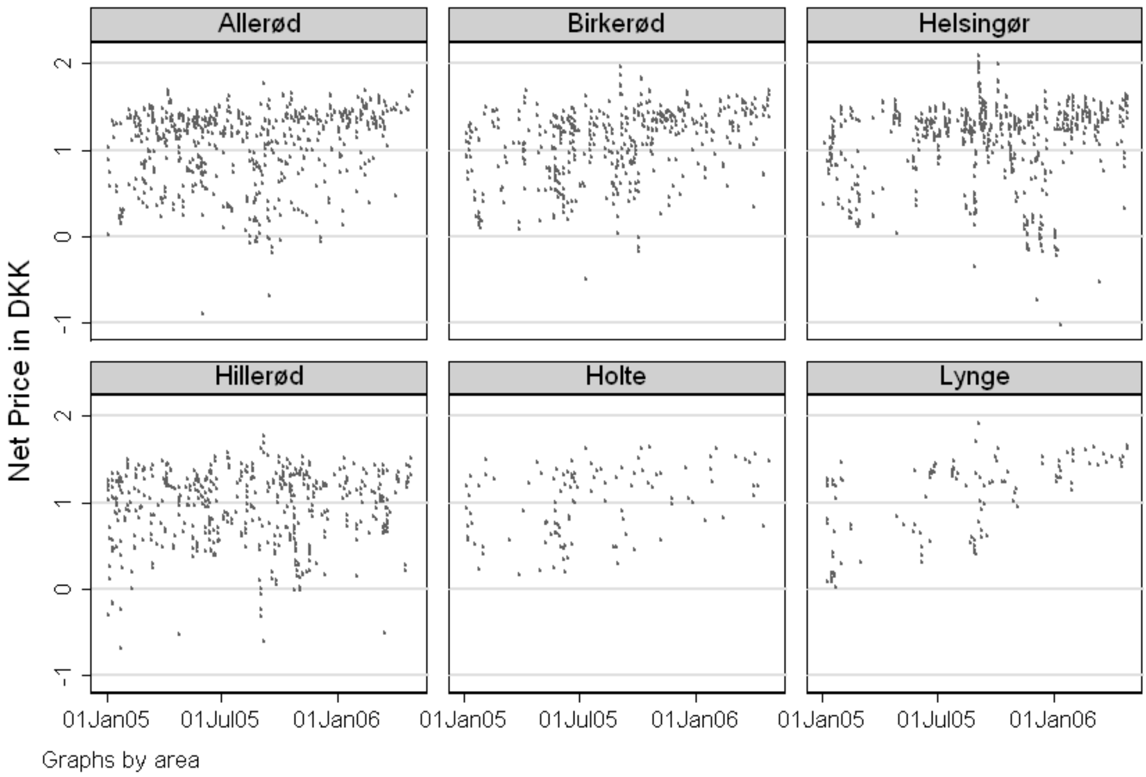
We will attempt to classify the degree of competition in each market by ranking the cities according to the average net price. We will then investigate whether differences are observed in price setting behavior between markets with high and low net prices respectively. We denote the 6 cities with the highest prices *relatively weak competition*, the middle 5 cities *intermediate competition*, and the 6 cities with lowest lowest prices *relatively tough competition*.

Figures 6.3(a) and 6.3(b) illustrate that there are remarkable differences in the price setting behavior between markets with relatively tough and relatively weak competition. In markets with a relatively high degree of competition, net prices are dispersed, while in markets with ineffective competition the prices are more constant. Some markets seem to switch between periods with high, stable prices and periods with more dispersed prices. In Section 6.4.3 we will focus on Helsingør and see that one explanation for these shifts could be changes in the share of informed consumers.

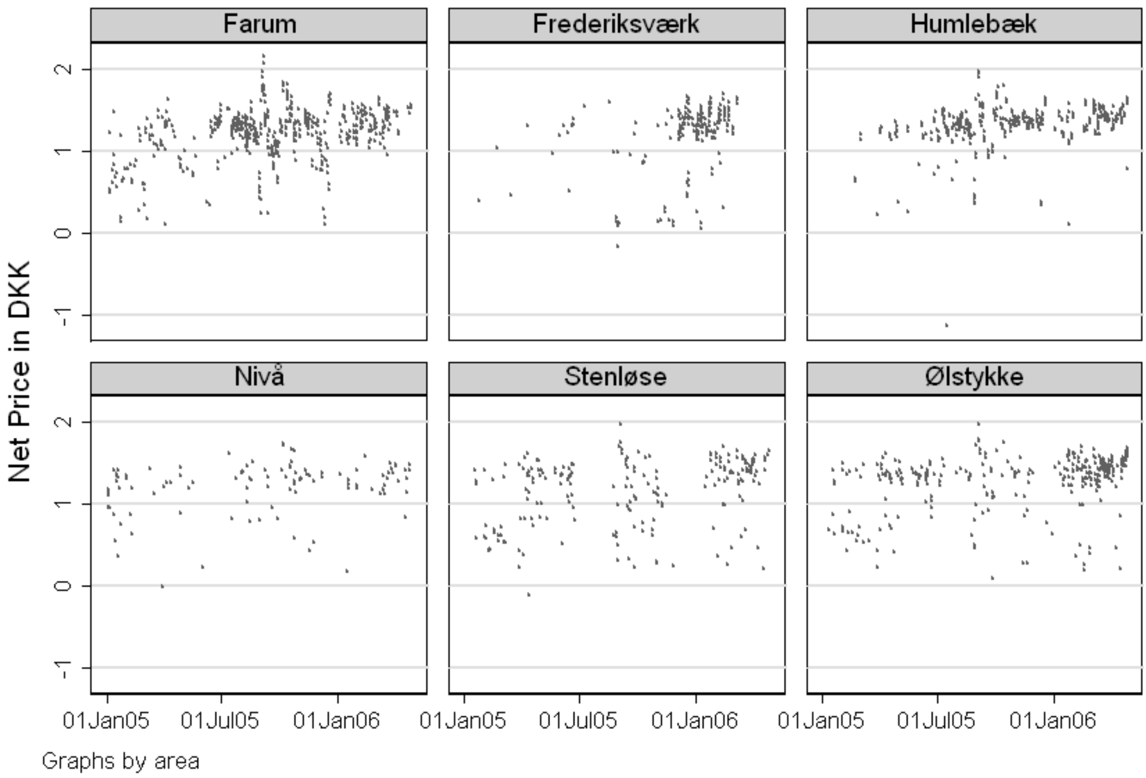
If list prices can be perceived as the parent companies' suggestion to a collusive price, another way to distinguish competitive markets from non-competitive markets is to look at how often stations set the list price. We define a price-cut as the difference between the

[14] A more in-depth analysis would have to take each station's location into consideration. It is natural to regard two closely located stations as competitors, even if they are located in two different postal code areas. However, if they are located at two different roads (e.g. at a highway intersection) they may be competing at different markets, if it is costly for consumers to leave their route. Moreover, such an analysis would be complicated by overlapping markets.

Figure 6.3: Distribution of net prices



(a) Markets with relatively tough competition



(b) Markets with relatively weak competition

Source: Federation of Danish Motorists and the Energy Information Administration.
Note: The figure shows the distribution of net prices for competitive and non-competitive cities respectively. Net prices are defined as the station's local gasoline price minus the estimated cost price.

list price and the local price. Figures 6.4(a) and 6.4(b) show how often stations charge the list price. Again, the picture is clear; in markets with low competition firms set the list price in the majority of periods and large price-cuts are rare. In competitive markets list prices are set relatively seldom and large price-cuts are observed more often.

It seems clear that there are substantial differences in the stations' price setting behavior from city to city, although this geographical division of markets is inadequate. This makes us confident using the mean net price and the standard deviation in a city to distinguish between markets with tough and weak competition.

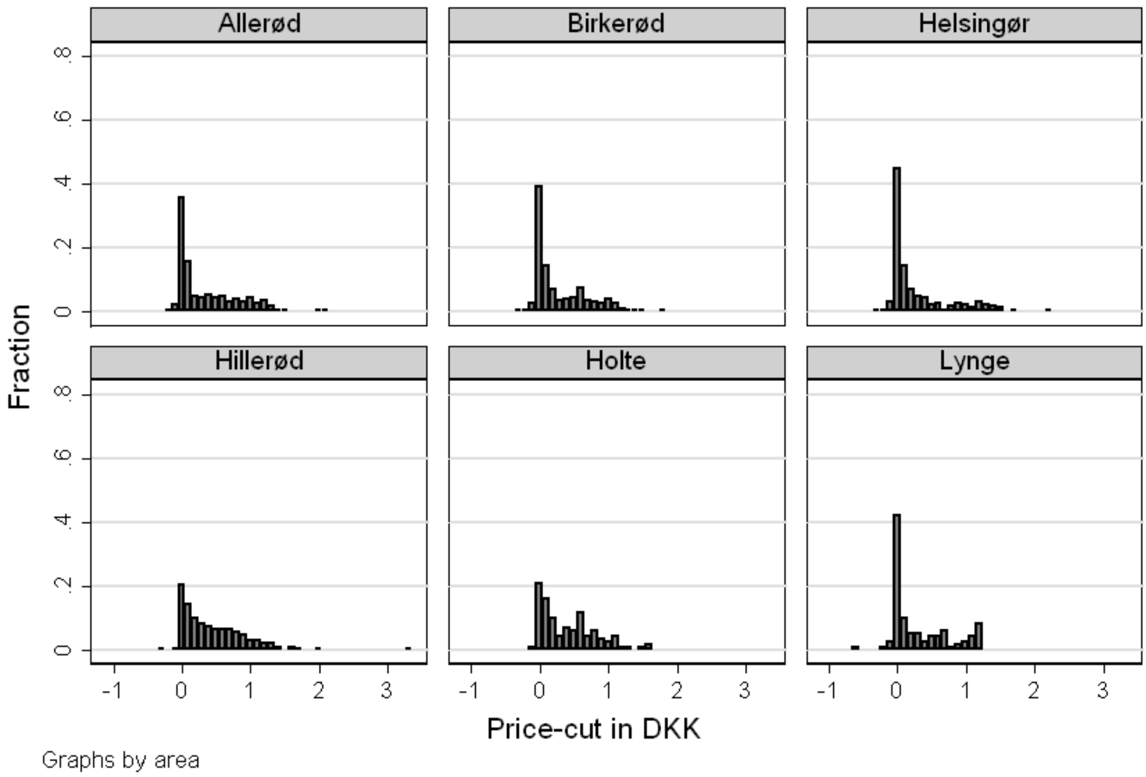
6.4 Evidence from the Danish gasoline market

having established the classification of markets by degree of competition, we now turn to the actual analysis of how well data from the gasoline market fits the predictions suggested by the theory. The section is structured as follows. First, we establish that prices are dispersed. Second, we investigate whether temporal or spatial price dispersion is a better description of the market. The analysis indicates that the identity of the firm offering the lowest and the highest price changes, hence temporal price dispersion seems to give the most adequate description of the gasoline market. Third, we find indications of transparency promoting competition by analyzing the tourist season's effect on prices in Helsingør.

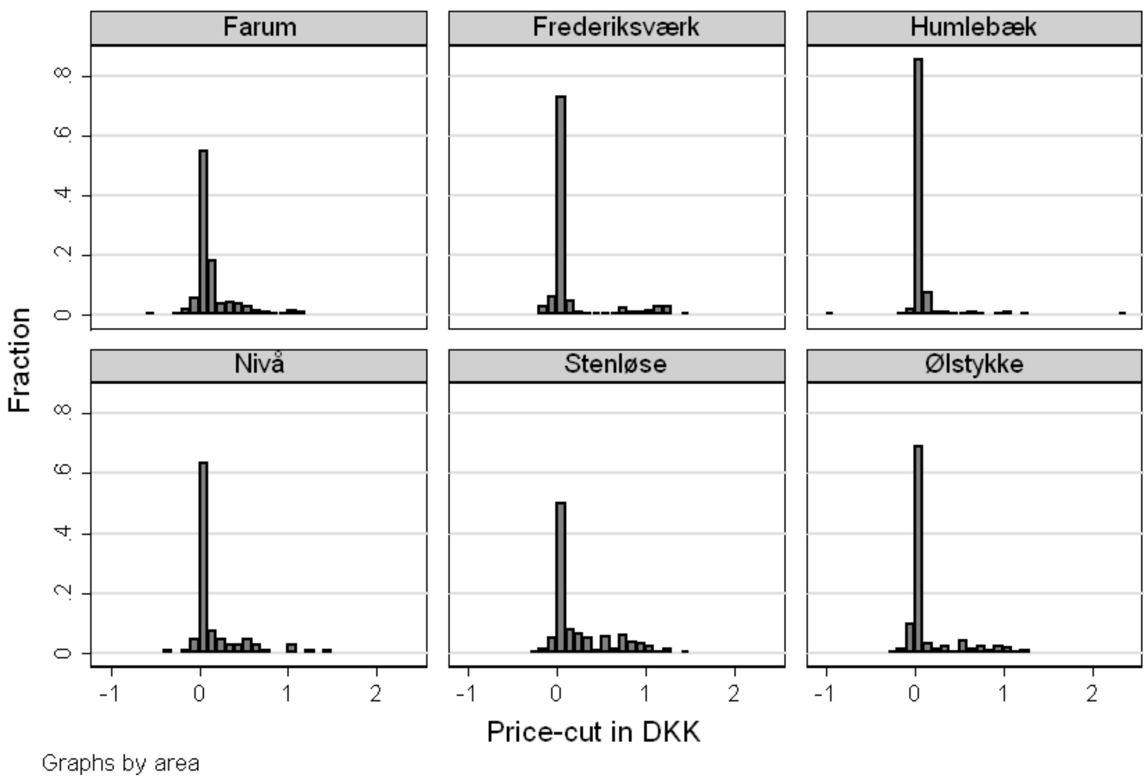
6.4.1 Price dispersion

One of the key learnings from the literature of competition and imperfectly informed consumers is that equilibrium prices are dispersed and do not settle on a single price. In our data this should result in significant variance between prices observed on the same market on the same day. From Figure 6.5 we see that this is indeed the case in the Danish gasoline market. Since the models predicting price dispersion are most likely to apply in competitive markets, the variance in prices is expected to be higher when the average net price is low. The significant negative slope of the regression line supports this prediction. Since Bertrand models with consumer side homogeneity predict zero variance

Figure 6.4: Price-cuts



(a) Markets with relatively tough competition



(b) Markets with relatively weak competition

Source: Federation of Danish Motorists
Note: The figure displays the distribution of price-cuts for competitive and non-competitive cities respectively. Price-cuts are defined as the list price minus the local price. A zero price-cut is tantamount to the station charging exactly the list price.

in prices, the figure shows that these models are not very successful in describing the Danish gasoline market.

Figure 6.5: Correlation between standard deviations and mean prices

Source: Federation of Danish Motorists and the Energy Information Administration.
Note: The figure displays combinations of means and standard deviations of local price observations. Both standard deviations and mean prices are calculated for each city on a daily basis. All markets are included in the figure regardless of the level of competition. The regression line is estimated using simple OLS. The coefficient is -0.770 and the t-value is -36.41.

Identical prices are often perceived as a signal of weak competition. Our data shows that, at least on the gasoline market, this supposition is correct, since uniform prices are indeed an indication of high net prices. The theory described in the previous chapters offers two explanations to why we observe little price dispersion together with high net prices. The most obvious explanation is that firms collude in some cities, thereby setting (nearly) identical prices. Another explanation is that the share of informed consumers is low so that the spread between the minimum price firms are willing to set and the monopoly price is small. However, we see no reason to believe that the share of uninformed consumers varies greatly between cities, and thus, we expect collusion to be the most attractive explanation.

6.4.2 Spatial vs. temporal price dispersion

Since the pattern seen in Figure 6.5 can be a sign of both temporal and spatial price dispersion we will continue by analyzing whether stations randomize their prices or whether the dispersion is caused by some stations persistently setting low prices while other set high prices.

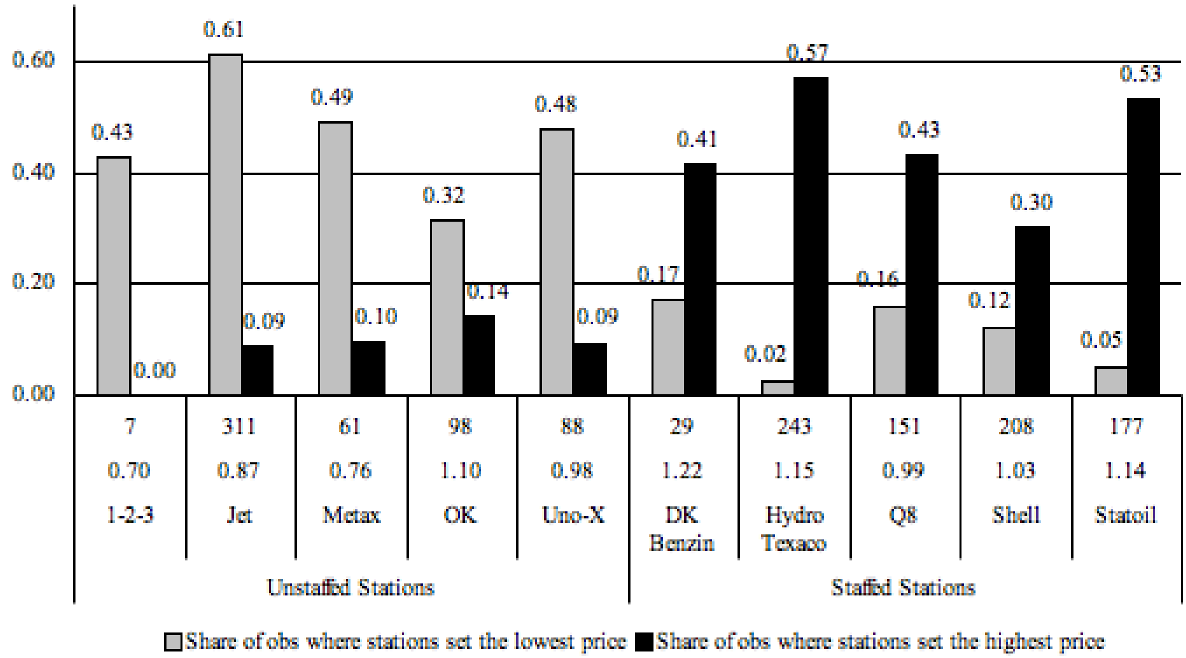
To do this we rank the station in each city on a given day by price. If the gasoline market is characterized by spatial price dispersion, we would expect some companies to set systematically lower prices than others. In contrast, if temporal price dispersion prevails, there should be a significant turnover in the identity of the firm offering the cheapest and the highest price. Only observations from the most competitive markets are included, since these are most suited for analyzing static games.[15] Before we turn to the result, bear in mind that there are some obstacles when comparing prices across companies on a daily basis. Especially, as data is collected at different times of the day, prices may not be completely comparable, since prices can have changed between the two observations. Moreover, since we have price observations from different stations on different days, the peer group changes from day to day. To cope with this we have only included days when there are observations from both staffed and unstaffed stations.

Figure 6.6 shows the identity of companies offering the lowest or the highest price. The figure does not seem to give any conclusive evidence to how the price dispersion can be characterized. On the one hand there is a significant difference between the price setting behavior of unstaffed and staffed companies; unstaffed companies are very seldom observed having the highest price, and staffed stations rarely offer the lowest price. On average unstaffed stations are DKK 0.17 cheaper than staffed stations. Together this points in the direction of spatial price dispersion and seems to reject temporal price dispersion with identical firms.

However, staffed and unstaffed stations are presumably not identical, since unstaffed stations are likely to have lower costs than staffed stations, due to differences in salaries etc. In this case our extension to Varian (1980) applies, and we would expect to see some

[15]Holte was left out, since we only have observations from one station in this area, and Allerød was omitted since there are only unstaffed stations.

Figure 6.6: The identity of low and high price firms in competitive markets



Source: Federation of Danish Motorists and the Energy Information Administration.
Note: The figure displays how often each company has the lowest (highest) observed price on a given date in a given city. We only include dates when we have local price observations from at least two stations in the same city. Only data from cities with relatively tough competition is included.
The first number above the name of the companies is the average net price, the second is the number of observations. Only days containing observations from both staffed and unstaffed stations are included. Note that adding up shares when firms are cheapest equals more than one. The reason is that different companies are compared on different days. The same goes for the highest price.

changes in the ranking of firms, with the unstaffed stations being cheapest most of the time. The pattern seen in Figure 6.6 seems to be in line with this prediction.

It could be argued that the observed price dispersion is caused by a gasoline company being cheapest in one city and expensive in other cities. Table 6.4.2 shows that this is not the case, as the pattern observed in Figure 6.6 recurs on each single market.

There are, however, at least two alternative explanations to why we sometimes observe unstaffed firms setting the highest price and staffed firms offering the lowest price. The first has to do with the quality of data and the second concerns differences in service.

It could be suspected that the relatively few observations supporting temporal price dispersion are faulty and are due to either insufficient observations on that particular day or a consequence of a greater time difference between the observations. However, a closer look reveals few differences between observations supporting temporal price dispersion

Table 6.3: The identity of low and high price firms in competitive markets, by city

		Unstaffed stations					Staffed stations				
city	Share of obs. with	1-2-3	Jet	Metax	OK	Uno-X	DK Benzin	Hydro Texaco	Q8	Shell	Statoil
Birkerød	Lowest price		0.65					0.00	0.06	0.17	0.07
	Highest price		0.13					0.72	0.42	0.32	0.63
	No. obs.		147					43	50	72	54
Helsingør	Lowest price		0.60		0.19	0.45	0.17	0.03	0.17	0.08	0.05
	Highest price		0.03		0.10	0.06	0.41	0.61	0.42	0.25	0.43
	No. obs.		113		48	53	29	109	48	118	77
Hillerød	Lowest price	0.43	0.53	0.49	0.29	0.51		0.03	0.19	0.22	0.02
	Highest price	0.00	0.10	0.10	0.17	0.14		0.45	0.24	0.56	0.59
	No. obs.	7	51	61	24	35		91	21	18	46
Lynge	Lowest price				0.58				0.28		
	Highest price				0.19				0.59		
	No. obs.				26				32		
Weighted Average	Lowest price	0.43	0.61	0.49	0.32	0.48	0.17	0.02	0.16	0.12	0.05
	Highest price	0.00	0.09	0.10	0.14	0.09	0.41	0.57	0.43	0.30	0.53
	No. obs.	7	311	61	98	88	29	243	151	208	177

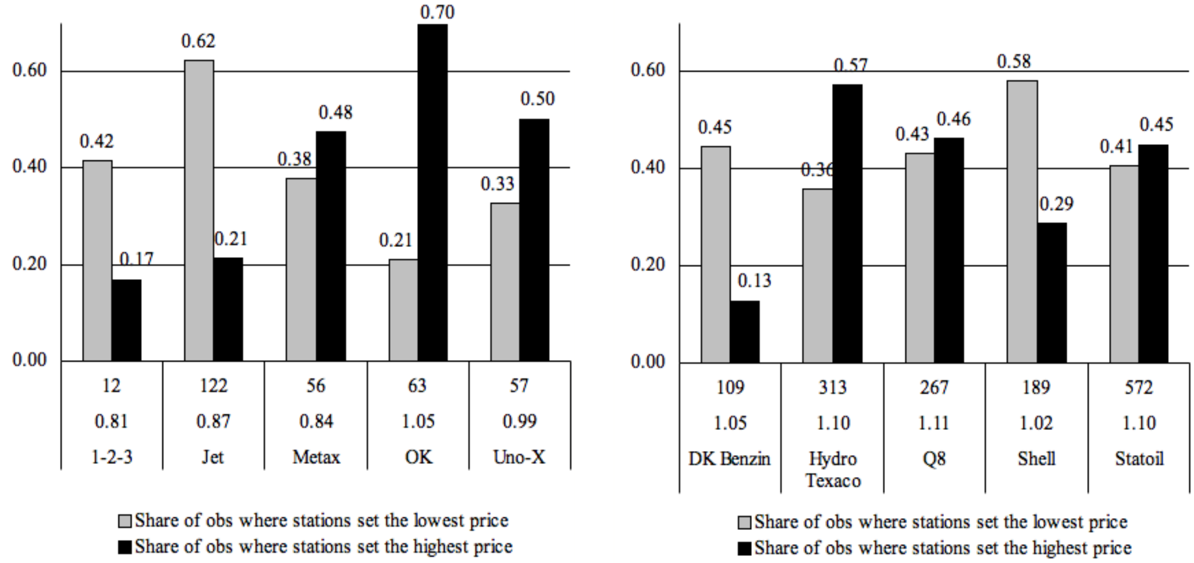
Source: www.benzinpriser.dk
* The data is weighted averages of observations from stations from the same oil company in the city.
Note: The table shows how often a station was the cheapest (most expensive) in the city on a given day. 1175 observations where left out when we only had prices from one station.

and observations supporting spatial price dispersion.[16] For both kinds of observations, there is an average of approximately 6 hours between the first and the last observation on a day. Moreover, prices supporting temporal price dispersion are on average compared to 3.1 prices. This number is 3.7 for observations supporting spatial price dispersion. However, the observed difference can still be caused by stochastic variances in data.

Second, as described earlier, gasoline from an unstaffed station is not exactly the same as gasoline from a staffed station. Hence, we should expect that staffed stations are able to charge a service premium. In the most extreme interpretation the gasoline market consists of two submarkets; one for gasoline including service and one for gasoline alone. To exclude effects from differences in service levels, we compare prices between stations of the same type. This is done in Figure 6.7(a) and Figure 6.7(b) where we see that when differences in service are taken into account, there is significant turnover in the identity of the firm offering the lowest and highest price. In appendix B we see that this is not due to the aggregation over cities, since the changes in ranking exist in all competitive cities. Hence, spatial price dispersion seems to be an inadequate description of the competition between stations of the same type, whereas the results are consistent with temporal price

[16] Observations where a staffed station is cheapest or an unstaffed station is most expensive support temporal price dispersion, while the opposite supports spatial price dispersion.

Figure 6.7: Comparison between stations of the same type



(a) Unstaffed stations (b) Staffed stations

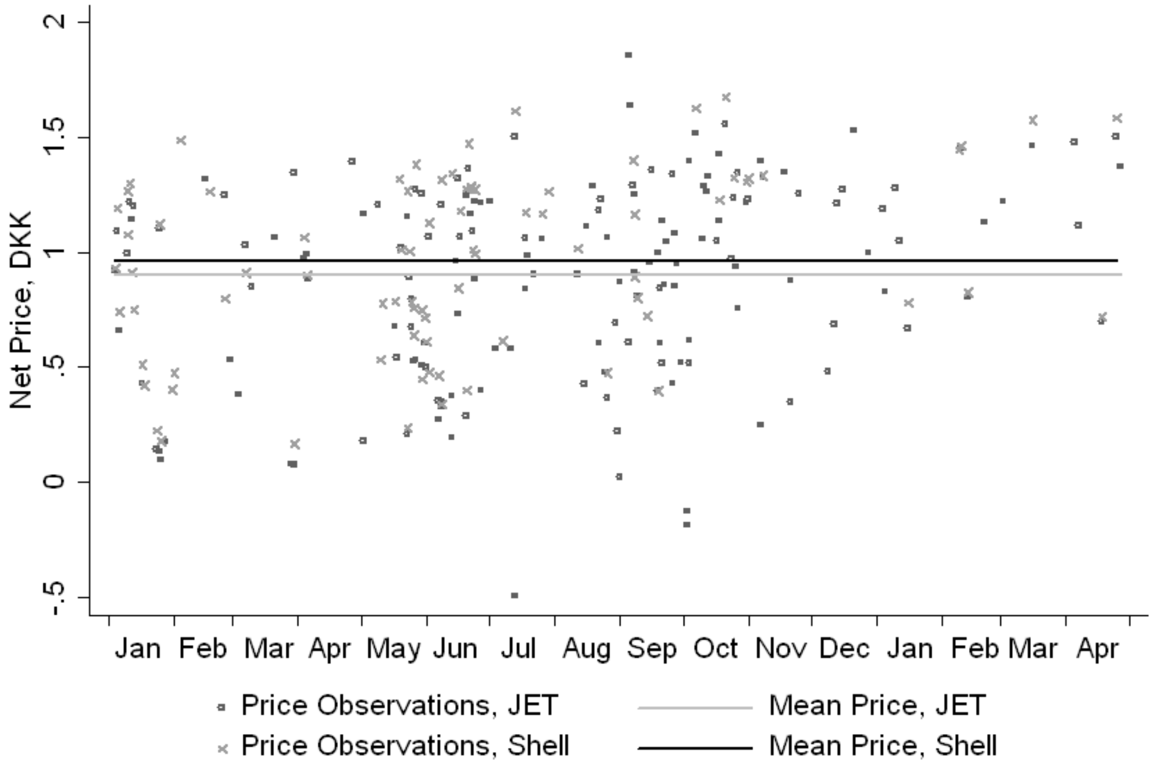
Source: Federation of Danish Motorists and the Energy Information Administration.
Note: The figure displays how often each company has the lowest (highest) observed price on a given date in a given city. We only include dates when we have local price observations from at least *two stations of the same type*, staffed or unstaffed. Only data from cities with relatively tough competition is included. The first number above the name of the companies is the average net price, the second is the number of observations. Only days containing observations from both staffed and unstaffed stations are included. Note that adding up shares when firms are cheapest equals more than one. The reason is that different companies are compared on different days. The same goes for the highest price.

dispersion as described in Varian (1980).

With the insights obtained from Figure 6.7(a) and Figure 6.7(b) we feel confident concluding that the pattern shown in Figure 6.6 does not indicate spatial price dispersion, but rather temporal price dispersion, where firms have different costs and offer slightly different products. Temporal price dispersion is also supported by Figure 6.8, where prices from to neighboring stations are displayed. There is easy access to both stations from the road, so the stations compete for the same customers. The figure illustrates that the two stations change prices repeatedly in order to be unpredictable.

From the data at our disposal, we are not able to separate the effects of cost and service. However, one way to test the importance of the differences in services would be to test whether people fill up fewer liters at the traditional gas stations compared to discount stations. The hypothesis would be that having the possibility of shopping at a traditional gas station is more expensive when consumers need a lot of gasoline, and thus, we would expect people to refuel less at traditional companies. Another way to test this would be to

Figure 6.8: Jet and Shell in Birkerød



Source: Federation of Danish Motorists.
Note: The figure displays prices obtained from Jet and Shell in Birkerød. The two stations are located on either side of Kongevejen, so that motorists can easily compare prices from the two stations.

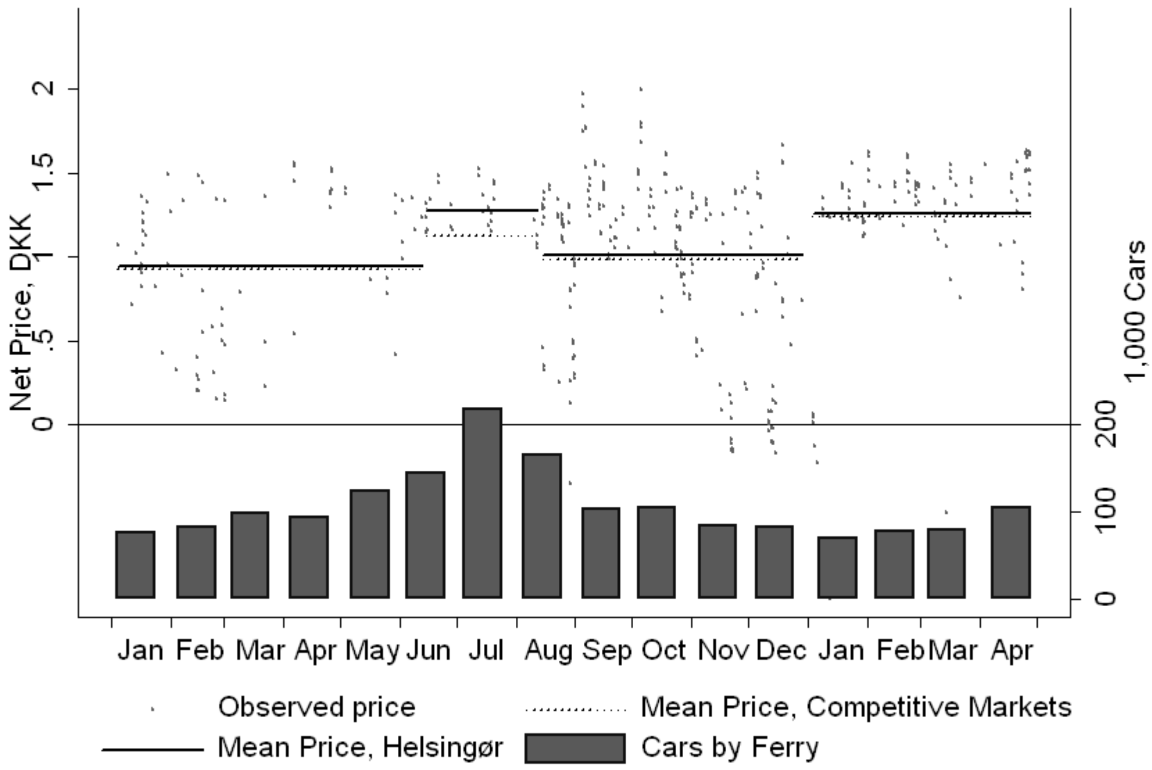
look at the share of consumers who uses the services at the traditional stations. Consumers who do not use the services would save DKK 0.17 per liter on average by visiting an unstaffed station instead. Unfortunately, our data does not allow us to investigate any of these hypothesizes.

6.4.3 Does transparency promote competition?

All the theories described in Chapter 2 to 4 predict that transparency promotes competition in a static setting. However, when the possibility of collusion is taken into account, the predictions are more ambiguous. One way to determine the effect of an increase in transparency is to investigate it empirically. A feasible approach is to look for natural experiments where the level information changes abruptly and exogenously.

Such an 'experiment' may be found in Helsingør during the summer, when the number of motorists traveling between Denmark and Sweden increases by more than 100 percent, see Figure 6.9.[17] It is easily imaginable that the large number of tourists passing through the

Figure 6.9: Net prices in Helsingør



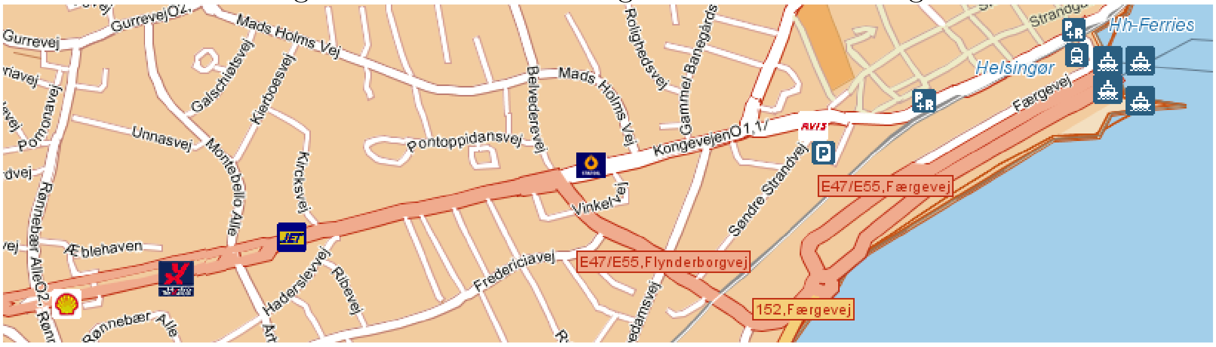
Source: Federation of Danish Motorists, the Energy Information Administration and Scandlines.
Note: Compared to other competitive markets, the mean price in Helsingør is high during summer holidays when there are many tourists in the city.

city during the holiday season are more concerned with enjoying their holiday than saving a few kroner on their gasoline bill. Moreover, foreigners may not know the characteristics of the Danish gasoline market and, hence, it is likely that the share of informed consumers in Helsingør decreases during the summer. In Figure 6.9 the prices from gas stations in Helsingør are shown along with the number of passenger cars traveling by the Scandline ferries each month. Only the four gas stations situated along the main road in Helsingør are included, see Figure 6.10, as these are the stations competing for the ferry passengers.

The figure indicates that the market in Helsingør shifts between periods with dispersed prices and periods with uniform prices. In general the prices follow the patterns observed on other competitive markets and thus may reflect underlying changes in the way stations

[17] Data for the number of cars was delivered by Scandlines in a telephone interview. As we are interested in the development in traffic rather than the level, we have made no attempt to collect data from HH-Ferries who services the same passage. HH-Ferries have a market share of approximately 35 percent.

Figure 6.10: Locations of gas stations in Helsingør



Source: www.map24.com
Note: The figure only includes the four gas stations located on the main road leading to the ferries.

compete. However, in the summer holidays from June 15th, 2005 to August 14th, 2005, where the number of cars passing through the city is the highest, prices in Helsingør are remarkable higher than prices on other competitive markets.[18] If this difference is due to the change in the share of informed consumers, the theories described in this thesis offer two explanations.

First of all, an explanation might be taken from the theory of collusion described in chapter 4. When the share of uninformed consumers increases, stations are less tempted to deviate from the collusive price, as they can capture fewer consumers. On the other hand, the punishment phase is softer too, as the competition is less fierce when few consumers are informed. Contrary to our extension most existing literature provides ambiguous results regarding the sum of the two effects. If the observed behavior is indeed caused by changes in firms' ability to collude, the case from Helsingør may illustrate that transparency is pro-competitive in a dynamic setting. After the summer, when the share of informed consumers increases, firms are no longer able to collude, as the temptation to deviate from the collusive agreement increases relatively to the deterrence effect.

Secondly, another explanation is offered by our extension to Varian's model formulated in chapter 5. If the numerous tourists make the share of informed consumers drop to a sufficiently low level, high cost firms are no longer willing to compete for the informed consumers, since the loss on uninformed consumers of doing so is too large. Without competition from the high cost firms, the low cost firms set their monopoly price too and we observe high prices. In the fall, when the number of tourists decreases, the share of

[18]Unfortunately we only have data from the summer of 2005, so we were not able to check whether this is a repeating pattern or merely a coincidence in this particular year.

informed consumers increases, and the high cost firms are now tempted to compete for the informed consumers so that we observe relatively low and dispersed prices.

Unfortunately, there is no obvious way to test empirically what lies behind the observed behavior, as both explanations result in the same behavior. However, discussing the Helsingør story with a gas station manager, his first comment was "*Of course stations do not fight a price war during the tourist season. Foreigners do not know the prices anyway.*" His perception of the market supports the explanation given by our extension.

Before we draw hasty conclusions it might be helpful to look at explanations offered by theories not related to consumer side information. When tourists swarm trough Helsingør, gas stations may take capacity constraints into consideration, as there is a limit to how many consumers a gas station can serve. In this case, a station can not benefit from charging a low price, since it cannot handle extra consumers. Hence, stations will set their price with regard to capacity rather than the competitors' prices.

Green & Porter (1984) develop a model where firms collude under imperfect information about demand. If low prices are observed, firms do not know if they are caused by other firms cheating or if they are a consequence of a recession. To deter other firms from undercutting in the future, the punishment phase has to be initiated when sufficiently low prices are observed - even if no firm has actually cheated. In the Helsingør case, the many tourists passing through the city during the summer month clearly increase demand, making it possible for the gasoline stations to maintain a high price. When the tourists season ends firms observe low prices and initiate the punishment phase. The only caveat to this explanation is that the argument hinges on demand being unobservable and unexpected. With seasonal fluctuations this is unlikely to be the case. It is more realistic that firms are aware of the increase in demand, as assumed in Rotemberg & Saloner (1986). Their model predicts that collusion on the monopoly price is harder to sustain during booms, which tends to lower the collusive price. On the other hand, the monopoly price is higher during booms, and this tends to increase the collusive price. Whether the first or the latter effect dominates is ambiguous, and thus the observed price may be higher during booms. As firms always collude in their model, we should not expect to observe any changes in dispersion over time. However, as seen in Figure 6.9, prices in Helsingør tend to be more dispersed when the average price is low, indicating that firms do not collude in these phases. Hence, our data does not seem to support Rotemberg & Saloner's model.

To summarize, the data from Helsingør illustrates that the share of informed consumers in a market does have implications for firms' price setting. Investigating whether the observed behavior is due to changes in firms' ability to collude or caused by the lack of competition for informed consumers is a difficult task. However, anecdotal evidence suggests the latter might be of greater importance.

6.5 Concluding remarks

Our study of the Danish gasoline market reveals that when firms compete, prices do not settle on a single low price. Instead, the data indicates that there is considerable price dispersion, and the turnover in the identity of the lowest and highest price firm suggests that firms randomize prices to be strategically unpredictable. Hence, it seems that firms do indeed use mixed strategies to prevent being systematically undercut by competitors, while still being capable of exploiting uninformed consumers.

OECD (2001) states that for the gasoline market *parallel pricing is not in itself sufficient proof of anti-competitive behavior*. This view is challenged by the data from the Danish gasoline market where we found significant differences in the price setting behavior between cities. We find that these differences are reflected in average prices, with prices being higher in cities with uniform – or parallel – prices, compared to cities where prices are dispersed.

In Helsingør we identified a 'natural experiment', where the share of uninformed consumers is likely to increase during the tourist season. The gasoline market in Helsingør is generally quite competitive, but during this period prices are higher and less dispersed compared to other competitive markets. We argue that this phenomenon has two possible explanations: First, the pure strategy Nash equilibrium from chapter 5 may apply, and firms charge their monopoly price, since competing for the informed consumers is not worthwhile. Secondly, it may be explained by changes in collusive behavior. In this case the data suggests that an increase in transparency is pro-competitive.

Summing up, our main findings in this chapter are the following:

- When markets are competitive prices are dispersed. When markets are non-competitive, gasoline prices are high and dispersion is low. Hence, low price dispersion is a signal of weak competition.
- Price dispersion in competitive markets is temporal rather than spatial, indicating that stations act as if they play mixed strategies.
- In Helsingør we find that an presumable abrupt decrease in the share of informed consumers results in higher and less dispersed prices.

Chapter 7

Conclusion

By surveying the existing literature, we have studied how firms compete in markets with imperfect transparency. When some consumers are uninformed, the consensus is that the market outcome will be dispersed and that 'the law of one price' fails to apply. The literature studied in this thesis suggests that price dispersion can be *spatial*, where some firms persistently set high prices while others set low prices, or it can be *temporal*, where firms randomize prices in order to be unpredictable.

The fact that imperfect transparency is likely to result in dispersed equilibrium prices is useful for competition authorities, who are often confronted with the argument that identical market prices are not due to collusion, but rather a consequence of fierce competition. This view is found in OECD (2001) p. 13, which states that "*...parallel pricing behavior is not in itself sufficient proof of anti-competitive behavior.*" This thesis challenges this view, since identical prices cannot be the equilibrium outcome when firms compete in partly transparent markets.

When prices are non-transparent, there are significant costs associated with gathering information about prices. The conventional wisdom has been that initiatives aiming at reducing the search costs will lead to more intense competition, to the benefit of consumers. The papers on static game competition studied in this thesis suggest that transparency does promote competition, since more informed consumers make it more profitable for firms to set low prices. This result may, however, change in a dynamic setting, where firms potentially engage in tacit collusion. Here, increased transparency has two countervailing effects. Firms' temptation to disregard the collusive agreement and set a low price is higher when more consumers are informed about prices. This effect may, however, be offset by a more competitive punishment phase. Which of the two effects that dominates depends on the specific market characteristics, and to the best of our belief, the literature is still too vague to give precise policy recommendations. However, the literature on tacit collusion and consumer side transparency can serve as a warning that transparency may not always promote competition, even if producer side information is left unchanged.

This thesis contributes to the existing theoretical literature on competition and consumer side transparency by analyzing how asymmetric costs affect competition. The model is an extended version of Varian (1980), where a high and a low cost firm, facing a downward sloping demand curve, compete on prices. We show that two types of equilibria can exist in the static game. When the degree of transparency is very low, competition is absent, and firms set their monopoly prices. When the market is sufficiently transparent, firms either set their monopoly price or randomize prices in a lower price range. In line with other papers on transparency and static game competition, average prices are lower when more consumers are informed. Furthermore, we show that if the stage game is repeated, increased transparency unambiguously make it easier for impatient firms to sustain collusion, and thus transparency has anti-competitive effects in our model. Since competition may be absent when the degree of transparency is either very low or very high, this model suggests that intermediate levels of transparency are preferable. If, however, firms are too impatient to sustain collusion even when the market is fully transparent, more transparency will promote competition. This leads us to conclude that policy makers should only be cautious of improving transparency in markets where the potential risk of collusion is already considerable.

The theory is likely to apply to the majority of retail markets where prices are low compared to the search costs. In this thesis, we investigate whether the theoretically predicted price setting behavior is supported by data from the Danish gasoline market. We find that prices are dispersed, and the identity of the cheapest firm varies over time in competitive markets. This temporal dispersion suggests that gas stations set prices as if they play a mixed strategy. In Helsingør, which is generally a competitive market, we compare gasoline prices during the holiday season – when there are many uninformed tourists – with prices in the rest of the year. We find that prices are higher and less dispersed when the share of uninformed consumers is likely to be high. This supports the static part of our model, although we cannot distinguish the effect from possible collusive behavior.

7.1 Future research

The theoretical models described in this thesis do not reach a consensus on how changes in transparency affect firms' ability to collude. Small changes in a model's setup can potentially change the qualitative results, which suggests that a more general understanding of this topic is needed. In particular, a deeper theoretical knowledge is needed into which market characteristics are important when assessing the impacts of changes in transparency. The existing literature tells us that transparency is potentially anti-competitive, but general advices is not possible based on the existing literature.

Whether transparency promotes competition or facilitates collusion is ultimately an empirical question, especially since the theoretical predictions are ambiguous. Hence, empirical research is needed to deliver credible results. While several empirical papers have documented the existence of equilibrium price dispersion, few studies consider how changes in consumer side transparency affect competition. One way to do this is to look for natural experiments such as the one we identified in Helsingør. An obvious starting point is to compare prices before and after the implementation of internet shopping facilities and price comparison websites. When performing such an analysis, one should be careful not to mistake effects caused by increased consumer side transparency with the consequences of more information among firms. In addition, one should carefully consider if the change in transparency can be treated as being exogenous.

Appendix A

Proofs

Proof of $iii)$ in proposition 5

We show that $\frac{\partial \rho_i}{\partial \alpha} < 0$ for A and B separately. First recall from the definition of p^* in (5.6) that $\pi_B^s(p^*) = p_B^f(p_B^M)$. Hence, the probability that A sets the monopoly price can be written as

$$
\begin{aligned}
\rho_A &= \frac{4\frac{1-\alpha}{2}}{\alpha}\frac{\frac{(1-c)^2}{4}}{1-2c} - \frac{1-\alpha}{2\alpha} \\
&= \frac{(1-\alpha)}{2\alpha}\frac{(1-c)^2}{1-2c} - \frac{1-\alpha}{2\alpha} \\
&= \frac{1-\alpha}{2\alpha}\left(\frac{c^2}{1-2c}\right)
\end{aligned}
$$

which is clearly decreasing in α.

Since A has zero cost, the probability that B sets his monopoly price reduces to

$$
\rho_B = \frac{2(1+\alpha)}{\alpha}(1-p^*)p^* - \frac{1-\alpha}{2\alpha} \tag{A.1}
$$

Differentiating ρ_B with respect to α yields

$$
\begin{aligned}
\frac{\partial \rho_B}{\partial \alpha} = -\frac{2}{\alpha^2}(1-p^*)p^* + \frac{\partial p^*}{\partial \alpha}(1-2p^*)\frac{2(1+\alpha)}{\alpha} + \frac{1}{2\alpha^2} &< 0 \quad \Leftrightarrow \\
(-4(1-p^*)p^*+1) + 4(1+\alpha)\alpha(1-2p^*)\frac{\partial p^*}{\partial \alpha} &< 0 \quad \Leftrightarrow
\end{aligned}
$$

$$\begin{aligned}
\left(p^* - \frac{1}{2}\right)^2 - 2(1+\alpha)\alpha\left(p^* - \frac{1}{2}\right)\frac{\partial p^*}{\partial \alpha} &< 0 \qquad \Leftrightarrow \\
\left(p^* - \frac{1}{2}\right)\left(\left(p^* - \frac{1}{2}\right) - 2(1+\alpha)\alpha\frac{\partial p^*}{\partial \alpha}\right) &< 0
\end{aligned}$$

Since the sign of the first bracket is always negative for $\alpha > \alpha^*$, the sign of the second bracket has to be positive in order for ρ_B to be decreasing in α. Inserting p^* from (5.7) and $\frac{\partial p^*}{\partial \alpha}$ from (5.23) and reducing the second bracket yields

$$\begin{aligned}
\frac{1}{2} - \frac{1}{2}\left(1 + \sqrt{\frac{2\alpha}{1+\alpha}}\right)(1-c) - 2(1+\alpha)\alpha\left(-\frac{1}{2}(1-c)\frac{\sqrt{1+\alpha}}{\sqrt{2\alpha}(1+\alpha)^2}\right) &> 0 \qquad \Leftrightarrow \\
1 + (1-c)\left(-1 - \sqrt{\frac{2\alpha}{1+\alpha}} + \frac{2\alpha}{\sqrt{2\alpha(1+\alpha)}}\right) &> 0 \qquad \Leftrightarrow \\
1 - (1-c) &> 0 \qquad \Leftrightarrow \\
c &> 0
\end{aligned}$$

Hence, $\frac{\partial \rho_B}{\partial \alpha} < 0$. ■

Appendix B

Empirics

Comparison between stations of the same type, by city

		Unstaffed stations					Staffed stations				
city	Share of obs. with	1-2-3	Jet	Metax	OK	Uno-X	DK Benzin	Hydro Texaco	Q8	Shell	Statoil
Allerød	Lowest price						0.47	0.38	0.24		0.39
	Highest price						0.09	0.39	0.51		0.38
	No. obs.						87	67	143		393
Birkerød	Lowest price							0.25	0.69	0.63	0.50
	Highest price							0.73	0.51	0.25	0.70
	No. obs.							37	64	52	71
Helsingør	Lowest price		0.72		0.12	0.27	0.36	0.27	0.55	0.59	0.37
	Highest Price		0.14		0.86	0.46	0.27	0.70	0.33	0.29	0.46
	No. obs.		67		41	26	22	114	40	128	68
Hillerød	Lowest price	0.42	0.50	0.38	0.39	0.38		0.50	0.76	0.28	0.48
	Highest price	0.17	0.30	0.48	0.39	0.53		0.48	0.19	0.50	0.65
	No. obs.	12	55	56	22	31		95	20	9	40
Weighted Average	Lowest price	0.42	0.62	0.38	0.21	0.33	0.45	0.36	0.43	0.58	0.41
	Highest price	0.17	0.21	0.48	0.70	0.50	0.13	0.57	0.46	0.29	0.45
	No. obs.	12	122	56	63	57	109	313	267	189	572

Source: www.benzinpriser.dk

* The data is weighted averages of observations from stations from the same oil company in the city.

Note: The table shows how often a station was cheapest (most expensive) in the city on a given day. 1175 observations where left out when we only had prices from one station.

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