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A SURVEY OF COLLUSION IN GASOLINE MARKETS

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A Survey of Collusion in Gasoline Markets*

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Abstract

This paper describes and surveys in a comprehensive way theoretical and empirical tools that might be used to analyze pricing mechanisms on gasoline markets. The theoretical part reviews static and dynamic oligopoly models. The latter suggest how can collusion be achieved without any explicit agreement. The empirical part surveys studies identifying and explaining asymmetry of price responses and empirical tests of models of collusion in gasoline markers. The results are further supported by several experimental studies.

Keywords: oligopoly, leadership, collusion, gasoline markets
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1 Introduction

Gasoline markets are often suspected of the existence of cartel agreements on prices. Such agreements are illegal in EU countries.[1] In 1999, the representatives of major Swedish petrol distribution companies met in secret to plan and implement an agreement on prices. They did not lower prices to normal levels when the cost of raw materials decreased in September and October. The companies that controlled 90% of the market got a fine of 740 million SEK. If there exists a direct evidence on cartel agreement or record of illegal communication, it is an easy task for the Competition Authority to make the decision.

On the other hand, the decision is more complicated when such direct evidence is absent. In March 2003, the French Competition Council has fined for a total amount of 27 million Euro the main oil companies for price fixing on fuel distribution markets on highways. The Council considered the information provided by highway petrol stations to their petrol suppliers on prices as anticompetitive exchange of information. In December 2003, the Paris Court of Appeal annulled the fines and held that there was no collusion since the information exchange could not have been regarded as having an impact on the commercial autonomy of the petrol companies in their pricing

[1] Each country has a law on the protection of competition that is harmonized with Article 81 of the EC Treaty. The law itself as well as the enforcement of the law may differ country to country but in general there exists a Competition Council in each country that enforces the law and makes decisions on penalties in case of infringement and companies can appeal against the decision to a court.

policy.[2]

Starting from this controversy, the aim of this paper is to describe in a comprehensive way the theoretical and empirical tools that can be useful for economic analysis of price mechanisms and firms' behavior on gasoline markets. First, we review relevant theoretical models and mechanism through which collusion[3] and competition works. Later, we survey empirical literature on behavior of firms on gasoline markets and relevant experimental literature.

The reminder of the paper is organized as follows. In Section 2, we describe basic characteristics and models of oligopolistic markets. Section 3 reviews modern game-theoretical methods used to describe collusion. In Section 4 we survey empirical literature on gasoline markets, and in Section 5 relevant experimental literature. Section 6 concludes.

2 Basic models and characteristics of oligopolistic markets

The structure of the market crucially depends on the number of firms on the market, their market power, and barriers to entry. If the barriers to entry are significant only a small number of firms can coexist on the market. In an extreme case there can be only one monopolistic firm with absolute control over the price. On the other hand, in oligopolistic markets (with more than one firm), each firm's decision also has an effect on rivals' profits. Therefore,

[2]Source: `www.lw.com/resource/Publications/_pdf/pub969_1.pdf`.

[3]In the framework of economic analysis the term "collusion" includes both the explicit collusion (cartel agreement) as well implicit or tacit collusion.

firms react to rivals' actions and in every decision the firms consider not only the direct effect on their profit, but also the effects of rivals' reactions. This fact is called *oligopolistic interdependence* and it is the key difference between oligopoly and other market structures, e.g., monopoly and perfect competition.

While in the case of perfect competition or monopoly, economic theory offers explicit solutions for pricing decisions of firms, in the case of oligopoly there is no universal model, which can capture all its features and cover all possible cases. There are numerous models, each of which adopts simplifying assumptions (similarly as in the case of perfect competition and monopoly) and therefore is appropriate for other types of markets. In this section we survey the theoretical models of oligopolistic markets with a homogeneous product. One reason for this restriction is that collusion, as the main focus of ours, is difficult to sustain in markets with heterogeneous products. Therefore, collusion is not frequently observed in such markets (see Section 3.1). Another reason is that we focus on gasoline markets and gasoline can be considered a homogeneous product.

Carlton and Perloff (1999) specify the following basic assumptions and characteristics of oligopolistic markets with homogeneous products:

1. Consumers are pricetakers (i.e., there are many consumers who cannot affect the price of the product).

2. Consumers consider the products produced by all firms identical (homogeneous).

3. The number of firms is constant over time (i.e., barriers to entry are

significant).

4. A small number of firms have market power in aggregate (i.e., they can set prices above the marginal cost).

5. Each firm decides on its price or output (i.e., we assume that other variables have no significant effect on the demand in the relevant time span).

Earlier models of oligopolistic markets consider only static environments (one-shot games) in which all firms decide simultaneously either on prices or quantities. The former is described by the Bertrand model, the latter by the Cournot model. We illustrate the basic versions of these models in the case of a market with two firms and provide discussion on the cases with more firms. In order to find the outcomes of the model, the concept of Nash equilibrium[4] is used. It is necessary to point out that Nash equilibrium is established when each firm is perfectly rational and chooses the strategy that maximizes its profit given the others' strategies. Therefore, it is an outcome of rational behavior without any explicit agreement.

2.1 The Cournot model

In the Cournot model, firms choose the quantities of the good they want to produce. The aggregate demand $D(p)$ determines the market clearing price. More precisely, if q_1, q_2 are the quantities produces by the firms, then the price is determined by the equation $q = D(p)$, where $q = q_1 + q_2$ is the

[4] We consider only Nash equilibrium in pure strategies.

total quantity produced. Moreover, assume that both firms exhibit constant marginal cost c of producing one unit of the good. If $P(q)$ denotes the inverse demand,[5] the profit of the first firm can be written as $\Pi_1 = P(q_1+q_2)q_1 - cq_1$.

As an example consider demand $D(p) = 160 - 100p$ and constant unit costs $c = \$1$, yielding the inverse demand $P(q) = 1.6 - q/100$. It can be easily established that $q_1 = q_2 = 20$ in equilibrium, yielding the price $p = \$1.2$ and profits $\Pi_1 = \Pi_2 = \$4$. The equilibrium price is higher than the competitive price \$1 and this price is the result of rational behavior of all firms. However, if the number of firms increases, each firm produces less output and the equilibrium price decreases to the competitive level \$1 (see Table 1).

Number of firms	2	3	4	...	30	60	...	∞
Firm's output	20.0	15.00	12.00		1.94	0.98		0
Price [$]	1.2	1.15	1.12		1.02	1.01		1
Firm's profit [$]	4.0	2.25	1.44		0.04	0.01		0

Table 1: Equilibrium in the Cournot model

2.2 The Bertrand model

In the Bertrand model the firms are assumed to choose their prices. The consumers simply compare these prices and buy the product from the firm with the lowest price. If $D(p)$ is the aggregate demand, the individual demand of the first firm (analogically for the second firm), when it sets the price p_1 and

[5] This means $P(q) = p$ if and only if $D(p) = q$.

its rival sets the price p_2, can be written as follows:

$$d_1(p_1, p_2) = \begin{cases} D(p_1), & \text{if } p_1 < p_2, \\ \frac{1}{2}D(p_1), & \text{if } p_1 = p_2, \\ 0, & \text{if } p_1 > p_2. \end{cases}$$

This means that the firm with a lower price captures the whole market, the firm with a lower price earns nothing, and a tie is broken evenly. Note that the individual demand has two arguments (the prices set by both firms) capturing the effect of oligopolistic interdependence.

If we again assume constant unit cost c, then the profit of the first firm can be formally written as $\Pi_1 = p_1 d_1(p_1, p_2) - c d_1(p_1, p_2)$. It is well known that in this case, the only equilibrium is when both firms set their prices equal to the marginal cost,[6] formally $p_1 = p_2 = c$.

Obviously, when prices are equal to marginal cost c, no firm earns a positive profit. Note that this outcome is the same as in the case of perfect competition, where price is equal to marginal cost, but the argument used in that case is different.[7] Moreover, the above result can be generalized to more firms, where all earn zero profits in equilibrium.

The equilibrium in the Bertrand model may appear counterintuitive because it predicts the price equal to marginal cost even in the case of two firms. This is partially caused by the fact that we model the oligopoly as a "one-shot game," i.e., the firms choose their prices only once and the game

[6]Otherwise, one of the firms wants to undercut its rival, i.e., to set the price slightly lower.

[7]In perfect competition, where entry is costless, no firm can earn a positive profit in equilibrium. Otherwise other firms can recognize the opportunity and enter the market. This will decrease profits of all firms in the market.

ends.[8] However, this is not the case in reality and recent models of oligopoly work with repeated interaction (see Section 3).

2.3 Quantity leadership

Leadership, in general, is defined as a situation where one firm (leader) sets the price or quantity and other firms follow, i.e., they set their price or quantity after they learn the leader's decision. This can occur when the rivals on the market are not symmetric (they can have different size, cost structure, information about the market, etc). Similarly as in simultaneous choice models (Cournot and Bertrand, described above), we can also distinguish between two types of leadership: quantity leadership and price leadership.

The theoretical literature knows two basic models of leadership in quantity competition:[9] the Stackelberg leader-follower model and the Forchheimer dominant-firm model. The Stackelberg model describes quantity competition with one firm being a leader in quantity. This firm chooses its output before the others as opposed to the Cournot model, where the decisions are made simultaneously. If the leader knows the cost structure of the followers, it can anticipate their reaction and make a decision accordingly. This gives an advantage to the leader firm which earns a higher profit in equilibrium than in the Cournot model. On the other hand the followers earn lower profits in equilibrium than in the Cournot model.

The Forchheimer model describes a situation with a dominant firm[10] and a "competitive fringe," i.e., followers which are assumed to be too small to

[8] See Varian (1992, p. 292), for more extensive discussion.

[9] See Scherer and Ross (1990, ch. 6) for further reference.

[10] Usually, a firm is considered dominant if its market share is at least 40%.

have an effect on the price. Therefore, the followers can be considered as pricetakers and form a purely competitive “fringe,” which means that they accommodate their output so that their marginal cost is equal to the price set by the leader. If the marginal costs are increasing, then the effect of the competitive fringe is such that they decrease output when the price falls and increase output when the price rises. More detailed description can be found in Scherer and Ross (1990, ch. 6).

2.4 Price leadership

The essence of price leadership is rather different from quantity leadership.[11] Analogically as it is possible to extend the Cournot model to the Stackelberg one, it is also possible to extend the Bertrand model. However, this model is not very realistic. In such case a firm would never accept to be a price leader, because of possible undercutting. This means that the follower can offer the product at a slightly lower price than the leader to capture the whole market. In reality, price leadership refers to a situation where “price changes are normally announced by a specific firm accepted as a leader by others who follow the initiative” (Scherer and Ross 1990, p. 248). The leader position is not fixed, but it may change over time depending on its ability to lead the industry and its influence on other firms. Economic theory distinguishes three types of price leadership:[12] dominant firm, collusive, and barometric

[11] This difference is caused by the nature of price and quantity competition. It is well known that quantities are strategic substitutes, whereas prices are strategic complements. See Tirole (1992, pp. 207–208) or Vives (1999, p. 203) for details.

[12] The presented classification and discussion follow Scherer and Ross (1990, pp. 248–261).

firm.[13]

From the firms' point of view, the dominant firm and barometric leadership are perfectly rational and are established without any cooperative agreement. On the other hand, collusive leadership may be caused by an illegal explicit agreement among the firms to match their prices or it may be a consequence of rational behavior when firms maximize long-run profits — so called *tacit collusion*[14] (see Section 3 for details).

Dominant firm leadership occurs when there is a single firm dominating the industry (see above). The dominant firm sets its price taking into account the supply reactions of the followers (usually characterized as competitive fringe). The dominant firm and its followers usually differ by cost structure,[15] access to production inputs (this can be related to vertical integration), or limits on production.

Collusive price leadership was introduced by Markham (1951) in order to support the monopolistic solution to the oligopolist's pricing coordination problem. He argues that it is likely to occur when:

1. the number of firms is small,

2. barriers to entry are significant,

[13]A clear distinction between the first and the third type was pointed out by Stigler (1947), the second type was introduced by Markham (1951).

[14]"Tacit collusion" must be distinguished from "collusion" in the legal sense (meaning a cartel agreement also called explicit collusion), which is forbidden. Tacit collusion does not require any communication between the firms and it may be a result of completely rational behavior.

[15]If the average unit costs are decreasing with quantity produced, production of high quantity is more effective and small firms are not able to compete. Therefore, there are only a few large firms on such markets; in the extreme case there is only one firm (e.g., electricity distribution).

3. the product is homogeneous,

4. demand is relatively inelastic,

5. firms exhibit similar cost structure.

In case when the collusive price leadership is caused by a cartel agreement it requires only an opponent's promise to follow. On the other hand collusive price leadership may be a consequence of tacit collusion (see Subsection 3.1), which is not forbidden as rational behavior.

Barometric leadership refers to a situation when one firm serves as a barometer of the market conditions. This firm may have no significant market power, but it either responds more quickly to changes in demand or costs, or it has some superior knowledge about the market conditions. The position of the leader is assured only by its acceptance by other firms and it may change over time.

Scherer and Ross (1990) point out that it is not possible to clearly distinguish between collusive and barometric price leadership. They provide examples of several U.S. industries where price leadership was identified (in the relevant period). These are: tobacco, steel, cars, ready-to-eat cereals, turbogenerators, and gasoline. Among them they characterize the case of the gasoline market in Ohio during the 1950s as closest to barometric price leadership (pp. 259–260). To illustrate the concept of barometric price leadership, Scherer and Ross (1990), following Stigler (1947), the executives of Standard Oil Company of Ohio (Sohio):

> The major sales executives of all companies watch carefully the number and size of subnormal markets. ... If the number

> of local price cuts increases, if the number and amount of secret concessions to commercial customers increase, it becomes more and more difficult to maintain higher prices. ... Finally, some company, usually the largest marketer in the territory, recognizes that subnormal price has become the normal price and announces a general price reduction throughout the territory. ...
>
> On the other hand, in our own interest we must usually take the lead in attempting higher price levels when we believe that conditions will permit. Having substantial distribution in our market we are conformed with the fact that few marketers, especially those with a lesser consumer acceptance, can take the lead in increasing prices. ...
>
> Upward moves in our market are made by us only when, in our opinion, general prices and the economic pressure from industry costs are such that our competitors in their own interest will follow. It is notorious that when we guess wrong, or when we advance our market too far, immediate market disintegration sets in.

3 Modern methods: Repeated interaction

Modern methods of game theory analyze repeated interaction and provide a deeper insight into oligopoly pricing. Because the interaction is repeated, a firm takes into account also its rivals' past behavior (to learn from it) and possible future responses to its current behavior. Hence the action taken in each period is not only a plan of how to play in that period (as it would be when playing an one-shot game), but it is also contingent on rivals' behavior up to date. The strategy is then a complete plan of actions for future each period contingent on all possible histories. The firms' objective is to maximize the future stream of profits,[16] not only the profit of the current period. We describe three major approaches to modelling of repeated interaction known in the literature: concept of supergames, "trigger sales" model by Green and Porter (1984), and "theory of dynamic oligopoly" by Maskin and Tirole (1988).

When the interaction is repeated, perfectly rational (profit maximizing) behavior where firms decide individually may lead to apparently cooperative path of prices. This was pointed out already by Stigler (1964) and it is also present in both approaches mentioned above. Such a situation is known in game theory as tacit collusion. It is important to note that repeated interaction is a necessary condition for tacit collusion.

3.1 Supergames

Game theory considers a repeated game as a large multistage game with an infinite number of periods, called *supergame*. A number of academic papers have focused on supergames explanation of tacit collusion as perfectly rational behavior. A good textbook explanation can be found, for example, in Tirole (1992, ch. 6). Hay (1999) uses the theory and to analyze a particular anti-trust case. An excellent theoretical exploration with anti-trust applications is provided by Ivaldi, Jullien, Rey, Seabright and Tirole (2003).

[16]This means the sum of discounted profits from each period; see below.

For a better illustration of the supergames approach we consider the following example by Hay (1999), modified for the parametrization specified in Subsection 2.1. There are two essentially identical gas stations (firms) A and B on opposite sides of the road with no rivals and no possibility of entry, both with costs of \$1 per gallon. Since consumers consider the gasoline from both firms as a perfect substitute, we assume that when both firms have the same price the market is split equally. In the past the price had been equal to \$1 per gallon (the competitive level). Suddenly station A raises its price to \$1.3 which is the monopoly price.[17] This will be profitable for firm A only if firm B follows the increase; otherwise B gets the whole market.

Such action may be considered unwise from the point of view of station A, but only if it maximizes short-run profits. Similarly, if firm B is "short-sighted," it will undercut firm A (set the price slightly less than \$1.3, e.g., \$1.29 or even \$1.299 if possible). However, this will be followed by a "punishment" from firm A by setting the price again to \$1 (the next day). This punishment may be temporary (for several days) or permanent. The result of such behavior is that firm B will gain the whole market with almost a monopoly price for one day. On the other hand, if firm B follows firm A and increases its price to \$1.3, both firms keep sharing the monopoly profits equally. This strategy may be more profitable for both firms. If the firms value this stream of half of the monopoly profit forever more than they value one day's monopoly profit, firm B will follow A's increase and firm A will take the risk on increasing its price.

[17] In general, firm A may increase its price to another value, so called *focal price*. In such case the firms will share a lower profit.

Firm B's decision in the second period can be described as follows.[18] Firm B decides between having an almost monopoly profit $1.3 \cdot 30 - 1 \cdot 30 = \$9$ for one period (and zero profits forever assuming that the punishment is permanent) and experiencing a stream of future profits of \$4.5 (which is half of the monopoly profit) forever. This has a value

$$4.5 \cdot (1 + \delta + \delta^2 + \delta^3 + \ldots) = 4.5 \cdot \frac{1}{1-\delta},$$

where δ is a discount factor ($0 < \delta < 1$). This stream of profits is higher than 9 if and only if $\delta > \delta^* = \frac{1}{2}$. The value of δ^* represents a critical threshold such that collusion is possible whenever δ lies above it. In this case firm B will prefer to follow the increase and it will be profitable for firm A to "suggest" the increase. Note that this may be also characterized as firm A's attempt to become a barometric firm. If firm B follows the increase, this may be characterized as price leadership.

From the theoretical point of view the behavior described above is perfectly rational and is achieved only by individual decision without any agreements. However, these are not the only rational strategies the firms can choose; see Tirole (1992, ch. 6) or Scherer and Ross (1990, pp. 208–220), for further details. Moreover, tacit collusion as described above may also be established when the costs of all firms decrease (e.g., when the price of crude oil drops) and one of them "proposes" to keep the price at the previous level.

[18] We assume, as in Subsection 2.1, that the firms face demand $D(p) = 160 - 100p$.

3.2 Facilitating and complicating factors

Although the above example may look artificial, it provides valuable intuition about factors which discourage tacit collusion (complicating factors) and factors that help to establish and sustain tacit collusion (facilitating factors). Ivaldi et al. (2003) argue that complicating factors increase the value of the threshold δ^* making collusion more difficult, whereas facilitating factors decrease it making the collusion easier to sustain. The authors provide an overview of relevant factors and analyze their impact on the critical threshold. In the following we briefly summarize the arguments by Ivaldi et al. (2003):[19]

1. Number of firms: Obviously, the higher the number of firms, the lower share of the monopoly profit each firm can gain. Hence undercutting is more attractive, which makes collusion more difficult to sustain.

2. Entry barriers: Collusion cannot be sustained without significant entry barriers. In the period of collusion, the existing firms earn high profits. This makes entry more attractive. If there is a threat of entry the firms are less willing to collude because they will share the monopoly profit only for a shorter period.

3. Frequency of interaction: In the gas station example the sales were made frequently, to a large amount of separate consumers in relative small amounts. This facilitates coordination. On the other hand, a low frequency of interaction (for example in the case when the prices are set

[19]Compare also with Markham's conditions supporting collusive price leadership, Subsection 2.4.

for a longer period) increases the incentives to deviate since deviation delivers the monopoly profit for a longer period.

4. Transparency of prices: When prices are less transparent the threat of punishment for a firm which deviates from the collusive price is lower. Hence, collusion is easier in industries where prices are transparent and public (as, for example, at gas stations).

5. Demand changes: Collusion is easier in periods when the demand is growing than in periods when it is declining. Furthermore, when the demand is fluctuating, collusion is more difficult, because undercutting becomes very profitable at the time when the demand starts to decline (current demand is high, but there is a negative perspective of future demand).

6. Technological changes: When there is a possibility of innovation, the punishment after deviation from the collusive price may not be very harmful. Hence collusion is more difficult in industries that are subject to innovation opportunities.

7. Asymmetries: Any type of asymmetry among firms (e.g., cost structure, capacities) makes coordination more difficult. In particular, a low-cost firm is less willing to collude with a high-cost competitor because equal market sharing may be not attractive for it.

8. Product heterogeneity and complexity: Much like for asymmetries, when the products are differentiated vertically (e.g., gasolines of different octane rating) or complex (e.g., they include additional services),

collusion is more difficult. On the other hand, when the products are differentiated horizontally, the effect on collusion is ambiguous.

9. Multiple markets: Interaction on multiple markets facilitates collusion.

10. Demand elasticity: With a lower elastic demand, the firms gain more by sustaining a high price.

11. Buying power: When the buyers have a certain power, they may not be willing to pay high collusive prices. Hence, collusion is more difficult.

3.3 Trigger sales

Green and Porter (1984) provide another explanation for tacit collusion. They develop a "trigger sales" model of repeated interaction in the Cournot type quantity competition. The authors consider a model with demand fluctuations that are not directly observed by the firms. Firms behaving as monopolists in times when the price is high will lower their quantities to Cournot equilibrium level when the price is low. In particular, there exists a "trigger price," which may be an outcome of a tacit or explicit agreement, such that the firms behave as monopolists when the market price is above the trigger price, and divert for certain number of periods to Cournot type oligopolistic behavior when the market price is below the trigger price.[20] This corresponds to the punishment phase from the previous Subsection 3.1.

The explanation of such behavior is the following. Since firms do not observe the demand perfectly, they may consider a drop in price as either

[20]An analytical solution of this model is provided by Tirole (1992, p. 264).

drop in demand or an increase of a rival's production (which corresponds to undercutting from the previous subsection). The trigger price represents the threshold, at which the firms decide to lower their quantities to the Cournot equilibrium level. A typical price pattern generated by this behavior is that the price drops, remains low for certain number of periods and then suddenly rises without any external shock. Traditional view suggests that this may be a result of several unsuccessful attempts to form a cartel. On the other hand, Green and Porter (1984) argue that this price instability is actually "a feature of a stable, time-stationary pattern of prices" (pp. 95–96).

The authors note that in equilibrium the firms following the above strategies actually never deviate from the collusive behavior. Despite this it is rational for firms to increase the production to the Cournot equilibrium level when the price falls, since this threat of "punishment" makes the collusion self-enforcing.

3.4 Theory of Dynamic Oligopoly

A different approach to repeated interaction (of the Bertrand price competition) was introduced by Maskin and Tirole (1988). They use the concept of Markov perfect equilibrium to study two phenomena: the Edgeworth cycle and the kinked demand curve. In the Edgeworth cycle, firms undercut each other to increase their market share (a price war) but only until the war starts to be costly and one firm raises its price. On the other hand, in the kinked demand curve scenario, the price is stable. This is a consequence of two facts: (a) a "focal" price is sustained by a firm because it fears further undercutting if it does so and (b) each firm has no incentive to raise the price above the focal price because the rivals may not follow.[21]

The authors introduce a model of duopoly where firms alternate in their pricing decisions and respond to the rival's price in the previous period. They argue that there are many Markov perfect equilibria, but each of them is either of the kinked demand type (where the market price stabilizes to a unique focal price[22]) or the Edgeworth cycle type (where the Market price never stabilizes).

To illustrate these types of equilibria Maskin and Tirole (1988) provide the following example. Assume that the demand curve is $D(p) = 36(1 - p)$ and production exhibits zero costs. For simplicity, the firms are restricted to charge only the following prices: 0, 1/6, 2/6, 3/6, 4/6, 5/6, and $6/6 = 1$, yielding profits $0, 5, 8, 9, 8, 5, 0$ respectively. Table 2 shows examples of equilibria of the above types. Its third column contains the firm's optimal response to the rival's price (in the second column) in the kinked demand curve equilibrium. The fourth column contains the firm's optimal response in the Edgeworth cycle equilibrium. The authors argue that when both firms behave according to the strategy described described in the third column or both firms behave according to the strategy described described in the fourth column, an equilibrium is established.[23] In the first case, the price will stabilize on the value 3/6 after a finite number of periods and none of the firms will want to change it (the best response to price 3/6 is just the

[21] Compare to the quotation of Sohio executives, Subsection 2.4.

[22] In one of the equilibria, the focal price is the monopoly price.

[23] The optimal response to the price of 1/6 is a mixed strategy over prices 1/6 and 3/6. Particular probabilities depend on the discount factor.

same price). The second case corresponds to a cycle where undercutting is the best response to price increases which leads to price wars. However, in the periods of transition, they exhibit high profits. Example of such price pattern is shown in Figure 1. Note that in equilibrium both firms' strategies are perfectly rational. However, because of multiple equilibria, it is not possible to obtain a unique prediction for the price path.

profit	price	kinked demand curve	Edgeworth cycle
0	1	3/6	4/6
5	5/6	3/6	4/6
8	4/6	3/6	3/6
9	3/6	3/6	2/6
8	2/6	1/6	1/6
5	1/6	mix{1/6, 3/6}	0
0	0	3/6	mix{0, 5/6}

Table 2: Examples of equilibria (following Maskin and Tirole (1988))

4 Empirical studies

In this part empirical research on the behavior of the firms in gasoline markets will be surveyed. Gasoline is a relatively homogenous product and its prices are posted at each station. The quantity sold can be estimated from the number of customers. The major determinant of the costs of gasoline is the oil price. Development of oil prices and their relation to gasoline prices is illustrated on Figure 2. Common exogenous shocks (attack on the WTO in September 2001, war in Iraque in March 2002, recent development) cause

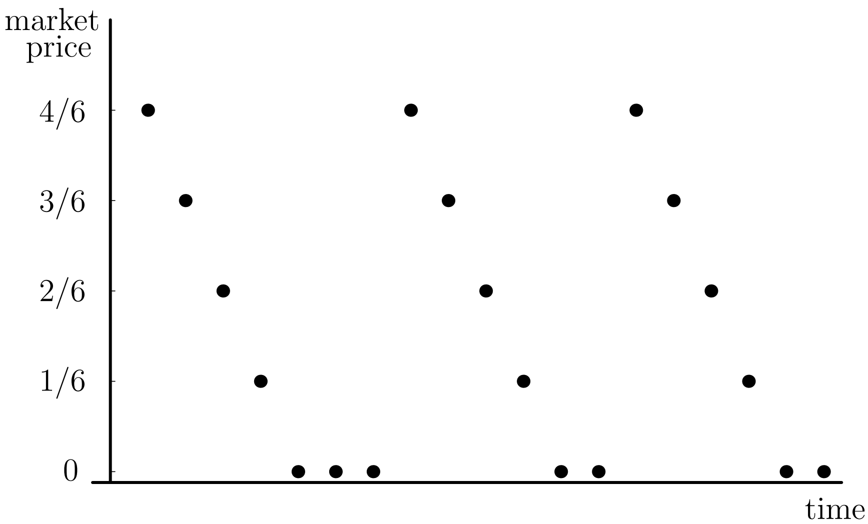

Figure 1: Edgeworth cycle (following Maskin and Tirole (1988))

increases in the input price of all suppliers. Similarly the suppliers react to changes in exchange rates, as in most countries gasoline is imported, and to increases in inflation. All these lead to parallel changes in prices of all sellers.

4.1 Asymmetric price response

There exist numerous empirical studies that analyze the firms' behavior on gasoline markets. In the following we mainly focus on empirical research dealing with asymmetric price response (or simply price asymmetry). This means that an increase in price is passed through from an upstream price (such as price of crude oil) to wholesale price and from wholesale price to a retail price, faster than a decrease in price. As a rule it is tested whether or not prices accommodate faster the upward shift of cost than the downward shift. Such a research is motivated by objection that gasoline stations are

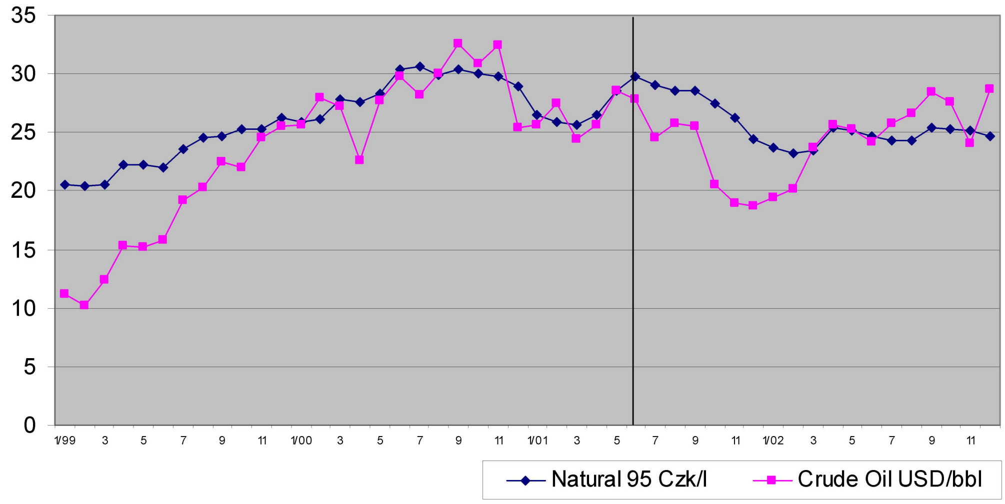

Figure 2: Price of gasoline in the Czech Republic and price of crude oil (Brent); source: `www.mpo.cz/CZ/Energetika_a_suroviny/Statistika`

more willing to increase the price than the opposite.[24]

The first who examined the phenomenon of asymmetric price response is Bacon (1991). He analyzes a response of the retail price to spot price changes. He builds a price adjustment model where the speed of upward and downward adjustment can be measured. Using semi-monthly data in the UK for period 1982–1990, Bacon (1991) finds a price asymmetry and estimates adjustment rates around two months. He argues that though there is an asymmetry in the price adjustment, it is short-lived and hence British gasoline market can still be competitive. This study was extended by Manning (1991) who also exploits UK monthly data but an earlier time period 1973–1988. Using the

[24]We skip on our survey topics as the analysis of the impact of policy measures on gasoline prices (Anderson and Johnson 1999, Johnson and Romeo 2000) and the estimates of the demand for gasoline (Schmalensee and Stoker 1999, Baltagi and Griffin 1997).

error correction model (ECM) he similarly finds an asymmetry but does not perform any formal statistical tests for asymmetric price response.

In the U.S. gasoline markets, Karrenbrock (1991)[25] examines monthly data for the period 1983–1990. He studies the relationship between wholesale and after tax retail gasoline price. His results show that in response to wholesale price, retail gasoline prices rise faster than they fall. Karrenbrock (1991) estimates the total time for prices to pass-through about two month and claims that wholesale prices were completely reflected in retail prices after that time.

Lanza (1991) focuses on the German gasoline market during the period 1980–1990. He employs monthly data and uses a two stage modelling: at the refinery and at the consumer level. The is done using a partial adjustment model with asymmetry results, which are much stronger for the retail gasoline price. A comparable analysis of German market was conducted by Kirchgässner and Kübler (1992). They estimate monthly data for two different time periods, in the 1970s and 1980s and find asymmetry only in the former one. They employ the ECM and estimate the response of both consumer and producer gasoline prices to the spot price on the Rotterdam market. The authors argue that the asymmetry in the first period was caused by distributors who had some price setting power and that structural break in the 1980s indicates that the market has become more competitive.

In contrast to Karrenbrock (1991), in the U.S. gasoline market, Norman

[25]Karrenbrock (1991) uses a partitioning model instead of the adjustment model. In this approach, data are divided into two parts, one in which there are rising prices and the other in which there are falling prices. In this approach there is a problem with determining the true lag structure.

and Shin (1991) come to an opposite result — symmetry. Using monthly and weekly data for the period 1982–1990 and applying the adjustment model, the authors conclude that retail prices move symmetrically with respect to both crude oil price and wholesale gasoline price. However, later on Shin (1992) reviews the previous literature and concludes that different price asymmetry conclusion might arise not only because of the different types of models (such as adjustment model versus partitioning), but also because of different data being used in the studies. Shin (1992) exchanges the data series of Karrenbrock (1991) and Norman and Shin (1991) and he uses exactly the same models. However, he comes to opposite results in both models as the original papers.

Another study of the U.S. gasoline market was conducted by Duffy-Deno (1996) who focuses on the local market in the Salt Lake City region. The author claims that national averages are inappropriate for testing asymmetry in gasoline price responses, because, for example, a different supply environment might significantly change the final retailer's prices and hence the symmetry-asymmetry result. Duffy-Deno (1996) uses the partitioning model and weekly data for the period 1989–1993. He finds asymmetry and estimates the complete price adjustment within three weeks. However, he finds no asymmetry during market shocks.

After the gasoline is produced in a refinery it might be resold several times until it is finally distributed to the retail outlets, therefore the transmittal of a price change from crude oil to retail gasoline depends on the response in many intermediate margins. Borenstein, Cameron and Gilbert (1997) examine price responses in these various levels of gasoline transmission. Applying the ECM and weekly data for 1986–1992, they confirm retail gasoline prices respond more quickly to increases than to decreases of crude oil prices. However, by analyzing the price transmission, they find that spot prices for generic gasoline show asymmetry in responding to crude oil price changes, which may reflect inventory adjustment effects. Asymmetry also appears in the response of retail prices to wholesale price changes, possibly indicating short-run market power among retailers.

Much like Bacon (1991) and Manning (1991), Reilly and Witt (1998) examine the UK market. They extend the previous work and include the dollar-pound exchange rates into the model. They use monthly data and their results also support the asymmetry hypothesis.

There also exist other studies which support symmetric pricing behavior. One of them is a paper by Godby, Lintnera, Stengos and Wandschneider (2000). Using weekly data for thirteen cities for the period 1990–1996 they examine the Canadian gasoline market.[26] The authors suggest that the reason for this different result (symmetry) is related to differences in market structure, in the dataset, and in the methodology.

Asplund, Erriksson and Freiberg (2000) explore the Swedish market. They use daily data for 1980–1996 of retail prices of the biggest retail seller of gasoline in Sweden. They also find using the ECM that the retail price is stickier downwards than upwards in response to cost shocks. The authors ex-

[26]Godby et al. (2000) use the Threshold Autoregressive (TAR) model within the ECM framework, because they find it more appropriate for Canadian market. In comparison with the TAR model, the asymmetric full adjustment model allows that there is a different response to crude cost increases and decreases, but it requires that the threshold for this asymmetric response be a zero change in the crude cost and does not allow for a dynamic threshold effect. This problem is resolved in the TAR model.

plain the different price response to exchange rates and spot prices by means of the volatility of both series.

In a recent study, Manera, Galeotti and Lanza (2001) examine very recent monthly data and compare five countries: Germany, France, UK, Italy, and Spain. They use a model with two stages: first refinery stage and second distribution stage. Performing the ECM they find asymmetric price behavior in both stages for all countries.[27]

On the contrary to previous studies, Bettendorf, van der Geest and Varkevsser (2002) examine the Dutch retail gasoline market and come up with mixed results. They divide daily data into groups according to days from Monday to Saturday and estimate a regression for each day. Their results are very sensitive to the choice of the day. The authors find an asymmetry for Monday, Thursday, and Friday, whereas for Tuesday and Wednesday dataset symmetry cannot be rejected. They conclude that the effect of asymmetry on Dutch consumers is negligible. Their work provides evidence that the chosen data and their frequency can influence the obtained results.

The findings in the literature about asymmetric price behavior of gasoline are mixed, however the prevailing result is asymmetry. Mixed results are obtained due to different methodologies applied and model specifications used, but also due to different data frequencies, sample periods, and countries studied. Each country has a different seasonal demand pattern, a different tax structure and further, except U.S., it is necessary to include exchange rate effects into a model.

The chosen frequency is an important issue in estimating asymmetry and

[27] Manera et al. (2001) use improved F-statistics in order to test their results.

the results are highly sensitive to it. Frequency should be very high, daily or higher, which is not usually the case in empirical studies. In reality prices at the gas station change with daily frequency (don't even mentioning crude oil price, which changes with even higher than daily frequency). The volatility of those series is very high, and hence using a lower frequency data may influence the result in a way that certain price adjustment would not be covered in the estimation. For example, an upward shift followed by downward shift with similar intensity within one week will not appear in a weakly or monthly data and that would generate an information loss. A higher frequency might be a reason for different results for full path trough of prices. Karrenbrock (1991), using monthly data, estimates full path-through of prices as two months. On the other hand, Duffy-Deno (1996), using weekly data, finds price adjustment lasting in three weeks.

The same problem as with using monthly or weekly averages applies to country or regional averages. Prices are usually spatially differentiated and different firms in the market react with different lags. Therefore there might be an important data loss in the averaged data.

Moreover, the chosen period is important. The behavior of retailers as well as market structure can change over time (for example, due to entry and mergers). The sensitivity for time period is nicely showed in Kirchgässner and Kübler (1992), who obtain opposite results for the 1970s and 1980s. They argue that there were different competitiveness environment in these two periods. In addition to market structure, there are also possible price shocks[28] that also might influence the result.

[28]For example, the Exxon Valdez oil spill in 1989 and the Persian Gulf War in 1990 and

There is a need for data with higher frequencies, weekly and daily and it is better to use more specified data not country averages. Furthermore, not all of the studies perform the most recent statistical tests and hence may obtain different results. Therefore, whatever are the results (symmetry or asymmetry), they might be weak and can be possibly attacked.

In general, markets with an asymmetric price adjustment to a cost change are deplored from non-competitive behavior. Assuming a competitive market, prices are very close to the marginal cost and in addition independently on the cost change, prices should change in the same direction as well so that in the new equilibrium prices are again close to the marginal cost. Moreover, there is a hidden assumption that the competitive environment forces firms to react quickly and symmetrically while adjusting their prices, otherwise they would face a negative profit and that is why the asymmetric adjustment is suspicious.

4.2 Possible explanations for the asymmetric price response

The reasons for asymmetric response of gasoline prices to the cost change are not well explained in the literature. Current mainstream economic theory failed to explain asymmetric price response to changes in the crude oil price. Because the asymmetry is a dynamic problem it cannot be resolved using a static approach. Nevertheless, there are several hypotheses that try to explain this issue.

1991.

Borenstein et al. (1997), do not only estimate and analyze the asymmetry, but also try to explain why there might be the asymmetry in the data. They provide three possible explanations. The first hypothesis states that asymmetry in the reaction of wholesale (refinery) prices to changes in the prices of oil can be explained by the asymmetry in costs of changes in inventories. The authors provide the following example. If half of the world deposit of oil disappeared, then the price of gasoline would increase, and its consumption would decrease significantly. Oil companies could accommodate that change quickly by raising gasoline prices and store the excess gasoline until production accommodates as well. On the other hand, if world deposit of oil suddenly doubles, the refiners would be unable to fulfill the whole demand even by using inventories, since inventories should be nonnegative and they can not immediately increase production. Thus the gasoline price would be higher than the equilibrium price until the production does not accommodate.

The second hypothesis states that the asymmetry in the reaction of retail prices to changes in wholesale prices can be explained by tacit collusion. They argue that the trigger sales model by Green and Porter (1984), described in Subsection 3.3, may explain the asymmetry in the price responses. The model is consistent with different speeds of responses to negative and positive shocks. However, it does not explain how retailers will coordinate on a particular price. The authors argue that the old price may well serve as a natural focal price (see footnote 17). After a negative shock, the firms may not cut their prices, but rather maintain the old price as a focal price. On the other hand, they naturally accommodate after a positive shock.

In the last hypothesis Borenstein et al. (1997) argue that when crude oil prices are more volatile, retailers can have more market power. Since consumers are aware of the volatility, their search cost increases and they are more likely to believe that increased prices at gasoline station reflects an increased crude oil price. This implies a temporary decline of demand elasticity and thus increases the margin of retailers. They might even overshoot the price. Sellers may maximize their profits by randomizing their price in order to price discriminate between informed and uniformed consumers.

Marvel (1976) argues similarly with a story describing a tourist's behavior. He explains that it does not pay for a tourist to search for low prices, since the gain from obtaining a low price quotation applies only to one purchase. Similarly, in the gasoline market we expect the price behavior of high-volume stations located on major intercity routes to be quite different form that observed at stations on intracity arteries frequented by the same buyers over time.

Though, there are some hypotheses about the connection between asymmetry and market power, they are neither satisfactory approved by theory, nor there is any empirical evidence for this claim. On the other hand, in a recent paper Borenstein and Shepard (2002) analyze and test the connection between asymmetry and market power. The authors examine how gasoline prices response to cost shocks (changes in crude oil price) and how those responses might be affected by market power. They try to disclose irregularities in price setting behavior (asymmetry) with increasing market power. Borenstein and Shepard (2002) claim that adjustment rates are affected by market power as well as by cost and demand. "For example, all else constant, a monopolist facing a linear demand curve will adjust price less quickly than would a competitive market, but a monopolist facing a constant-elasticity demand curve will adjust price more quickly." (p. 118).

In particular, the authors examine the relationships between refiners and terminals (wholesalers) for both branded and unbranded gasoline.[29] They conclude (upon the results of their econometric model) that it is more likely that a higher market power leads to a slower adjustment in both directions upward and downward. Their result does not support the hypothesis that market power results in asymmetry. Though, there are some indications of asymmetry in unbranded gasoline because there is a slightly quicker upward price adjustment. This is interesting since branded sellers have more market power. In general a firm with market power would choose a different adjustment rate than occurs in a perfectly competitive market.

4.3 Empirical tests using theoretical models of collusion

Borenstein and Shepard (2002) together with others who examine asymmetric behavior of gasoline prices ignore demand shocks and deal only with cost shocks in their models. However there is a literature discussing price wars. Price wars usually start after a demand shock. The reason for the price wars occurrence is that firms after a shock want accommodate their prices and production to a new demand and split the market and customers.

Slade (1992) offers a deeper insight into the topic of price wars and col-

[29]Branded gasoline is gasoline sold by well established gasoline stations with certain reputation.

lusion. She introduces an econometric model for the Vancouver, British Columbia region. The author wants to uncover the pricing behavior of gasoline stations after a demand shock. She ignores the effect of cost change on the price setting behavioral and assumes that marginal costs are constant over time. Slade (1992) applies a game theoretical model with players corresponding to the gas station managers who compete daily and use strategies that depend on previous prices. She assumes that gasoline is a differentiated product and firms in the gasoline market choose its price to maximize their profits. It is the classical profit maximization problem, besides the demand for gasoline in a particular station depends on price set by that station as well as on prices of other stations. Therefore, the pricing behavior is a game where gasoline stations are players and price setting is their strategy.

If this game is played once it has a unique Bertrand-Nash equilibrium. However, as argued in Section 3, repeated interaction introduces a possibility to tacitly collude on a better equilibrium than the Bertrand-Nash from a one-shot game. The game starts after the demand shock is realized. Every period, firms observe new price-quantity combinations and update their prices accordingly. Players use continuous strategies, where price depends on intertemporal reaction functions, which means that it responds to the price change of other firms. The slope of the intertemporal reaction function determines the level of collusion. Slade (1992) shows that for a one-shot game the zero slope yields Bertrand-Nash price whereas if the slope of intertemporal reaction function equals one, equilibrium price is perfectly collusive — monopolistic.

According to this model, and having the appropriate price, cost and quantity sold data, it is possible to estimate the level of collusion. In the empirical part of her paper, Slade (1992) estimates demand functions for each firm and slopes of intertemporal reaction functions. Comparing the actual results with theoretical predictions she shows that the actual profit lies somewhere in the middle between the Bertand-Nash and monopoly. The continual interaction among firms in the market forces them to use cooperative strategies and in finite time they can coordinate on equilibrium prices better than Bertrand-Nash and hence they create a tacit collusion.

Slade's analysis shows that in an environment of gasoline stations, firms may tacitly collude on higher prices than perfectly competitive prices (see Section 3.1). With the mechanism of supergame strategies, and under certain assumptions that firms value future profits and punish defection, gasoline stations can even collude on monopolistic prices. Therefore, if in reality we see too high price of gasoline, we cannot precisely distinguish whether it is due to cartel agreement, which is prohibited or whether it is a result of tacit collusion, and hence a result of rational long-term strategic behavior.

Borenstein et al. (1997), Borenstein and Shepard (1996) as well as Slade (1992) provide empirical evidence consistent with local retail market power. They consider independent retail gasoline stations and fully vertically integrated stations. Both have different cost structures. In case of independent retail petrol stations, the retail price is set by a residual claimant with market power, as the case may be for dealer-run stations, the dealer may set a super-competitive mark-up over the refiner's wholesale price of gasoline. A company-operated station does not have this second margin, therefore the company-operated contract may lead to lower prices since it avoids the double marginalization problem.

Recent research by Clemenz and Gugler (2004) is motivated by the possibility to determine whether there is price competition or collusion in the spatial competition model. They analyze relationships between population density, density of outlets, and prices for the Austrian gasoline market. The authors find that a higher station density reduces average prices. Estimation of the pricing and entry equations as simultaneous equations does not alter their conclusions, and suggests that causality is running from station density to price. Moreover, market concentration does not have a significant relation to the price.

In order to decide whether firms behave anti-competitively a benchmark model against which to compare actual market conduct is needed. Gasoline markets are characterized not only by a large fixed or sunk entry and exit costs but also by a strong spatial dimension. As Clemenz and Gugler (2004) argue, the spatial dimension of markets allows to identify whether a market conduct is competitive or collusive. The competition hypothesis assumes that, the nearer gasoline stations are next to each other, on average, the lower should be the equilibrium price they can charge. The collusion hypothesis would be no or even a positive relation between station density and price. Such an approach allows companies that are suspected from cartel to prove that they do not collude. On the other hand, an opposite result still does not provide a direct evidence of cartel agreement for the competition authority.

5 Other supporting evidence: Experimental studies

In this section we describe briefly the results of several economic experiments relevant to tacit collusion in general and gasoline markets in particular. Roth and Murnighan (1978) report the results of an experiment with the "Prisoners' Dilemma" game. This game has a structure similar to the Bertrand model where firms choose prices.[30] The authors report that in the experiment, the subjects chose to cooperate more times when they knew that there was a high probability of continuation (meaning high probability to punish the opponent if he defects). This phenomenon is consistent with the factors facilitating and complicating collusion as described by Ivaldi et al. (2003); see Subsection 3.1.

An experimental study by Deck and Wilson (2003) focuses directly on gasoline markets and offers a deeper insight into so called "zone pricing." This means that the prices in relatively small isolated regions are higher than the prices in central regions with more gas stations. The authors argue that the prices in central regions react faster to cost increases, but the prices in isolated regions react symmetrically to both cost increases and cost decreases.

Another type of experiment was conducted by Axelrod (1984)[31] who asked several experts to submit a strategy (in the form of a computer program) for repeated Prisoners' Dilemma. Then a one-on-one tournament was played.

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[30] The strategies "defect" (or "confess") and "cooperate" (or "not confess") can be considered a low and a high price.

[31] The description in this paper follows Scherer and Ross (1990, pp. 216–219).

Although the strategy "defect in every round never" lose.[32] the winner of the tournament was a strategy called "Tit-for-Tat" according to which the player cooperates in the first round and then plays the same as the opponent did in the previous round. In the oligopolistic market this would correspond to behavior as a price follower. Hence this result suggests that price leadership may be explained as rational behavior from the follower's point of view when opponent's future strategy is not known.

6 Conclusion

As we already pointed out, current economic theory does not provide a basis that would allow to clearly distinguish between a cartel agreement and tacit collusion. Inferring infringement of the competition laws from the market data requires reliable and detailed data. A higher level of prices or price parallelism is indication that firms collude, however the firms might have previously agreed on prices but they could also have made the decision on prices implicitly without any communication or agreement.

As non-collusive equilibrium price is lower than the collusive one and the incentive to coordinate the behavior in order to get higher profits is strong. In praxis firms can coordinate on a particular collusive price in different ways. Firm's managers can come together and agree on coordination and create cartel in order to get the monopoly price. However such as such coordination is illegal, firms prefer to solve the coordination without communication. We described several mechanisms which may solve coordination problem. One of

[32]This corresponds to the Nash equilibrium (price being equal to marginal costs) in the Bertrand model.

them is price leadership, where firms can use public announcements of price changes and signals (in daily newspaper or via internet, in case of petrol stations prices are posted at each station). Another explanation suggests that when demand or costs decrease, the old price may serve as a focal price. Therefore, much of outcomes that indicate cartel agreements may be as well explained by firms' rational behavior.

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