Abstract
We study the initiation of collusion in the German retail market for gasoline in the year 2015 following the introduction of a price matching clause by a major supplier, Shell. Before the clause, the Edgeworth cycles common for gasoline markets had been observable, which consists of a regular upward jump by stations in the evening and mutual undercutting following rush hours in the morning. One month after the introduction of a price matching clause and directly before an expected negative demand shock caused by the major summer holidays, a noon upward jump interrupts mutual undercutting occurring against the downward trend around noon. The first, initial break of the regular cycle is performed by ARAL, the major competitor of Shell. During the three-week long emergence phase of collusion, however, the noon jump occurs alternatingly at noon between Shell and ARAL, the two leaders seeming to play mixed strategies and determine the jump time. These “Eagles” are first in the pecking order followed by “Hawks” and “Vultures” lagging behind to a different degree, depending on whether they are chains or small independent stations as well as distance to a peer “Eagle”. Roughly 3 cents/liter can be maintained throughout the entire rest of the day and correspond to roughly 3 billion of Euro customer damage per year. After some weeks, Shell experimented with an extension of this increase to earlier times of day. Both the mixed strategy at noon as well as in the evening, however, prevail.

JEL Class: L1, L5, L9
Keywords: Price Matching Clauses, Emerging / Establishing Collusion, Gasoline Retail Market, Edgeworth Cycle, Commodity Good
1 Introduction

We investigate the emergence of collusion. This is a relevant topic of great interest in practice, which is still underresearched in particular form an empirical point of view. In addition to the existing literature on explicit agreements such as price fixing, not much is known about implicitly coordinated behavior. This is a blank spot in the literature, as it can be as detrimental to efficient allocation as explicit allocation. Byrne and De Roos (2016) investigate the tedious process of establishing collusion by sending price signals to repeatedly fix focal points of tacit collusion. They observe the long horizons of up to several years necessary to establish implicit collusive behavior. What if firms want to accelerate this process? Which kind of instruments can help them to credibly convey a signal to competitors that they would like to collude?

The German gasoline retail market has been characterized by a stable Edgeworth cycle including an evening jump and a mutual undercutting phase starting in the morning after rush hour at around 9 am ending in the evening at around 6 pm before the restart of the cycle. Then Shell introduced a price matching clause (PMC) on May 27, 2015, serving as a credible coordination device to establish substantial price jumps at noon. Together with the other dominant firm ARAL (41%, Shell 29% market share), both firms acted as a market leaders, we term them “Eagles”, followed by their competitors lagging behind by up to three hours, we term them “Hawks” and “Vultures” depending on the magnitude of lag. Hawks are typically branded stations following in the subsequent hour, whereas Vultures belong to smaller chains or are unbranded and range between one and three hours after the peer Eagles’ jump. They succeed to implement this “high noon” 28 days after the introduction of the PMC, on a Wednesday before the major summer holidays in Germany started. They succeed to coordinate gradually over the subsequent three weeks after the first noon jump to spread their coordinative behavior over the whole geographical region.

This is a remarkable empirical finding, because there is rare research on the emergence of collusion, cf. e.g. Harrington and Chen (2006), Harrington and Chan (2009), in particular (causal) empirical evidence is sparse. In a non-causal empirical matching study, Arbatskaya, Hviid and Shaffer (2006) e.g. found the opposite effect of PMCs increasing competition. Theoretical research suggests that PMCs might well be anti-competitive (see e.g. Schnitzer 1994). The wish to coordinate among the Eagles ARAL and Shell is not new to the German market. In the past, the German Cartel Office found Shell and ARAL coordinate on price increases irregularly during the course of a week, also alternatingly but then always with the other one to follow after exactly three hours (GCO 2011). The other stations then followed at a certain lag, which is similar to the new, regular noon jump behavior that we find in this study. Similar to the Western Australian case studied in Wang (2009), suppliers re-established collusion also after a change of game – in Australia the day-ahead price announcement rule replacing permanent adjustments, in the German case the introduction of a market transparency platform – and right away established picture book Edgeworth cycles. Then, after Shell’s PMC introduction, ARAL and Shell succeed to extend collusion to the noon jump.

We investigate the change of firms’ behavior in the German gasoline retail market after the introduction of the Shell PMC. Firms’ price setting actions are observable on a minute-by-minute basis. Disposing of a sample of 15,000 firms over 2 years we restrict our sample to four months and roughly 600 gas stations including Shell and Aral stations as well as all other stations serving either as followers in the same market or as control group in different local markets. With regard
to the control group, we conduct sensitivity analyses varying the composition according to the spatial distance to Shell and Aral markets and, in addition, choose by different matching criteria on the basis of local market characteristics.

Applying diff-in-diff regressions we find all stations to increase prices, also in control markets, but Shell and ARAL to increase prices earlier than the rest of the market, thereby infecting the other stations in their markets and other local markets belonging to the control group. It takes firms several weeks to implement this midday price increase, but coordination is monotonously reinforced over the entire period and stable extending the number of stations participating in the coordination on a day-to-day basis. We show Shell and ARAL to coordinate on the noon upward jump playing mixed strategies by the test for uniform distribution of upward jumps conditional on firm identity used in Wang (2009). Otherwise firms play Edgeworth Cycles.

We thereby contribute to the literature by showing in detail how PMCs making demand more inelastic can facilitate the implementation of collusion. This is a riskless unilateral firm action and collusive offer by the second biggest player Shell, which is answered by the major player in the market, ARAL, accepting by the initial jump on June 24, 2015, three days before the expected summer holidays demand shock.

The next section gives an overview of market players’ actions in the German gasoline retail market before and after the implementation of the PMC. Section three describes the empirical strategy. This includes the different diff-in-diff approaches and identification as well as the tests for mixed strategies. It further describes the data set and describes the intuition of the game and the change of the game by diverse diagrams. It also gives regression results in a last subsection. Section four concludes.

**Review of Related Literature**

With regard to the empirical literature on the implementation of collusion refer to Byrne and De Roos (2016). To our knowledge, this is the only study on the implementation of tacit collusion. There have been studies on the impact of explicit agreements such as cartelization. There have also been studies on the impact of price matching clauses (PMC) such as Arbatskaya, Hviid and Shaffer (2006) finding mixed evidence. The authors e.g. find the opposite effect of PMCs increasing competition. There is, however, no empirical literature on the use of price matching as a collusive device finding causal evidence and investigating in detail how single market participants find focal points facilitated by the PMC.

There exist two studies by Wilhelm (2016) and Schwalbe and Dewenter (2015, in German), which investigate the aggregate effect of the price matching clause, but not the way it is used as a device to establish collusion and a corresponding focal point. Wilhelm (2016) finds that the price matching clause by Shell rose prices by 1.68 Euro cents per liter E5 after the introduction of a price matching clause. The effect on nearby stations is with 0.07 Euro cents in economic term not relevant and even statistically given the high amount of observations hardly significant. However, the price-increase following the introduction of the price matching clause is mainly driven by higher prices at night times, leading to a higher amplitude (43 per cent) of the daily Edgeworth cycle. Hence, the author follows that the best price clause in this case is mainly motivated by price discrimination motive to charge higher prices to price-inelastic consumers without losing demand by price sensitive consumers. However, the midday increase is ignored in this investigation.
Schwalbe and Dewenter (2015) investigate daily prices after simple averaging. This severely neglects the demand pattern shown in figure 2 below and also ignores the midday increase by the two colluding firms Shell and ARAL.

2 The German Gasoline Market

Exemplary Effects of the Price Matching Clause on Two Local Markets

The gasoline retail market is typically characterized by Edgeworth Cycles. Maskin and Tirole (1988) characterized this difference game in alternating moves and derived different equilibrium trajectories: Depending on the discount factor monopoly pricing, competitive pricing and Edgeworth Cycle pricing might emerge. Edgeworth Cycle players play mixed strategies: minimum cost pricing with a positive probability to jump to a market power (monopoly) price followed by a mutual undercutting at the minimum price increment. As in many other markets (see Eckert 2013) this pattern had been observed in German gasoline retailing as well as following diagrams reveal. Starting from an initially high price level during the night, stations successively decrease prices from around 9 am on, i.e. after the morning rush hour. They pursue undercutting unless they reach a (slightly differentiated) minimum price level, which endures from around 3 to 6 pm, for single stations until 9 and 10 pm. The first stations, typically an Eagle station, i.e. ARAL or Shell, relent and jump up for around 10 to 20 cents/liter.

![Figure 1](image-url)

Figure 1 Individual stations’ prices before the introduction of the price matching clause (PMC) by Shell

However, stations not only find no customers during the night-time in this high-price state, but the choice of the states might even be influenced by expected and deterministic demand shifts. Following diagram shows that the price jumps occur in the evening when demand drops to levels near zero (6 to 9 pm) and the undercutting just kicks in when demand reappears on the market (6 to 9 am).
These demand shifts are not changing the Maskin/Tirole game investigated empirically e.g. by Noel (2007) completely. The critical discount rate determining the different equilibrium paths changes conditional on the demand level. Thereby, decreasing or expected low demand and a lower share of searchers induces price jumps, whereas increasing or expected high demand and a higher share of searchers induces the undercutting phase (Rotemberg and Saloner (1986)). This explains the supporting nature of fundamental demand shifts during the day for the pattern of the Edgeworth cycle with an upward jump in the evening (beginning of low demand period) and the initiation of mutual undercutting during the morning (beginning of high demand period).

This well-known pattern is interrupted four weeks after the introduction of the PMC by Shell, three days before an expected major demand decline caused by the summer holidays. Following diagram shows the midday increase in two exemplary local markets, which clearly happen during the decreasing phase of the Edgeworth Cycle. The noon jump only occurs after the implementation of a PMC making search less attractive and by the additional support of a negative demand shock caused by the summer holidays.

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2 The author investigates e.g. the probability for a successful upward jump conditional on the number of participants in the local market (which is decreasing).
3 See Appendix I.
The noon jump also prevails after the end of the summer holidays. On the other hand, the summer holiday demand shock in the preceding year without the PMC was not sufficient to allow for an additional upward jump at noon. Therefore, this effect can well be attributed to the implementation of the PMC.

Furthermore, the demand for the PMC was substantial. The bonus program used to implement this automatic discount is called Shell Clubsmart. 6.8 mln customers dispose of a Clubsmart card. The Clubsmart card is 5th most widely distributed single company bonus program in Germany and 7th in the overall ranking (10% of households, Dec, 2014).  

79% of existing Clubsmart card owners find price-matching offer ‘moderately interesting’ to ‘very interesting’ (65% ‘interesting’ to ‘very interesting’) and, in addition, 13% of non-Shell customers would think about switching to Shell for the program. 16% of regular Shell customers would take part in the program. We therefore deem the influence of the program to be significant.

**Market-wide Effects of the Price Matching Clause**

It is interesting to take a look at the margins in the market. We take a quantity weighted average. Following figure shows a steady margins increase after the introduction of the PMC. On the day of the official start of the program though, May 27, ARAL and Shell stick to their historical Edgeworth cycle pattern and abstain from the jump at noon. Stations are not able to coordinate on the noon jump unless the negative demand shock caused by the summer holidays realizes. During the transitional phase margins increase, but especially in the aftermath of the noon jump stations increase margins and maintain them on a high level.

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5 “More than every second household (54 per cent of households) has a payback card. The Ikea Club Card (27 percent), the Tchibo Card (18 percent), the DeutschlandCard (17 percent), the Douglas Card (16 percent), the Peek & Cloppenburg customer card (12 percent), the Shell ClubSmart card 10 percent), the bahn.bonus Card (9 percent), the Miles & More card and the online provider Groupon each with 8 percent.” Retrieved on TNS Emnid Medien- und Sozialforschung GmbH im Auftrag der Payback GmbH im Zeitraum von November bis Dezember 2014, [https://www.marktforschung.de/nachrichten/marktforschung/kundenkarten-die-meisten-verbraucher-vertrauen-payback/](https://www.marktforschung.de/nachrichten/marktforschung/kundenkarten-die-meisten-verbraucher-vertrauen-payback/)

6 Retrieved June, 2016, exeo Strategic Consulting AG / Rogator AG.
During the school holidays, daily traffic is reduced by about 2.5 per cent as the following estimation results table shows. Traffic volume is simply regressed on weekdays and holidays as well as an adjustment phase dummy. The adjustment phase reveals to be insignificant, whereas weekdays and public holidays are highly significant. The long school summer holidays are the only expected, lasting structural shock.
Table 1 Traffic explained by temporal dummies

<table>
<thead>
<tr>
<th></th>
<th>(1) Ln of daily traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public holiday</td>
<td>-0.3087***</td>
</tr>
<tr>
<td></td>
<td>(0.0109)</td>
</tr>
<tr>
<td>School holiday</td>
<td>-0.0246***</td>
</tr>
<tr>
<td></td>
<td>(0.0081)</td>
</tr>
<tr>
<td>Adjustment phase</td>
<td>-0.0021</td>
</tr>
<tr>
<td></td>
<td>(0.0069)</td>
</tr>
<tr>
<td>Sunday</td>
<td>-0.2574***</td>
</tr>
<tr>
<td></td>
<td>(0.0128)</td>
</tr>
<tr>
<td>Monday</td>
<td>-0.0126**</td>
</tr>
<tr>
<td></td>
<td>(0.0062)</td>
</tr>
<tr>
<td>Tuesday</td>
<td>0.0000</td>
</tr>
<tr>
<td></td>
<td>(.)</td>
</tr>
<tr>
<td>Wednesday</td>
<td>0.0236***</td>
</tr>
<tr>
<td></td>
<td>(0.0072)</td>
</tr>
<tr>
<td>Thursday</td>
<td>0.0284***</td>
</tr>
<tr>
<td></td>
<td>(0.0058)</td>
</tr>
<tr>
<td>Friday</td>
<td>0.0336***</td>
</tr>
<tr>
<td></td>
<td>(0.0108)</td>
</tr>
<tr>
<td>Saturday</td>
<td>-0.1462***</td>
</tr>
<tr>
<td></td>
<td>(0.0110)</td>
</tr>
<tr>
<td>Constant</td>
<td>9.9938***</td>
</tr>
<tr>
<td></td>
<td>(0.0054)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.9274</td>
</tr>
<tr>
<td># Obs.</td>
<td>118</td>
</tr>
</tbody>
</table>

The two exemplary local study case markets show a switch to an additional at noon, which amounts to 3 cents/liter and successively spreads throughout the whole market. Together with the regional aggregate market effect of raising margins following the PMC introduction, this suggests PMC having been introduced to facilitate implicitly coordinated behavior.

The detailed process of how players’ change their actions and the development of resulting market equilibrium in the aftermath of the PMC introduction is highly interesting. The gradual path to the new focal point of coordination and the strategies players play merits tells us a lot about how firms coordinate and how they use legal facilitating devices for implicit coordination. We will therefore take a closer look at the data in subsequent section, followed by a description of the empirical strategy to show, first, market equilibrium effects, and, second, the players’ price setting behavior shedding light on their strategies. Results are presented in a subsequent section.

3 Empirical Analysis

3.1 Data

The price data, we are using in our empirical analysis stems from the price-comparison website ‘spritpreismonitor.de’\(^7\). Here, we obtained minutely prices for the cities Düsseldorf, Wuppertal,

\(^7\) http://www.spritpreismonitor.de/
Gladbach, Duisburg, Essen, Dortmund, and Leverkusen with a radius of 50 kilometers. This allows us to observe the entire Ruhr area plus the metropolitan area around the city of Cologne. The entire catchment area is shown in figure 6. The red area is the core area for creating the local markets, while the gas stations in the yellow area only serve as reference stations for stations in the core area. It covers the lion’s share of densely populated of North Rhine–Westphalia, which disposes of approximately 17.84 mln inhabitants.

**Figure 6: Catchment area**

Table 2 summarizes the dataset that we use in our empirical specification. The period the entire data set covers is May 1 to August 26, 2015. 41 per cent of day-station observations are ARAL stations. This corresponds to a share of 29 per cent ARAL stations in the data sample, indicating that ARAL stations show an above-average probability for a midday increase and are closed less often than other gas stations. The same is true for Shell that represent 29 percent of the sample observations and a share of 22 per cent of all gas stations. The average number of competitors in a local market (radius of 1.25 miles) is 5.64 station with a maximum of 13 and a minimum of only one station.

For a subset of statistical analyses we focus on the emergence of midday collusion. The dataset is then restricted to the time period with midday price increases and consists of 18,200 station-day observations, including 502 unique gas stations on 55 days (23rd of June – 26th of August 2015). The midday price increase is defined as an additional increase between 11:00 am and 12:30 am and has been observed for the first time since the introduction of the market transparency platform. However, not every station shows a midday increase every day or participates in the market on

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8 Generally, this is a time span of 65 days, however, we are missing ten days (June 25th and 29th, July 10th to 13th and 22nd to 24th, and August 1st) where the crawler failed to obtain the price data.
each day (as the outlet might be closed on weekends or public holidays). The variable Minutes measures the time after midnight when the price increase for gas station s was observed. This measure allows us to see who jumped first on a given day. On average this midday jump took place 727 minutes after midnight which translates into 12:07 am. The price was on average 1.45 cents/liter at the time of increase and 1.48 cents/liter after the increase. This is in line with the observation that nearly every price increase (90 percent) was in the magnitude of three cents.

Table 2: Summary Statistics (1) only time after first midday jumps are seen

<table>
<thead>
<tr>
<th></th>
<th>Count</th>
<th>mean</th>
<th>Stand. Dev.</th>
<th>min</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minutes</td>
<td>18,200</td>
<td>727.10</td>
<td>14.17</td>
<td>661.00</td>
<td>750.00</td>
</tr>
<tr>
<td>Price at increase</td>
<td>18,200</td>
<td>1.45</td>
<td>0.05</td>
<td>1.30</td>
<td>1.80</td>
</tr>
<tr>
<td>Price after increase</td>
<td>18,200</td>
<td>1.48</td>
<td>0.05</td>
<td>1.32</td>
<td>1.83</td>
</tr>
<tr>
<td>ARAL station</td>
<td>18,200</td>
<td>0.41</td>
<td>0.49</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Shell station</td>
<td>18,200</td>
<td>0.29</td>
<td>0.46</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Other station</td>
<td>18,200</td>
<td>0.29</td>
<td>0.46</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td># of Competitors</td>
<td>18,200</td>
<td>5.64</td>
<td>2.66</td>
<td>1.00</td>
<td>13.00</td>
</tr>
<tr>
<td>Monday</td>
<td>18,200</td>
<td>0.13</td>
<td>0.34</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Tuesday</td>
<td>18,200</td>
<td>0.13</td>
<td>0.34</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Wednesday</td>
<td>18,200</td>
<td>0.17</td>
<td>0.38</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Thursday</td>
<td>18,200</td>
<td>0.16</td>
<td>0.37</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Friday</td>
<td>18,200</td>
<td>0.14</td>
<td>0.34</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Saturday</td>
<td>18,200</td>
<td>0.13</td>
<td>0.34</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Sunday</td>
<td>18,200</td>
<td>0.12</td>
<td>0.33</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>School holidays</td>
<td>18,200</td>
<td>0.68</td>
<td>0.47</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Car density</td>
<td>18,200</td>
<td>503.23</td>
<td>51.48</td>
<td>430.00</td>
<td>599.00</td>
</tr>
<tr>
<td>Population density</td>
<td>18,200</td>
<td>117.95</td>
<td>260.87</td>
<td>1.07</td>
<td>974.00</td>
</tr>
<tr>
<td>Oil price</td>
<td>18,200</td>
<td>33.61</td>
<td>3.43</td>
<td>26.93</td>
<td>39.77</td>
</tr>
</tbody>
</table>

68 percent of our sample spanned the summer school holidays which lasted from June 27 (Saturday) to August 11, 2015 (Tuesday) in the North Rhine–Westphalia, the state where our sample’s stations are located. About half of the population owned a car as the car density is 503 on 1000 persons and the population density was 117 persons per square kilometer, confirming the general metropolitan character of the area. Last but not least, the oil price for Brent ranged between 26.93 and 39.77 Euro cents/liter.10

Figure 7 shows the share of stations with a price increase during the midday hours over the observation period. School holidays are shaded in light blue while missing days are in light grey. We can observe that ARAL immediately starts with a very high share of 98 percent and Shell following with 94 percent. Then again on the first weekend Shell did not increase at noon, but increasing its share of midday increase stations to 97 percent afterwards. The other stations only gradually started to increase their prices at noon reaching their steady state of 91 per cent by July

9 The car and population density was obtained from inkar.de which in turn uses the federal statistical office as data source.
10 Obtained by Thompson Reuters Data stream.
14. The noon price increase actions of the “Eagles” Shell and ARAL are spatially independent as the adaptation of the noon jump according to brand depicted in the regional map shows in Appendix III.

**Figure 7: Percentage of stations showing midday increase**

![Percentage of stations with increase over observation period](image)

(Source: own calculations based on data from spritpreismonitor.de)

The following figure 8 visualizes which of the players, i.e. brands, participates to which degree, i.e. number of its stations, and at which time around noon. On the vertical axis, it shows the exact time of day of the midday increase. On the horizontal axis, the days of the observation period are depicted. School holidays are shaded in light blue while missing days are in light grey. The size of the circle indicates the number of stations involved in an increase at a time. The small circle represents between five and 50 stations, the medium sized circle 51 to 100 stations and the large one above 100 stations. Finally, the colors represent the type of the station, cranberry for ARAL and lavender for Shell, the two Eagles, and navy for the other stations. On June 24, more than one hundred ARAL stations coordinately increased prices at 12.02 am. Not shown in the figure are the 91 Shell stations following at 3:01 pm. Two days later, Shell joins and 101 stations increase their prices on 12:01 am. ARAL follows with 142 stations only one minute later on 12:02 am. This is also the first day that other stations follow about half an hour later. At this point in time already a more or less stable pattern has been found where both Shell and ARAL increase their prices a few minutes after 12:00 am and the others follow about 30 minutes later. Then, by the end of the observation period (and the summer holidays), Shell in some way tries to prepone this increase to 11:00 am first and later to 11:30 am, maintaining the actions after the summer holidays.
Following figure 9 shows which of the two “Eagle” firms, ARAL or Shell, is first for the noon jump. Except the periods Shell tries to extend its price rise to half an hour or one hour before, both Shell and ARAL seem to randomly change leading position. This suggests “Eagle” brands to play mixed strategies on their relenting action, the upward jump at noon. The exact empirical effect in this case is interesting and useful, because Shell is first or on a shared first position in the majority of cases (ARAL only leads in 7 out of 55 cases, given the 10 missings (65 days -10 missings = 55 days)). It is therefore not clear whether players follow a mixed strategy or leadership strategy.

(Source: own calculations based on data from spritpreismonitor.de)
This noon strategy seems to be an extension of the evening relenting strategy, where a similar pattern is observable. Following figures 10 and 11 show evidence for a duopoly leadership by the two Eagles playing mixed strategies in the duopoly leadership situation between each other.

**Figure 10: Evening price increase distribution of branded stations over time of day**
Figure 11: Branded stations jumping first in the evening

Player increasing first in the evening over observation period

14
Following two figures show the price effect of the midday price increase. The \textit{lhs} diagram shows the minute before the respective stations’ noon price jump, whereas the \textit{rhs} diagram shows the price in the minute of the price jump. The price jumps can therefore be at different points in time, only the magnitude of the price jump matters for this figure. The black line depicts the oil price to give a reference.

\textbf{Figure 12: Prices immediately before and after the midday price increase}

The prices in \textit{rhs} diagram are roughly 3 cents/liter above the prices in the \textit{lhs} side diagram. Furthermore, this price difference can be maintained by the firms throughout the entire afternoon.

\textbf{Table 3: Summary statistics (2) entire observation period}

<table>
<thead>
<tr>
<th></th>
<th>count</th>
<th>mean</th>
<th>Std. Dev.</th>
<th>min</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>e5 price at 12:10</td>
<td>36,862</td>
<td>1.47</td>
<td>0.05</td>
<td>1.28</td>
<td>1.83</td>
</tr>
<tr>
<td>Number of Competitors</td>
<td>36,862</td>
<td>5.43</td>
<td>2.59</td>
<td>1.00</td>
<td>13.00</td>
</tr>
<tr>
<td>Stations in greater environment</td>
<td>36,862</td>
<td>65.87</td>
<td>26.51</td>
<td>8.00</td>
<td>127.00</td>
</tr>
<tr>
<td>Time between dummy</td>
<td>36,862</td>
<td>0.20</td>
<td>0.40</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Time between dummy x ARAL</td>
<td>36,862</td>
<td>0.08</td>
<td>0.27</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Time between dummy x Shell</td>
<td>36,862</td>
<td>0.06</td>
<td>0.23</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Volume of traffic</td>
<td>36,862</td>
<td>1159.11</td>
<td>920.98</td>
<td>0.00</td>
<td>6503.00</td>
</tr>
<tr>
<td>Post treatment dummy</td>
<td>36,862</td>
<td>0.54</td>
<td>0.50</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Post treatment dummy x ARAL</td>
<td>36,862</td>
<td>0.21</td>
<td>0.41</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Post treatment dummy x Shell</td>
<td>36,862</td>
<td>0.16</td>
<td>0.36</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Monday</td>
<td>36,862</td>
<td>0.15</td>
<td>0.36</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Tuesday</td>
<td>36,862</td>
<td>0.14</td>
<td>0.35</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Wednesday</td>
<td>36,862</td>
<td>0.16</td>
<td>0.37</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Thursday</td>
<td>36,862</td>
<td>0.15</td>
<td>0.36</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Friday</td>
<td>36,862</td>
<td>0.13</td>
<td>0.34</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Saturday</td>
<td>36,862</td>
<td>0.13</td>
<td>0.34</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Sunday</td>
<td>36,862</td>
<td>0.14</td>
<td>0.35</td>
<td>0.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>
Table 3 shows the summary statistics for the entire observation period which spans the days from the 1st of May until 26th of August 2015. Overall, these are 100 days (18 missing days). The price was on average 1.47 Euro and on average there were 5.43 Number of competitors in the same local market and 66.87 in stations in the greater environment. The time between is specified as the time after the introduction of the best-price clause by Shell but before the day we see the midday increase for the first time i.e. May 27th to June 24th. (20 days in our sample due to missing values).

The post treatment dummy is defined as the time after the 24th of June, when the jumps began. The volume of traffic is measured in hundreds, so on average 1,159 vehicles have been observed in the respective closest traffic counting station and 6,503 at the maximum. In our sample we see 4 days of public national holidays and 35 days of school holidays. The car density is 516 cars per 1000 inhabitants on average and the population density is 1,644 persons per square kilometer at the mean. The Brent crude oil price index was 37 cents on average spanning a range of 27 to 43 cents per liter.

3.2 Empirical Strategy

It is clear from the previous descriptive observations that there is a price jump at noon. “Eagle” brands initiate the “high-noon”-phase and the other stations follow. They do not, however, succeed immediately after the PMC introduction by the “Eagle” Shell to coordinate on a noon jump. After the transition phase from May 27 to the first jump on June 24, they alternate in their leadership position.

(A) The Diff-in-Diff: Brands’ Average Prices during “High Noon”
A natural next step is to examine the impact of the midday price increase on the average market price throughout the day during the before phase (until May 26), adjustment phase (between May 27 and June 23) and after phase (following June 24). A minute-based resolution and the differentiation according to the brand identity of each station’s price choice allows to draw conclusions on leader-follower on an aggregate brand basis. We can therefore investigate brand average actions with respect to timing on the entire market.

We estimate the individual price for each gas station $s$ at time $t$ running an individual regression, first, for each single minute between 11.00 am and 1.59 pm (180 regressions) and, second, for each hour of the day (24 regressions). The number of stations in the direct local market environment (3 km; 1.875 mi) is instrumented with the number of gas stations in the greater environment (5-20 km; 3.125-12.5 mi). The vector $X_{\text{control}}$ includes the following control variables: day of week, public holiday, school holiday, car density, population density, oil price, and traffic volume.

Competitive intensity in a local market typically has a major effect on the price level. The number of competitors is a natural proxy for competitive intensity, i.e. gas stations, in the price estimation equation. The number of competitors, however, is determined by endogenously by entry decisions based on local market price. We use an approach similar to the one proposed by Nurski and Verboven (2016) instrumenting for the endogenous number of local market participants. In this flavor, a natural micro instrument for this is the number of stations in the greater environment. We thereby find an instrument, which builds on a similar environment with regard to demand and supply conditions generating an expected equilibrium number of stations in the market, but is at the same time exogenous to the local market and its outcomes itself.

First stage:

$$\#\text{Comp} = \beta_1 \#\text{Comp}_{\text{greater Env}} + \beta_2 \text{postTreatment} + \beta_3 \text{adjustmentPhase}$$
$$+ \beta_4 (\text{postTreatment} \times \text{ARAL}) + \beta_5 (\text{postTreatment} \times \text{Shell})$$
$$+ \beta_6 (\text{postTreatment} \times \text{TOTAL}) + \beta_7 (\text{postTreatment} \times \text{ESSO}) + \beta_8 \text{ARAL}$$
$$+ \beta_9 \text{Shell} + \beta_{10} \text{TOTAL} + \beta_{11} \text{ESSO} + X_{\text{control}} + \varepsilon_{it}$$

The price equation on the second stage is then only dependent of the exogenized variable number of competitors, $\#\text{Comp}$.

Second stage:

$$\text{price}_{st} = \gamma_1 \text{postTreatment} + \gamma_2 \text{adjustmentPhase} + \gamma_3 (\text{postTreatment} \times \text{ARAL})$$
$$+ \gamma_4 (\text{postTreatment} \times \text{Shell}) + \gamma_5 (\text{postTreatment} \times \text{TOTAL})$$
$$+ \gamma_6 (\text{postTreatment} \times \text{ESSO}) + \gamma_7 \text{ARAL} + \gamma_8 \text{Shell} + \gamma_9 \text{TOTAL}$$
$$+ \gamma_{10} \text{ESSO} + \gamma_{11} \#\text{Comp} + X_{\text{control}} + \varepsilon_{it}$$

A single regression thus chooses all stations’ prices of a fixed minute of the day, e.g. the minute 12.01 pm, and then includes the entire panel from May 1 to August 26, 2015. The post treatment period starts on June 24, 2015.

Similarly, we estimate the minutes elapsed starting from midnight. This regression, of course, does not dispose of a minutely resolution, but is based on daily observations of minute counts.
\[
\text{minutes}_{sd} = \beta_1 \text{ARAL} + \beta_2 \text{Shell} + \beta_3 \#\text{Comp} + X_{\text{Control}} + t + \epsilon_{it}^q
\]  

This diff-in-diff estimation contains the temporal interaction terms for the post treatment and for the different brand stations. In particular, these are the two “Eagles” Shell and ARAL, the two “Hawks” Total and ESSO and the rest of the market, the “Vultures” listed in table 3. It should be remembered at this point that this sample also contains the control group consisting of stations from non-“Eagle” markets at a distance greater than 3 km (1.875 mi) from the next “Eagle” station.\footnote{The results do not change with a reasonable extension of this distance to up to 5 km (3.125 mi).}

(B) The Leader-Follower Game: Mixed Strategies in the Leadership Game

We determine leadership outcomes contingent on the outcome of the previous price war. Following the Maskin and Tirole idea of the price war situation, if firms are in a low price state, each firm has a certain probability to relent and to jump up to a higher price level. This is a ransom event. Following the leadership idea, a leader would remain the leader under the same conditions. If a brand is leader on one day, then it would remain leader on the next day in cases without a major (unexpected) structural change, which will typically be the majority of cases.

Based on binary variables \(l_b\) we create Bernoulli sequences of different leadership situations for each brand, \(b\).

Let \(r\) be the number of runs in the Bernoulli sequence \(l_b\) with \(W\), the number of wars in the sample, and \(S = \sum_{w=1}^{W} l^w_b\), the number of successes. The expected number of runs in the sequence under the null of serial independence is \(\mu_r = 2S(W - S)/W + 1\), and the variance is \(\sigma^2_r = 2S(W - S)(2S(W - S) - W)/[W^2(W - 1)]\). The test statistic is \(z = (r - \mu_r)/\sigma_r\) and it is approximately distributed as the standard normal distribution.

3.3 Estimation Results

(A) The Diff-in-Diff: Brands’ Average Prices during “High Noon”

The following diagrams show the predicted prices of minute-based diff-in-diff regressions. This is e.g. a panel of prices of all stations at minute 12:02 of each of the days for all days in the sample (May 1 to August 26, 2015). Dotted lines show the forecasted prices after June 24, 2015, the date of the first noon jump after the implementation of the Shell PMC, whereas solid lines depict the forecasted prices before the PMC’s introduction on May 27. The \(lhs\) diagram is based on regressions including all stations of randomly selected control groups. The \(rhs\) diagram is based on regressions based on a control group selected by a matching procedure\footnote{See Appendix II.}. During the time of high demand (roughly 6 am to 7 pm) coefficients do not differ much between the two samples. Increased prices can be maintained throughout the whole afternoon until stations jump up in their regular Edgeworth cycle rhythm. The evening jump, interestingly, is most of the times led by ARAL, quite decisively at around 7 pm.
Zooming into the diagrams of figure 13, it is then clear from subsequent figure 14 that the two “Eagle” leaders ARAL and Shell jump first and then the remainder of the market follows. The remainder can further be split in two subgroups, “Hawks” consisting of the two chain stations Total and ESSO, and “Vultures” comprising the remainder of stations listed in table 3. “Vultures” do not differ from the control groups in our sample. Also, in particular visible for the matched sample, Shell on average jumps up a tiny time step ahead of ARAL.

This upward jump at noon is highly significant as following figure 15 shows. The figure depicts only interaction coefficients of the respective brand and the post treatment dummy. ARAL
again jumps up more decidedly and then successively and monotonously the remainder of the market (not visible in the diagrams, because they are the reference group) reduces the gap to ARAL. Shell on the other hand jumps up with many stations, but increases the gap to the remainder of the market by jumping up with further stations until 12.30. Then also the ‘Shell vs. rest of the market’-gap reduces.

Figure 15: “High Noon” – diff-in-diff regression results: brand coefficients (treatment) after PMC introduction
Table 4 shows the estimation outcomes exemplarily some of the noon minute-based slices. This regression is based on the reduced sample (June 23 to August 26, 2015). ARAL and Shell jump up much earlier than the rest of the market. The 12.30 slice is just after the jumps by ARAL and Shell, and also at a nearly half an hour of distance, Total. The post treatment dummy is associated with a coefficient of approximately one cent higher prices after the treatment while the interaction terms from ARAL and Shell show increases of circa two and a half to three cents/liter in comparison to the rest of the market. It is clear from the later slices that this gap closes.

This demonstrates how this collusive strategy works: Shell and ARAL, but in particular Shell, succeed to infect to rest of market and to increase to price level in the market by a substantial 3 cents/liter. The two “Eagles” Shell and ARAL first infect the “Hawks” Total (in particular) and ESSO following more hesitantly already. “Vultures” follow thereafter.

Otherwise, the Shell’s and ARAL’s price difference to the rest of the market over the entire time series is maintained.

Table 4: Diff-in-diff OLS regression results of prices on brand dummies

<table>
<thead>
<tr>
<th></th>
<th>(1) e5 price at 11.00 am</th>
<th>(2) e5 price at 11.30 am</th>
<th>(3) e5 price at 12.00 am</th>
<th>(4) e5 price at 12.30 am</th>
<th>(5) e5 price at 1.00 pm</th>
<th>(6) e5 price at 1.30 pm</th>
</tr>
</thead>
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<tr>
<td>Post treatment period</td>
<td>0.0133***</td>
<td>0.0134***</td>
<td>0.0134***</td>
<td>0.0086***</td>
<td>0.0212***</td>
<td>0.0225***</td>
</tr>
<tr>
<td></td>
<td>(0.0017)</td>
<td>(0.0018)</td>
<td>(0.0019)</td>
<td>(0.0019)</td>
<td>(0.0019)</td>
<td>(0.0019)</td>
</tr>
<tr>
<td>Adjustment phase</td>
<td>0.0130***</td>
<td>0.0141***</td>
<td>0.0140***</td>
<td>0.0139***</td>
<td>0.0135***</td>
<td>0.0145***</td>
</tr>
<tr>
<td></td>
<td>(0.0013)</td>
<td>(0.0014)</td>
<td>(0.0015)</td>
<td>(0.0015)</td>
<td>(0.0015)</td>
<td>(0.0014)</td>
</tr>
<tr>
<td>Post treatment period</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>x ARAL</td>
<td>0.0005</td>
<td>0.0009</td>
<td>0.0043**</td>
<td>0.0284***</td>
<td>0.0104**</td>
<td>0.0092***</td>
</tr>
<tr>
<td></td>
<td>(0.0016)</td>
<td>(0.0017)</td>
<td>(0.0018)</td>
<td>(0.0018)</td>
<td>(0.0018)</td>
<td>(0.0018)</td>
</tr>
<tr>
<td>Post treatment period</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>x Shell</td>
<td>-0.0026</td>
<td>-0.0051***</td>
<td>-0.0017</td>
<td>0.0263***</td>
<td>0.0058***</td>
<td>0.0028</td>
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<tr>
<td></td>
<td>(0.0016)</td>
<td>(0.0017)</td>
<td>(0.0018)</td>
<td>(0.0019)</td>
<td>(0.0018)</td>
<td>(0.0018)</td>
</tr>
<tr>
<td>Post treatment period</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>x Total</td>
<td>0.0014</td>
<td>0.0008</td>
<td>0.0005</td>
<td>0.0265***</td>
<td>0.0110**</td>
<td>0.0119***</td>
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<tr>
<td></td>
<td>(0.0025)</td>
<td>(0.0026)</td>
<td>(0.0027)</td>
<td>(0.0027)</td>
<td>(0.0027)</td>
<td>(0.0027)</td>
</tr>
<tr>
<td>Post treatment period</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>x Esso</td>
<td>-0.0036*</td>
<td>0.0014</td>
<td>-0.0004</td>
<td>0.0004</td>
<td>0.0078***</td>
<td>0.0040</td>
</tr>
<tr>
<td></td>
<td>(0.0021)</td>
<td>(0.0023)</td>
<td>(0.0025)</td>
<td>(0.0026)</td>
<td>(0.0025)</td>
<td>(0.0025)</td>
</tr>
<tr>
<td>ARAL</td>
<td>0.0304***</td>
<td>0.0315***</td>
<td>0.0310***</td>
<td>0.0297***</td>
<td>0.0350***</td>
<td>0.0329***</td>
</tr>
<tr>
<td></td>
<td>(0.0016)</td>
<td>(0.0016)</td>
<td>(0.0017)</td>
<td>(0.0018)</td>
<td>(0.0017)</td>
<td>(0.0017)</td>
</tr>
<tr>
<td>Shell</td>
<td>0.0402***</td>
<td>0.0446***</td>
<td>0.0475***</td>
<td>0.0357***</td>
<td>0.0412***</td>
<td>0.0405***</td>
</tr>
<tr>
<td></td>
<td>(0.0016)</td>
<td>(0.0017)</td>
<td>(0.0018)</td>
<td>(0.0018)</td>
<td>(0.0018)</td>
<td>(0.0018)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>0.0014</td>
<td>0.0023</td>
<td>0.0008</td>
<td>-0.0023</td>
<td>0.0016</td>
<td>-0.0003</td>
</tr>
<tr>
<td></td>
<td>(0.0021)</td>
<td>(0.0022)</td>
<td>(0.0024)</td>
<td>(0.0024)</td>
<td>(0.0024)</td>
<td>(0.0023)</td>
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<td>ESSO</td>
<td>0.0025</td>
<td>-0.0038</td>
<td>-0.0047*</td>
<td>-0.0031</td>
<td>-0.0022</td>
<td>-0.0019</td>
</tr>
<tr>
<td></td>
<td>(0.0023)</td>
<td>(0.0024)</td>
<td>(0.0026)</td>
<td>(0.0026)</td>
<td>(0.0026)</td>
<td>(0.0026)</td>
</tr>
<tr>
<td># Competitors</td>
<td>-0.0170***</td>
<td>-0.0177***</td>
<td>-0.0197***</td>
<td>-0.0200***</td>
<td>-0.0196***</td>
<td>-0.0194***</td>
</tr>
<tr>
<td></td>
<td>(0.0011)</td>
<td>(0.0011)</td>
<td>(0.0012)</td>
<td>(0.0012)</td>
<td>(0.0012)</td>
<td>(0.0012)</td>
</tr>
<tr>
<td>Sunday</td>
<td>0.0045***</td>
<td>0.0046***</td>
<td>0.0041***</td>
<td>0.0042***</td>
<td>0.0045***</td>
<td>0.0044***</td>
</tr>
<tr>
<td></td>
<td>(0.0011)</td>
<td>(0.0011)</td>
<td>(0.0012)</td>
<td>(0.0012)</td>
<td>(0.0011)</td>
<td>(0.0011)</td>
</tr>
<tr>
<td>Monday</td>
<td>0.0013</td>
<td>0.0027**</td>
<td>0.0029**</td>
<td>0.0027**</td>
<td>0.0024**</td>
<td>0.0024**</td>
</tr>
<tr>
<td></td>
<td>(0.0010)</td>
<td>(0.0011)</td>
<td>(0.0011)</td>
<td>(0.0011)</td>
<td>(0.0011)</td>
<td>(0.0011)</td>
</tr>
</tbody>
</table>
Robustness checks as well as the regression results of regressions explaining minutes after midnight by the same variables are deferred to the appendix. They mainly show the significantly earlier jumps by Shell and ARAL.

(B) The Leader-Follower Game: Mixed Strategies in the Leadership Game

We can right away reject all hypothesis that any other firm than the two “Eagles” Shell and ARAL are leaders of the noon jump. The Leadership hypothesis or mixed strategy hypothesis is then only interesting to test for these two brands. Following Wang (2009), the test of a leadership or mixed strategy corresponds to a test on serial independence within wars of attrition of the same type. Serial independence indicates that brands do not stick to a certain leadership pattern, but rather alternate randomly in their leadership position. The outcome of a period’s price war should therefore not depend on the outcome of the previous period.

We therefore count the events of either brand being a leader in relenting and inducing the upward jump phase. We then conduct simple tests of serial correlation according to Wang (2009). The tests each depend on the outcomes of the previous leadership outcome.

With the null hypothesis of serial independence, in particular the last set of results is interesting. These results exclude ‘unstrategic’ moves, i.e. moves with less than five stations at a time, often conducted by very small market participants unsystematically and very rarely increasing prices as exceptional actions. According to this set of results, Shell’s and ARAL’s jumps are both not characterized by any serial dependence property.
### Table 5: OLS regression results on the test of serial independence

<table>
<thead>
<tr>
<th></th>
<th>Number of 1's</th>
<th>Number of runs</th>
<th>z-Statistic</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Either Shell or ARAL lead previously:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>72 Wars</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shell is a leader</td>
<td>41</td>
<td>33</td>
<td>-0.94</td>
<td>0.34</td>
</tr>
<tr>
<td>Shell is the only leader</td>
<td>17</td>
<td>22</td>
<td>-1.69</td>
<td>0.09</td>
</tr>
<tr>
<td>ARAL is a leader</td>
<td>35</td>
<td>30</td>
<td>-1.76</td>
<td>0.08</td>
</tr>
<tr>
<td>ARAL is the only leader</td>
<td>11</td>
<td>13</td>
<td>-3.12</td>
<td>0.00</td>
</tr>
<tr>
<td>Both lead</td>
<td>24</td>
<td>24</td>
<td>-2.47</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>Entire Sample:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>101 Wars</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shell is a leader</td>
<td>56</td>
<td>47</td>
<td>-0.79</td>
<td>0.43</td>
</tr>
<tr>
<td>Shell is the only leader</td>
<td>23</td>
<td>26</td>
<td>-3.01</td>
<td>0.00</td>
</tr>
<tr>
<td>ARAL is a leader</td>
<td>50</td>
<td>40</td>
<td>-2.30</td>
<td>0.02</td>
</tr>
<tr>
<td>ARAL is the only leader</td>
<td>17</td>
<td>23</td>
<td>-2.26</td>
<td>0.02</td>
</tr>
<tr>
<td>Both lead</td>
<td>33</td>
<td>38</td>
<td>-1.69</td>
<td>0.09</td>
</tr>
<tr>
<td><strong>Entire Sample (&lt;5 stations excluded)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>101 Wars</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shell is a leader</td>
<td>85</td>
<td>25</td>
<td>-1.11</td>
<td>0.27</td>
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<tr>
<td>Shell is the only leader</td>
<td>56</td>
<td>50</td>
<td>-0.18</td>
<td>0.86</td>
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<tr>
<td>ARAL is a leader</td>
<td>45</td>
<td>50</td>
<td>-0.18</td>
<td>0.86</td>
</tr>
<tr>
<td>ARAL is the only leader</td>
<td>16</td>
<td>25</td>
<td>-1.11</td>
<td>0.27</td>
</tr>
<tr>
<td>Both lead</td>
<td>29</td>
<td>42</td>
<td>-0.08</td>
<td>0.93</td>
</tr>
</tbody>
</table>

But what about the fringe followers? Figures 13 and 14 indicate that followers to somehow lag behind any increase by the “Eagles” at noon. From these aggregate regressions it is not completely clear how this happens and how “Hawks” and “Vultures” follow.

It is visible, that gas stations and gas station chains follow in a smoothly looking, gradually adapting way, successively approaching the temporal focal point of 3 cents/liter, which is set by the “Eagles”. It is however not clear, which coordination device is used. Either the stations might follow in a deterministic way, mix over time elapsed since the increase by the Eagles, or use an additional metric such as distance to coordinate. It is clear from Figure 10 that some gas stations, such as ESSO, ignore space and follow the Eagles’ increase 30 minutes later. Following Figure depicting marginal probabilities contingent on the increase of the closest Eagle and the distance to this peer station sheds light on the process for ESSO and the other stations: most stations precisely follow the peer stations. It is noteworthy that the Vultures differ in their coordination strategies: (1) Some, such as ESSO, are spatially independent, but coordinate only through the time lag, (2) some react through space (smaller chains), and (3) some react very imprecisely and vary in their behavior, in particular the totally independent stations (“Freie”, “BFT”).

23
4 Summary and Conclusions

We find detailed evidence on the process of how Shell used a PCM to facilitate and implement collusion. This happened in coordination with its main collusive partner, ARAL. An additional trigger, however, was necessary to start the collusive process: We find school summer holidays to kickstart collusion. This roughly leads to a yearly consumer damage of three billion Euro. In addition, firms’ strategies seem to be mixed and each company acts with respect to the whole region and abstains from restrictions to local markets for price coordination (Ruhr-area-wide in North Rhine-Westphalia, see Appendix III).
References


Appendix I: Quantities in the market and the major summer holidays
Appendix II: Matching the stations

After propensity score matching with two nearest neighbors, neither the Shell nor the ARAL group is significantly different from the group of other gasoline stations.

|            | Robust Coef. | Std. Err. | t   | Pr>|t| | [95% Conf. Interval] |
|------------|--------------|-----------|-----|---------|----------------------|
| pub_holl   | -61.00951    | 19.05637  | -3.21 | 0.001  | -98.43987 to -23.73915 |
| school_holl| -34.2225     | 6.854785  | -5.00 | 0.000  | -47.68783 to -20.81717 |
| day_d_1    | -99.06875    | 11.68544  | -8.48 | 0.000  | -121.9721 to -76.16536  |
| day_d_2    | -31.09271    | 11.51612  | -2.70 | 0.007  | -53.66622 to -8.521203 |
| day_d_3    | -41.4287     | 11.33877  | -3.50 | 0.000  | -63.69261 to -19.2048 |
| day_d_4    | -15.0294     | 11.58859  | -1.37 | 0.172  | -38.34296 to 6.884156 |
| day_d_5    | 0 (omitted)  |           |      |        |                      |
| day_d_6    | 79.88662     | 12.37767  | 6.45 | 0.000  | 55.62568 to 104.1468  |
| day_d_7    | 66.88116     | 12.36433  | 5.41 | 0.000  | 42.64715 to 91.11517  |
| _cons      | 1143.289     | 8.857074  | 129.08 | 0.000  | 1125.93 to 1160.649  |

### Linear regression

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### Diagrams

#### Population density

- **ARAL**
- **Shell**
- **Other**

#### Car density

- **ARAL**
- **Shell**
- **Other**
Appendix III: Spatial analysis over the day
### Normal, matched

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Matched, extended

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<td>(0.0012)</td>
</tr>
<tr>
<td><strong>Friday</strong></td>
<td>-0.0035***</td>
<td>(0.0011)</td>
<td>-0.0021**</td>
<td>(0.0011)</td>
<td>-0.0019*</td>
<td>(0.0012)</td>
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<tr>
<td><strong>Public holiday</strong></td>
<td>0.0045***</td>
<td>(0.0015)</td>
<td>0.0035**</td>
<td>(0.0016)</td>
<td>0.0029*</td>
<td>(0.0016)</td>
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<tr>
<td><strong>School holiday</strong></td>
<td>0.0273***</td>
<td>(0.0009)</td>
<td>0.0271***</td>
<td>(0.0009)</td>
<td>0.0248***</td>
<td>(0.0009)</td>
</tr>
<tr>
<td><strong>Car density</strong></td>
<td>0.0000**</td>
<td>(0.0000)</td>
<td>0.0000</td>
<td>(0.0000)</td>
<td>0.0000</td>
<td>(0.0000)</td>
</tr>
<tr>
<td><strong>Oil price</strong></td>
<td>0.8743***</td>
<td>(0.0115)</td>
<td>0.8562***</td>
<td>(0.0118)</td>
<td>0.8197***</td>
<td>(0.0125)</td>
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<tr>
<td><strong>Traffic volume</strong></td>
<td>0.0043***</td>
<td>(0.0003)</td>
<td>0.0044***</td>
<td>(0.0004)</td>
<td>0.0046***</td>
<td>(0.0004)</td>
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</tbody>
</table>

**Endogeneity Test**

- Cragg-Donald-Wald F Test: 436.1898 (p-value: 464.0525)
- Kleibergen Paap F-Test excl. instr.: 410.2050 (p-value: 409.3600)
- F Test: 428.3093 (p-value: 427.3571)

**# Obs.**

- 36,762 (2000 observations)
<table>
<thead>
<tr>
<th></th>
<th>(1) Minutes</th>
<th></th>
<th>(2) Price level at increase</th>
<th></th>
<th>(3) Price level after increase</th>
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<tbody>
<tr>
<td></td>
<td>coefficient</td>
<td>Stand. errors</td>
<td>coefficient</td>
<td>Stand. errors</td>
<td>coefficient</td>
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<tr>
<td>ARAL</td>
<td>-22.3215***</td>
<td>(0.1221)</td>
<td>0.0186***</td>
<td>(0.0005)</td>
<td>0.0202***</td>
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<td>Shell</td>
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<td>(0.2042)</td>
<td>0.0187***</td>
<td>(0.0006)</td>
<td>0.0193***</td>
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<td>other</td>
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<td>0.0000</td>
<td>(.)</td>
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<tr>
<td># Competitors</td>
<td>0.0685***</td>
<td>(0.0227)</td>
<td>-0.0009***</td>
<td>(0.0001)</td>
<td>-0.0009***</td>
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<td>Monday</td>
<td>0.0000</td>
<td>(.)</td>
<td>0.0000</td>
<td>(.)</td>
<td>0.0000</td>
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<tr>
<td>Tuesday</td>
<td>0.4962**</td>
<td>(0.2180)</td>
<td>-0.0072***</td>
<td>(0.0009)</td>
<td>-0.0069***</td>
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<tr>
<td>Wednesday</td>
<td>0.9085***</td>
<td>(0.2304)</td>
<td>-0.0085***</td>
<td>(0.0009)</td>
<td>-0.0075***</td>
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<tr>
<td>Thursday</td>
<td>0.3855</td>
<td>(0.2568)</td>
<td>-0.0092***</td>
<td>(0.0010)</td>
<td>-0.0083***</td>
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<td>Friday</td>
<td>-0.2667</td>
<td>(0.2341)</td>
<td>-0.0054***</td>
<td>(0.0009)</td>
<td>-0.0049***</td>
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<tr>
<td>Saturday</td>
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<td>(0.2260)</td>
<td>-0.0075***</td>
<td>(0.0009)</td>
<td>-0.0069***</td>
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<tr>
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<td>(0.2232)</td>
<td>-0.0055***</td>
<td>(0.0010)</td>
<td>-0.0053***</td>
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<td>0.0156***</td>
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<td>0.0145***</td>
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<td>Oil price</td>
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<td>(0.1221)</td>
<td>-0.0028***</td>
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<td>-0.0027***</td>
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<td>(0.0283)</td>
<td>-0.0028***</td>
<td>(0.0001)</td>
<td>-0.0027***</td>
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<tr>
<td>Constant</td>
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<td>(6.4201)</td>
<td>1.7116***</td>
<td>(0.0229)</td>
<td>1.7362***</td>
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<td>R^2</td>
<td>0.6780</td>
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<td>0.6397</td>
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<td>F Test</td>
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<td>2,163.13</td>
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<td># Obs.</td>
<td>18,200</td>
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Standard errors in parentheses * p<0.1, ** p<0.05, *** p<0.01