Brandenburg
University of Technology
Cottbus - Senftenberg

Working Paper

2020/01

Who really performs *Rockets and Feathers*?
And actually when?
Gaining insights into the occurrence and causes of *Rockets and Feathers* in the German retail diesel market

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ABSTRACT

The phenomenon of Rockets and Feathers occurs in various markets, can yield different outcomes and its analysis is conducted using diverse methods, periods and types of data. But still, faster-rising price increases and slow-moving price cuts after corresponding input price changes, is politically and economically compelling, especially in the retail fuel market. We analyse an enormous data set from fuel retailers in Germany – the largest European economy – for various characteristics over two consecutive and recent years. The paper focuses on several aspects: Amidst just one in eight stations showing Rockets and Feathers, collusion aspects are in parts established. Just a selection of German major brands and especially expensive stations are more likely to exercise Rockets and Feathers. Additionally, we analyse the results with respect to shorter periods within our time frame (rolling windows). One main finding is that aspects of consumer search frictions triggering Rockets and Feathers can partly be proven. Nevertheless, a fairly but given small base of stations show Rockets and Feathers independent of potential consumer search behaviour.

Keywords: Asymmetric pricing, Market power, Price transmission, Retail fuel, Sticky pricing, Time-series models

JEL classification codes: C22 Time-Series Models, L11 Production, Pricing, and Market Structure, L13 Oligopoly and Other Imperfect Markets, L91 Transportation: General, Q41 Energy Prices

1 INTRODUCTION

The relationship between retail fuel prices and prices of fuel input goods, such as crude oil, is a widely and intensively discussed topic. Since the early 1990s, research in that area has focused mostly on econometric models to investigate the connection between retail fuel prices and its input costs for numerous countries and regions. This relationship is usually tested for asymmetric price responses or price transmission, i.e. the different adjustment speeds of retail fuel prices after input price increases are compared to input price decreases. Therefore, an essential goal of numerous published studies is to test whether retail fuel prices rise fast like rockets with input price increases but decline significantly more slowly like feathers as input prices decrease (Rockets and Feathers, R&F).[1] Typically, the phenomenon is attributable, either to questions regarding certain forms of tacit collusion, or alternatively to consumer search and informational frictions accelerating asymmetric price distortions. The latter one describes theories explaining the occurrence of R&F with consumers' lacking price information and by that showing different search intensities over time. Both concepts contain certain forms of market power, but are different explanations for the phenomenon, as revealing the actual reason is crucial for regulation efforts.

One essential reason for the continued interest, is that 'changes in gasoline prices are always under public scrutiny' (Balke et al. 1998). Public awareness of the topic, e.g. local public protests (Deltas 2008) centre the topic and as a result, regulatory institutions, such as the Federal Cartel Office in Germany (Federal Cartel Office 2011a, 2011b) or the Spanish Antitrust Authority (Bello et al. 2018), monitor pricing strategies transmission in the retail fuel markets. Some authors label the discussion regarding R&F still as 'unsettled' (Apergis and Vouzavalis 2018, p. 519), 'unexplained' (Tappata 2009, p. 684) or 'not fully understood' (Heim 2019, p. 16). Although literature on R&F has been published for some decades, Bayer and Ke (2011) opine that the economic theory explaining R&F is still 'only emerging' (p. 2) and argue that 'it is not possible to easily draw a clear and simple policy implication from the observation of asymmetric price adjustment' (p. 28). Haucap et al. (2017) evaluate the general discussion related to the retail gasoline market as still being 'poorly understood by policy-makers' (p. 100) and identifies 'suspicions sometimes voiced in policy circles' (p. 101). Thus, there remain open questions about whether and why R&F is or is not observed. Therefore, explanations for R&F have high relevance for policies and regulation approaches within the retail fuel market and beyond. This is given because different reasons for R&F might lead to diverging policy recommendations.

Some general characteristics of the retail fuel market, such as large-scale refinery infrastructure, an oligopolistic market structure and homogenous fuels sold by price-setting firms, are mentioned often and might favour price coordination (Bellos et al. 2018). On the other side, high competition intensity can be supported by the additional presence of

[1] In the literature, this phenomenon is also frequently called 'asymmetric cost pass-through', 'asymmetric price transmission' or 'vertical price transmission'. In this paper, we will use the often referred term of 'Rockets and Feathers' (R&F) based on Bacon (1991).

independent petrol stations or "maverick" firms, which might make price coordination of major brands more difficult. Moreover, retail prices can be changed rapidly by station owners[2] or companies and due to technical improvements at very low cost. Additionally, transparent and widespread price information is nowadays available at very low costs. This can favour competition and restrict market power as consumers have a more transparent market overview.[3] Contrary to that, Dewenter et al. (2017) and further the German Federal Cartel Office (2011b) argue that more widespread and transparent information within certain oligopolistic markets can be harmful for customers as prices can increase. Ivaldi et al. (2003) argue that collusion is at least more difficult to sustain when transparency is less apparent. Therefore, transparency makes it very easy to detect price defection by competitors. Borenstein and Shepard (1996) conclude that 'the gain from defecting will be small, making tacit collusion easier to sustain' (p. 431).

Within this paper, we analyse recent German data of retail fuel prices of the Market Transparency Unit for Fuels[4] from the years 2014 to 2016. The Market Transparency Unit for Fuels collects real-time data related to gasoline price changes for nearly all petrol stations in Germany. Our work focuses on price asymmetries regarding the phenomenon of R&F, which results in faster fuel price changes after oil price increases, compared to decreases for the retail diesel market. We use station-specific data from about 8,600 petrol stations from June 2014 to May 2016 (about 60 % of all German petrol stations). First, we test for a long-run cointegration relationship and, second, for pricing asymmetries by optimising error correction models for each retail station. We consider several characteristics regarding the issue of asymmetric price responses within the German diesel fuel sector, such as specific brands, price levels and spatial attributes[5]. Furthermore, we analyse the development of R&F over the given data period with the help of rolling windows. This aspect is particularly interesting and offers complementary analyses of the dynamics of R&F. It allows us to evaluate whether the share of R&F changes over time and enables us to identify relevant triggers.

Certain aspects of our analysis are new: We use a highly disaggregated and recent daily data set, which provides even more valuable results regarding price systematics than lower frequency data (see e.g. Bachmeier and Griffin 2003). By considering more than half of all German petrol stations, we focus on a broad perspective on the biggest European economy. Besides testing for pure asymmetries, we also analyse which characteristics influence the likelihood of R&F at a specific retail station, such as brands, price levels and indicators for potential competition intensity. To the best of our knowledge, a comparable deep analysis has

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[2] This is just given, if it is legally allowed, as some countries restrict the amount of price changes for a certain time period (see e.g. Byrne and Roos 2017 for Australia).

[3] Furthermore, for the retail fuel market, consumer ability of observing input price fluctuations is easier today, compared to other daily life products such as food (Bayer and Ke 2011).

[4] The Market Transparency Unit for Fuels does not publish the data directly. Rather, the information is published by homepage providers. The authors obtained the data from Tankerkönig (2018), which procures the data straight from the Market Transparency Unit for Fuels in Germany.

[5] By that, we follow Borenstein and Shepard (1996), who argue that the main difference of petrol stations is among others the specific brand and the location.

to this extent not been conducted.[6] Additionally, as a meta-analysis of Perdiguero-García 2013 argues, the occurrence of R&F is not static. Rather it varies over time as firms do not keep constant pricing strategies.[7] Therefore, we analyse, to the best of our knowledge the first time in that resolution, the occurrence of R&F over time with the help of rolling regression (rolling windows) within shorter time periods (sub samples). By using rolling windows, we try to detect characteristics for the existence and disappearance of R&F as the phenomenon seems to change over time.

The analysis shows that (a) for the German market, just about 13 % of retail stations display characteristics of R&F over the whole period. In addition, (b) certain characteristics are related to higher shares of R&F: Our results show, that just a selection of the so-called dominant firms in Germany (Federal Cartel Office 2011a, 2011b) and stations with higher general price levels, show higher shares of R&F. Finally, (c) R&F varies over time and is not a steady or invariant phenomenon within the German market. We see those variations partly related to retail fuel prices, margins and cointegration levels.

We analyse price movements after the implementation of the Market Transparency Unit for Fuels and therefore during a period of improved levels of information and price transparency for customers and companies. Therefore, frictions regarding search and information cannot be the only reason for the detected levels of R&F, while tacit collusion is left as another major explanation. By that, both concepts can be seen as explanations for certain shares of R&F in the German diesel market. Nevertheless, due to the low levels of R&F over time, the market shows little sign of prevalent restrictions of competition.

The paper is structured as follows: Section 2 gives an overview of the literature, focusing on the two most prominent reasons for asymmetric price transmission and further presents relevant empirical examples. Section 3 describes the data set used, while section 4 shows the methodological approach. Section 5 analyses the results regarding the entire data set and additionally regarding the used approach of rolling windows. Section 6 concludes and presents further research questions.

[6] Frondel et al. (2019) are focusing on the German market with comparable research questions but do not analyse certain characteristics of stations in that detail. Asana-Otoo and Dannemann (2019) analyse a slightly higher amount of stations for the German gasoline (Super E5) market and just partly for diesel. Besides country-wide and additionally regional price data aggregation, the authors further analyse station-specific data for certain brands, but lack a comparable deep analysis for specific characteristics.

[7] Further studies regarding that point are e.g. Slade (1987), who analyse changing market environments, with price wars and periods with cooperation of market players in the retail fuel market in Canada. Radchenko (2006) tests for the influence of oil price volatility on price asymmetries for two different periods. Hosken et al. (2008) show in their analysis that pricing strategies of retail stations change over time. Additionally, Contin-Pilart et al. (2009) analyse two periods, before and after policy regulation changes for the Spanish market. Equally, Frondel et al. (2019) compare results for two different periods, before and after the introduction of the Market Transparency Unit for Fuels in Germany.

2 LITERATURE

One of the first papers dealing with asymmetric price transmission and R&F for retail fuel prices and, for the first time naming the phenomenon ‘rockets and feathers’, was published by Bacon (1991). Therein, the author finds evidence for R&F in the United Kingdom from 1982 to 1989. Nevertheless, asymmetric pricing does not just exist in retail fuel markets, but also in banking (Neumark and Sharpe 1992, O’Brien 2000), electricity markets (Heim 2019), the dairy product market (Loy et al. 2016) and the agriculture sector (Cramon-Taubadel 1998, Meyer and Cramon-Taubadel 2005). Meyer and Cramon-Taubadel (2005) even argue that agricultural economics in particular, had been responsible for most of the research publications related to R&F at that time.

The following literature section shows the general relevance of the R&F phenomenon, with a strong focus on oil and fuel markets. Section 2.1 discusses theories and reasons for the existence of asymmetric price transmission. Section 2.2 gives a summary of actual research results which are related to the methods and research questions used in this paper.

2.1 Theoretical background

Conventional microeconomic theory would usually suggest that input price changes correspond to marginal cost changes. These price changes should move in a symmetric way. Borenstein and Shepard (2002) generally state that the ‘price adjustment rate in an imperfectly competitive industry, to a given cost shock, will differ from the adjustment rate of a competitive industry’ (p. 118). Hence, symmetric price responses might give evidence of efficient and competitive markets. So what are the reasons that firms do not see grounds to decrease prices after input price reductions, as they increase prices after price surges? Balke et al. (1998) summarizes several reasons to explain the presence of asymmetric price responses between oil and retail fuel prices. Examples are tacit collusion, consumer response to changing prices as well as search costs, inventory management, accounting practices and refinery adjustment costs. Out of these, (1) tacit collusion[8] as well as (2) consumer search characteristics[9] are – from our research – the most prevalent theories analysed in recent studies (see e.g. Borenstein et al. 1997, Johnson 2002, Bachmeier and Griffin 2003, Abosedra and Radchenko 2006, Yang and Ye 2008, Tappata 2009, Lewis 2011, Bayer and Ke 2011, Remer 2015). Consequently, our paper focuses on these two mainly discussed reasons for R&F.

First, tacit collusion can be defined as repeated interactions of firms in the way that each of them is e.g. adapting prices with an understanding that the other firms might or will cooperate, follows the same behaviour and act jointly (see e.g. Borenstein and Shepard 1996, Stiglitz and Walsh 2006). If collusion is absent, firms would charge marginal costs. In the case of perfect collusion, each firm charges monopoly prices and receives a share of the

[8] Alternatively used terms are implicit or tacit/implicit oligopolistic collusion.

[9] Alternatively used terms are ‘search frictions’ (Bayer and Ke 2011), ‘reference price search behaviour’ (Lewis 2011) or ‘consumers’ response asymmetry to changes in costs’ (Deltas 2008).

monopoly rent. Eventually, firms would charge a collusive price as long as no other firm deviates.

Bringing that into the context of R&F, after input price increases, petrol stations aim to maintain their individual margins and therefore quickly raise prices (Balke et al. 1998). However, firms slow their price adjustment speed if input price decreases occur. By that, they show competitors their interest in maintaining or even starting a tacit agreement by not cutting their own margin. Borenstein et al. (1997), argues that decreasing input prices offer a natural focal point for collusion of sellers.[10] With decreasing input costs, collusion is very easy to realize for the overall market environment simply by not changing prices. If sales remain above a certain threshold level, firms may choose to uphold prices above the competition levels. This strategy can be conducted until certain demand conditions force them to change prices. Dropping sales would otherwise indicate price cutting efforts by rival firms, which could then be punished and would harm the margins of all stations. Hence, in the case of collusion, stations 'might very well be less willing to cut price if the resulting retaliation [by their competitors, S.K.] will occur' (Borenstein and Shepard 1996).

Contradicting to the hypothesis of tacit collusion as a reason for R&F, Peltzman (2000) finds asymmetries in 'competitive' and 'oligopolistic' markets, analysing more than 240 products of different sectors. One reason for less asymmetric pricing patterns might be volatile input prices, which has special relevance in most modern retail fuel markets. Likewise, Ritz (2015) argues that asymmetric pricing can be given in markets with perfect competition and that R&F says nothing about the mode of competition. Therefore, competition intensity does not need to be related to cost pass-through patterns.

Related to these arguments is a **second important** reason in the given literature. It claims that consumer search characteristics, respective search costs, as well as imperfectly informed consumers (asymmetric information), violating the complete information assumption (Heim 2019), can be the cause for R&F. Therefore, consumer behaviour itself can be a reason for market power of retail stations and by that initiate asymmetric pricing patterns (Johnson 2002, Deltas 2007, Lewis 2011, Remer 2015). Hereby, variable search intensity of consumers corresponds to inconstant competitive pressure for retail stations, creating R&F. As consumers are searching for low prices, overall market prices and margins squeeze. On the other hand, if consumers are not investing in price search due to their limited information regarding market prices and production costs, market players can establish the chance for R&F as competition intensity is lower. Therefore, temporary market power of retailers and by that R&F can occur.

But why does consumer search behaviour create asymmetric pricing with lower price adjustment after decreasing input price levels? Among others, Lewis (2011) argue that consumer's imperfect knowledge influences pricing strategies of retail stations. Due to price changes, consumers face the challenge to uphold accurate price information. Therefore,

[10] Some authors name that phenomenon 'focal price tacit collusion', as firms orientate on the focal retail price before oil price decreases (Lewis 2011, Ederington et al. 2019).

consumers have expectations of the market price based on a reference price from the previous known period. This creates a situation in which the relationship between retail price changes and related search intensity creates asymmetric price response characteristics. While in the situation that prices are increasing and price expectations of consumers are lower than given market prices, consumer search intensifies, retailers face a more elastic demand and competition intensity increases. This results in prices to be closer to marginal costs, lower margins and less potential for R&F. While prices are decreasing, price expectation by consumers is higher compared to the given market prices which results in less consumer search, higher margins and higher potential for R&F. Johnson (2002) equally argues, that search intensity is lower for price decreases as for price increases. Analysing Australian data, Byrne and Roos (2017) argue along the same line, that before and even during price increases, consumers have strong incentives for search. Hence, firms have the incentive to lower retail prices just enough to discourage consumers from further searching. As search intensity is low, firms are not able to gain customers by undercutting rivals.[11]

2.2 Empirical results

Research in the field of R&F can usually be distinguished for the methods and models used, the years, the regions or countries and input data characteristics (e.g. data frequencies). The following paragraphs focus on empirical results regarding R&F within the retail fuel sector for these distinctive features of studies of the last years.

Kpodar and Abdallah (2017) compare monthly data from 162 countries and find that R&F is a worldwide phenomenon. The authors find asymmetric responses worldwide. Especially the market-based advanced economies show the fastest and most asymmetric responses, while countries in the Middle East and North Africa show less. The authors conclude that the arguments for both, tacit collusion and consumer search characteristics, are more related to advanced economies, while less asymmetry for emerging markets might be given as governments intervene in the fuel price setting.

Nevertheless, most of the papers related to R&F deal with data from North America and Europe. One of the early and most influential studies related to the retail fuel sector was Borenstein et al. (1997). The authors analysed retail, terminal, and spot market prices from March 1986 to the end of 1992. Retail prices are from 33 cities in the United States. They conclude that asymmetric price setting is given between retail and crude oil prices. Deltas (2008) uses monthly data from 48 states in the US from 1988 to 2002 from which he concludes that R&F is existing. Furthermore, he states that the degree of asymmetric pricing patterns depends on the average margin between retail and wholesale prices within different US states. Without analysing further regional characteristics, he concludes that states with higher price margins, fewer sellers and by that a higher degree of local market power, show more asymmetry. Liu et al. (2010) conclude for New Zealand that the diesel market shows

[11] Still, within that line of argumentation regarding R&F and consumer search characteristics, several authors do not agree on all aspects of this hypothesis and papers still debate outcomes (see e.g. Yang and Ye 2008, Tappata 2009, Eleftheriou et al. 2019).

significant price asymmetry. This is given due to an inelastic demand by diesel customers, who are mainly business clients.

Other authors are able to use data sets with more detailed and often brand- or even station-specific data. Verlinda (2008) finds price-response asymmetry for southern California from September 2002 to May 2003 for a weekly station-level data set. Brand identity, proximity to and the number of rival stations in a certain radius influence the price-response asymmetry. Unbranded stations show lower price-response asymmetries. Asymmetries are reduced by additional nearby rivals and asymmetry levels rise with increasing distance to the nearest rivals. The author concludes that there is no relationship between population size and asymmetries. Lewis (2011) argues that consumer's lacking knowledge of existing prices results in R&F. As a first data set, he uses weekly station-level data form the San Diego area in southern California from 2000 to 2001. His second data set includes weekly city average prices from Los Angeles from June 2000 to July 2007. Lewis claims that margin size is related to the speed of price response. He finds that margins are more determining for the speed of price responses than the direction of the cost change (p. 437). This is given as positive (negative) cost changes are usually related to periods of low (high) margins for retail stations (see also Antoniou et al. 2017 and NACS 2016). Furthermore, Lewis argues that even stations charging the lowest prices are equally responding asymmetric to cost decreases compared to stations charging median prices. Faber (2015) analyses the Dutch fuel market for the period from May 2006 to July 2008. He uses daily price data for gasoline (Euro 95) from 3,600 retail stations. His results show that for 38 % of the stations analysed, R&F has been prevalent. Furthermore, he discovers that specific brand stations and competition intensities influence the probability of R&F. Remer (2015) analyses the relationship between aggregated daily retail price data from 11,000 retail stations in the US over 13 months from June 2008 to July 2009 and gasoline spot prices. He founds asymmetric price transmission and reasons that his results can be interpreted that consumer search frictions are the main reason for the occurrence of R&F. Farkas and Yontcheva (2019) analyse the Hungarian market, which is characterized by substantial vertical integration. As a result, the authors argue that the market shows a positive relation between R&F and developing retail market shares of the largest market player.

Further studies show contradictory results for the German case. Galeotti et al. (2003) find asymmetries between 1985 and 1997 with monthly data. Furthermore, Grasso and Manera (2007) find evidence for R&F for the period from 1985 to 2003. The German Federal Cartel Office (2011a, 2011b) indicates in its *Fuel Sector Inquiry*, that fuel 'price increases often occur simultaneously at the majority of the petrol stations of an oil company whilst price reductions are generally offered only at specific individual petrol stations.' Asane-Otoo and Schneider (2015) analyse gasoline and diesel prices on a weekly level. In the case of diesel, the authors find positive asymmetries between 2003 and 2007, i.e. more rapid price reactions to oil price increases than decreases, but no R&F for the years 2009-2013. They also analyse city level data for the four largest German cities but get ambiguous results. Some city-level retail fuel price data do not show a long-run relationship with oil prices (cointegration). Other models have insignificant price adjustment parameters. For diesel prices in Berlin and Munich, the authors find no R&F and even negative asymmetric price transmission, i.e. more rapid price reactions to Brent crude oil price decreases than increases. Kreuz and Müsgens (2019) find evidence of R&F in the German Diesel market with a weekly data set for the period of 2011 and 2012. Furthermore, the authors conclude that splitting their data set in subsets of independent petrol stations (IPS) and non-IPS, as well as station in high and low population densities, show that asymmetric price adjustment is given in each of the subgroups. The top five brands (Aral, Shell, Total, Esso and Jet) show high asymmetry, while non-top five stations do not. Frondel et al. (2019) analyse daily retail fuel prices for a 10 % bioethanol fuel mixture (E10) for about 5,000 German petrol stations before (January 2011 – November 2012) and after (January 2014 – November 2015) the implementation of the Market Transparency Unit for Fuels. The authors find R&F before (contradicting trends of Asane-Otoo and Schneider 2015) and negative asymmetry (faster response to negative cost shocks than to positive cost shocks) after the execution of the Market Transparency Unit for Fuels. Contradicting to these results, Asana-Otoo and Dannemann (2019), analyse a higher amount of stations for the German gasoline (Super E5) market and partly for diesel for the years 2014 to 2018. Besides country-wide and regional price data aggregation, the authors further analyse station-specific data. The authors conclude that about 88 % of the analysed stations in Germany show R&F, with shares of independent petrol station on average comparable to brand stations, while selected cities showing lower shares.[12]

Moreover, meta-analysis approaches have been conducted. Due to the huge amount of literature, meta-analyses regarding retail fuel prices and R&F is performed, focussing on the evaluation of different and contradicting results, especially regarding data characteristics, methods and results by authors such as Frey and Manera (2007), Perdiguero-García (2013) and Eckert (2013). Perdiguero-García (2013) reports that asymmetry in the retail fuel sector is less frequent in more recent analyses. Additionally, using daily data increases the chance of finding asymmetries. He concludes that R&F occurs ‘in specific geographical markets and at specific points in time’ (p. 396) rather than over larger regions and long time periods.

Furthermore, some papers do not focus on R&F but use comparable research questions for potential connections of market occurences as in this paper. Barron et al. (2004) analyse the influence of seller densities on price levels and price dispersion for four western and south-western urban areas in the US in 1997. The authors conclude that an increase in seller densities decreases both retail price levels and price dispersion. Firgo et al. (2015) focus on the characteristics of price correlations between retail stations in Austria. They conclude that central retail stations, which are stations which compete with more rivals than others, do have a higher impact on market prices than less central stations. Therefore, remote retail stations are significantly less correlated to prices of more central competitors. Haucap et al. (2017) work with German data and focus on price levels. The authors show that price levels are

[12] Regarding results and ‘recent findings’ (p. 4) for the German market, the authors survey a highly selective variety of studies, ignoring recent and partly contradicting results compared to their specific outcomes, such as Haucap et al. (2017), Frondel et al. (2019) and Kreuz and Müsgens (2019).

related to characteristics of specific retail stations, such as shopping opportunities, the presence of car wash facilities and brand names.

3 Data and research focus

In many countries high-quality fuel price data is currently more widely available, which makes in-depth empirical analyses easier and far more common. One main reason for the increase in superior data is that private websites publish retail prices. Those homepages are often updated by customers with their smartphones during refueling or passing by. A second reason for improved data quality is that petrol stations are sometimes required to notify government agencies of price changes. In 2013, the German government established the Market Transparency Unit for Fuels. It collects real time data related to gasoline price changes for nearly all petrol stations in the country, making the available pricing data far more comprehensive. The unit is part of the German Federal Cartel Office and is established to increase market transparency in the retail fuel market. Such forms of disaggregated data can give a more detailed insight into markets than aggregated data, usually used before. Therefore, transparent and instantaneous station-specific price data offers an improved look into pricing strategies of certain petrol stations and their respective characteristics, not just for research, but further for companies itself, regulators and customers.

The following analysis is based on a data set from the Market Transparency Unit for Fuels. The data used in that paper is collected from the homepage Tankerkönig (2018). Our original data set in this study contains more than 66.2 million diesel prices from about 14,500 retail stations in Germany. Therefore, the analysis improves earlier work (e.g. Kreuz and Müsgens 2016, 2019) as we use station-specific data instead of aggregated data. Our data for the period from 8 June 2014 to 1 May 2016 contains diesel prices for roughly 8,600 retail stations in Germany, about 60 % of all retail stations in Germany (see Figure 1 for the distribution of all analysed stations). The data for the remaining stations was unfortunately not available for a comparable length of time. Included in our data set is each individual price change for each retail station. Within the data set, each retail station can be identified by an ID number. If any diesel price change occurs, the current price is transferred to the Market Transparency Unit for Fuels and therefore included in our data set. Further information provided includes the location of the retail station and the brand. Out of this data, we calculate daily station-specific averages. We take prices before taxes and without levies and use logged data for all further calculations.

Wrong data, e.g. prices of “-1” and “0”, has been deleted. From the data set, we use 8,576 data series from the same number of retail stations of which 6,772 have at least one price per day over our analysed period. The remaining retail stations (1,804) have just one day missing in the given period of about 700 days. We decided to additionally use this part of the data set by replacing the missing diesel price information of one day by the daily average of all other retail stations in the data set.

We analyse the respective diesel prices for certain characteristics. First, we differentiate for certain brands, such as top five brands (Aral, Shell, Total, Esso and Jet) and independent brands. The selection of top five brands is based on the Federal Cartel Office (2011a, 2011b), which considers all of these five brands in Germany as dominant firms. On the contrary, competition intensity can be influenced by the additional presence of independent petrol stations[13] (see e.g IEA 2014). In many cases, these stations have independence from other brand stations with respect to pricing and marketing strategies (Federal Cartel Office 2011a, 2011b). Besides, independent stations might have altered or no incentives for strategic pricing. Unlike stations with a high market share, such as top five brands, independent stations may have no motivation to strategically alter prices as they do not control other stations profiting from that.

Moreover, we separate stations for regions of high and low population densities. This can be seen as a test if stations have different pricing characteristics regarding R&F in an environment of higher demand and potentially higher levels of competition, such as regions with higher population densities, and vice versa. As we know the exact location of each station, we can separate stations on population densities of the respective districts (Federal Statistical Office 2013). The threshold value for the separation of more urban from less urban market environments is 1,000 people per km^2 (Kreuz and Müsgens 2019). Furthermore, we separate stations according to their average price level, as this can be seen as an indicator for potential forms of market power. Likewise, daily price spreads and by that, stations with higher or lower daily margins are an examined group in our analysis.

Comparing retail diesel prices with its input prices, we choose Brent crude oil prices, as oil prices being the most important drivers of retail gasoline prices (Eckert 2013). We use daily averages of oil prices from Finanzen.net (2019) (see .

Table 1 presents the summary statistics and illustrates that all average diesel prices and shares of characteristics are similar for both data sets, either with 8,576 or with 6,772 stations.[14] Furthermore, our data set shows very similar shares of certain sub-groups to overall market shares (PIA 2019a, Tankerkönig 2018).

[13] These stations are also known as “no-logo retailers” or “maverick” stations.

[14] Comparing our final results just with the 6,772 retail stations does not show any significant differences in results and interpretations.

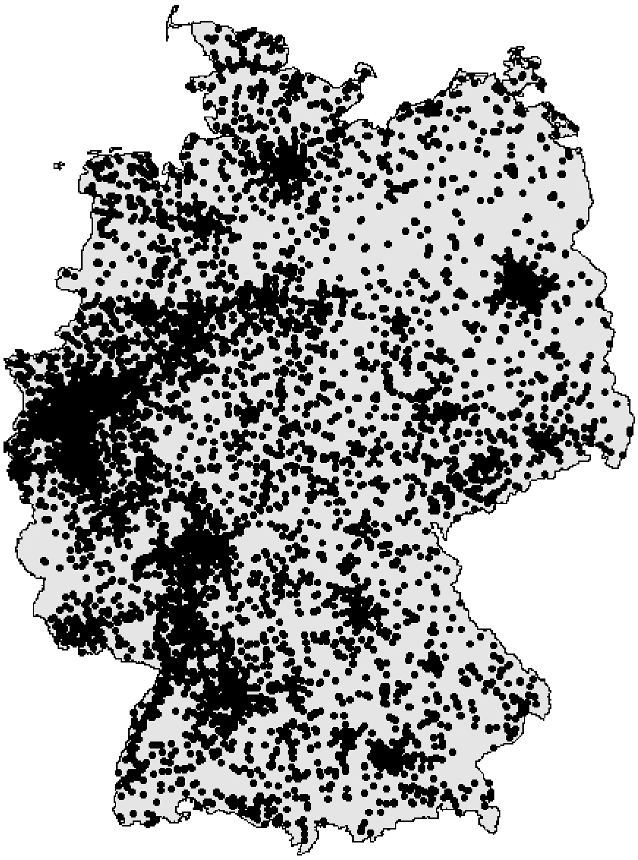

Figure 1: Spatial distribution of the analysed petrol stations in Germany of the used database (#8,576 retail stations) over the respective time period (8th June 2014 to 1st May 2016). Own illustration based on data of Tankerkönig (2018).

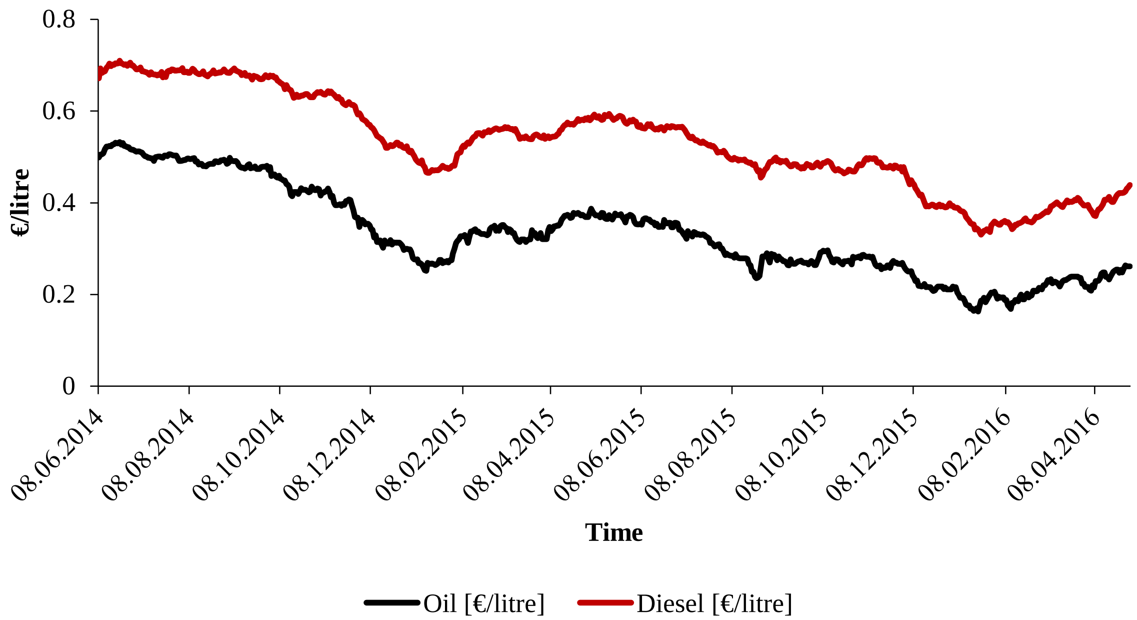

Figure 2: Oil prices and diesel prices before taxes and without levies over the respective period (8th June 2014 to 1st May 2016). Own calculation based on data of Tankerkönig (2018).

Table 1: Summary statistics. Comparison between the used data set with 8,576 stations, the respective data set with just 6,772 retail stations and current overall market share data (PIA 2019a, Tankerkönig 2018). Prices are without taxes and levies. Top five brands: Aral, Shell, Esso, Jet and Total. High daily price spreads are given if the specific station has a higher average price spread than the average over all petrol stations (0.12 €/litre). PopDens high (PopDens low) stands for stations in regions with high (low) population densities. We define high (low) population densities as higher (lower) than 1,000 people per km^2 (Federal Statistical Office 2013).

	All data	Data with sufficient information
Number of stations	8,576	6,772
All data: Mean [€ per litre]	0.5326	0.5321
Standard deviation	0.1059	0.1059
Number of daily price observations	5,951,744	4,699,768

	Average price [€ per litre] (8,576)	Number of price observations (8,576)	Average price [€ per litre] (6,772)	Number of price observations (6,772)	Overall market share (2014 – 2016) (PIA 2019a, Tankerkönig 2018)
Top five brands	0.5404	4,874 (56.8 %)	0.5396	3,962 (58.5 %)	47 %
Non-top five brands	0.5222	3,702 (43.2 %)	0.5216	2,810 (41.5 %)	53 %
Independent	0.5306	792 (9.2 %)	0.5305	583 (8.6 %)	16 %
Non independent	0.5327	7,784 (90.8 %)	0.5323	6,189 (91.4 %)	84 %
PopDens high	0.5284	2,135 (24.9 %)	0.528	1,746 (25.8 %)	21 %
PopDens low	0.5339	6,441 (75.1 %)	0.5336	5,026 (74.2 %)	79 %
cheapest 20 %	0.5067	1,715 (20 %)	0.5066	1,354 (20 %)	-
20-40 %	0.5216	1,715 (20 %)	0.5212	1,355 (20 %)	-
40-60 %	0.5331	1,715 (20 %)	0.5326	1,354 (20 %)	-
60-80 %	0.5426	1,715 (20 %)	0.5422	1,355 (20 %)	-
most expensive 20 %	0.5588	1,716 (20 %)	0.558	1,354 (20 %)	-
High daily price spreads	0.5423	4,225 (49.3%)	0.5417	3,369 (49.8 %)	-
Low daily price spreads	0.5231	4,351 (50.7 %)	0.5226	3,403 (50.3 %)	-

4 METHODOLOGY

To analyse the relationship between retail fuel prices and price fluctuations of input prices, such as oil prices, different methodological approaches can be used. Frey and Manera (2007) as well as Perdiguero-García (2013) name autoregressive distributed lag models, partial adjustment models, error correction models, regime switching models and, as a last subgroup, their multivariate extensions (e.g. vector autoregressive models). Within that methodological tool kit, the error correction model (ECM) proposed by Engle and Granger (1987) is one of the most widely used approaches to answer questions regarding R&F. Therefore, in that approach, we use error correction models to test for potential asymmetries of specific retail stations.

The Engle-Granger procedure comprises three steps: first the test for stationarity of all relevant time series data, second the estimation of the long-run (cointegration) relationship between retail prices and oil prices and third the estimation of error correction models (ECM), in our case for each retail station. The estimation of the long-run relationship will be conducted in step 2 only if retail fuel and oil prices are I(1), i.e. the data in levels is non-stationary and differences of the data are stationary on the first order of integration. Furthermore, the third step can only be carried out if the residuals of the long-run relationship (cointegration relationship) in step 2 are stationary. If this precondition is fulfilled, we use the residuals from the long-run relationship (cointegration relationship) to estimate the ECM in step 3.

The first step is to test for the stationarity of the given time series data in both, levels and their first differences. To this end, we use the Augmented Dickey-Fuller test (ADF-Test) (critical values from MacKinnon 2010).

The second step is to test for cointegration between retail fuel prices and oil prices. Cointegration is given when the linear combination of the potentially cointegrated variables return stationary residuals. We use three different approaches to model the long-run cointegration relationship between retail fuel and oil prices (see Eq. (1), (2) and (3)). By using these different models for potential forms of cointegration, we want to make sure to select the best fitting cointegration model and ensure a degree of robustness by choosing diverse models.

Regarding step 2, i.e. the selection of the specific cointegration relationship, Eq. (1) shows an ordinary and widely used OLS approach to test for a stable, long-run price relationship between oil and retail fuel prices without lags. Coefficient θ is a constant and can also be interpreted as a price markup representing costs of building rental, refining, labour, marketing and transportation (Balke et al. 1998, Johnson 2002), while τ are the residuals of the long-run relationship and σ_l is a dummy for the day of the week to control for weekly price variations. Coefficient μ_i measures the significance of current oil prices for the dependent variable.

Eq. (2) is likewise Eq. (1) but chooses one station-specific lagged oil price as an independent variable. The optimal lag k is chosen for the highest correlation between lagged oil prices to the station-specific fuel prices ($diesel_{i,t}$) for up to 14 lags.[15] As in Eq. (1), weekday dummies are included.

Alternatively, Eq. (3) follows a different approach (see Contín-Pilart et al. 2009), which includes up to 14 lags of input prices, representing two consecutive weeks).[16] To optimise each retail station on its own, we choose the optimal number of lagged oil prices for each retail station with the help of the BIC by reducing the number of lags of oil prices stepwise starting with 14 lags. Furthermore, as in Eq. (1) and Eq. (2), weekday dummies are included.

$$diesel_{i,t} = \theta_i + \mu_i oil_t + \sum_{l=1}^{6} \sigma_l weekday_l + \tau_t \quad (1)$$

Following e.g. Borenstein et al. 1997, Johnson 2002, Kaufmann and Laskowski 2005, Remer 2015, Frondel et al. (2019).

$$diesel_{i,t} = \theta_i + \mu_i oil_{t-k} + \sum_{l=1}^{6} \sigma_l weekday_l + \tau_t \quad (2)$$

Following Faber 2015.

$$diesel_{i,t} = \theta_i + \mu_{1,i} oil_t + \sum_{k=1}^{n} \mu_{2,i,k} oil_{t-k} + \sum_{l=1}^{6} \sigma_l weekday_l + \tau_t \quad (3)$$

Following e.g. Stock and Watson 1993, Contin-Pilart et al. 2009.

Testing for a long-run relationship reveals which retail stations have a cointegration relationship with oil prices. Comparable to step 1, we use the ADF-test to test for stationarity and, by that, we test whether there exists a long-run cointegration relationship between retail diesel and oil prices. For the stations which show stationary residuals τ, it is possible to formulate an error correction model (ECM) to test for possible R&F characteristics.

The third step is to establish an error correction model. This model is in our case used to test for potential asymmetric price responses between retail fuel prices and oil price changes after positive or negative price movements of oil prices. We test the difference between positive and negative diesel price responses with the help of a Wald-test. For the establishment of the ECM, we use the residuals of the cointegration relationships explained above in step 2. We use a standard asymmetric ECM (Eq. (4)).

$$\Delta diesel_{i,t} = \gamma_i^+ \tau_{t-1}^+ + \gamma_i^- \tau_{t-1}^- + \sum_{m=0}^{K} \vartheta_{1,i,m}^+ \Delta oil_{t-m}^+ + \sum_{m=0}^{K} \vartheta_{1,i,m}^- \Delta oil_{t-m}^- \quad (4)$$

---

15 This approach is related to Faber (2015) who uses a fixed two-day lagged input price but does not account for a station-specific approach. Using the specific approach, in the given data set with an optimal three-day lagged oil prices for each station, provides comparable results.

16 Furthermore, we used more and less lags (e.g. 3 and 25 lags). The respective results are comparable to the our cointegration outcomes.

$$+\sum_{n=1}^{L}\vartheta_{2,i,n}^{+}\Delta diesel_{t-n}^{+}+\sum_{n=1}^{L}\vartheta_{2,i,n}^{-}\Delta diesel_{t-n}^{-}+\varepsilon_t$$

$$\tau_t^+ = \tau_t \wedge \tau_t^- = 0\ if\ \tau_t > 0,\ \tau_t^- = \tau_t \wedge \tau_t^- = 0\ if\ \tau_t < 0;$$

$$\Delta oil_t^+ = \Delta oil_t \wedge \Delta oil_t^- = 0\ if\ \Delta oil_t > 0,\ \Delta oil_t^- = \Delta oil_t \wedge \Delta oil_t^+ = 0\ if\ \Delta oil_t < 0;$$

$$\Delta diesel_t^+ = \Delta diesel_t \wedge \Delta diesel_t^- = 0\ if\ \Delta diesel_t > 0,$$

$$\Delta diesel_t^- = \Delta diesel_t \wedge \Delta diesel_t^+ = 0\ if\ \Delta diesel_t < 0,$$

$$K, L = 14$$

Within Eq. (4), ϑ measures the short run impact of positively (+) or negatively (-) lagged oil price changes (ϑ_1) and lagged diesel price changes (ϑ_2). The variable τ_{t-1} represents the lagged residuals from the cointegration relationship between retail fuel prices and oil prices in step two. This coefficient measures the adjustment speed between retail and oil prices after input price changes and can therefore be interpreted as a long-run equilibrium adjustment parameter. As the value shows the speed of adjusting back to the long-run equilibrium, it should always be negative. The threshold value to decompose both, price data and error terms, is zero. Positive error-correction terms (τ_{t-1}^+), which are the residuals from Eqs. (1-3), show that the real fuel price is higher than the predicted equilibrium level. In that case, as we have tested for long-run linear relationship, we would assume that the fuel price will decrease. On the other side, as error-correction terms are negative (τ_{t-1}^-), the real fuel price is lower than the predicted equilibrium price level and will increase. Therefore, the coefficients $\gamma^+(\gamma^-)$ is a price adjustment speed level for decreasing (increasing) fuel price adjustments. Consequently, for the test of long-term asymmetry using a Wald-test, R&F would be given if a significant difference between the adjustment parameters is given in the way that $\gamma^+ < \gamma^-$.

5 RESULTS

The results are presented in two sub-sections. The first part (section 5.1), shows the results regarding the mentioned research questions from chapter 3, analysing the data set at once. We follow the Engle-Granger procedure, as described in the last section. The second part (section 5.2), shows the results after a comparable analysis of the given data set, but with an approach of rolling windows. Therefore, we additionally examine changing market characteristics and triggers for R&F over time.

5.1 Characteristics on the occurrence of Rockets and Feathers

Following the described three-step methodology in section 4, the results are presented for all three steps: (I) testing for the stationarity of the given time series data in levels and their first differences, (II) testing for cointegration and (III) estimating station-specific error correction models.

For (I), each station's diesel price series, as well as the crude oil price series, are stationary in their first differences and non-stationary in their levels.[17] Consequently, the data satisfies the condition of the following Engle-Granger approach.

As to (II), the results in Table 2 show a high degree of cointegration, which means widespread, stable, long-run relationships between retail diesel prices and crude oil prices. The outcomes illustrate, that a clear majority of stations have this cointegration relationship. Using Eq. (1) to test for cointegration, 98 % of the retail stations show a cointegration relationship between diesel prices and crude oil prices on a 99 % significance level. Testing the residuals for stationarity with the station-specific selected optimal OLS relationship of Eq. (2), our results indicate that about 80 % of stations are cointegrated, while Eq. (3) gives lower cointegration levels with about 58 %. As Eq. (1) reveals the highest cointegration levels, we choose that model as our standard one as it reproduces the highest correlation between input and output price levels.[18]

Furthermore, the estimated long-run effect of oil on retail fuel (μ_i in Eq. (1) and Eq. (2), $\sum_{k=0}^{n} \mu_{i,k}$ in Eq. (3)), averaged over all retail stations without taking the logarithm of the data, is 1.04 (1.05 for Eq. (2) and Eq. (3)) and, therefore, close to unity. Thus, the results show that there is a full passthrough of a cost shock within the retail fuel market. These findings correspond to earlier work (see e.g. Johnson 2002, Verlinda 2008, Remer 2015). Johnson (2002) classifies the result of a full passthrough for the retail sectors as a constant cost industry.

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[17] These results are available upon request.

[18] Using Eq. (2) or Eq. (3) in cases of retail stations, for which Eq. (1) does not show cointegration, but Eq. (2) or Eq. (3) do, does not change any of the presented results.

Table 2: Shares of cointegration between retail station price series with oil prices for three different cointegration model approaches.

	99 % significance level [in %]	95 % sigificance level [in %]
Eq. (1)	98	100
Eq. (2)	79	95
Eq. (3)	58	85

Third (III), Table 3 shows the share of retail stations with asymmetric price setting characteristics. [19,20] It shows the percentages of stations with asymmetric pricing out of all cointegrated stations for the different subsets (top five brands, independent stations, population densities, differently priced stations, high and low daily price spreads) (column 1). Additionally, we perform a two-proportion Z-test to identify any potential significant difference of the two-part subgroups (e.g. top five brands vs. non-top five brands) (column 2).

The first row indicates that about 13 % of the stations reveal R&F, with faster reactions of diesel prices to oil price increases than to decreases. Moreover, results illustrate significantly higher than average shares of asymmetries for the overall group of **top five brand stations** (Aral, Shell, Esso, Jet and Total) (rows 2-3).[21] In addition, lower shares are given for **independent petrol stations** (rows 4-5) and sigtnificantly higher shares of R&F can also be seen in **regions with lower population** densities and, therefore, potentially lower competition intensities (rows 6-7). Furthermore, the findings illustrate that R&F is significantly more prevalent for **high-priced stations**, where about a quarter of the most expensive stations show R&F characteristics (rows 8-12). Similarly, stations with **higher than average daily price spreads** are significantly more likely to have R&F than those with smaller price spreads (rows 13-14). Therefore, stations with higher margins or peaks of margins during the day have an increased chance of asymmetrical pricing.

[19] Additionally, we performed the analysis for one aggregated data set of all 8,576 retail stations. Results confirm the outcome above. They show that cointegration between oil price data and the aggregated diesel data is given. The error correction terms do show higher adjustment speed levels for price increases (negative error-correction terms) than for price decreases (positive error-correction terms). Nevertheless, Wald-test results show no significant difference between adjustment parameters. This is in line with the calculated share of R&F (about one in eight stations) in the overall data (Table 3).

[20] We used the Breusch-Pagan-test to control for potential heteroscedasticity for the ECM models of each retail station. If heteroscedasticity is detected, we calculated the specific ECM model with heteroscedasticity-consistent standard errors (white standard errors). Using different levels of significance for the BP-test (1 %, 5 %, and 10 %) or even using heteroscedastic robust standard errors for all retail stations does not show significant different results. The presented outcomes are calculated with the significance levels of 1 %.

[21] The selection of top five brands is based on the Federal Cartel Office (2011), which considers these five brands as dominant firms.

Table 3: Shares of all retail stations showing R&F overall and for certain sub-groups. Two-proportion Z-test (one-tailed) for the difference in shares of R&F with significance codes: 0.01 (***), 0.05 (**), 0.1 (*). For detected cases of heteroscedasticity with a significance level of 1 %, we used heteroscedasticity-consistent standard errors (white standard errors). Top five brands: Aral, Shell, Esso, Jet and Total. High daily price spreads are given if the specific station has a higher average price spread than the average of all stations (0.12 €/litre). Low (high) amount of competitors in a 10 km radius is given if the amount of competitor is lower (higher) than half the arithmetic mean (1.5*arithmetic mean). Using the same categories with the help of averages as for the 10 km radius (i.e. for 1 km: low = 0 and high > 1), we would get comparable results as with the chosen categories of low = 0 and high >2.

Cases	Shares of R&F [Residuals from Eq. (1)]	Two-proportion Z-test
Rockets and Feathers	13.0 %	
Top five brands	16.1 %	(***)
Non-top five brands	9.0 %	
Independent	9.3 %	(***)
Non independent	13.4 %	
PopDens high	10.4 %	(***)
PopDens low	13.9 %	
cheapest 20%	5.7 %	
20-40%	8.6 %	
40-60%	13.0 %	
60-80%	14.8 %	
most expensive 20%	23.5 %	
High daily price spreads	15.7 %	(***)
Low daily price spreads	10.4 %	
Aral	25.1 %	(***)
Esso	18.7 %	(***)
Shell	10.2 %	(***)
Jet	3.8 %	(***)
Total	8.2 %	(***)
Number of competitors in 1 km radius equals 0	13.0 %	( )
Number of competitors in 1 km radius is higher than 2	12.5 %	
Number of competitors in 10 km radius is low	13.0 %	(**)
Number of competitors in 10 km radius is high	11.5 %	

Analysing the origins of R&F even more closely, we further split the retail station into **specific top five brands (Aral, Esso, Shell, Jet, Total)**. Results display differences in chances of R&F for certain brands (rows 15-19). While Aral and Esso show higher shares of R&F than the average, other brands such as Shell and Jet show even lower shares over the whole data set. Therefore, the group of dominant top five brands (Federal Cartel Office 2011a, 2011b) do not price consistently in regards to R&F. The market position of the German retail fuel brand Jet is already controversially discussed: Although the Federal Cartel Office claims that Jet is part of the market-dominating position of the five mentioned brands, the market position is actually less clear, as it shows different pricing characteristics compared to other major brands (Haucap et al. 2017, Kreuz and Müsgens 2019). Therefore, separating Jet from the other four brands, sharpens the significant difference regarding the share of R&F: With 17.1 % (top four brands) vs. 8.5 % (non-top four brands).

In addition, the **number of competitors** within a specific radius as a trigger for R&F show inconclusive results. Although Alderighi and Baudino (2015) see general pricing dependence of retail stations up to the distance of about 1 km, we could not find a significant effect on the probability of R&F for a radius of 1 km (rows 20-21). Nevertheless, following the argumentation of Kvasnicka et al. (2018) for a relevant driving distance of customers of around 6 km, we tried higher values for radii (rows 22-23). We find significantly lower shares of R&F related to higher amounts of competitors within a 10 km and 7.5 km but not for a 5 km radius or lower (the last two cases are not shown in Table 3). Nevertheless, the share in numbers is always lower for higher amounts of competitors and vice versa.

5.2 Time-related analysis of Rockets and Feathers

Additionally, we investigate relevant factors on the occurrence of R&F over time. One main reason for that approach is that the environment of a market can change. Adjustments of pricing strategies of firms can occur and deviate from earlier developments (Stiglitz and Walsh 2006). Consequently, fuel pricing strategies in general and particular R&F can change over time (see e.g. Hosken et al. 2008, Perdiguero-García 2013). As an example, markets with potential collusive behaviour are predominantly difficult to coordinate. By that, the strength of the collusion mechanism or the composition of involved firms might change over time. Therefore, the advantage of an analysis over time is to analyse for patterns and reasons for potential changes of R&F within a specific period.

There has been no in-depth and detailed investigation of R&F over time. In most analyses, just one specific period of time was investigated. Exceptional cases are among others Slade (1987), who finds evidence for changing market environments, with price wars and otherwise periods with cooperation of market players in the retail fuel market of Vancouver (Canada). Additionally, Contin-Pilart et al. (2009) and Frondel et al. (2019) each analyse two specific periods. While the former investigates prices before and after policy regulation changes for the Spanish market, the latter analyse prices before and after the introduction of price transparency regulations.

Complementary and advanced from that, we establish time periods (rolling windows) of 200 consecutive days within the given data set of 694 days.[22] For each of these rolling windows, we calculate the share of R&F for all the given 8,576 petrol stations over the respective 200 days and further market indicators. By that, we get e.g. 495 shares of R&F for our given data set.

From the analysis, three implications can be concluded:

a. R&F occurs more often in time periods of low diesel prices.

First, lower diesel prices result in higher shares of R&F. This relationship can be seen in Figure 3. It shows the shares of R&F for the 495 rolling windows of 200 days each. Additionally, Figure 3 illustrates the average daily diesel prices over the respective time period. The share of R&F is not stable over time. In fact, it increases at the end of the period to about 25 %. Simultaneously, Figure 3 shows that the averaged diesel prices over 200 days each, decrease over time and reach its lowest level at the end of the period.

[22] We analysed different ranges of rolling windows, e.g. up to 400 consecutive days. Results are comparable with different lengths of rolling windows.

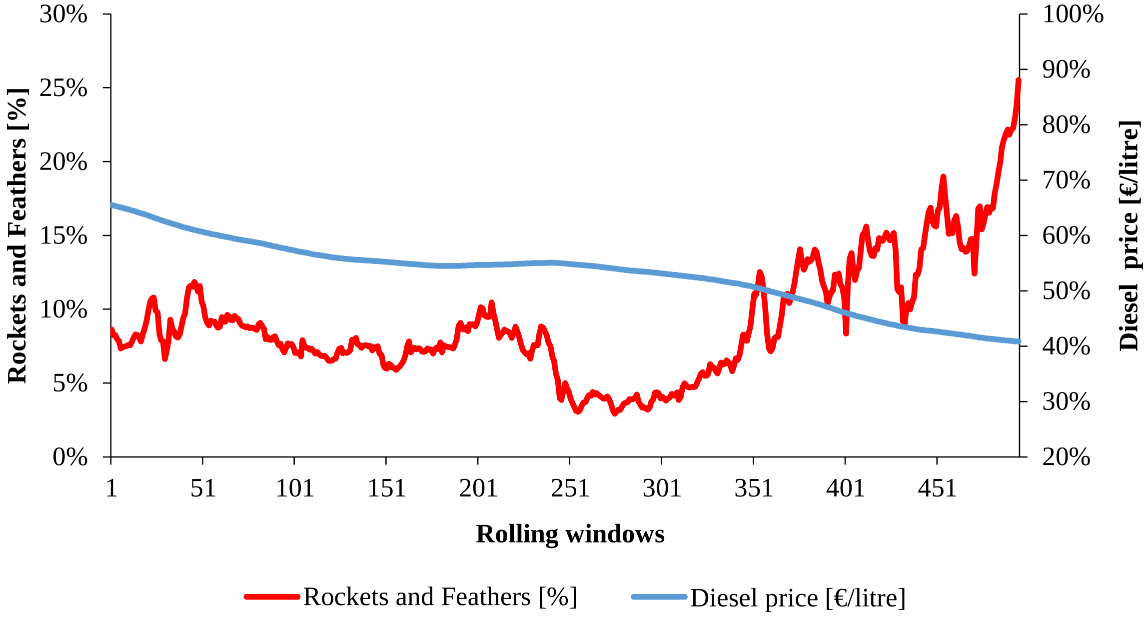

Figure 3: Shares of R&F and averaged diesel prices for 495 rolling windows of 200 daily data points each. Diesel prices show 200-day averages of diesel prices of all daily data of 8,576 petrol stations.

b. R&F occurs more often in time periods of higher margins and lower shares of cointegration between oil and diesel prices.

First, Figure 4 shows, besides the share of R&F as in Figure 3, relative diesel margins increasing over time and reaching the maximum at the end of the period. We calculate the relative diesel margin for every rolling window with averages of oil and diesel prices over 200 consecutive days. These margins are calculated as the difference between diesel and oil price levels for each rolling window in relation to the respective diesel price level.

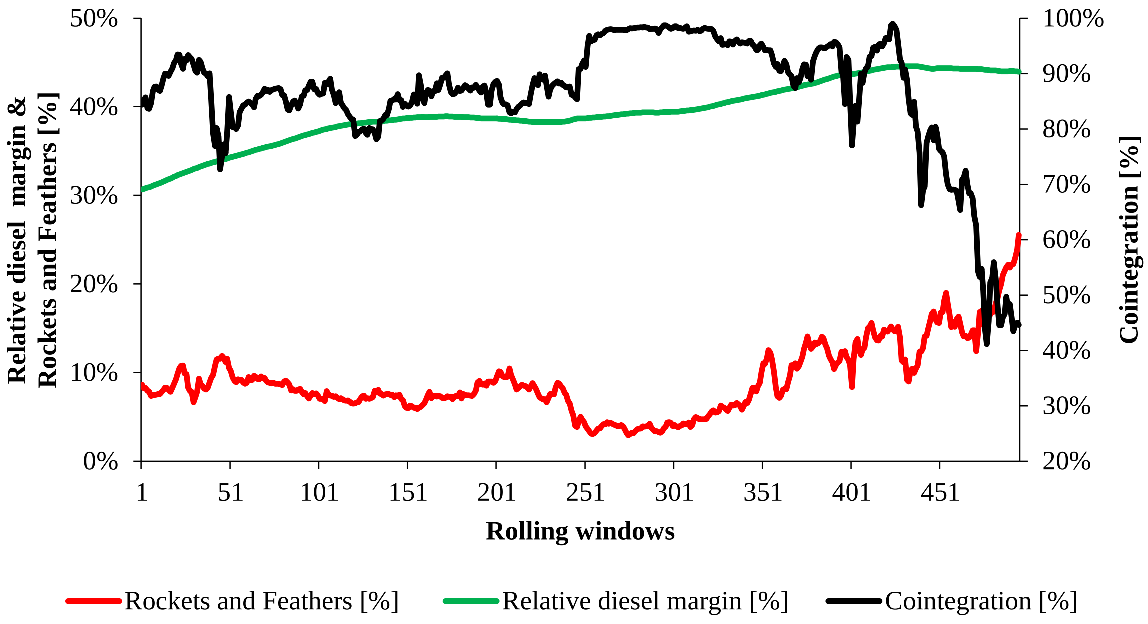

Figure 4: Share of R&F, relative diesel price margin and the share of cointegrated retail stations for 495 rolling windows of 200 daily data points each. Diesel price margins are calculated out of 200-day averages of diesel prices of all daily data of 8,576 petrol stations and 200-day averages of oil prices.

Second, as can be seen in Figure 4, the level of cointegration changes over time. For most of the calculated rolling windows, the share of cointegrated retail stations is between 80 % and 100 %. Conversely, the amount of cointegration decreases in the end of our respective period, starting in August 2015 (roughly with the rolling window number 438). Within that period, the level of cointegrated stations is often even less than 50 %. Therefore, cointegration is no stable condition and is rather precarious.

Nevertheless, during that period, the increasing share of R&F is also related to an increase in the total amounts of retail station with cointegration and R&F: The average of stations with R&F over all rolling windows is 645. For the period starting from rolling window 389, roughly the point when the share of R&F is increasing significantly, on average 929 stations show R&F. Therefore, despite decreasing cointegration levels, within the group of cointegrated stations, the total number of cointegrated retail stations with R&F increases.

c. Diesel price levels, diesel margins and cointegration levels explain R&F changes to a high degree.

As mentioned before, the share of R&F over time is related to diesel price levels (as discussed in point a.) and as well to diesel price margins and levels of cointegration (as discussed in point b.). Table 4 shows regression results of shares of R&F over time subject to diesel price development, diesel margins and the level of cointegration. Each regression consists of 495 data sets (number of rolling windows), with the share of R&F as the dependent variable. The table displays different regression results between R&F and the respective independent variables for an improved analysis.

Table 4: Regression results for outcomes of the analysis of rolling windows. Dependent variable: Share of R&F [%]. Amount of data points of each regression: 495. Model 1b and 6b:
$\boldsymbol{R\&F = a * exp(b\ *\ diesel\,price\ [or\ diesel\,margin]) + c.}$

Dependent variable : $R\&F\_Share_t$[%]

Estimators	1a	1b	2	3	4	5	6a	6b
$Intercept_t$	0.31***	-	0.31***	0.40***	-	0.12***	-	-
$Diesel\ Price_t$ [€/l]	-0.41***	-24.84***		-0.28***	-	-	-	-
$Relative\ Diesel\ Margin_t$ [%]	-	-		-	0.61***	0.42***	0.23***	55.71***
$Cointegration_t$ [%]	-	-	-0.25***	-0.19***	-0.17***	-0.22***	-	
a		3,336						1.59e-12
c		0.07***						0.07***
Correlation/ Adj. R^2	0.63/ 0.40	0.83/ 0.68	0.7/ 0.49	0.8/ 0.64	0.76/ 0.93	0.78/ 0.61	0.51/ 0.86	0.77/ 0.59

First, the occurrence of R&F over time is for most parts of the data negatively related to diesel price movements, i.e. lower diesel prices increase the chance of R&F (regression 1a, 1b and 3 in Table 4, further see Figure 5). Nevertheless, the conclusion of a linear increasing share of R&F with decreasing prices is not prevalent for the whole data set. Far more, an exponential approach (regression 1b) shows stable or even slightly increasing shares of R&F for diesel price levels higher than 0.55 Euro per litre.[23] By that, it can be concluded that a base of stations show R&F independent of price developments, while a significant share of stations take advantage of decreasing prices and realise R&F exclusively in those periods.

[23] In fact, the exponential approach $(e.g. R\&F = a * \exp(b\ *\ diesel\,price) + c)$ and a non-linear least square approach $(e.g. R\&F = a * \frac{1}{diesel\,price^b} + c)$ show very comparable regression results. Therefore, we just show the results for the exponential model in Table 4.

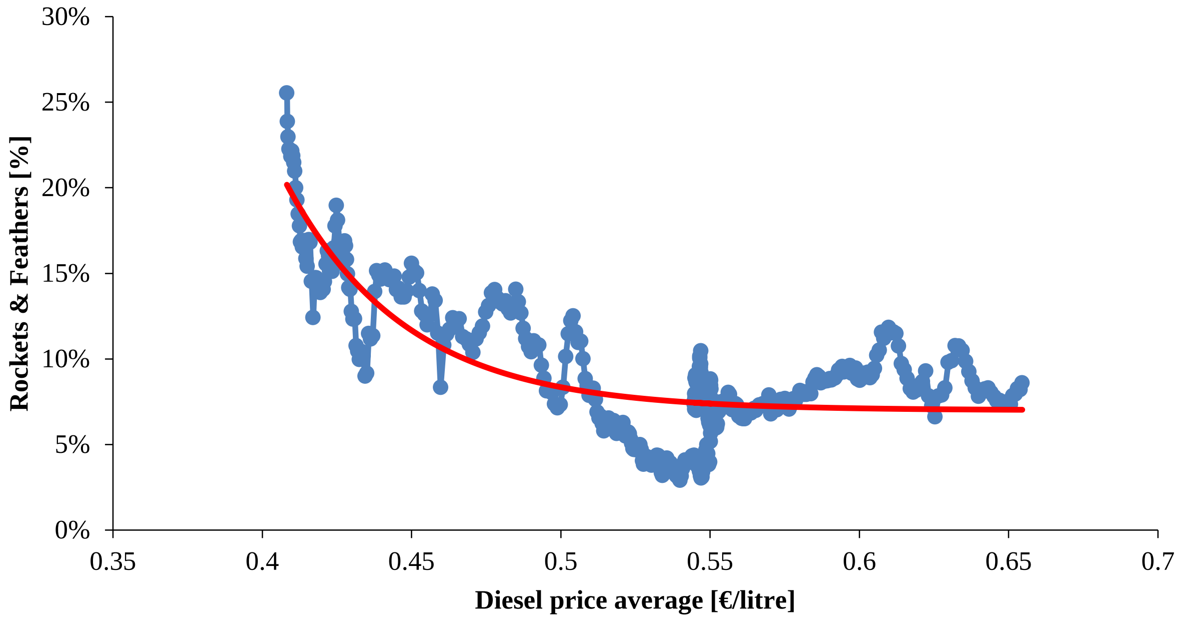

Figure 5: Correlation between diesel price averages [€/litre] and the share of R&F [%] for 495 rolling windows of 200 daily data points each. Red: Exponential regression to predict the data:
$\boldsymbol{RaF = a * exp(b \, * \, diesel\,price) + c}$ (regression 1b in Table 4).

Second, triggered by these results, retail diesel margins are negatively related to the occurrence of R&F. As the share of R&F increases, the retail price margin increases for most of the time as well (regressions 4 to 6a and 6b in Table 4 and Figure 6). However, as described for the case of diesel price levels, an exponential approach (regression 6b) improves the model. This is given, as a base of stations shows R&F despite decreasing margins. Therefore again, we cannot find a straightforward linear relationship between increasing shares of R&F and increasing margins for the whole data set. Rather, a specific share of stations showing R&F seem to be unrelated to margin changes within the market and keep their asymmetric pricing.

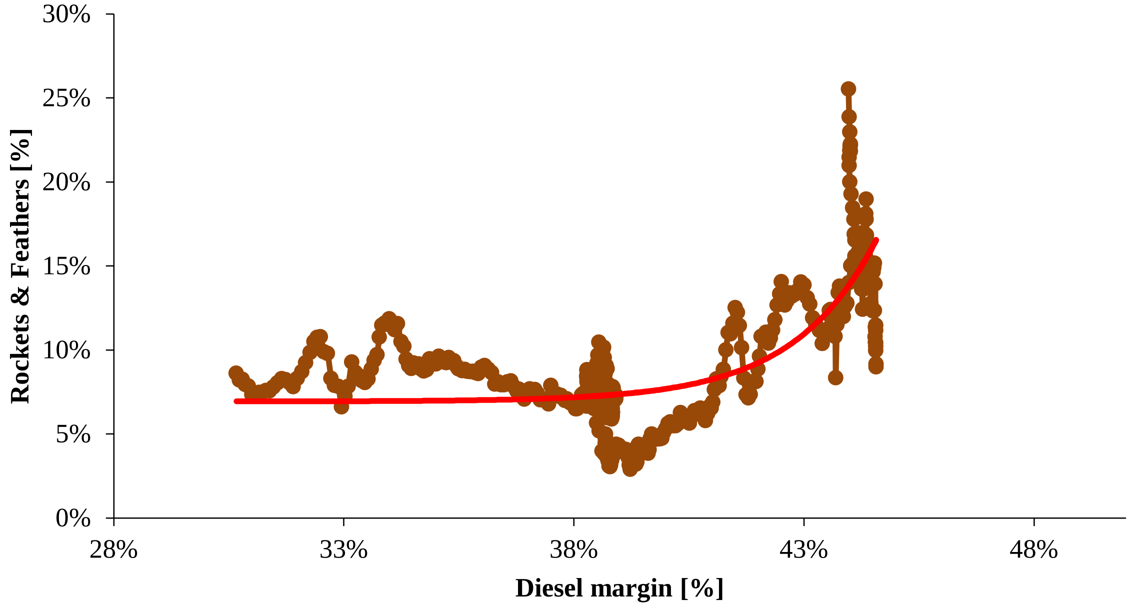

Figure 6: Correlation between diesel margins [€/litre] and the share of R&F [%] for 495 rolling windows of 200 daily data points each. Red: Exponential regression to predict the data.
$\boldsymbol{RaF = a * exp(b * relative\ diesel\ margin) + c}$ (regression 6b in Table 4).

Third, our results show a significant negative dependence of the occurrence of R&F on the share of cointegration of all respective retail stations analysed (regression 2 to 5 in Table 4, Figure 7). Lower levels of cointegration in the market increase the share of retail stations, which on the one side still have given cointegration between their diesel prices and oil prices and on the other side show R&F. Therefore, as uncoupling from the input prices is more prevalent in the market and cointegration levels decrease, stations still pricing diesel fuel related to oil prices and by that express a cointegrated relationship, show more often R&F.

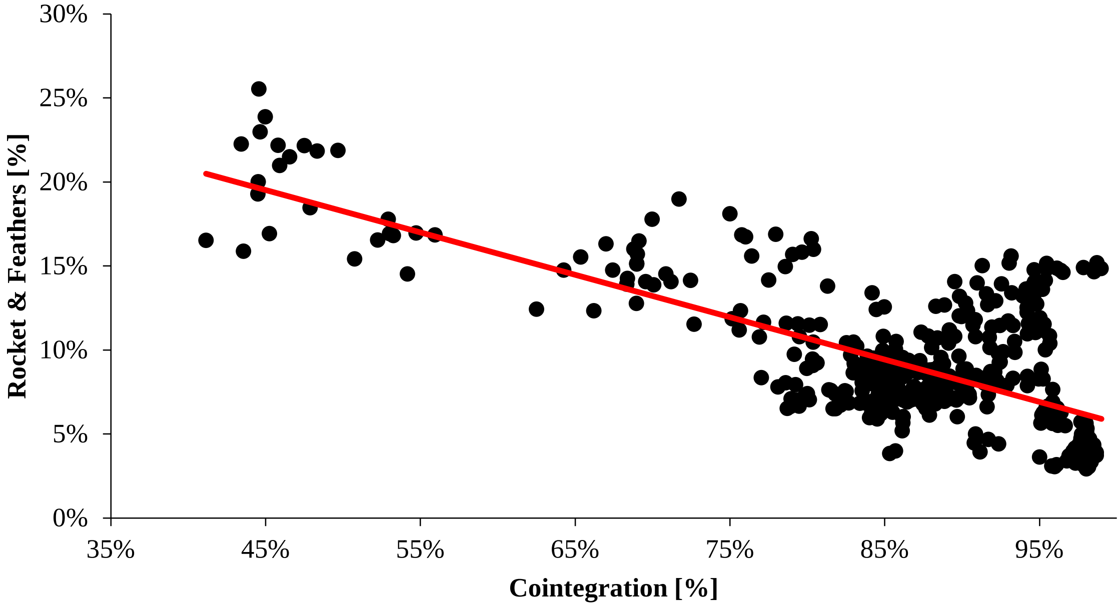

Figure 7: Correlation between the share of cointegrated stations [%] and the share of R&F [%] for 495 rolling windows of 200 daily data points each. Red: Regression 2 in Table 4.

We found specific rolling windows, where the cointegration relationship of Eq. (2) performs with higher cointegration rates than Eq. (1). Otherwise, Eq. (3) never shows the highest cointegration rates and therefore is not further included. Consequently, we executed combined regressions, deciding for each rolling window for the cointegration relationship (Eq. (1) or Eq. (2)) with the highest cointegration rate. Results indicate that trends found as shown before are stable but in parts slightly less distinct.[24] Nevertheless, we see our results as robust, as Eq. (1) performs as the best model regarding the cointegration relationship in general with our data (see Table 2) and is widely used within the literature (see section 4).

5.3 Analysis and Summary

In our analysis, we find characteristics and stimulations for the occurrence of R&F. Table 5 summarises the presented results and brings them into context. We see both, tacit collusion and consumer search characteristics as potential explanations for the emergence of R&F.

[24] See Table 7 in the appendix.

Table 5. Summary of cases and results.

	Relationship with R&F frequency	Characterisation	Review
Top five brands	↑ - ↑	Top five brands show higher shares of R&F.	Potentially tacit collusion related
Independent stations	↑ - ↓	Independent stations show lower shares of R&F.	Potentially tacit collusion related
Population density	↑ - ↓	Stations within higher populated regions show lower shares of R&F.	Potentially tacit collusion related
Station specific price level	↑ - ↑	Stations with higher price levels show higher shares of R&F.	Potentially tacit collusion related
Daily price spreads	↑ - ↑	Stations with higher daily price spreads show higher shares of R&F.	Potentially tacit collusion related
General diesel price level	↓ - (↑)	Decreasing general diesel price levels partly increase the chance of R&F.	Potentially consumer search characteristics related
Diesel margin	↑ - (↑)	Increasing margins partly corresponds to increasing shares of R&F.	Potentially consumer search characteristics / potentially tacit collusion related
Level of cointegration	↓ - ↑	Decreasing levels of cointegration corresponds to increasing shares of R&F.	Potentially tacit collusion related

First, the **first five characteristics** (top five brand vs. non-top five brand, independent petrol stations vs. non independent petrol stations, high population density vs. low population density, high average price level stations vs. low average price level stations, high daily price spreads vs. low daily price spreads) point in the same direction of tacit collusion as a potential reason for the higher appearance of R&F.

Top five brand stations, expensive stations as well as non-independent stations and stations with high daily spreads, show significant higher chances of R&F. At first glance, our findings regarding **top five brands** and **non-top five brands** follow earlier results from Balmaceda and Soruco (2008). On the other side, we see that especially two out of these **top five brands**, Aral and Esso, do utilise significantly higher capacities regarding R&F compared to the overall average over the whole data set (see Table 3). Nevertheless, the ranking of the selected five main brands is not static and changes over time, with nearly every brand having periods with the highest share of R&F for specific periods (see Figure 8). As can be seen, fuel stations such as Esso and Jet, display certain rolling windows with very high shares related to the market average. However, during most of the periods, the specific brands show comparable trends.

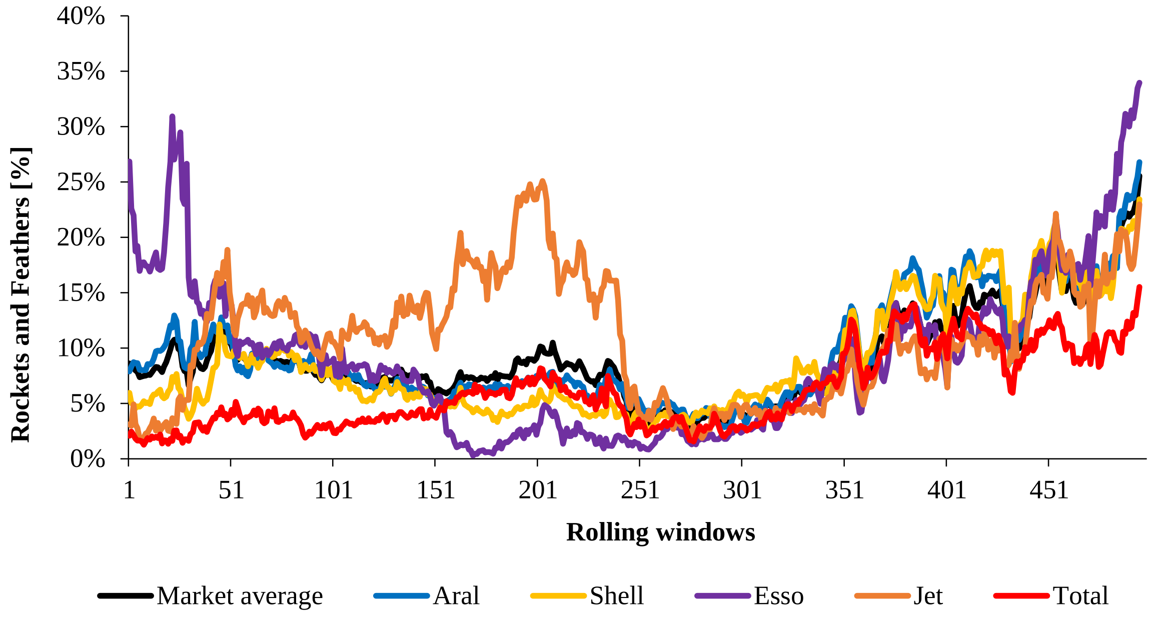

Figure 8: Share of R&F of specific brands and the market average of R&F for 495 rolling windows of 200 daily data points each.

One reason for a **selection of top five brands** realising R&F can be their high market power due to high market shares and better access regarding refinery capacities. These two aspects can be seen as the main difference, compared to **independent stations** (Federal Cartel Office 2011a, 2011b). First, stations of one major brand with huge market shares can coordinate prices more easily and widespread, offering chances to participate for further brands which can improve the stability of tacit collusion agreements. Additionally, higher market shares enable brands to sanction stations which price out of the leading structure of market dominating firms. This can also be a reason for changing levels of R&F over time. Sanctions against rival firms leaving the tacit agreement can go in line with an end of R&F over a specific period. Second, access regarding refinery capacities is an essential power factor, e.g. regarding chances for a market entry of potential new competitors without refinery capacities (Federal Cartel Office 2011a, 2011b). Interestingly, the refinery owners cooperate in an essential way. As every major brand has country-wide market presence, they do not own refinery capacities all over the country. Therefore, these major brands cooperate and supply each other's stations from refineries in proximity to their stations. By that, those brands have a mutual dependency in regards to fuel supply.

Potential additional reasons for higher shares of R&F for **major brands** and also **expensive stations,** can be due to higher quality services and by-products, as well as customer loyalty, through service cards and related discounts, and is therefore linked to lower switching rates of customers. **Independent stations** compete less on consumer loyalty and more intensively on prices (Remer 2015, Bello et al. 2018). These findings can be seen as further explanations for their significantly smaller amount of R&F. For instance, the General German Automobile

Club (2019) grants its more than 20 million members in Germany between one and two Euro-cents per litre fuel, purchased at certain brands, such as Shell. Chesnes (2016) argues that higher rates of R&F of major brands compared to unbranded stations can also be seen as consistent with consumer search explanations.[25] Nevertheless, we see that argument as less applicable for our case. The group of major brands, all with mentioned customer and marketing programs, show considerable different and changing pricing characteristics in regards of R&F, sometimes even with lower shares than independent stations.

Our results regarding **expensive stations** partly contradicts earlier work of Lewis (2011) and Remer (2015). Both authors argue that as no significant difference between high priced and low priced stations exist, tacit collusion can not be used as a determinant for the existing cases of R&F in their respective study. This result is concluded in their analyses, as firms having the highest potential for collusion are stations with higher than average prices. In fact, we found that expensive stations have significant higher shares of R&F, presenting collusion as a potential explanantion for their specific behaviour (Johnson 2002).

Stations with high daily spreads can be seen as stations with higher margins or peaks of margins during the day and likewise facing less competition intensity. In our case, those stations show significantly higher shares of R&F. Our results regarding these stations are comparable to findings of Deltas (2008), who argues that high price-cost margins are related to higher levels of R&F as local market power exists.

A further argument for tacit collusion can be applied for stations in **lower populated regions** which show higher shares of R&F. Lower amount of competitors in those areas give consumers less refuelling options. Therefore, higher transaction costs to reach alternative stations exist. By that, the location of a specific station can be included as a characteristic into an otherwise homogeneous product market (Firgo et al. 2015, Eleftheriou et al. 2019). Therefore, those stations can implement not just asymmetric price transmission more widespread, but additionally – as we can confirm from our data[26] – higher price levels (see also Barron et al. 2004, Clemenz and Gugler 2006, Haucap et al. 2017). Tacit collusion as a potential explanation is supported by Johnson (2002). He argues that the existence of significant search costs, such as in lower populated regions with fewer outlets, does imply a presence of market power and potential for oligopolistic coordination 'at least [to, S.K.] some degree' (p. 48). R&F is, as our findings show, apparently more likely in those markets, while oligopolistic behaviour can here be seen as 'the culprit' (Johnson 2002, p. 48).

Regarding the effect of the **amount of competitors** on the occurrence of R&F, we could not find a strong and significant result. One reason for a less strong relationship between intensive competition due to a high amount of stations and the share of R&F can be that several

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[25] Remer (2015) argues along similar lines. Customers of premium gasoline, usually, especially provided by major brands, are less price sensitive and less informed. On the other side, customers of regular fuel are more likely to be a "shopper". This argument is not relevant for our case, as we focus on regular diesel with the same features for all German retail stations.

[26] See Table 1.

stations, which appear to be independent from top five brands, are actually price dependent upon those firms (Federal Cartel Office 2011). This is given as even though a high amount of stations are not owned by the five main brands, some are dependent on price setting decisions via contracts with those brands.

Second, analysing R&F with the help of rolling windows over time, we find three estimators further explaining the occurrence of R&F in certain market characteristics: diesel price levels, diesel margins and cointegration levels.

First, there exists a negative relationship between **diesel price levels** and the share of R&F. This linkage supports findings of authors mentioning consumer search characteristics as a reason for asymmetric pricing (see section 2.1, e.g. Johnson 2002, Lewis 2011, Hastings and Shapiro 2013). Therefore, outcomes can be used to confirm the respective hypothesis: As diesel price levels decrease, the market is characterised by lower search intensity and sellers face less market pressure for price decreases. By that, stations have an opportunity to price asymmetrically.

Nevertheless, our data shows that the relationship is not straight linear. Higher diesel price levels are related to lower degrees of R&F just for parts of the rolling windows, and by that following assumptions of consumer search frictions just in parts. However, for the highest levels of averaged diesel prices, shares of R&F are stable, revealing that a base of stations show R&F independent of price developments.

Summing up, we find further evidence for an affiliation between changing levels of R&F due to retail price changes. Nevertheless, we are not able to confirm the hypothesis of consumer search frictions as reasoning in their entirety. Further reasons, such as earlier mentioned collusion characteristics might be responsible for an unchanging base of stations showing R&F in the market.

Second, **retail diesel margins** increase with growing shares of R&F. We see two potential reasons for this relationship:

The result can be brought in relation to **consumer search theories** as well. The relationship between R&F and margins is partly positively related, with higher amounts of margins linked to higher shares of R&F. Lewis (2011) interprets increased margins and lower price transmission in times of decreasing prices as an effect of customers' fewer searches and by that of respective imperfect knowledge of consumers. Stations price asymmetric as fast price reductions do not help to attract customers, due to low search levels. His raw results fit partly to our findings, that in times of decreasing (increasing) prices, margins are higher (lower). Antoniou et al. (2017) and NACS (2016) confirm the finding of increasing margins during general price level decreases for the US market. This, as our results show, corresponds to higher (lower) shares of R&F.

In line with this analysis, Deltas (2008) concludes that markets with high price-cost margins experience a more asymmetric response, while margins can be taken as an indicator for market power. The author is reluctant to interpret his empirical results in favor of one of the two main hypotheses to explain R&F. Still, he associates the existence of R&F and respective margins to market power ‘originating from costly consumer search’ (p. 624). For an input price decline, retailers do not pass the entire price effect into their market price. This expands their margins and makes consumer search costlier, preventing faster price adjustment through consumers learning new prices. This situation is given as customers already tend to have lower search efforts during input price decreases.

Nevertheless, diesel price margins decrease with decreasing shares of R&F just to a certain point. From there on, a stable base of R&F is given despite decreasing margins. Following consumer search theory, consumer search should increase with decreasing margins and increasing diesel prices. If this actually happens, it actually does not influence levels of R&F in our case. By that, consumer search frictions can just partly be used for explaining R&F in the German market. Rather, a certain level of R&F seems to be unrelated to consumer search assumptions.

In addition to the explanation by consumer search frictions, high margins can further be related to **changing market characteristics**. We see high demand and decreasing oil prices related to high levels of R&F. Borenstein and Shepard (1996) as well as Helman (2015) argue that asymmetric price adjustment happens in times of oil price decreases and strong (future) demand.[27] That situation enables 'gas stations to keep prices higher for longer' (Helman 2015). This finding is described in a similar way by Borenstein and Shepard (1996). The authors argue that margins in the retail fuel sector are positively related to anticipated demand and negatively related to input prices. Borenstein and Shepard (1996) see tacit collusion as a possible explanation. Additionally, Borenstein and Shepard (2002) also find in their data a relationship between slowly price adjustments when price-cost margins are higher. Nevertheless, they do not find the expected asymmetry of price responses related to margins and by that to market power that we have found.

Relevant German data approves these findings regarding prices and demand. As Figure 9 shows downright, seven months within our respective period fit into the group of lower than average oil prices (mean: 0.33 €/litre) and higher than average monthly diesel demand in Germany (mean: 3,042,737 tons). All these seven months represent data from July 2015 (starting point rolling windows: 389) until April 2016 and therefore far more in the end of our respective period, where we determined higher shares of R&F (see Figure 3).[28] Three months (black dotted) are within that final time frame, but show significantly lower diesel demand during the winter period in Germany.

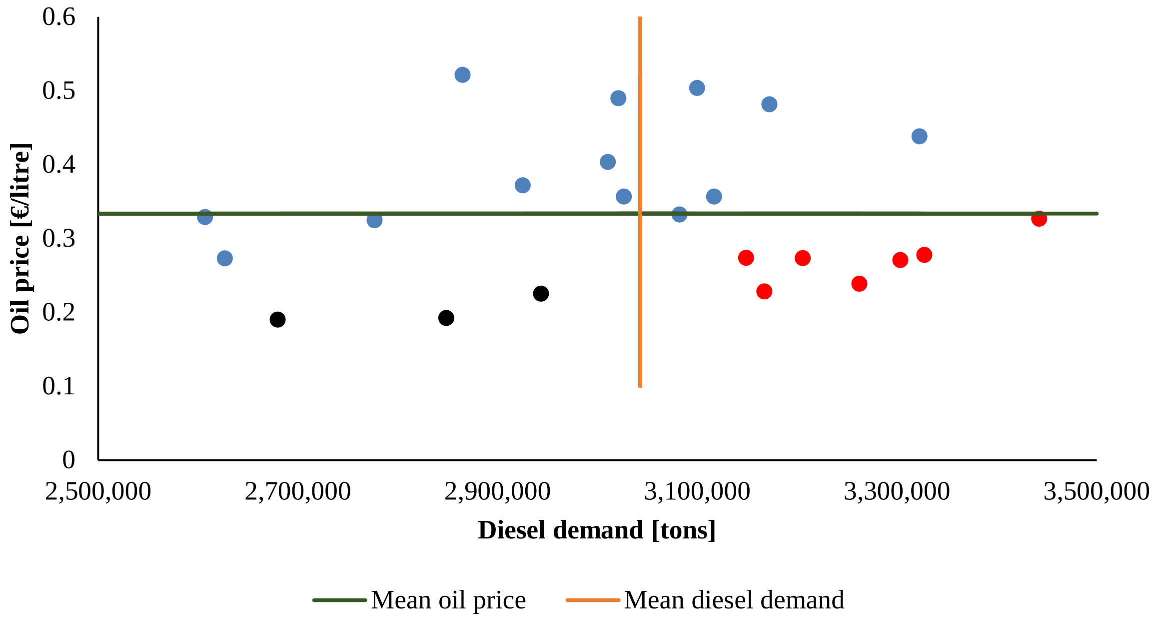

Figure 9: Monthly oil prices and diesel demand in Germany from June 2014 to April 2016 (PIA 2019b, Finanzen.net 2019). Raw data can be seen in the appendix (Table 6). Red data shows oil prices and diesel

[27] As German demand is small in relation to the world oil market, oil price movements affect in just one direction, i.e. from world market to the domestic German market, while German demand has no influence on world crude oil prices.

[28] The month with lower than average oil prices and higher than average diesel demand is March 2015.

demand from July 2015 to November 2015 and March and April 2016, when R&F shares start to increase (see Figure 3). Black dotted data is from December 2015 to February 2016.

That means that not just consumer search characteristics can be responsible for high margins in relation to higher shares of R&F. Rather specific and even seasonal demand conditions can lead to an increased level of asymmetric pricing behaviour of firms. Therefore, adjustment of retail stations regarding their pricing strategies are realised in times of higher demand, such as summer, autumn and spring and simultaneous decreasing levels of oil prices.

Though, higher retail fuel margins during times of higher levels of R&F are included in the two main explanations for R&F, consumer search frictions and tacit collusion. Therefore the outcome in our case cannot be assigned to just one hypothesis.

Third, there exists a negative relationship between R&F and the **share of cointegration** within the market, i.e. the long-run relationship between retail stations diesel prices and the oil price, which has not been a key argument so far in the literature. Lower cointegration levels correspond to higher shares of R&F. As many other stations have prices uncoupled from input prices, stations maintaining cointegration (long-run relationship) tend to price more asymmetric and by that follow the process of uncoupling. Therefore, generally disconnected diesel prices from oil prices, in our case at the same time with high margins, correlate with an increasing probability of R&F. This outcome can be associated with potential tacit collusion characteristics from above. It matches the development of decreasing oil prices, less strong diesel price reactions/reductions and by that a growing uncoupling of the retail price development from international oil prices. Input price developments are not transmitted to retail fuel prices and as described before, high margins are more prevalent during the same period triggering lower cointegration levels.

6 CONCLUSION

Our paper started with two questions: *Who performs Rockets and Feathers? And actually when*? We showed characteristics and conditions facilitating R&F, e.g. a selection of top five brands, high price stations and a general decreasing price level. Nevertheless, this happens in a market environment showing, as we state, relatively low shares of R&F (about 13 %). For different periods, we find shares of R&F between 5 % and 25 %. By that, our results are broadly comparable to over-all market results for Germany of Frondel et al. (2019).

Nevertheless, R&F in Germany still exists and interestingly varies over time, questioning earlier studies such as Peltzman (2000) who is arguing R&F is usually 'durable' (p. 466). By that, our results follow the meta-analysis results of Perdiguero-García (2013), who argues that R&F occurs in specific markets (such as regions) and at unambiguous points in time, as firms do not keep constant pricing strategies over longer periods. This is somewhat surprising as our results are given beside a stable deregulated and competitive environment in the respective market. Still, from the perspective of an individual petrol station, besides the setting of regulation, market environment can change tremendously, e.g. input prices, as well as demand conditions and changing price strategies of close competitors. This might imply changing pricing strategies by stations.

The diverse reasons for the occurrence of R&F make the phenomenon and our respective results interesting from a public, political and regulative point of view. By that, solutions for potential reasons have high relevance for policies and regulation approaches. Primarily, by establishing the Market Transparency Unit for Fuels in Germany, accessing information regarding prices is far easier for customers and sellers nowadays. As we show variable and partially higher shares of R&F even during the presence of transparent and easy-to-access price information, search and informational frictions can clearly not be the only reason for asymmetric pricing. As Bayer and Ke (2011) argue, 'improving price transparency would be an immediate policy implication' (p. 27 f.) for the existence of related informational market frictions. As such an institutional approach already exists in Germany, search and informational frictions might not be the only or even prevailing explanatory variable. Therefore, Luco (2018) argues that price transparency policies can even have anti-competitive effects, besides pro-competitive reactions, 'depending on whether consumer search - the demand-side response to disclosure - or price coordination - the supplyside response – dominates' (p. 303). The rather low shares of R&F can be interpreted as a high degree of competition within the German diesel market. Still, certain market environments are more vulnerable for R&F and therefore show occasionally environments for market power and tacit collusion. This can be seen against the background of existing price cycles in Germany (Edgeworth cycles), where likewise tacit collusion can be seen as a reason (Linder 2018). As a policy recommendation, we argue that price transparency as the only measure would be short-sighted.

The frequently quoted paper of Lewis and Marvel (2011) close their paper with the conclusion that 'any analysis of asymmetric pricing should take into account the asymmetric response of consumer search to cost and price movements' (p. 482). We like to add that any analysis, furthermore, needs to evaluate diverse and even variable causes of R&F over time, leaving behind the assumption that only one theory explains asymmetric pricing in a changing market.

Although trends have been concluded in the literature and the given paper, more in depth analyses of changing environments and input parameters related to the existence of R&F need to be carried out further, as the availability of data has improved tremendously over the last years. By using a country-wide disaggregated data set, further research can focus on questions regarding pricing strategies of certain regional markets, their specific brand composition, as well as station attributes within local market environments. Additionally, as stations have diverse legal characteristics, such as brand-owned, franchise agreements, lease contracts (see Federal Cartel Office 2011a, 2011b), they can just partly be categorized by the brand on their signs itself. Therefore, combining the given data with improved information regarding the legal status might uncover further pricing characteristics of certain business approaches.

ACKNOWLEDGEMENT

The author is grateful for helpful suggestions regarding this research to attendees and organizers at the *InfraTrain autumn school 2017 at the DIW* in Berlin (Germany), the *2nd AIEE Energy Symposium - Current and Future Challenges to Energy Security (2017)* in Rome (Italy) and the *12th Conference on Energy Economics and Technology (ENERDAY 2018)* in Dresden (Germany).

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8 APPENDIX

Table 6: Monthly oil prices and diesel demand in Germany from June 2014 to April 2016 (PIA 2019b, Finanzen.net 2019).

Month	Diesel demand [tons]	Oil price [€/litre]
June 2014	2,865,079	0.5212
July 2014	3,099,960	0.5033
August 2014	3,021,168	0.4894
September 2014	3,172,503	0.4813
October 2014	3,322,786	0.4378
November 2014	3,010,469	0.4034
December 2014	2,776,953	0.3241
January 2015	2,627,178	0.2728
February 2015	2,607,247	0.3285
March 2015	3,082,262	0.3321
April 2015	3,026,468	0.3565
May 2015	2,925,256	0.3714
June 2015	3,116,925	0.3564
July 2015	3,442,480	0.3268
August 2015	3,148,720	0.2739
September 2015	3,205,514	0.2734
October 2015	3,327,369	0.2777
November 2015	3,303,431	0.2708
December 2015	2,943,547	0.2253
January 2016	2,679,631	0.1901
February 2016	2,848,550	0.1925
March 2016	3,167,124	0.2285
April 2016	3,262,320	0.2389

Table 7: Regression results for outcomes of the analysis of rolling windows for the best model of cointegration, either Eq. (1) or Eq. (2). Dependent variable: Share of R&F [%]. Amount of data points of each regression: 495. Model 1b and 6b: $\boldsymbol{R\&F = a * exp(b \ * \ diesel\,price\ [or\ diesel\,margin]) + c.}$

Dependent variable : RaF_Share_t[%]								
Estimators	1a	1b	2	3	4	5	6a	6b
$Intercept_t$	0.21***	-	0.34***	0.35***	-	0.27***	-	-
$Diesel\ Price_t$ [€/l]	-0.22***	-34.9***	-	-0.10***	-	-	-	-
$Relative\ Diesel\ Margin_t$ [%]	-	-	-	-	0.42***	0.12***	0.26***	45.03***
$Cointegration_t$ [%]	-	-	-0.26***	-0.21***	-0.07***	-0.23***	-	-
a	-	1.403e+05	-	-	-	-	-	1.059e-10
c	-	0.09***	-	-	-	-	-	0.09***
Correlation/Adj. R^2	0.37/0.13	0.59/0.34	0.49/0.24	0.51/0.26	0.38/0.90	0.5/0.25	0.27/0.89	0.5/0.25