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Selling gasoline as a by-product: The impact of market structure on local prices

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Selling Gasoline as a By-Product: The Impact of Market Structure on Local Prices*

Justus Haucap† Ulrich Heimeshoff‡ Manuel Siekmann§

December 2016

Abstract

We use a novel data set with exact price quotes from virtually all German gasoline stations to empirically investigate how a temporary variance in local market structure – induced by restricted opening hours of specific players – affects price competition. We focus on stations selling gasoline as a by-product and find that, during their exogenously determined hours of opening, they have a significant negative price effect on nearby major-brand competitors. Applying a difference-in-difference framework with hourly average prices, our findings explicitly account for counterfactual market scenarios.

JEL-Classification: L11, L71
Keywords: Gasoline Markets, Intraday Pricing, Supermarkets, Difference-in-Difference

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1 Introduction

Retail gasoline prices are a topic of significant public interest around the world (see OECD 2013). Consumers and regulators frequently observe significant inter- and intraday price volatility. While price volatility can, at least partly, be traced back to the associated volatility of crude oil or refinery prices (see, e.g., Frondel, Vance, and Kihm 2016; Haucap, Heimeshoff, and Siekmann forthcoming), intraday price fluctuations are mainly driven by demand factors and competition. The increasing extent of price fluctuations has raised public concerns in policy circles, the media, and at competition authorities alike. Only recently, the German Federal Cartel Office has observed an average price spread of seven to ten Eurocents/liter per gasoline station and day, and even a 15 to 20 Eurocents/liter average daily price spread within the same city in Germany (Bundeskartellamt 2014). Consumers face significant uncertainty resulting from four to five price changes per gasoline station and day. While there has been a number of papers that study interday price fluctuations, virtually no study on intraday price fluctuations exists, typically due to a lack of data.

In this paper, we investigate how a temporary, recurring variance in market structure affects gasoline prices across our period of observation of 2014. We choose stations selling gasoline as a by-product as our main objects of investigation. While such stations, for instance next to supermarkets, play a minor role in Germany in terms of their overall nationwide market share (see, e.g., EID 2014), they often have a favorable feature we will exploit in the course of this paper. Namely, their opening hours are typically restricted and exogenously determined by their primary business activity (e.g., selling groceries). We argue that the opening hours of a station selling gasoline as a sideline business can be seen as an exogenous variation of the local market structure and temporarily increase the degree of price competition for nearby competitors. To isolate and quantify these effects in light of decreasing prices throughout the day in many market areas, we include counterfactual scenarios in our analysis and use a difference-in-difference framework. Our analysis uses a novel data set including a census of price quotes from virtually all German gasoline stations. With this data set, we are able to report intraday price changes and connect them with data on weekday-specific opening hours.

We find that stations selling gasoline as a by-product have a statistically significant negative price effect on nearby major-brand competitors during their hours of operation. With a gasoline station associated to a supermarket or car wash facility in the surrounding area, particularly major brands show a temporary price reaction beyond their usual daytime price reductions. The effect is largely consistent across rural and urban areas as well as different supermarket and car wash chains, and it

is more pronounced during working days.

The remainder of this paper is structured as follows: Section 2 provides an overview of relevant empirical literature. In section 3, we briefly describe the German retail gasoline market (section 3.1) and specifically focus on stations selling gasoline as a by-product (section 3.2). Section 4 explains our data set before section 5 presents the empirical analysis. The latter includes both an introduction to observable intraday pricing patterns (section 5.1) as well as our identification strategy (section 5.2), and presents our findings in detail (section 5.3). Finally, section 6 concludes.

2 Related Literature

Numerous empirical studies investigate pricing on retail gasoline markets in different regional areas.[1] Most studies have focused on retail markets in North America (e.g., Borenstein and Shepard 1996; Doyle, Muehlegger, and Samphantharak 2010; Hosken, McMillan, and Taylor 2008; Lewis and Noel 2011; Shepard 1993 for markets in the U.S. or Atkinson 2009; Byrne, Leslie, and Ware 2015; Carranza, Clark, and Houde 2015; Noel 2007a, 2012, 2015; Slade 1987, 1992 for markets in Canada). While several studies use either cross-sectional price data or a single time series of prices, the majority relies on panel data with either daily, weekly, monthly or other (irregular, varying) frequencies of station-level or city-average prices. Regarding focus areas, Eckert (2013) suggests to distinguish between studies focusing on price dynamics, on the one hand, and studies analyzing determinants of price levels, on the other hand. Among the first-mentioned category are analyses of upstream (wholesale, crude oil) costs pass-through to retail prices, specifically with regards to response asymmetry (e.g., Kihm, Ritter, and Vance 2016; Noel 2009), as well as investigations exploring special aspects of Edgeworth cycles on gasoline markets (e.g., Doyle, Muehlegger, and Samphantharak 2010; Isakower and Wang 2014; Noel 2007b). Recurring, asymmetric price cycles, known as Edgeworth cycles, were theoretically explained by Maskin and Tirole (1988). They are characterized by a relenting phase with fast and large price increases (up to a level slightly above the monopoly price) and an undercutting phase consisting of a longer sequence of small price-cuts (down to the level of marginal cost).[2] The group of studies focusing on price level determinants, in turn, includes both studies examining the impact of mergers or regulatory changes (e.g., Dewenter, Heimeshoff, and Lüth 2017; Simp-

[1] Eckert (2013) presents a comprehensive classification of existing empirical gasoline market studies along different criteria.

[2] See Noel (2011) for a non-technical introduction to Edgeworth cycle theory. Moreover, Byrne (2012) includes an overview of literature on retail gasoline price cycles.

son and Taylor 2008; Wang 2009) and studies looking at price dispersion and price differentials among stations (e.g., Haucap, Heimeshoff, and Siekmann forthcoming; Lewis 2008; Pennerstorfer et al. 2015). Lach and Moraga-González (2009), for instance, investigate how the number of stations affects the daily distribution of prices with data from the Netherlands. They find an asymmetric effect of competition on prices and an increase in consumer welfare induced by an increase in the number of gasoline stations in the market.

In this paper, we will regionally focus on the German market. While in Germany, as in other countries, retail gasoline pricing is a topic of high public attention, empirical studies are rarely available. A noteworthy exception is a sector inquiry on fuel retailing conducted by the Bundeskartellamt (2009, 2011a,b). This investigation includes a price survey in four model regions, revealing evidence of recurring price cycles, a market-dominating oligopoly and implicit collusion.[3] Furthermore, in recent papers, Kihm, Ritter, and Vance (2016) and Frondel, Vance, and Kihm (2016) investigate the pass-through of crude oil price changes in Germany by using a large data set of prices.[4] Regarding retail price data, we will rely on a novel data set provided by the market transparency unit for fuels ("Markttransparenzstelle für Kraftstoffe", MTS-K), covering price changes of virtually all gasoline stations in Germany.[5] Haucap, Heimeshoff, and Siekmann (forthcoming) use exactly this data set to analyze price drivers on a large-scale basis in Germany. Among other things, they find that the degree of local competition, measured by the number of different players in a given area, negatively affects average price levels.

Motivated by this finding, our goal is to investigate whether retailers selling gasoline as a sideline business have an impact on local prices during their opening hours or, generally speaking, whether a (recurring) exogenous variance of market structure affects market area price levels. For this purpose, we apply a difference-in-difference framework and, thereby, explicitly account for counterfactual scenarios. Applying a difference-in-difference framework is an approach frequently used in contributions analyzing effects of mergers or regulatory changes on gasoline prices. As an example, Dewenter and Heimeshoff (2012) apply such a framework to estimate the impact of a one-off regulatory change on average prices (weekly, nationwide). The authors com-

[3]Model regions were Cologne, Hamburg, Munich, and Leipzig; in total, price movements at 407 gasoline stations were analyzed with data from 1 January 2007 to 30 June 2010.

[4]Similarly, Asane-Otoo and Schneider (2015) analyze the adjustment of retail fuel prices in Germany to international crude oil prices over a longer time horizon. Their findings suggest symmetric price adjustments in recent years (i.e., 2009-2013). Their data set of weekly national or daily city-level data, however, does not allow a differentiation by brand.

[5]The emergence of the MTS-K was mainly motivated by findings described above in Bundeskartellamt (2011a,b). For descriptive statistics on prices during the first months of MTS-K operation, please see Bundeskartellamt (2014).

pare an asymmetric pricing rule in Austria and a symmetric pricing rule in Western Australia vis-à-vis unrestricted pricing regimes. While, for Austria, a decrease in price levels can be observed, there is no significant effect on Western Australian price levels. In a similar framework, comparing 27 European countries, Dewenter, Heimeshoff, and Lüth (2017), find evidence for increased gasoline and diesel prices as a result of the introduction of the so-called MTS-K in Germany. Moreover, Hastings (2004) and Taylor, Kreisle, and Zimmerman (2010) use a difference-in-difference-type model to study the effect of brand conversion (i.e., gasoline stations subject to a change of branding without impact on site location or station characteristics) on local prices. The two studies, however, yield ambiguous results regarding the price effect associated with a stronger presence of independent retailers.

Empirical literature specifically focusing on selling gasoline as a by-product is rare and largely related to stations associated to supermarkets. Zimmerman (2012) estimates the impact of hypermarket gasoline sales on annual average state-level gasoline prices in the U.S. from 1998 to 2002. He finds a significant competitive effect from hypermarkets, lower price levels with higher shares of hypermarkets, and increased consumer welfare. Ning and Haining (2003) focus on the Sheffield, UK, market with self-surveyed (bi-)weekly price data (from 1995 to 1997). Their regression results show that being attached to a supermarket location is a significant supply-side driver of prices. Finally, Wang (2015) investigates bundled discounts of supermarket and associated gasoline purchases, having access to daily price quotes from Western Australian stations before and after the introduction of bundled discount programs. Wang interprets the effect of introducing gasoline bundling programs by supermarkets as pro-competitive in the short-term while being neutral in the long-run.

Utilizing restricted opening hours of (supermarket or car wash) gasoline stations as an exogenous change in market structure is, to the best of our knowledge, a novel approach we will follow in this paper. This is enabled by having access to a granular price data set. After an introduction to the German retail gasoline market and the data set employed, we will present our empirical analysis in section 5.

3 The German Retail Gasoline Market

3.1 General Market Characteristics

Gasoline is reasonably homogeneous in terms of its chemical product characteristics. Typically, different gasoline products are sold at distributed retail stations. The most common product types sold in Germany are the two unleaded gasoline

products "Super E5" (with a minimum research octane number, RON, of 95 and 5% of added ethanol) and "Super E10" (with an RON of 95 and 10% added ethanol) in addition to a standard diesel product. While most consumers can freely choose among different gasoline products, changing between gasoline and diesel is not an option due to different technical engine specifications. Given a lack of short-term substitutability for consumers, gasoline and diesel are typically regarded as different product markets.

Competition in gasoline markets (with fairly homogeneous products) is largely driven by price as well as other factors such as a station's brand recognition, its spatial location, or additional service offerings, for instance, in form of affiliated shops (see, e.g., OECD 2013, pp. 9-30). In Germany, pricing is not restricted by regulatory rules. Along with low menu costs, prices can be changed at virtually any time. At the same time, consumers can easily observe prices and switch suppliers at low costs. In practice, however, competition among stations is confined to reasonably small, local market areas.

The majority of stations is owned by vertically integrated oil companies. Five of these integrated players have both a broad, nationwide network of retail sites and substantial, direct access to refinery capacities in Germany (e.g., through joint ventures among some of these players). These five players are, thus, considered by the Bundeskartellamt (2011b) to form a market-dominating oligopoly. The players are Aral/ BP, Shell, Total, Esso/ ExxonMobil, and Jet/ ConocoPhilipps and they roughly servce two thirds of market demand. Given Jet's ambiguous and legally disputed position within the group of the so-called oligopoly-type players (see, e.g., Bundeskartellamt 2011b, p. 13 or Haucap, Heimeshoff, and Siekmann forthcoming), we group stations operating under a brand of one of the remaining four players as "major brand" stations.[6] Apart from a few other integrated players (e.g., Star/ Orlen or Agip/ ENI), numerous stations in Germany are run independently. Many of these independent players cooperate in associations (e.g., AVIA or bft). For all integrated players, but also for most independents, selling gasoline is considered the primary business activity while, among others, the sale of car-related products (e.g., oil, windscreen fluid), car wash services, or groceries might generate ancillary revenues. There are, however, a small number of independent stations, for which gasoline is not the core product. As these stations are, in our view, particularly interesting objects of investigation, we will introduce them in the following section.

[6]Brand affiliation and station ownership might not always coincide (see, e.g., Shepard 1993, pp. 60-66 or Bundeskartellamt 2011b, pp. 166-171). In this paper, we, strictly speaking, analyze brand affiliation, not station ownership.

3.2 Stations Selling Gasoline as a By-Product

In Germany, as in most other countries, the majority of retailers selling gasoline regards this as their primary business activity, independent of brand and other characteristics. However, a smaller number of retailers sell gasoline as a by-product. Typically, such a retailer has an associated gasoline station on site, next to its primary business facilities. Gasoline might be sold at lower or even negative margins (i.e., priced as a "loss leader") to promote core sales (see Wang 2015; Zimmerman 2012). Most of these stations have the favorable feature that their opening hours – defining our "treatment effect" (see section 5.2) – are determined exogenously by the primary business activity. While opening hours are often limited by choice, they are also restricted by German law for many retailers (e.g., opening on Sundays is generally prohibited, restrictions on Saturdays, or even on other weekdays, are common).[7] Gasoline stations and certain other businesses (e.g., airports, pharmacies) are exempted from these regulations. Stations that sell gasoline as a by-product typically have opening hours that are identical (or, at least, similar) to the primary retail business. They usually do not determine their hours of operation strategically in response to gasoline-specific (local) competition or demand.

Among retailers selling gasoline as a by-product are, first of all, certain supermarket chains.[8] On the German market, there are more than 10,000 supermarkets plus an even higher number of grocery discounters.[9] Only a few of these supermarkets have associated gasoline stations, often with varying brand and ownership types: Some stations are owned and operated by the respective supermarket (chain), while others are typically located on supermarket premises but operated (and largely branded) by oil companies active in the gasoline retail segment. In its July 2014 gasoline station market survey, the independent German service provider "Energie Informationsdienst" (EID) identified approximately 560 supermarket stations in Germany, of which around 290 are located on supermarket premises but operated by oil companies with their respective brands.[10] This leaves around 270 "pure" supermarket

[7] Opening hours in Germany are regulated by state laws. In the most populated state North Rhine-Westphalia (NRW), for instance, the so-called "Ladenöffnungsgesetz – LÖG NRW" defines legal requirements. In NRW, retailers are allowed to open for up to 24 hours from Mondays to Fridays. State law requires retailers to close by 10:00 pm the latest on Saturdays and prohibits them from opening on Sundays (with up to four local exceptions per year; see `https://recht.nrw.de/lmi/owa/br_text_anzeigen?v_id=10000000000000000525`).

[8] We will use the two terms supermarket and hypermarket synonymously for retail suppliers of groceries and other general merchandise.

[9] See, e.g., `www.bvlh.net/infothek_daten-fakten.html`.

[10] In an international context, this represents a rather low market share of <5% (given a total of roughly 14,000 German gasoline stations). Wang (2015) presents indicative hypermarket station market shares for a few other countries. They range from around 6% in the U.S., 28% in the U.K., 44% in Australia, up to even 56% in France (also see Gauthier-Villars 2004). According to

stations owned and operated by the respective supermarket itself (EID 2014). Examples of supermarket chains in Germany with self-operated gasoline stations at selected sites include Famila (Nordost), Globus, and V-Markt. Among them, only Globus offers bundled discounts on gasoline prices (of up to 4 Eurocents/liter) based on the value of supermarket purchases.[11]

A second group of retailers selling gasoline as a by-product comprise car wash operators. Most car washes in Germany are themselves a by-product of gasoline stations. The German association "Bundesverband Tankstellen und Gewerbliche Autowäsche Deutschland e.V." (BTG) lists approximately 12,000 so-called in-bay automatic car washes (also called "roll-overs" as automatic machines typically clean the exterior of a stationary vehicle by rolling over it), most of which are located at gasoline stations' sites. On top, there are around 2,400 self-service car wash facilities, and around 1,500 conveyorized (automatic) car washes (also called "tunnel washes" where vehicles are moved through different cleaning components via a conveyor belt, which might include both exterior and interior cleaning).[12] The latter, most sophisticated category includes car wash chains with a primary focus on washing and cleaning services, some of which operate gasoline stations at selected sites, examples include Mr. Wash or CleanCar. In contrast to supermarkets, primary business activities (i.e., providing car wash services) and sideline business activities (i.e., selling gasoline) are closely related to each other as both are car-related activities.

In the empirical analysis in section 5, we will utilize stations associated to either of the two groups, supermarkets and car wash operators, and analyze their impact on pricing by nearby stations selling gasoline as their core product.[13]

4 Price and Station Data

Several empirical studies on retail gasoline markets use either aggregated or self-collected price data or, more recently, rely on data from customer-collected price websites. The latter usually offers considerably higher frequency than the former,

EID (2014), the 290 supermarket stations operated by oil companies include around 200 stations operated by Jet at Metro supermarkets, 30 stations operated by Shell at Edeka supermarkets, 30 Total-operated stations largely at Kaufland supermarkets, and 30 Orlen-operated (and star-branded) stations mostly at Famila supermarkets.

[11] Globus' discount program is called "Tankeschön". A discount between 1 and 4 Eurocents/liter for up to 250 liters per month is granted depending on prior-month supermarket purchase volume. To get the maximum discount, more than 300 Euro of supermarket purchases per month are required (see `www.globus.de/de/services/tankeschoen/tankeschoen.jsp`).

[12] See `www.autowaschen.de/waschanlagen.html`.

[13] There might be other groups of retailers selling gasoline as a by-product (e.g., some car dealerships). In this study, we focus on supermarkets and car washes only.

but these data sets typically not fully reflect intraday pricing patterns of individual stations, especially of small, independent players.[14] In Germany, the Federal Cartel Office has set up the creation of a so-called market transparency unit for fuel ("Markttransparenzstelle für Kraftstoffe", MTS-K), which started its regular operations on 1 December 2013.[15] Since then, the MTS-K collects all gasoline (i.e., Super E5, Super E10) and diesel prices and price changes from virtually all German gasoline stations.[16] Using this rich data set, inter alia, we are able to use exact station-level prices on an intraday level and to identify price spreads as well as the number and extent of price changes. Hence, the impact of individual players (here, supermarkets and car wash stations) on local prices can also be analyzed by this data set. As a number of stations – especially among the group of independents – failed to submit prices at the beginning of MTS-K's operation phase, we deliberately exclude the first month of data submission (i.e., December 2013) and rely on the first full year of price data, from January to December 2014.[17] We also exclude all stations located on highway service areas (i.e., Autobahn stations) for two reasons: First, these stations compete in a different competitive environment as they are (almost) exclusively leased out by Tank & Rast GmbH, a private company, which emerged from formerly state-owned Autobahn gasoline station companies (see Bundeskartellamt 2011b, pp. 213-218). Secondly, consumers have limited accessibility to Autobahn stations as they can be reached solely via highways. Thereby, these stations are usually not a practicable alternative to road stations, even if they are nearby.[18] In its sector inquiry, the Federal Cartel Office also considered them to constitute a separate market. All retail prices are nominal end-customer prices in Euro(cents) per liter and include all taxes and duties (i.e., value-added tax, energy tax, and a fee for the Petroleum Stockholding Assocation "EBV"). For our empirical analysis in section 5, we compute hourly average prices for selected stations. For this purpose, we aggregate precise price quotes by weighting all prices charged throughout an hour with the specific length of their validity. When computing

[14] Analyzing potential sample selection biases associated with publicly available gasoline price websites, Atkinson (2008) concludes that such prices are reliable to identify certain features of price competition, while "features that require data for certain types of independent stations or very high frequency data might not be well identified" (p. 174).

[15] For more information on the market transparency unit for fuel, please visit `www.bundeskartellamt.de/DE/Wirtschaftsbereiche/Mineral%C3%B6l/MTS-Kraftstoffe/mtskraftstoffe_node.html`.

[16] See Appendix A for a description of price and station data included in the MTS-K data set.

[17] The data set was kindly provided by authorized consumer information provider "1-2-3 Tanken"

[18] To identify Autobahn stations within the MTS-K data set, we link information available on the Tank & Rast website (see `www.tank.rast.de`) with MTS-K station data. All Tank & Rast locations are found; additionally, further Autobahn stations (not operated by Tank & Rast) are identified on the basis of a keyword search (e.g., "A*" or "BAB*") of the MTS-K address field.

hourly prices, we see numerous hours, in which no price change is recorded. In these instances, we simple use the last valid price.

While wholesale prices are not registered on an intraday level, we account for regionally different, daily wholesale prices. Daily wholesale prices "ex-refinery" are taken from the Oil Market Report (O.M.R.), a widely used, independent information service provider. This price data suggests to differentiate between eight major refinery regions in Germany.[19] We assign each gasoline station to one of the refinery regions based on minimum linear distance to the region's market place (see the following paragraph for the calculation methodology). Ex-refinery wholesale prices are nominal and quoted in Euro(cents) per liter free on tank-lorry (fot) as of German refinery or storage including energy tax and "EBV" fees.[20]

To allow for a geographic delineation of market areas, we calculate linear distances ("as the crow flies") between each pair of stations on the basis of geographical coordinates (latitude, longitude) included in the MTS-K data set.[21] With information on distances between all stations, the number and type of competitors within specific areas can easily be determined.

A crucial prerequisite for our empirical analysis is to identify gasoline stations located on premises of and operated by specific supermarket or car wash chains, where selling gasoline and diesel is considered a by-product. We select Mr. Wash and CleanCar, two car wash chains, as well as V-Markt and Famila (Nordost), two supermarket chains for our analysis (see Appendix B for details on stations' opening hours and local market structures).[22] Altogether, we have identified around 80 distinct locations with numerous other gasoline stations in the surrounding areas. With Famila being active in the North, V-Markt in the South, and Mr. Wash and CleanCar with several locations in the West, the selected chains also cover a broad geographic area within Germany (see Figure 1).

[19]Refinery regions are North (with market place Hamburg), East (Berlin), Seefeld, South-East (Leuna), West (Duisburg, Gelsenkirchen, Essen), Rhine-Main (Frankfurt), South-West (Karlsruhe), and South (Neustadt, Vohburg, Ingolstadt).

[20]Ex-refinery prices can differ depending on whether they are sold "branded" or "unbranded", which, however, is not reflected in the data set. Price quotes are, moreover, not available on weekends and public holidays. We, therefore, assume prices to remain constant on previous-day levels in these cases.

[21]Linear distance is computed as the shortest distance between two geo-coded locations ("orthodromic distance"). Using $dist = arccos(sin(lat1) * sin(lat2) + cos(lat1) * cos(lat2) * cos(lon2 - lon1)) * earthradius$ to compute "arc length" distances in kilometers, with $(lat1, lon1)$ and $(lat2, lon2)$ as coordinates of start and end point given in radians (converted from degrees by multiplying with $2\pi/360$), and $earthradius = 6,378km$.

[22]We do not include gasoline stations associated to Globus supermarkets in our analysis. First, retail prices at Globus-associated stations are influenced by bundled discounts (see section 3.2), which we cannot control for. Secondly, numerous gasoline stations at Globus markets offer 24-hour automatic fuel terminals beyond regular opening hours and are, hence, practically open 24/7.

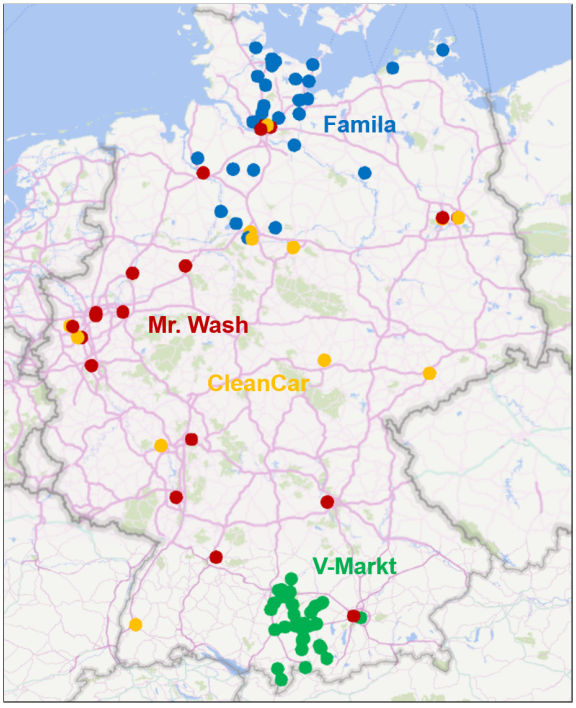


Figure 1: Gasoline Stations at Mr. Wash, V-Markt, Famila, and CleanCar

5 Empirical Analysis

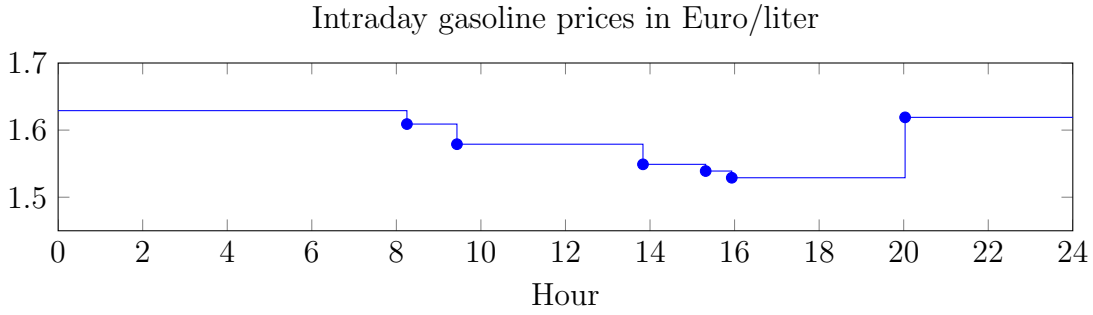
5.1 Pricing Patterns

In this first section of the empirical analysis, we will introduce typical pricing patterns of German gasoline stations. This facilitates a better understanding of the price data used in our analysis and emphasizes the importance of including counterfactual scenarios in light of recurring (intraday) patterns, on which we will further elaborate in section 5.2.

Throughout the day, individual stations' prices are rarely constant. Instead, they vary, on average, by around nine Eurocents/liter resulting from, on average, between four and five price changes per day (also see Bundeskartellamt 2014 or Haucap, Heimeshoff, and Siekmann forthcoming, pp. 11-15). A typical intraday pattern comprises constant price levels during nighttime and rather volatile prices throughout the day. At numerous stations, prices are stepwise decreasing between morning and evening hours[23] until a single price increase takes place between about 8:00 pm and 10:00 pm. While price decreases throughout the day are often small and a result of local competitive dynamics (e.g., a station reacts to a price cut of a

[23]There are a few exceptions to this rule. Noteworthy, numerous Shell-branded stations temporarily increase prices around noon, occasionally followed suit by selected nearby competitors.

nearby competitor), price increases in the evening are usually significantly larger and offset intraday downward movements. Figure 2 shows such an exemplary intraday pricing pattern of a major station.



Note: Pricing of Aral station in Drolshagen on Monday, 4 August 2014.

Figure 2: Examplary Intraday Pricing Pattern

The pattern shown in Figure 2 is arguably similar to Edgeworth-type cycles (see Eckert 2003; Maskin and Tirole 1988; Noel 2008 for a formalization). In most of the empirical literature, Edgeworth cycles are usually associated with price movements across several days instead of within a single day.[24] In contrast to an Edgeworth-typical "war of attrition" with varying lengths at the cycle bottom, intraday cycles on the German market seem to be regularly restored following clear time patterns. Across the country, for example, Aral-branded stations typically lead price restorations with significant price jumps at around 8:00 pm (except for occasionally delayed price jumps on Mondays). Shell-branded stations, in turn, increase prices at around 8:15 pm, often as a follower in markets with Aral-branded competitors. Variations of (average) prices across weekdays do not follow a universal pattern. In its analysis, the Bundeskartellamt (2011b, pp. 89-92), for instance, found the highest average prices on Friday and Saturday, while price levels on Mondays tended to be lowest. Shifts in wholesale prices (as key input costs) certainly are a driver of price level differences over time, so are varying demand characteristics across weekdays.

In our analysis, we will focus on station-specific price differences, acknowledging a potential, persistent gap in price levels among stations (e.g., due to brand recognition or station characteristics, see Eckert 2013). We will analyze differences in local pricing dynamics on an intraday level and across different weekdays. With lower daytime prices being common in most market areas, irrespective of market structure (as described above), it is essential to identify different magnitudes of price spreads.

[24]Most empirical studies investigating (elements of) Edgeworth cycles on gasoline markets use daily (average) prices observed across several months or years and find varying cycle lengths (e.g., biweekly, weekly, or even bimonthly, see Noel 2011, 2016).

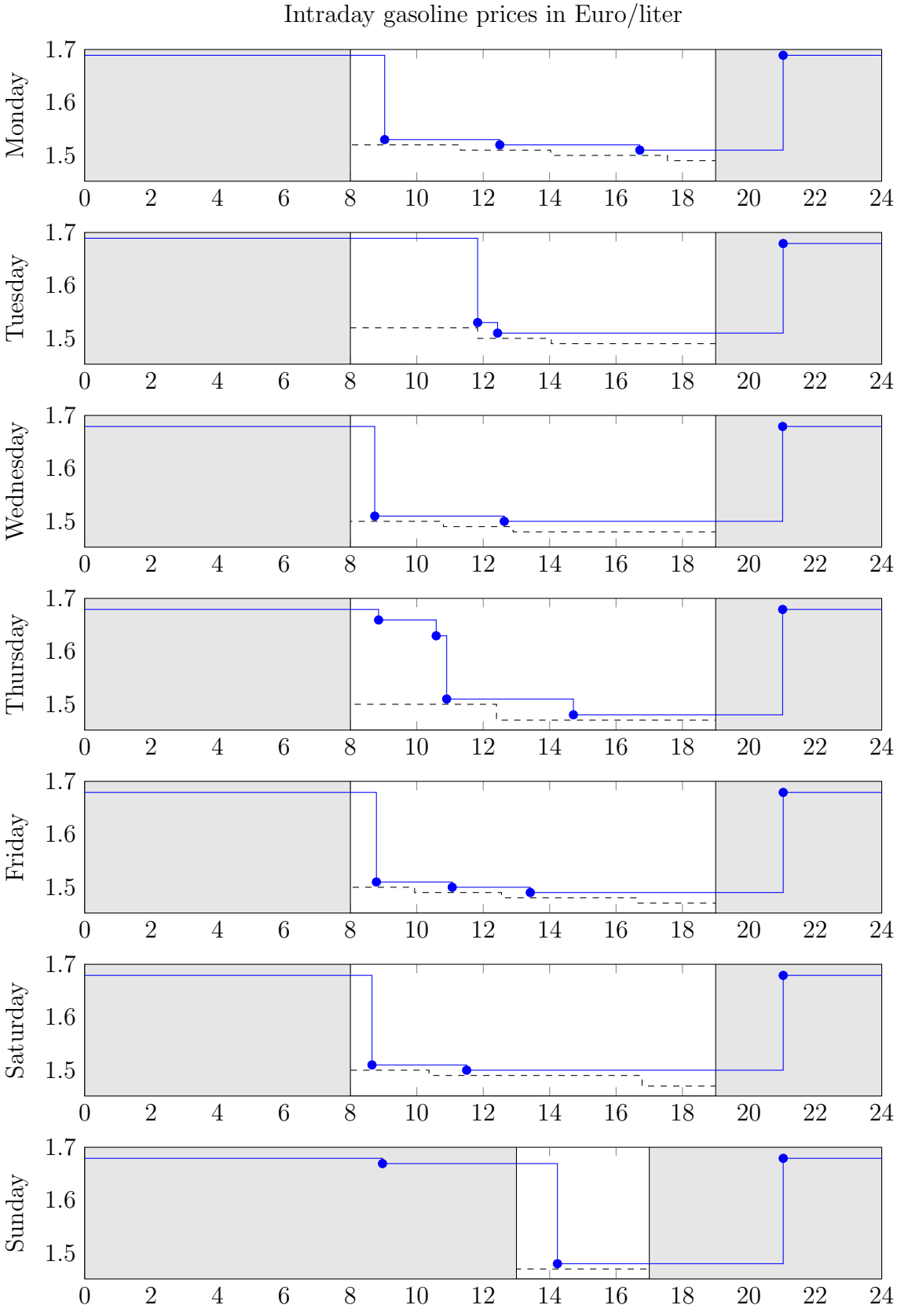
Our strategy for isolating the competitive effect of stations selling gasoline as a by-product on nearby competitors will be introduced in the next section.

5.2 Identification Strategy

We want to isolate and quantify the effect of variations in local market structures on gasoline retail prices. We, therefore, identify stations in our data set, whose primary business activity is not selling gasoline (i.e., Mr. Wash, V-Markt, CleanCar, and Famila). Restricted opening hours of these gasoline stations that are associated to supermarket or car wash operations act as an exogenous shock for other stations located in the same local area. We posit that such a market structure variance over time can be considered exogenous since opening hours of supermarkets or car wash facilities determine the opening hours of their associated stations. This is an intuitive assumption largely supported by our data set: Whenever the supermarket or car wash opens or close, they also open or close the gas station (also see Appendix B).

The hypothesis used in the course of the analysis is that a temporary presence of a station selling gasoline as a by-product increases the competitive pressure on nearby gasoline stations. We expect to see a price reaction, specifically visible at major-brand stations with sufficient leeway to lower prices if needed. In Figure 3, we present anecdotal evidence of this hypothesis. We choose a major station located near a station selling gasoline as a by-product (here, a car wash station), and plot actual price quotes of both players across a week. In this example, prices appear to stay on a higher level when the car wash station is closed, both during nighttime and during (parts of) daytime on Sunday. In contrast, sharp price-cuts begin as soon as the car wash station opens and competes in the market with lower-than-average price levels. While on some days during the exemplary week, reactions seem to follow almost immediately (i.e., within an hour), on other days (i.e., Tuesday, Thursday), it takes significantly longer until the price gap is diminished.

While this example is illustrative, its validity is limited: Price movements often follow similar patterns and have several reasons other than variations in market structure. A robust approach to isolate the price effect solely driven by the temporary market structure variance is to apply a difference-in-difference framework (see Wooldridge 2010, pp. 147-151; Angrist and Pischke 2009, pp. 227-243). By using such a framework, we specifically account for counterfactual scenarios, namely price developments in comparable local market areas without exogenously determined market structure variations. Therefore, we allocate all stations within a small range around a supermarket or car wash station in a so-called treatment group, and all



Note: Pricing of Aral (solid) and Mr. Wash (dashed) stations at Stresemannstr., Hamburg in w/c 4 August 2014. Distance b/w stations: 0.18 km. Mr. Wash station is closed when shaded.

Figure 3: Exemplary Intraday Pricing in Local Market with Car Wash Station

Table 1: General Gasoline Station Selection Criteria

Criteria	Selection
Product type	Gasoline (i.e., Super E5) fuel
Opening hours	24/7 opening hours
Brand type	Major brands (robustness check: all brands)
Location	Urban areas ("same cities") or rural areas ("same ZIP code areas")
Competition	Comparable number of local competitors

stations in comparable local market settings in a so-called control group. Moreover, enabled by our rich panel data set, we use dummy variables reflecting whether a supermarket or car wash station is open during a specific hour of observation or not. Only by observing prices in both treatment and control groups as well as in hours with and without an additional (supermarket or car wash) player, we are able to identify the true "treatment effect". Using a difference-in-difference method is, thus, appropriate.

Selecting stations to be included in either treatment or control group is not trivial. We first define general selection criteria valid for both treatment and control group stations based on product type, opening hours, brand type, location, and local competition (see Table 1). As argued in section 3.1, we treat gasoline and diesel as distinct product markets. In our analysis, we will focus on Super E5 gasoline as the predominant fuel type in Germany. Furthermore, as we are interested in exploring the effect of restricted opening hours of supermarket or car wash players on other (non-restricted) local players, we include stations with 24/7 opening hours only. While we focus on major brands (i.e., Aral, Shell, Total, and Esso) with market power and leeway to adapt pricing to external shocks, we also check for the robustness of our results in specifications including all brands. We carefully select stations in comparable locations, reflecting a similar market setting and demand structure. Depending on the specification, this means we either look at stations in the same set of large cities or in the same rural areas (i.e., same set of first two-digit ZIP code areas). Finally, we only include stations with a comparable number of local competitors across control and treatment groups.

With the general selection criteria as described above, delineating between treatment stations (i.e., stations affected by the presence of a nearby supermarket or car wash station) and control group stations is based on the local market area (see, e.g., Shepherd and Shepherd 2003, pp. 62-68). We apply linear distance measures to delineate markets, in line with Eckert and West (2005) and others, that means we choose a local market area definition of 2 km circular distance. Hence, gasoline stations in a 2 km surrounding around a supermarket or car wash station are consi-

Table 2: Treatment Group Stations and Treatment Effect

Criteria	Selection
Treatment group	Stations within 2 km linear distance of treatment stations
Treatment effect	Opening hours of treatment stations (retail chain-specific)

dered to be part of the treatment group, while all other stations fall into the control group, given general selection criteria are met. Our treatment effect is determined by the opening hours of the respective stations (Table 2 summarizes selected treatment groups and effects). In section 5.3, we will estimate regressions for each supermarket or car wash chain separately as opening hours are largely homogeneous within a chain of stations selling gasoline as a by-product, but they differ across chains (see Appendix B). Moreover, as discussed above, we vary the composition of treatment and control group stations across specifications to account for player-specific local market conditions (i.e., location in either rural or urban areas and different ranges of local competitors).

In the next section, we will introduce our generic regression model and present results for different specifications, taking selection criteria as described above into consideration.

5.3 Results

In this section, we document our empirical findings from regressing gasoline prices on dummies indicating treatment and control group as well as opening hours and relevant covariates. We estimate pooled difference-in-difference regressions described below in equation (1),

$$p_{it} = \alpha + \beta open_t + \gamma nearby_i + \delta(open_t * nearby_i) + \boldsymbol{x}_{it}\boldsymbol{\lambda} + u_{it} \tag{1}$$

with p_{it} as station i's hourly average gasoline (i.e., Super E5) retail price, $open_t$ as a dummy reflecting opening hours of stations selling gasoline as a by-product (equal to one when a supermarket or car wash station is open, and zero otherwise), and $nearby_i$ as a second dummy to distinguish between treatment area stations (i.e., equal to one) and control area stations (i.e., equal to zero). Furthermore, the expression $(open_t * nearby_i)$ interacts both dummies to measure the difference-in-difference between treatment and control areas as well as periods with and without an additional (supermarket, car wash) player in the local market area. Opening hours of stations selling gasoline as a by-product are, thus, only used as a shock to (major brand) stations' prices in local markets. Finally, $\boldsymbol{x}_{it}$ represents a vector

of covariates, which includes a full set of weekday dummies as well as regional ex-refinery prices.[25] On top of using a standard difference-in-difference approach, we also utilize the panel structure of our data set by running fixed effects models. While being comparable to equation (1), our fixed effects specifications additionally include gasoline station-fixed effects to account for unobserved heterogeneity.

Mr. Wash car washes (and associated gasoline stations) are usually located at the periphery of large cities, facing a high competitor station density. Nearby competitors are mostly affiliated to major brands and have a high share of 24/7 opening. In contrast, all 19 Mr. Wash locations are characterized by restricted and highly homogeneous opening hours (i.e., 8:00 am to 7:00 pm from Mondays to Saturdays; see Appendix B and, specifically, Table 6 for details). Table 3 presents results of a number of gasoline price specifications.[26] All specifications include stations surrounding Mr. Wash with unrestricted opening hours in the treatment group. As explained in section 5.2, the control group, in turn, comprises similarly-specified stations (i.e., between 5 and 14 direct competitors with 24/7 opening), located in the same set of large cities. Specifications differ in that either solely major brands or all brands are present, and hourly prices from Mondays to Saturdays (for all 19 Mr. Wash locations) or all weekdays (for 13 locations closed on Sundays) are included. Most importantly for our research question, we see a significant negative difference-in-difference coefficient $open * nearby$ of around -1 Eurocent/liter across all specifications with major brands. Thus, we find evidence of a price-decreasing effect of the temporary entry of Mr. Wash on major-brand stations in the surrounding area. Specifications including all brands also show negative coefficients, which, however, fall short of statistical significance (at least, if all days are included). Moreover, the importance of including counterfactual market scenarios is obvious: With around -6 Eurocents/liter, the *open* dummy coefficients indicate a significant price difference between daytime and nighttime hours, irrespective of treatment or control group.[27] Only by interacting *open* and *nearby* dummies, we see the true treatment effect, which reflects deeper price-cuts in treatment areas. With the *nearby* coefficients not being significantly different from zero, we do not observe a disparity

[25] As selected stations' input cost movements might not be in sync, we control for regionally-different (daily) ex-refinery prices on a station-level.

[26] All coefficients are denoted in Eurocents/liter of fuel. Instead of using clustered standard errors as in Table 6, we also estimated regressions with bootstrapped standard errors, leading to largely comparable results.

[27] We also estimate the same specifications with a full set of hour dummies. This leads to a large difference in magnitude of *open* dummy coefficients between specifications with prices from Monday to Saturday (of about -10 to -9 Eurocents/liter) and specifications with prices from Monday to Sunday (of about -1 Eurocent/liter). Hence, even without a Mr. Wash station in the market on Sundays, a certain spread between day- and nighttime prices is observable.

between stations in either group. Finally, in line with expectations, ex-refinery price changes are highly significant predictors of day-to-day retail price movements. In addition to results in Table 3, Figure 4 shows coefficients of hour dummies from separate regressions of treatment and control group stations included in Mr. Wash specifications. We see both the typical downward trend during daytime, but also a deeper price-cut for treatment group stations during Mr. Wash's operating hours.

In contrast to urban locations of car washes, *V-Markt* supermarkets are mostly situated in rural areas in Bavaria. Gasoline stations associated to V-Markt stores typically have just a few competitors, only part of which are open 24/7 (see Table 7 in Appendix B). V-Markt stations themselves largely open between 8:00 am and 8:00 pm from Monday to Friday, while often starting half an hour earlier on Saturday and remaining fully closed on Sunday.[28] Gasoline specifications for V-Markt can be found in Table 4. Similarly to above, we define treatment and control group stations to have a comparable number of competitors (here, zero to six), 24/7 opening, and a rural market setting. For the latter, we focus on areas with a first two-digits ZIP code[29] range between 86 and 89, which include all (valid) V-Markt station surroundings and mirrors South German rural areas for stations to be included in our control group. We find key similarities among V-Markt and Mr. Wash specifications. First and foremost, difference-in-difference coefficients are, again, significant for major brands (albeit the number of major-brand stations included in the treatment group is small). Indeed, the effect for V-Markt in major brand specifications is slightly smaller but less volatile to including Sundays, possibly related to a rural market setting with lower competition intensity and less interferences. For specifications including all brands, in turn, we see *open* dummy coefficients with only half the size (indicating overall less dynamic pricing) and non-significant treatment effects. Common to all estimations, and particularly obvious for V-Markt, is a smaller coefficient of determination in specifications with all brands. Adding further but more heterogeneous players, hence, does not increase the explanatory power of the model.[30] Comparing findings in Tables 3 and 4, we see significant negative treatment effects in both car wash and supermarket settings with locations in urban and rural areas, respectively.

To check for robustness of results against using other players selling gasoline as a

[28] We exclude six V-Markt locations (and surrounding area stations) from our analysis, which offer 24-hour automatic fuel terminals and are, thus, practically open 24/7.

[29] In Germany, the first two digits of the five-digit ZIP code indicate regions.

[30] Again, including hour dummies in the model leads to a large difference in *open* dummy coefficients among specifications with and without Sunday prices (about -5 Eurocents/liter and 0 Eurocents/liter, respectively) with the remaining intraday price fluctuation being absorbed by hour dummies.

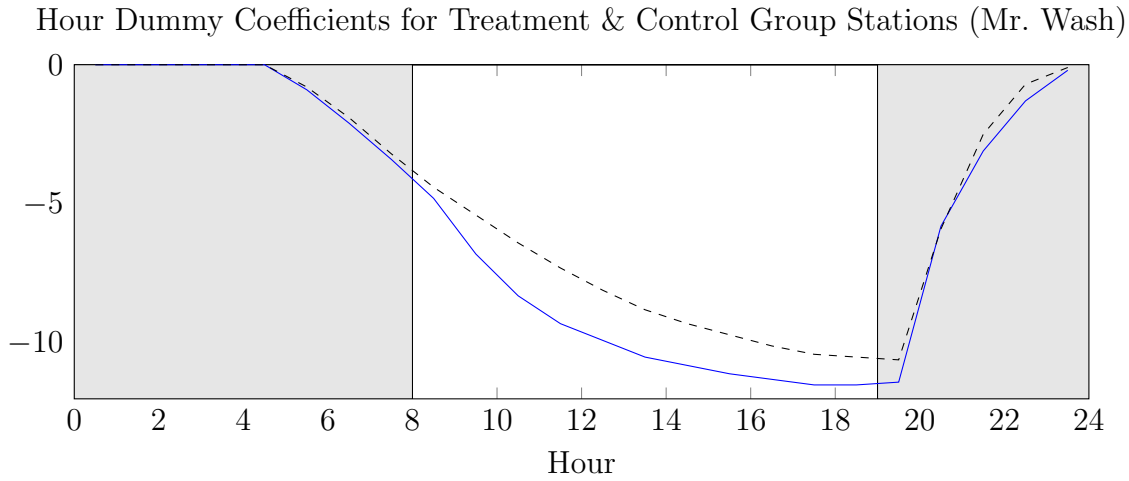
Table 3: Regression of Gasoline Retail Prices (Mr. Wash)

Dependent variable:	Difference-in-difference				Fixed effects	
Hourly price	Major brands		All brands		Major	All
	(1)	(2)	(3)	(4)	(5)	(6)
open ∗ *nearby*	-1.240***	-0.858**	-1.018***	-0.652*	-0.858**	-0.651*
	(0.00)	(0.01)	(0.00)	(0.08)	(0.01)	(0.08)
open	-6.214***	-6.586***	-5.357***	-5.913***	-6.586***	-5.914***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
nearby	0.362	-0.200	0.054	-0.430	–	–
	(0.33)	(0.63)	(0.91)	(0.39)		
Ex-refinery price	1.116***	1.117***	1.107***	1.108***	1.120***	1.112***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Constant	23.078***	23.790***	22.812***	23.809***	23.356***	23.212***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Weekday dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,523,402	1,374,250	3,549,617	1,770,816	1,374,250	1,770,816
Groups	–	–	–	–	158	205
R^2	0.744	0.732	0.699	0.694	0.731	0.694

Note: Heteroskedasticity- and cluster-robust p-values in parentheses (clustered by region).

Asterisks: Statistical significance at 1% (***), 5% (**), or 10% (*) level.

Specifications: (1), (3) include Mon-Sat; (2), (4), (5), (6) include Mon-Sun.



Note: Coefficients of hour dummies (in Eurocents/liter) from separate regressions on treatment group (solid line) and control group (dashed line) gasoline stations (omitted variable: 12 am dummy). Mr. Wash stations in treatment areas are closed when shaded.

Figure 4: Relative Hourly Prices for Mr. Wash Specification

Table 4: Regression of Gasoline Retail Prices (V-Markt)

Dependent variable:	Difference-in-difference				Fixed effects	
Hourly price	Major brands		All brands		Major	All
	(1)	(2)	(3)	(4)	(5)	(6)
open ∗ *nearby*	-0.732*	-0.700*	0.074	0.113	-0.700*	0.114
	(0.10)	(0.09)	(0.92)	(0.87)	(0.09)	(0.87)
open	-5.264***	-5.266***	-2.712***	-2.715***	-5.266***	-2.716***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
nearby	-0.286	-0.319	-0.440	-0.480	–	–
	(0.37)	(0.32)	(0.60)	(0.56)		
Ex-refinery price	1.139***	1.143***	1.075***	1.079***	1.148***	1.086***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Constant	21.856***	21.389***	25.705***	25.240***	20.805***	24.328***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Weekday dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	417,118	486,886	1,411,625	1,647,888	486,886	1,647,888
Groups	–	–	–	–	56	198
R^2	0.762	0.748	0.675	0.671	0.748	0.671

Note: Heteroskedasticity- and cluster-robust p-values in parentheses (clustered by region).

Asterisks: Statistical significance at 1% (***), 5% (**), or 10% (*) level.

Specifications: (1), (3) include Mon-Sat; (2), (4), (5), (6) include Mon-Sun.

Table 5: Regression of Gasoline Retail Prices (CleanCar, Famila)

Dependent variable:	Difference-in-difference			
Hourly price	CleanCar		Famila	
	Major	All	Major	All
	(1)	(2)	(3)	(4)
open ∗ *nearby*	-1.099***	-0.889**	-0.632	-0.847**
	(0.00)	(0.01)	(0.20)	(0.03)
open	-5.903***	-5.093***	-3.356***	-3.036***
	(0.00)	(0.00)	(0.00)	(0.00)
nearby	0.577**	0.384	1.597*	1.861***
	(0.04)	(0.39)	(0.05)	(0.00)
Ex-refinery price	1.119***	1.113***	1.106***	1.088***
	(0.00)	(0.00)	(0.00)	(0.00)
Constant	22.279***	21.770***	21.405***	23.164***
	(0.00)	(0.00)	(0.00)	(0.00)
Weekday dummies	Yes	Yes	Yes	Yes
Observations	1,122,368	1,540,246	2,857,599	4,592,057
Groups	–	–	–	–
R^2	0.747	0.711	0.635	0.643

Note: Heteroskedasticity- and cluster-robust p-values in parentheses (clustered by region).

Asterisks: Statistical significance at 1% (***), 5% (**), or 10% (*) level.

Specifications: (1)–(4) include Mon-Sat.

by-product in different geographic areas, we briefly discuss both a further car wash chain (i.e., *CleanCar*) and a second supermarket chain (i.e., *Famila*) in the following. CleanCar, as a player in the conveyorized car wash segment, has locations in larger cities with a slightly different regional footprint than Mr. Wash, while Famila, with locations in Northern Germany, usually operates associated gasoline stations in smaller cities (see Tables 8 and 9 in Appendix B for details). Both players are characterized by more heterogeneous opening hours across stations, also with regard to opening on Sundays (i.e., partly outside of usual business hours). Table 5 shows results for two specifications per brand (with major or all brands, respectively).[31] We, again, include stations in comparable ZIP code areas (for Famila) or the same set of cities (for CleanCar) in our control groups, in addition to further selection criteria as described above. Results in Table 5 are largely consistent with previous findings, especially with regards to negative difference-in-difference coefficients. Only for Famila's major brand specification, the coefficient is non-significant in light of a small number of rather scattered major stations with 24/7 opening in the surrounding of Famila markets.

6 Conclusion

In light of highly fluctuating prices, competition dynamics on retail gasoline markets are of major interest for consumers, policymakers, and competition authorities alike. Nonetheless, characteristics of local markets favoring a more competitive pricing behavior of individual stations during the day have not been fully understood, partly due to a lack of granular data sets for empirical investigations. In this paper, we have specifically examined the impact of stations selling gasoline as a by-product on local intraday prices in Germany. Analyzing this aspect of pricing dynamics is enabled by a rich data set including price quotes from all gasoline stations across the country.

Stations selling gasoline as a by-product are typically characterized by limited opening hours, which are exogenously determined by the primary business activities, in our example, either supermarket or car wash operations. We use this external shock to local market structures to explore the potential price effect a temporary low-priced alternative has on nearby competitors. Identifying this price effect requires

[31] We only use specifications with prices from Mondays to Saturdays (and, consequently, do not estimate fixed effects models) given heterogeneous hours of operation on Sundays. Furthermore, due to slight variations in working day opening hours, we use the median opening and closing times across stations to set respective dummy variables (i.e., for CleanCar from 6:00am–9:00pm from Monday to Friday and from 7:00am–8:00pm on Saturday; for Famila from 7:00am–9:00pm from Monday to Friday and from 7:00am–8:00pm on Saturday).

to take typical intraday pricing patterns, as found on numerous local markets in Germany, into consideration. Such patterns are similar to Edgeworth-type cycles in several respects: During daytime, prices often gradually decrease until a single large price increase in the evening offsets downward movements. In view of this pattern, including counterfactual market scenarios is crucial to isolate the sought-after effect from other price movements present in comparable market settings. Therefore, we have estimated models using hourly average price data in a difference-in-difference framework.

We find a significant negative price effect of stations selling gasoline as a by-product on nearby competitors. Our results indicate that, when a supermarket or car wash player is open, particularly major brands show a price reaction beyond usual daytime price reductions. These brands seem to have both the leeway and the willingness to temporarily reduce their otherwise above-average price positions in response to outside competitive pressure. The limited magnitude of price reactions compared with individual observations (e.g., as shown in Figure 3) may be explained by interferences contained in control group areas (i.e., other players with restricted opening hours). Still, the negative price effects identified in this study are statistically significant and robust against using different supermarket or car wash players. The effect tends to be more pronounced during working days with a higher competition intensity. From a policy perspective, a relevant contribution of this paper is empirical evidence that specific independent players can exert competitive pressure on local price levels, also with regard to market-dominating competitors.

Our findings are conditional on a few assumptions including the selection of stations for both control and treatment groups as well as our method of calculating average prices. Further research in the area of gasoline retail pricing is needed to fully comprehend intraday pricing mechanisms and could, among others, explore the presences and causes of intraday price cycling and establish a relation between such cycles and Edgeworth theory.

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A MTS-K Data Set

In this appendix, we provide the reader with additional information on the main data source used in this paper and explain any modifications of the data set prior to using it for the empirical analysis.

With the creation of the market transparency unit for fuel ("Markttransparenzstelle für Kraftstoffe", MTS-K), a novel panel data set including price quotes from virtually all German gasoline stations emerged. Since 1 December 2013, gasoline station owners are obliged to report any price alteration of Super E5, Super E10 and Diesel fuel to the MTS-K. In addition to price quotes, the MTS-K data set contains basic information on each station's location (including address and geographical coordinates), its brand affiliation, and opening hours (per weekday). The emergence of the MTS-K was mainly motivated by a sector inquiry conducted by the German Federal Cartel Office with findings described in Bundeskartellamt (2009, 2011a,b). Descriptive statistics on prices during the first months of MTS-K operation can be found in Bundeskartellamt (2014).

In our empirical analysis, we rely on the first full calendar year of data, from January to December 2014. Although MTS-K's standard operation phase ("Regelbetrieb") started on 1 December 2013, we deliberately exclude the first month as several stations failed to submit prices from the very beginning. As we do not impose (further) restrictions on the number of price quotes per station, we allow the data set to be unbalanced. Moreover, we slightly amend raw data as submitted by individual gasoline stations to the MTS-K: First of all, following validation rules proposed by the Bundeskartellamt (2011b, Appendix p. 3), we correct price data for incorrect input (e.g., empty price cells, zero price change, or price change greater than 20 Eurocents/liter). Secondly, we exclude both inactive stations as well as stations listed in the data set, which do not submit any price quotes. Finally, we conduct several quality checks of opening hour data (especially for selected stations selling gasoline as a by-product) and revise obvious misentries.

In total, the MTS-K data set comprises approximately 14,000 gasoline stations with roughly 25 million price quotes per fuel type within the twelve months considered in our analysis. Necessary data adjustments account for about 1% of all submitted prices.[32]

[32] Also see Appendix A in Haucap, Heimeshoff, and Siekmann forthcoming.

B Locations and Market Structure

In this appendix, we present a detailed overview regarding locations, opening hours, and market structure variables of stations selling gasoline as a by-product used in our analysis. Specifically, we discuss gasoline stations associated to Mr. Wash (see Table 6), V-Markt (see Table 7), Famila (see Table 8), and CleanCar (see Table 9) locations, which are included in the MTS-K data set.[33] Opening hours are presented by weekday (i.e., Monday to Friday, Saturday, and Sunday). Market structure variables comprise details on the number and type of nearby competitors in a surrounding area of 2 km as well as information on whether competitors have unrestricted (i.e., 24/7) or restricted (e.g., closed on Sundays) opening hours.

Mr. Wash currently operates at 30 locations in total, 19 of which have associated gasoline stations (see Table 6). Gasoline stations' opening hours are closely aligned to those of car wash operations: They either match car washes' opening hours or deviate by no more than one hour on all weekdays (i.e., gasoline stations might open up to one hour in advance of and close up to one hour later than car washes). Opening hours across Mr. Wash gasoline stations are highly homogeneous during all weekdays except Sundays. From Mondays till Saturdays, all 19 stations open for exactly eleven hours, from 8:00 am to 7:00 pm. On Sundays, car washes' and, consequently, gasoline stations' opening hours are more diverse: While 13 locations are closed, six other locations are open, between four and nine hours. Mr. Wash car washes are typically situated in the periphery of large cities (e.g., in commercial areas). As a result, the number of competitors, also with unrestriced opening hours, are above average. Competitors in 2 km distance range from 6 to 14, around two thirds of them with 24/7 opening hours. More than half of all competitors can be classified as major brands.

V-Markt, the brand name of Georg Jos. Kaes GmbH, operates at 54 locations (i.e., 42 V-Markt and twelve V-Baumarkt), 35 of which have associated gasoline stations (some also with car washes). Of these 35 locations, 30 submitted price data to MTS-K during January to August 2014 and are, thus, included in Table 7. Gasoline stations' opening hours are largely in line with opening hours of corresponding supermarkets and are quite homogeneous across locations: 20 locations open from 8:00 am to 8:00 pm from Mondays to Fridays and from 7:30 am to 8:00 pm on Saturdays.[34] While a few gasoline stations' hours of operation slightly vary, six stations

[33] Next to data included in the MTS-K data set, this appendix relies on further information from corresponding corporate websites (see `www.mrwash.de`, `www.v-markt.de`, `www.famila-nordost.de`, and `www.cleancar.de`).

[34] In the empirical analysis with hourly prices, we treat opening and closing between two (full) hours (e.g., at 7:30 am) as if they would occur at the next full hour (e.g., at 8:00 am).

notably deviate with 24/7 opening. These six stations are equipped with self-service terminals, which may be used after regular opening hours. To avoid misinterpretation, we disregard these stations from our analysis. V-Markt supermarkets (and, similarly, construction markets) are mostly located in rural areas in Bavaria, often with just a few (i.e., between zero and six) competitors in a surrounding area of 2 km.[35] Similar to V-Markt stations themselves, nearby competitors hardly open 24/7: Only a third of all stations are always open.

Under the umbrella of the **Famila** group, there are two independent supermarket chains: Famila Nordwest (with about 20 locations) and Famila Nordost (with about 80 locations). Famila Nordost (hereafter: Famila) operates 26 own gasoline stations, of which 23 submitted price data to MTS-K from January to August 2014 and are, thus, included in Table 8. Opening hours differ slightly across gasoline station locations, but are largely in line with opening hours of corresponding supermarkets, at least from Mondays to Saturdays.[36] At eleven locations, Famila gasoline stations also open on Sundays – independent of supermarket operations. Famila supermarkets, based in Northern Germany, are mostly located in rural areas or smaller cities. Except for locations in Hanover and Neumünster, local competition is limited to between zero and four other stations. While only about a third of all competitors open 24/7, within the subgroup of major brands, this share rises to above 50%.

Similar to Mr. Wash, **CleanCar** car washes are located in larger cities, although the regional footprint of the two players varies. CleanCar operates at 24 locations in Germany (plus three locations in Vienna), of which 13 have associated gasoline stations and twelve submitted prices to the MTS-K (see Table 9). Opening hours slightly vary across locations, on working days between 6:00 and 8:00 am in the morning and 6:00 and 10:00 pm in the evening. The majority of gasoline stations also opens on Sundays, not necessarily in line with car washes' hours of operation. CleanCar's local competitive environment (between three and 15 competitors) is characterized by a large share of major-brand stations and an above-average level of unrestricted opening hours.

With insights gained in this appendix, we affirm our focus on Mr. Wash and V-Markt locations with homogeneous opening hours and a clear match between primary operations and gasoline stations. Famila and CleanCar locations, with more diverse opening hours and partly autonomous Sunday opening, are instead used for robustness checks.

[35]The V-Markt station in Munich with 14 nearby competitors is an exception. We will exclude this station in our specifications in section 5.3.

[36]The Famila market in Kiel with 24/7 opening is an obvious exception, which we, consequently, exclude from the analysis.

Table 6: Opening Hours and Market Structure of Mr. Wash Gasoline Stations

#	Mr. Wash stations	Opening hours			Competitors					
					All brands			Major brands		
		Mon-Fri	Sat	Sun	All	Sun	24/7	All	Sun	24/7
1	Hammer Str. 169, Münster	8:00-19:00	8:00-19:00	closed	11	10	6	3	3	2
2	Stresemannstr. 13a, Bremen	8:00-19:00	8:00-19:00	closed	14	12	5	8	8	4
3	Raderthalgürtel 1, Köln	8:00-19:00	8:00-19:00	closed	7	7	4	5	5	4
4	Heiliger Weg 68, Dortmund	8:00-19:00	8:00-19:00	closed	12	12	10	8	8	7
5	Gladbecker Str. 415, Essen	8:00-19:00	8:00-19:00	closed	9	9	6	6	5	4
6	Ziegelstr. 71-75, Bielefeld	8:00-19:00	8:00-19:00	closed	9	9	3	2	2	2
7	Hanauer Landstr. 419, Frankfurt	8:00-19:00	8:00-19:00	closed	5	4	3	4	4	3
8	Dießemer Bruch 91, Krefeld	8:00-19:00	8:00-19:00	closed	11	10	6	5	5	4
9	Völklinger Str. 48, Düsseldorf	8:00-19:00	8:00-19:00	closed	8	7	5	7	7	5
10	Heilbronner Str. 309, Stuttgart	8:00-19:00	8:00-19:00	closed	10	9	6	6	6	5
11	Hans-Böckler-Str. 23, Essen	8:00-19:00	8:00-19:00	closed	9	9	6	5	5	4
12	Möhlstraße 7-17, Mannheim	8:00-19:00	8:00-19:00	closed	9	8	6	6	6	6
13	Nopitschstr. 80, Nürnberg	8:00-19:00	8:00-19:00	closed	7	7	4	4	4	3
14	Kollaustraße 71, Hamburg	8:00-19:00	8:00-19:00	13:00-17:00	11	11	9	4	4	4
15	Stresemannstr. 349-351, Hamburg	8:00-19:00	8:00-19:00	13:00-17:00	10	10	9	6	6	6
16	Landsberger Str. 420+426, München	8:00-19:00	8:00-19:00	12:00-18:00	5	5	2	3	3	2
17	Friedrich-Ebert-Damm 170, Hamburg	8:00-19:00	8:00-19:00	12:00-19:00	7	7	6	5	5	4
18	Nonnendammallee 27, Berlin	8:00-19:00	8:00-19:00	9:00-18:00	5	5	3	2	2	2
19	Rhinstr. 136, Berlin	8:00-19:00	8:00-19:00	9:00-18:00	10	9	7	4	4	1

Note: Sorted by increasing opening hours; competitors within 2 km distance around Mr. Wash, either all, with Sunday ("Sun") or unrestricted ("24/7") opening.
Source: MTS-K data set, Mr. Wash website.

Table 7: Opening Hours and Market Structure of V-Markt Gasoline Stations

#	V-Markt/ V-Baumarkt stations	Opening hours			Competitors					
		Mon-Fri	Sat	Sun	All brands			Major brands		
					All	Sun	24/7	All	Sun	24/7
1	Hauptstraße 41, Kirchheim	8:00-20:00	7:30-14:00	closed	1	1	1	0	0	0
2	Am Mühlbach 1, Saulgrub	8:00-19:00	7:30-18:00	closed	0	0	0	0	0	0
3	Justus-von-Liebig-Straße 1, Buchloe	8:00-20:00	8:00-20:00	closed	2	2	1	1	1	0
4	Sudetenstr. 50, Neugablonz	8:00-20:00	7:30-20:00	closed	5	5	3	2	2	1
5	Gutenbergstraße 4, Bobingen	8:00-20:00	7:30-20:00	closed	2	2	0	1	1	0
6	G.-Daimler-Straße 15, Bad Wörishofen	8:00-20:00	7:30-20:00	closed	1	1	0	0	0	0
7	Industriestraße 1, Burgau	8:00-20:00	7:30-20:00	closed	4	4	1	2	2	0
8	Saumweg 19, Illertissen	8:00-20:00	7:30-20:00	closed	2	2	0	2	2	0
9	Im Engelfeld 5, Immenstadt	8:00-20:00	7:30-20:00	closed	3	3	0	1	1	0
10	Josef-Landes-Straße 40, Kaufbeuren	8:00-20:00	7:30-20:00	closed	3	3	0	1	1	0
11	Weiler Weg 1, Ichenhausen	8:00-20:00	7:30-20:00	closed	2	2	0	1	1	0
12	Max-von-Eyth-Straße 4, Landsberg	8:00-20:00	7:30-20:00	closed	4	4	3	2	2	2
13	Dillingerstraße 25, Lauingen	8:00-20:00	7:30-20:00	closed	3	3	2	0	0	0
14	J.-G.-Fendt-Straße 33, Marktoberdorf	8:00-20:00	7:30-20:00	closed	4	4	1	2	2	0
15	Augsburger Straße 50, Günzburg	8:00-20:00	7:30-20:00	closed	3	3	0	1	1	0
16	Werner-Von-Braun-Straße 16, Memmingen	8:00-20:00	7:30-20:00	closed	6	5	3	1	1	0
17	Ammergauer Straße 60, Peiting	8:00-20:00	7:30-20:00	closed	2	2	1	1	1	0
18	Wiesenweg 15, Schongau	8:00-20:00	7:30-20:00	closed	1	1	0	1	1	0
19	G.-Daimler-Straße 6, Schwabmünchen	8:00-20:00	7:30-20:00	closed	1	1	0	1	1	0
20	Allgäuer Straße 19, Mindelheim	8:00-20:00	7:30-20:00	closed	5	4	1	3	3	0
21	Bürgerm.-Raab Straße 31, Thannhausen	8:00-20:00	7:30-20:00	closed	3	3	0	0	0	0
22	Herzog-Georg-Straße 1, Weißenhorn	8:00-20:00	7:30-20:00	closed	2	2	1	2	2	1
23	Danziger Straße 1, Türkheim	8:00-20:00	7:30-20:00	closed	1	1	0	0	0	0
24	Balanstr. 50, München	6:00-21:00	6:00-21:00	closed	14	13	8	7	7	5
25	Augsburger Straße 38, Leipheim	0:00-0:00	0:00-0:00	0:00-0:00	3	3	1	1	1	0
26	Kemptener Str. 107, Füssen	0:00-0:00	0:00-0:00	0:00-0:00	1	1	0	0	0	0
27	Sudetenstraße 5, Kaufbeuren	0:00-0:00	0:00-0:00	0:00-0:00	6	5	2	3	3	1
28	Frühmahd 1, Erkheim	0:00-0:00	0:00-0:00	0:00-0:00	1	1	1	1	1	1
29	Bundesstraße 16, Fischen/Langenwang	0:00-0:00	0:00-0:00	0:00-0:00	1	1	0	1	1	0
30	Grünzweigstraße 1, Kissing	0:00-0:00	0:00-0:00	0:00-0:00	1	1	1	0	0	0

Note: Sorted by increasing opening hours; competitors within 2 km distance around V-Markt, either all, with Sunday ("Sun") or unrestricted ("24/7") opening.

Source: MTS-K data set, V-Markt website.

Table 8: Opening Hours and Market Structure of Famila Gasoline Stations

#	Famila stations	Opening hours			Competitors					
		Mon-Fri	Sat	Sun	All brands			Major brands		
					All	Sun	24/7	All	Sun	24/7
1	Möllerung 11, Lübeck	8:00-20:00	8:00-20:00	closed	2	2	1	2	2	1
2	Bornumer Straße 141, Hannover	8:00-20:00	8:00-20:00	closed	11	9	4	5	5	3
3	Haart 224, Neumünster	8:00-21:00	8:00-21:00	closed	7	6	1	2	2	1
4	Ravensbusch 12, Stockelsdorf	8:00-21:00	8:00-21:00	closed	4	4	1	2	2	1
5	Kisdorfer Weg 13, Kaltenkirchen	7:45-20:15	7:45-20:15	closed	0	0	0	0	0	0
6	Kornkamp 50, Ahrensburg	7:45-21:30	7:45-21:30	closed	1	1	0	0	0	0
7	Lemker Straße 20, Nienburg	7:30-20:30	7:30-20:30	closed	4	3	1	1	1	1
8	Rudolf-Diesel-Ring 32, Neustadt a.R.	7:30-20:30	7:30-20:30	closed	2	2	0	1	1	0
9	Pascalstrasse 9, Quickborn	7:00-20:00	7:00-20:00	closed	1	1	1	1	1	1
10	Mecklenburger Straße 1-3, Lauenburg	7:00-21:00	7:00-20:00	closed	2	2	1	2	2	1
11	Am Vogelsang 12, Schneverdingen	7:00-21:00	7:00-21:00	closed	3	3	1	0	0	0
12	Westring 2, Pinneberg	7:00-21:30	7:00-21:30	closed	1	1	1	0	0	0
13	Plöner Landstraße 41861, Eutin	8:00-20:00	8:00-20:00	11:00-19:00	1	1	1	1	1	1
14	Rettiner Weg 77, Neustadt / Holstein	7:30-20:15	7:30-20:25	11:00-19:00	2	2	0	0	0	0
15	Am Vossberg 1, Oldenburg / Holstein	7:00-21:00	7:00-21:00	11:00-19:00	1	1	0	0	0	0
16	Schönkirchener Straße 80, Kiel	7:00-21:00	7:00-21:00	8:00-21:00	2	2	1	1	1	1
17	Schwarzer Weg 11, Perleberg	6:00-20:00	8:00-20:00	8:00-20:00	1	1	0	1	1	0
18	Sanitzer Str. 3, Ribnitz-Damgarten	6:00-21:00	7:00-21:00	9:00-21:00	2	2	1	2	2	1
19	Hördorfer Weg 52, Osterholz-Scharmb.	6:00-22:00	6:00-22:00	8:00-20:00	1	1	0	1	1	0
20	Auf dem Rusch 1, Rotenburg	6:00-21:30	6:00-21:30	7:00-21:30	4	4	2	2	2	2
21	Prinz-Heinrich-Str. 20, Kiel	6:00-22:00	7:00-22:00	8:00-22:00	3	3	1	2	2	1
22	Timmasper Weg 1, Nortorf	6:00-22:00	7:00-22:00	8:00-22:00	1	1	0	1	1	0
23	Grot Steenbusch 35, Kiel	0:00-0:00	0:00-0:00	0:00-0:00	1	1	1	0	0	0

Note: Sorted by increasing opening hours; competitors within 2 km distance around Famila, either all, with Sunday ("Sun") or unrestricted ("24/7") opening.

Source: MTS-K data set, Famila website/ customer service.

Table 9: Opening Hours and Market Structure of CleanCar Gasoline Stations

#	CleanCar stations	Opening hours			Competitors					
					All brands			Major brands		
		Mon-Fri	Sat	Sun	All	Sun	24/7	All	Sun	24/7
1	Marzahner Chaussee 232, Berlin	7:00-19:00	8:00-18:00	closed	6	6	2	4	4	1
2	Hildesheimer Str. 214, Hannover	7:00-19:00	7:00-18:00	closed	5	5	3	4	4	2
3	Vahrenwalder Str. 285, Hannover	7:00-19:00	7:00-18:00	closed	9	9	4	3	3	3
4	St. Töniser Str. 71, Krefeld	6:00-20:00	7:00-20:00	closed	7	6	3	2	2	2
5	Düsseldorfer Str. 26, Neuss	6:00-20:00	6:00-20:00	closed	3	3	2	3	3	2
6	Lembergallee 1, Freiburg	6:00-22:00	7:00-20:00	9:00-17:00	3	3	1	1	1	0
7	Kieler Str. 195, Hamburg	6:00-22:00	7:00-20:00	9:00-20:00	15	15	14	8	8	8
8	Zwickauer Str. 200, Chemnitz	6:00-21:00	7:00-21:00	8:00-20:00	6	6	1	4	4	1
9	Paul-Stieglitz-Str. 1, Erfurt	6:00-21:00	6:00-21:00	8:00-17:00	4	4	3	3	3	2
10	Charlottenburger Chaussee 53a, Berlin	6:00-21:00	6:00-21:00	8:00-20:00	6	6	4	3	3	3
11	Steilshooper Allee 5, Hamburg	6:00-21:00	7:00-21:00	7:00-21:00	7	7	4	5	5	3
12	Äppelallee 112, Wiesbaden	6:00-22:00	7:00-22:00	8:00-20:00	5	5	0	3	3	0

Note: Sorted by increasing opening hours; competitors within 2 km distance around CleanCar, either all, with Sunday ("Sun") or unrestricted ("24/7") opening.
Source: MTS-K data set, CleanCar website.

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