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Fuel Prices and Station Heterogeneity on Retail Gasoline Markets*

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Abstract

Price levels and movements on gasoline and diesel markets are heavily debated among consumers, policy-makers, and competition authorities alike. In this paper, we empirically investigate how and why price levels differ across gasoline stations, using the first full year from a novel panel data set including price quotes from virtually all German stations. Our analysis specifically explores the role of station heterogeneity in explaining price differences across gasoline stations. Key determinants of price levels across fuel types are found to be ex-refinery prices as key input costs, a station's location on roads or highway service areas, and brand recognition. A lower number of station-specific services implies lower fuel price levels, so does a more heterogeneous local competitive environment.

JEL-Classification: L11, L71

Keywords: Gasoline Pricing, Station Heterogeneity, Fuel Prices, Gasoline Stations

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1 Introduction

Competition and pricing on retail gasoline and diesel markets have already long been highly debated topics among consumers, media as well as regulatory and antitrust authorities in many countries around the globe (see OECD 2013). Gasoline and diesel markets, and their retail segments in particular, have also been a field of intensive empirical research, around (asymmetric) pass-through of wholesale prices, evaluation of market power, or the effects of regulatory interventions, to name just a few examples (see Houde 2011; Noel 2007a,b, 2009). In particular, studies focusing on dynamic pricing behavior and characteristics of price cycles as well as studies analyzing (station-level) price dispersion and determinants of price levels have received substantial attention (see Eckert 2013; Noel 2011). In addition, numerous competition authorities have conducted in-depth inquiries into the sector (see ACCC 2007; Bundeskartellamt 2011a; OECD 2013).

Given specific characteristics such as a high degree of product homogeneity, relatively low search costs, a high degree of market transparency and low menu costs, as well as a market structure dominated by a few vertically-integrated players, gasoline and diesel markets constitute an interesting field to study. Comprehensive pricing data sets for empirical investigations, however, are difficult to obtain as gasoline and diesel are sold through numerous locally distributed, stationary sales outlets. Several existing empirical studies, primarily for areas in the U.S. and Canada, hence, have relied on city-level data or survey data from a small sample of stations (e.g., Borenstein and Shepard 1996; Lewis 2009; Noel 2007a, forthcoming; Shepard 1993), in part with self-collected price observations (e.g., Atkinson 2009; Noel 2007b; Slade 1987, 1992). Recently, however, regulatory requirements on price transparency in some regions have led to more comprehensive and centrally collected databases. As an example, Wang (2009a) uses a census of daily prices for the city of Perth in Western Australia, collected by a regulatory body, to document oligopoly pricing strategies in a time-controlled market environment.[1]

A fascinating opportunity to learn more about retail gasoline pricing has recently emerged, as Germany introduced a gasoline price transparency platform. Since December 2013, virtually all gas stations are required to notify all price changes to Germany's antitrust agency, the Federal Cartel Office, which collects the data and makes it available to internet price comparison platforms. This data set allows us to analyze retail gasoline pricing in a market without pricing regulations.[2] By

[1] This represents a census of price data as Western Australian stations are restricted to a single price change per day.

[2] Station operators in Germany are neither restricted in the frequency nor in the direction of

combining price data with various stations characteristics (e.g., amenities such as shop offerings or car wash facilities) and measures for spatial competition, we are able to identify key factors determining station-level prices at different times of the day (e.g., day- and nighttime), in different segments (e.g., road and highway stations) and on different product markets.[3]

Our empirical investigation, thus, specifically looks at how and why price levels as well as the number of price changes differ across stations. Using average and point-in-time price metrics, we explore the impact a range of variables have on prices, subject to different levels of competition intensity across the day. We find that a significant part of the distribution of prices can be associated to observable station characteristics and wholesale price shocks. Ex-refinery prices are a good predictor of input cost changes, while stations located at highway service areas or associated to premium brands charge significantly higher prices. Analyzing brand categories as well as individual brands, we find that certain brands have distinctly different day- and nighttime pricing strategies in response to local competition intensity. Moreover, additional service offerings positively affect price levels, while heterogeneity among local competitors appears to imply lower prices. Finally, stations offering gasoline as a by-product (e.g., supermarket-owned stations) have distinctly lower prices, albeit opening hours are structurally different.

The rest of this paper is structured as follows: We will start with an overview of related empirical literature in the following section. Section 3 then introduces the German gasoline and diesel market as well as data sets used for the empirical investigation. The latter includes (retail and wholesale) price data as well as station characteristics. Section 4 follows with the empirical investigation and results. Finally, section 5 summarizes main findings, highlights limitations and gives ideas for further research.

2 Related Literature

Much of the literature on gasoline retail markets focuses on price dynamics, by either looking at how upstream costs are passed through to retail prices or by linking (elements of) what is known as Edgeworth cycles to empirically observed prices (see Eckert 2013 or Byrne 2012 for an overview). Studies of the latter group ana-

price changes.

[3]Road and Autobahn (i.e., highway service area) stations are considered distinct business segments (with a distinct competitive environment) as the single player "Tank & Rast GmbH" is responsible for leasing out all Autobahn stations. Gasoline (i.e., Super E5 and Super E10) and diesel represent non-substitutable product markets in the short- to medium-term due to technical characteristics of engines. For more details, see section 3.1.

lyze patterns resembling asymmetric price cycles formalized by Maskin and Tirole (1988).[4] These recurring cycles are characterized by a phase of fast and large price increases, in theory to a level slightly above the monopoly price ("relenting phase"), and a longer sequence of small step-wise price cuts, down to the level of marginal cost ("undercutting phase"). Another stream of empirical research focuses instead on identifying key determinants of station- or market-level prices, for instance, as a result of mergers (e.g., Simpson and Taylor 2008) or regulatory interventions (e.g., Carranza, Clark, and Houde forthcoming; Dewenter and Heimeshoff 2012). Within this stream, there are also studies that focus on price dispersion and price differentials (e.g., Barron, Taylor, and Umbeck 2004; Lewis 2008).

Most of the empirical studies on gasoline retail pricing focus on U.S. markets (e.g., Borenstein and Shepard 1996; Doyle, Muehlegger, and Samphantharak 2010; Lewis and Noel 2011; Shepard 1993; Zimmerman, Yun, and Taylor 2013), Canada (e.g., Atkinson 2009; Byrne, Leslie, and Ware 2015; Noel 2009, forthcoming; Slade 1987, 1992), and Australia (e.g., Valadkhani 2013; Wang 2008, 2009a,b; Wills-Johnson and Bloch 2010b). On a European level, fewer empirical studies are available. For the Norwegian market, Foros and Steen (2013), for instance, use a (consumer-submitted or self-observed) unbalanced panel data set of gasoline prices at Norwegian stations to estimate a fixed-effect model. Controlling for regional, brand, and weekday effects, among others, the model supports their observation of implicit price control mechanisms at the headquarters of leading companies. The authors find evidence of a significant "day-of-the-week" effect, where prices seem to regularly "jump up" on Mondays. Applying difference-in-differences and fixed effects models to weekly nationwide price data, Dewenter and Heimeshoff (2012), as a second example, compare the impact of different pricing rules on price levels in Austria, finding a significant price-lowering effect of Austria's regulations.[5] For Germany, a comprehensive pricing investigation was conducted by the Bundeskartellamt (2009, 2011a,b) as part of a sector inquiry on fuels. Within this inquiry, a market-dominating oligopoly and certain behaviors suggesting implicit collusion have been observed. Moreover, an empirical analysis of four model regions revealed the existence of recurring Edgeworth-type cycles.[6] In a recent paper, Kihm, Ritter, and

[4]The basic model of Maskin and Tirole (1988) has been refined over the last years, for example, by Eckert (2003), Noel (2008), and Wills-Johnson and Bloch (2010a). See Noel (2011) for a non-technical introduction to Edgeworth cycle theory. Numerous empirical studies focus on elements of Edgeworth cycles on gasoline markets, among them are Doyle, Muehlegger, and Samphantharak (2010), Isakower and Wang (2014), Noel (2007b), and Zimmerman, Yun, and Taylor (2013).

[5]The authors also look at Western Australian price rules in a different regulatory setting, finding no significant effect of regulation on price levels but on price volatility.

[6]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.

Vance (2014) examine how crude oil price increases are passed through by major brands vis-à-vis other brands. The authors use large-scale customer-submitted price data from January 2012 to February 2013 and find heterogeneity in the extent of cost pass-through as well as a statistically significant but economically small impact of competition metrics.[7]

In our empirical analysis, we will specifically look at how and why price levels differ across various stations in Germany. Therefore, among others, Hosken, McMillan, and Taylor (2008) provide valuable input. The authors use station-specific, weekly gasoline prices from a sample of 272 stations around Washington, D.C. from 1997 to 1999 to investigate the existence and dynamics of price dispersion as well as the impact of supplier and market characteristics on price levels. They find, for instance, frequently changing (relative) price positions (i.e., stations do not apply simple pricing rules) and differentiated impacts of brands. Moreover, in a recent paper, Pennerstorfer et al. (2014) look at quarterly diesel prices of Austrian stations to study the relationship between information (approximated by the fraction of commuters) and measures of price dispersion, and provide insight into routing-based measures for spatial competition and market area delineation.

In this paper, we will rely on a large-scale price data set and various station-specific characteristics to test for price distribution as well as the influence of local competition, supply characteristics and demand-side effects on price levels. After a brief introduction to the German gasoline market and to data sets used in the following section, we will present empirical findings on station-specific price levels for German gasoline stations in section 4.

3 German Retail Gasoline Market and Data

3.1 Market Characteristics

Gasoline and diesel are fairly homogeneous products (in terms of their physical characteristics) and sold exclusively via retail gasoline and diesel stations. Product differentiation results primarily from the spatial location of a specific station, its brand recognition, or by-products in form of shop offerings, while product innovation does not play a significant role (see, e.g., OECD 2013, pp. 9-30).[8] Most common fuel types sold at German stations are gasoline – specifically "Super E5", with a

[7] Empirical studies on asymmetric pass-through of wholesale costs to retail gasoline prices in other countries include, among others, Bachmeier and Griffin (2003), Bacon (1991), Borenstein, Cameron, and Gilbert (1997), Eckert (2002), Lewis (2009), Noel (2009), and Radchenko (2005).

[8] Several large retail players in Germany offer customer loyalty programs as a means of differentiation (e.g., Aral with Payback, Shell with ClubSmart, or Esso with DeutschlandCard).

minimum research octane number (RON) of 95 and up to 5% of ethanol or "Super E10", with 95 RON and 10% ethanol – as well as Diesel.[9] Gasoline and diesel constitute different product markets in the short- to medium-term as consumers cannot substitute between the two given different technical specifications of engines (see, e.g., Bundeskartellamt 2011a).[10] Notwithstanding the above, most consumers may freely choose between the two gasoline products Super E5 and Super E10, only very few (older) cars are not designed or not recommended to use Super E10.

Only a few vertically integrated oil companies have both a large nationwide network of stations (and, thus, comparably high market shares), and substantial direct access to refining capacities in Germany. These players have fairly similar interests and are well-connected (e.g., through joint ventures for refineries, tank farms, or pipelines; Bundeskartellamt 2011b, pp. 20-21, 2009, pp. 9-11). As these companies also supply other than their own retail stations, their influence is larger than reflected by the sheer number of branded retail sites. In general, brand affiliation and ownership of a station are not contingent on each other. It is, therefore, helpful to distinguish between oil company and dealer ownership of stations next to brand affiliation (see Shepard 1993, pp. 60-66 or Bundeskartellamt 2011b, pp. 166-171). Apart from "major" players, gasoline and diesel stations are operated either by other integrated oil companies with a rather regional footprint and without substantial access to refinery capacities, or by a large number of small-to-medium sized retailers ("independents"), many of which cooperate via associations. Among the latter are also stations at, for instance, car wash or supermarket sites, where selling gasoline and diesel is considered a by-product. From the consumers' perspective, competition between gas stations takes place at the local level within a practically meaningful market area.[11] A special characteristic of the German market is, moreover, a different competitive environment for the small number of so-called Autobahn stations (i.e., stations integrated in highway service areas) as opposed to the majority of road stations. This is a result of assigning responsibility for construction, operation, and leasing out of Autobahn stations (almost) exclusively to "Tank & Rast GmbH" after a privatization effort of formerly state-owned Autobahn gasoline station companies

[9] Other fuel types offered at German stations include, most notably, different "premium" fuels, with higher octane ratings (for gasoline) or special additives (for gasoline and diesel). Furthermore, several stations sell liquefied petroleum gas (LPG, "Autogas") or compressed natural gas (CNG, "Erdgas") as alternative fuel types. Finally, numerous stations offer special truck diesel at high-speed pumps (see, e.g., `www.adac.de/infotestrat/tanken-kraftstoffe-und-antrieb`).

[10] In the long-run, gasoline and diesel may indeed be considered substitutes, as most cars are available with different engine types and most stations in Germany – as opposed to other countries – offer gasoline as well as diesel fuel types.

[11] While there is no single dominant approach for local market delineation in the literature, we propose simple measures of spatial competition in section 3.3.

in 1998 (see Bundeskartellamt 2011b, pp. 213-218).

In contrast to other markets (e.g., in Austria or Western Australia), gasoline and diesel pricing in Germany is not subject to pricing regulations. German gasoline and diesel station operators are, thus, free to choose at which time, in which direction and by which amount they change prices for all fuel types offered. While station operators' menu costs are low, so are consumers' switching costs (Noel 2007a, p. 7). With product homogeneity and the chance to easily compare prices (within a regional market area), market transparency is, at least in theory, fairly high. The recent emergence of several mobile gasoline price comparison platforms in Germany has further helped to increase actual transparency for consumers (and suppliers) as prices can be retrieved from an up-to-date price database provided by the German Federal Cartel Office free of charge (e.g., via smartphones). Our empirical analysis will largely build on this novel database, which will be described in the next section.

3.2 Price Data

Empirical studies on gasoline and diesel retail pricing have until now largely utilized daily, weekly or quarterly price data of larger cities, on an average city-level basis or on a station-by-station level (see Eckert 2013). Price observations are often collected at specific daytimes and cover a sample of stations. Only more recently, with the emergence of larger data sets, more comprehensive investigations have become possible. Within this study, we make use of a rich panel data set comprising a census of gasoline (Super E5, Super E10) and diesel retail price quotes covering virtually all German gasoline stations. This novel data set is collected by the German market transparency unit for fuel ("Markttransparenzstelle für Kraftstoffe", MTS-K). Since 1 December 2013, gasoline station operators are obliged to instantaneously report any price change (including a precise time stamp), resulting in a comprehensive price data set across the country.[12]

Given the novelty of the data source, accuracy of price data might be a concern.[13] To ensure data quality, we analyze submitted price quotes along data validation rules defined in Bundeskartellamt (2011b, Appendix p. 3). We exclude the first month of data (i.e., December 2013), mainly as a number of active gasoline stations failed to submit prices in the first month. Looking at data from January 2014 onwards

[12]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`. The data set was kindly provided by authorized consumer information provider "1-2-3 Tanken" (on 18 February 2015).

[13]The technical infrastructure itself was tested by the MTS-K during a three-month testing phase before launching standard operation phase ("Regelbetrieb") on 1 December 2013.

only, price quotes considered "invalid" (e.g., empty price quote or price change of 0.00 Euro/liter) are at an acceptable level of about 1% of total observations (see Appendix A for an overview of data preparation steps). In our analysis, we rely on the first full year of price data, from January to December 2014. 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").

In the empirical analysis in section 4, we use station-level average price metrics (i.e., daily and daytime prices) as well as point-in-time prices (i.e., morning, evening, and midnight prices). The first requires an aggregation of precise price quotes to average prices per station and day with the help of two routines. First of all, we compute 24-hour average "daily prices" on a station-level by weighting all prices charged throughout the day with the length of their validity. Secondly, to compute "daytime prices", we follow the same logic but restrict the aggregation to prices charged from 8 am to 8 pm each day. We, thereby, focus on the part of the day, where most stations are indeed open and demand as well as the level of price competition is presumably highest. We use these two average price metrics as they incorporate the full variety of price levels (and precise times of validity) over the day or during daytime, and are arguably more accurate and unbiased with regard to a (random) time of observation as used in several earlier studies.[14] We, moreover, look at three point-in-time prices per station and day – namely "morning prices" (at 8 am), "evening prices" (at 8 pm), and "midnight prices" (at 12 am) – as they exemplarily represent different levels of competition dynamics across a typical daily price cycle (see section 4.1).

To account for main input cost variations, we, furthermore, use daily wholesale prices "ex-refinery" for Super E5, Super E10 and Diesel products. These prices are generated by Oil Market Report (O.M.R.), a widely used, independent information service provider, with the help of daily interviews of active market participants. We make use of the fact that this price data is available at a regional level, reflecting eight major refinery regions in Germany.[15] Individual stations are assigned to one of the eight refinery regions based on minimum linear distance to the region's market place (see section 3.3 for details on calculation methodology). Ex-refinery wholesale prices are nominal and quoted in Euro(cents) per liter free on tank-lorry (fot) as of German

[14]Note, however, that we do not observe varying intraday demand levels and do not incorporate opening hours differences at individual stations.

[15]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).

refinery or storage including energy tax and fees for the Petroleum Stockholding Assocation "EBV".[16]

3.3 Station Data

Apart from retail prices, the MTS-K data set includes station-specific data on virtually all gasoline stations across Germany, including geographical coordinates, detailed information on opening hours and brand affiliation. Similar to price data, we also check MTS-K station data for quality and exclude inactive entries and stations without submitted price quotes (per fuel type). Beyond this, we do not impose further threshold levels regarding, for instance, a minimum required number of price quotes per station and allow the data set to be unbalanced (see Appendix A).

In total, stations are allocated to around 70 single brands. On top of this, we group brands into two "brand categories" to reflect and comment on a proposal by the Bundeskartellamt (2011b, pp. 13/21). In the first categorization, based on its brand, a station is classified into one of the three groups: oligopolistic player, other integrated player, or independent player. The first group includes all stations branded as Aral (BP), Shell, Total, Esso (ExxonMobil), and Jet (ConocoPhilipps). Apart from a nationwide network of gasoline stations, these oil companies are vertically integrated with substantial direct access to refinery capacities in Germany. The Federal Cartel Office has classified these five vertically integrated oil companies as oligopoly players, which we also use for our analysis. The second group consists of all brands of other, typically regional, integrated oil companies, mainly Star (Orlen), Agip (ENI), HEM (Tamoil), and OMV. In the third group, several small- to medium-sized retail brands ("independents") are subsumed, many of which reflect affiliation to associations, which operate under joint brands such as AVIA, bft, or Raiffeisen. The second additional classification on the basis of brand information, in turn, focuses specifically on brand value: Here, the Bundeskartellamt (2011b) distinguishes "premium brands" (e.g., Aral, Esso, Shell, Total, Orlen, OMV, Agip, AVIA, Westfalen), "established brands" (e.g., Jet, Star, HEM, Q1, avanti24), and other brands or independent suppliers (e.g., bft). For both characteristics, ownership structure is not included in MTS-K data, but only the branding of stations. Oligopolistic players may potentially influence other retail sites through contrac-

[16] Wholesale prices might 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. Some studies use crude oil prices instead of wholesale (rack) prices to control for input costs (e.g., Chouinard and Perloff 2007). We argue, however, that regional ex-refinery prices more precisely reflect input costs of stations.

tual partnerships, too. In addition to the brand affiliation of stations, MTS-K data includes weekday-specific opening hours. We mainly use this information to distinguish between stations, which are closed on Sundays from stations that are open every weekday as well as stations opening 24 hours per day and seven days per week from stations with more restrictive opening hours.

Furthermore, we connect three other data sources to MTS-K station data in order to present a comprehensive picture of station characteristics beyond brand affiliation and differences in opening hours. First, as a relevant control variable, we distinguish the two segments, road and Autobahn stations (almost all of the latter operated by Tank & Rast GmbH). To separate the two groups, we link information on highway service stations available on the Tank & Rast website[17] with MTS-K station data. All stations listed on the Tank & Rast website are identified within the MTS-K station data set; additionally, a small number of other 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. Secondly, we apply a rich data set of station characteristics collected by "Petrolview", a data provider for gasoline and diesel stations across Europe. By connecting Petrolview's individual station characteristics to MTS-K's station and price data, we are able to account for several observable variables influencing station heterogeneity.[18] Station-specific variables used in this study include the type of station ownership, the presence and type of a shop, the presence of a car wash facility, the intensity of traffic around the station, and the number of gasoline and diesel pumps (also the presence of truck diesel, CNG, or LPG pumps). While some station characteristics are represented by discrete or binary variables (e.g., number of pumps), others are clustered into meaningful groups (e.g., traffic intensity from very high to low).[19] Thirdly, to test for price differences during public and school holidays, we include information on the state of each gasoline station with on the help of MTS-K's ZIP code data.[20] This is a prerequisite to include time series data on regionally different public and

[17] See `www.tank.rast.de`.

[18] We are able to connect around 98% of MTS-K stations with Petrolview station characteristics (see Appendix A for details).

[19] The number of (gasoline, diesel) pumps is an integer variable, representing full pump installations with one or more slots and plugs for different fuel types. The presence of pumps for truck diesel, CNG, or LPG, and the presence of a car wash are binary variables. Regarding ownership, company-owned (i.e., brand and ownership are in line), dealer-owned, or other (e.g., supermarket-owned) can be distinguished. Categories for traffic intensity include very high (traffic levels >25,000 vehicles per day), high (15,000 to 25,000), medium (5,000 to 15,000), or low (<5,000). Categories for shop type include none, kiosk (i.e., small shop), standard store (offering, e.g., oil, cigarettes, confectionery products, some food and drinks), or convenience store (with a wide range of items).

[20] Here, we make use of a comprehensive list of ZIP code and federal state combinations available via the "OpenGeoDB" website (see `www.opengeodb.org`).

school holidays. An overview of public holidays by state is available on the website of the German Ministry of Internal Affairs.[21] School holidays, which also differ by state, are published by the standing conference of the ministers of education.[22]

Finally, to complete our station characteristics, we include measures reflecting a station's exposure to local competition. Several empirical studies implicitly assume (larger) cities to represent distinct market areas. While using cities as a measure for market delineation allows to incorporate other available city-level data (such as population density), it remains an arbitrary view on competitive dynamics. Similar to Pennerstorfer et al. (2014), we, hence, propose a different logic of local market delineation, enabled by geographical coordinates (latitude, longitude) of all registered stations included in the MTS-K data set. Based on this information, we calculate simple distance measures of the level of spatial competition by comparing a station's spatial relationship to each other station in three ways: (1) linear distance ("as the crow flies"), (2) minimum driving distance, and (3) shortest driving time. Linear distance, on the one hand, is computed as the shortest distance between two geocoded locations ("orthodromic distance").[23] Retrieving minimum driving distance and time, on the other hand, requires road network data and corresponding routing algorithms. Therefore, these two measures are calculated with professional geocoding software. We report each station's distance to its single closest competitor as well as the number of competitors within a surrounding area defined by different critical values (e.g., 1, 2, or 5 km distance). Moreover, we look at the specific type of competitors by calculating shares of different brand categories (e.g., Federal Cartel Office's classification of oligopoly vs. independent players) within a surrounding area. With a similar logic, we calculate each station's distance to the first and second closest refinery region's market place, which we also use in our analysis.

In the following sections, we will present empirical findings based on combining all sources described above. A summary of variables used in the analysis and corresponding data sources can be found in Table 8 in Appendix B.

[21] In Germany, there are no further local holidays. The only exception is "Friedenfest" on 8 August, which is a public holiday in the city of Augsburg only (see `www.bmi.bund.de/SharedDocs/Downloads/DE/Lexikon/feiertage_de.html`).

[22] See `www.kmk.org/ferienkalender.html`.

[23] 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 $earthradius = 6,378km$.

4 Empirical Analysis

4.1 Descriptive Findings

In this section, we will briefly present relevant descriptive statistics on price levels, station characteristics, and measures of spatial competition. Underlying, granular data sets will afterwards be used to estimate the impact of station heterogeneity on price levels and price volatility (in section 4.2).

Across the period of observation, 24-hour average daily price levels of fuel type Super E5 are highest with an average of 1.541 Euro/liter, followed by Super E10 with 1.502 Euro/liter, and Diesel with 1.359 Euro/liter. Daytime prices (i.e., prices between 8 am and 8 pm), in turn, show lower average values across fuel types with 1.520 Euro/liter Super E5, 1.480 Euro/liter Super E10, and 1.336 Euro/liter Diesel, respectively. The lower average daytime prices reflect that the vast majority of stations show constant, high price levels at night, stepwise decrease prices during the day, and only in the evening hours restore price levels, often with a single large price increase.[24] To illustrate this observation, our three point-in-time price metrics show highest average price levels at midnight, only slightly lower values in the morning (where a few stations have already started to decrease prices), but substantially lower levels in the evening (shortly before prices jump up again). Stations, on average, change prices between four and five times a day (with a corresponding average validity of each price of around five hours). While some stations do not change their prices over several days, there are other stations with 15 or more price changes on certain days. Daily ex-refinery wholesale prices across the whole period and across regions are at an average level of 1.202 Euro/liter Super E5, 1.168 Euro/liter Super E10, and 1.043 Euro/liter Diesel, respectively. Across refinery regions, total average prices vary by up to 2 Eurocents/liter, with South-West (gasoline) or North (diesel) regions offering lowest and South-East region offering highest average price quotes.[25] While differences between ex-refinery prices and retail prices ("at the pump") are predominantly driven by the value-added tax of 19%, transport costs (from refinery to retail site), sales costs of the station operator, and, eventually, the retail margin are further elements to be considered. Table 1 shows summary statistics of price data by fuel type across all stations included in the data set. Figure 1, moreover, presents a time series of average daily retail and wholesale prices across all stations or regions. While prices of gasoline fuel types slightly increased during the first

[24] Figure 2 in Appendix B shows an exemplary station's pricing over a week, illustrating the typical pattern of high prices during nighttime and price decreases throughout the day.

[25] Based on shortest linear distance to a refinery region's market place, we assign between 910 (East) to 3,147 (West) stations to any single refinery region.

Table 1: Summary Statistics: Retail & Wholesale Prices

Variable	Super E5	Super E10	Diesel
Daily average price (24-hour, in Euro/liter)	1.541	1.502	1.359
Daytime average price (8 am to 8 pm, in Euro/liter)	1.520	1.480	1.336
Average midnight price (12 am, in Euro/liter)	1.574	1.536	1.395
Average morning price (8 am, in Euro/liter)	1.558	1.519	1.376
Average evening price (8 pm, in Euro/liter)	1.499	1.459	1.315
Average intraday price spread (in Euro/liter)	0.089	0.091	0.095
Price changes per day (in number)	4.7	4.8	4.7
Wholesale price "ex-refinery" (in Euro/liter)	1.202	1.168	1.043

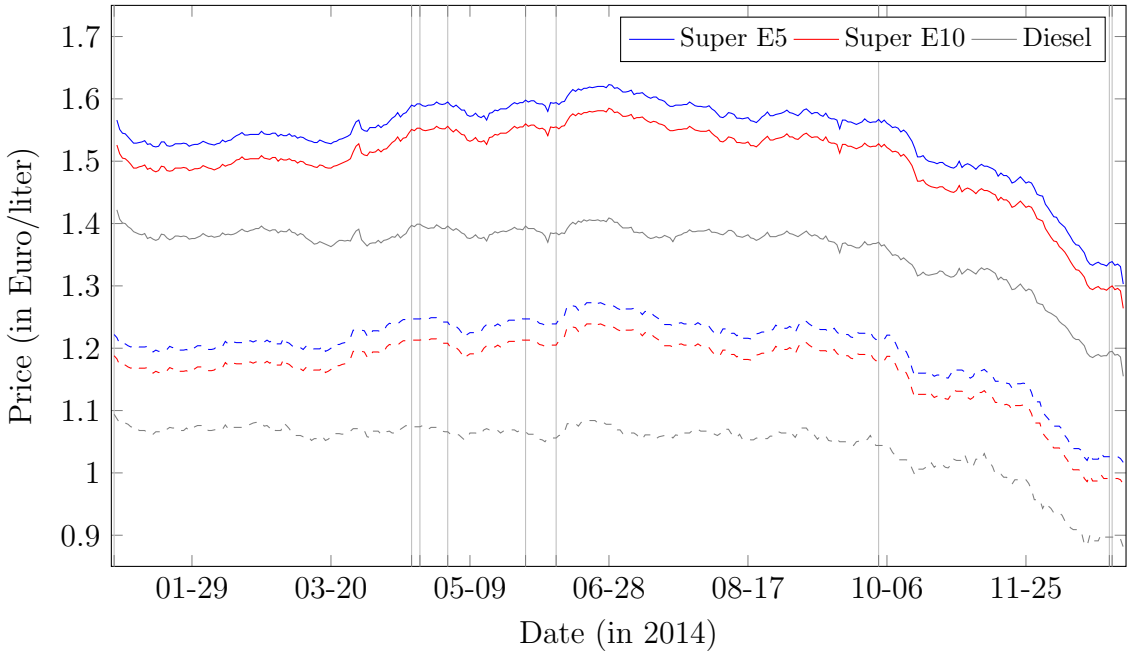
Note: Averages across all stations' or regions' daily metrics.
Source: MTS-K data (Jan-Dec 2014), O.M.R. data, own calculation.

half of the year, we see a sharp price decline across fuel types in the last quarter of 2014.[26]

In the MTS-K data set slightly less than 15,000 stations are registered. Excluding inactive stations as well as stations with a new brand or ownership and, moreover, focusing on stations with a complete set of station characteristics provided by Petrolview leaves us with 14,135 stations to be used for the empirical analysis. Except for just below 400 stations located on the Autobahn, all other retail sites are classified as road stations. Interestingly, almost all stations offer Diesel as a fuel type, reflecting the fact that Diesel-fueled engines are widespread among passenger cars in Germany (compared, for instance, to the U.S. market).[27] Only a very few stations do not offer Super E5, while around 5% of all stations do not sell Super E10, a recent fuel type introduced in 2011. In the data set, about 70 single brands can be identified. With 2,346 stations and 1,858 stations, respectively, Aral and Shell are the two largest single brands, together accounting for more than a quarter of all stations. Within the small segment of Autobahn stations, most of them leased out by Tank & Rast, Aral and Shell even operate more than half of all stations. Next to Aral and Shell, six other brands (Esso, Total, Avia, bft, Jet, and Star) can be found with more than 500 stations each. Classifying brands into categories introduced in section 3.3 shows that both the five oligopoly-player brands and the non-integrated independent brands comprise even more or slightly less than 6,000 stations. In total, 40% of stations are open "24/7", among those are 54% oligopoly-branded stations, compared to a smaller overall share of 47% oligopoly-branded stations in the mar-

[26] An Augmented Dickey Fuller test on average prices suggests that retail and wholesale price series of all fuel types are individually integrated of order one and pairwise cointegrated.

[27] According to the Kraftfahrtbundesamt (German Federal Motor Transport Authority), about 30% of all passenger cars in Germany are diesel-powered vehicles (see `www.kba.de/DE/Statistik/Fahrzeuge/Bestand/Umwelt/2014_b_umwelt_dusl_absolut.html`).



Note: Retail prices (i.e., average across all German stations' daily average prices) of indicated fuel type shown with solid lines, wholesale prices (i.e., average across all refinery regions' daily prices) with dashed lines. Vertical lines represent public holidays in majority of states.

Figure 1: Average Daily Retail & Wholesale Price Series

ket. While this classification based on MTS-K data merely reflects branding of stations and not ownership structure, a look at Petrolview's station characteristics shows that almost two thirds of stations are owned by dealers, the remaining part is largely owned by the company also owning the brand.[28] Nowadays, most stations have a shop offering, while size and variety differ. With data at hand, we can differentiate stations with a convenience store (41%), a standard store (46%) and a smaller kiosk-type store (4%). Moreover, more than 90% of stations have between one and four gasoline and diesel pumps, individual station data shows a maximum of 16 pumps. Beyond gasoline and diesel pumps, almost half of all stations have at least one additional truck pump and a corresponding bay, while a third offers LPG and no more than 5% offer CPG pumps. Regarding traffic at the (primary) street of a station's location, stations with very high (9%), high (36%), medium (43%), and low (12%) intensity can be differentiated. Furthermore, 4,619 stations also benefit from traffic of a secondary road (e.g., at a crossing). Table 2 shows summary statistics on the number of stations across various characteristics.

In Germany, the density of gasoline stations varies significantly across regions, with a high density, for instance, in the Rhine-Main area and a considerably lower density, for instance, in the Eastern part of the country. As an example, the dis-

[28] Other ownership types include supermarket-owned stations. Ownership type data might not be fully up-to-date and, thus, needs to be treated with caution.

Table 2: Summary Statistics: Gasoline and Diesel Stations

By type			By brand			By characteristics			By local competition	
Segment			*Brands (>500 stations)*			*Amenities*			*Linear distance*	
Road station	13,769	97%	Aral	2,346	17%	Convenience store	5,761	41%	Closest comp.	1.58
Autobahn station	366	3%	Shell	1,858	13%	Standard store	6,455	46%	Comp. in 1 km	0.92
Ownership type			Esso	1,048	7%	Kiosk	563	4%	Comp. in 2 km	2.64
Company-owned	5,455	39%	Total	834	6%	Car wash	10,432	74%	Comp. in 5 km	10.45
Dealer-owned	8,269	59%	Avia	738	5%	*Traffic intensity*			*Driving distance*	
Other	411	3%	bft	601	4%	Very high	1,266	9%	Closest comp.	2.21
Product offering			Jet	583	4%	High	5,054	36%	Comp. in 1 km	0.52
Super E5	14,005	99%	Star	536	4%	Medium	6,118	43%	Comp. in 2 km	1.54
Super E10	13,435	95%	*Brand category 1*			Low	1,697	12%	Comp. in 5 km	6.85
Diesel	14,130	100%	Oligopoly	6,669	47%	Secondary road	4,619	33%	*Driving time*	
Business hours by day			Other integrated	1,565	11%	*Number of pumps*			Closest comp.	6.07
Monday-Saturday	14,116	100%	Independent	5,901	42%	1 to 2 pumps	4,345	31%	Comp. in 2 min	0.40
All week	13,481	95%	*Brand category 2*			3 to 4 pumps	8,482	60%	Comp. in 5 min	1.19
Business hours by time			Premium	7,705	55%	5 to 6 pumps	1,196	8%	Comp. in 10 min	3.77
8 am to 6 pm	12,038	85%	Established	1,518	11%	>6 pumps	112	1%		
8 am to 8 pm	11,729	83%	Other	4,912	35%	Truck pumps	6,627	47%		
24 hours, 7 days	5,623	40%				LPG pumps	4,617	33%		
						CNG pumps	759	5%		

Note: Included are 14,135 active stations with price quotes (MTS-K) and all station characteristics (Petrolview);
closest comp(etitor) stated in kilometers or minutes, all other variables in number of stations.
Source: MTS-K data, Petrolview data, own calculations.

tance to the closest competitor – irrespective of segment, product offering, or brand – ranges from virtually zero to around 25 km. On average, across the country, there is a station every 1.6 km (linear distance), 2.2 km (driving distance), or six minutes (driving time). Within a circular surrounding area of 1 km linear distance around a given station, there are typically 0.9 competitors. Within 2 km and 5 km, this number increases to 2.6 and 10.5 other stations, respectively. In line with intuition, driving distance measures show higher values, as the road network virtually never represents the shortest possible connection between a pair of stations. For driving distance, there are 0.5, 1.5, and 6.9 competitors within a (non-circular) area of 1, 2, and 5 km.[29] In terms of driving time, averagely 3.8 stations are not more than ten minutes away (without traffic congestion). The type of local competition, subsumed by brand category, varies across areas between 0 and 100%, but, on average, reflects overall category shares of 47% oligopoly-branded players and 42% independent players. Finally, across the country, the closest refinery market place is averagely around 80 km in linear distance away from gasoline stations, with approximately another 90 km to the second closest refinery market place.

4.2 Impact of Station Heterogeneity

In this section, we will focus on the impact of time-variant refinery prices and demand-side controls as well as various time-constant station characteristics on retail price levels. While not visible for customers, (region-specific) refinery prices for gasoline and diesel products are an obvious determinant of retail price variation as they represent the major source of input costs (Hosken, McMillan, and Taylor 2008). Moreover, we include controls in form of weekday, state, and (school, public) holiday dummies to incorporate demand-side effects. Albeit gasoline and diesel are fairly homogenous products, a simple two-way fixed effects estimation (see Appendix C) reveals evidence of price dispersion induced by station heterogeneity rather than physical product characteristics. We, therefore, test for the impact of a wide range of (observable) station characteristics with a potential impact on price levels, informed by existing studies (Eckert 2013). Specifically, we control for variables representing brand and ownership structure, station location and amenities, and spatial competition metrics[30] in a random effects model setup. We are aware of the potential omitted variable bias of such a model (e.g., due to unobserved station characteristics). However, we assume a robust specification in light of the variety of control

[29] Routing-based algorithms do not show a direct competitor for a few stations (e.g., from island Sylt to mainland Germany).

[30] Similar to Eckert and West (2005), we focus on count and type of local competitors within a 2 km surrounding area. The local competition metric used for all estimations is linear distance.

variables included, similar to other empirical studies on gasoline markets estimating random effects models (e.g., Pennerstorfer et al. 2014). The specified model is described below in equation (1),

$$p_{it} = \alpha + \beta c_{it} + \boldsymbol{x}_i \boldsymbol{\gamma} + \boldsymbol{d}_{it} \boldsymbol{\delta} + u_{it} \tag{1}$$

with p_{it} as station i's average or point-in-time retail price at day t, $\boldsymbol{x}_i$ representing a vector of all time-invariant, station-specific control variables, c_{it} as region-specific refinery prices, and $\boldsymbol{d}_{it}$ as a vector of dummy variables to control for weekdays, states, as well as public and school holidays (varying by the state of a station's location). Table 3 presents results for a number of specifications of the generic model introduced in equation (1) for fuel type Super E5. Specifically, we estimate the model with two daily average price metrics (specification (1) with 24-hour daily and (2) with 8 am to 8 pm daytime prices) and three point-in-time price metrics (specification (3) with 8 am morning, (4) with 8 pm evening, and (5) with 12 am midnight prices) as the dependent variable (see section 3.2 for details on calculation routine).[31] All coefficients are denoted in Eurocents/liter of fuel. Similar to empirical findings in Kihm, Ritter, and Vance (2014), using a large-scale gasoline price panel data set, we find most regressors to be statistically highly significant, influenced by the sheer number of observations.[32] Most coefficients affect prices in the expected way (i.e., coefficients' signs are in line with expectations, cf. Eckert 2013, pp. 152-156). Moreover, the direction of price impact of all (significant) covariates is largely robust with regard to using different price metrics. In turn, the economic impact of individual variables is, ceteris paribus, significant for some variables, while being negligible for others. As expected, some coefficients vary in magnitude between daily and daytime average price and different point-in-time price specifications. This is due to the fact that pricing behavior of stations is, to a large extent, simply different across the day (e.g., more dynamic during the day than at nighttime, cf. section 4.1), as a result of varying competition intensity and different levels of demand. While daily and daytime price specifications are arguably more robust, looking at different points-in-time yields additional insights, which we will comment where reasonable.[33]

[31] The number of observations slightly differs among specifications (1) to (4) as, for example, some "partial" days are not considered for daily (24-hour) prices, while they are considered for daytime prices. In specification (5) with midnight prices, in turn, we only include stations with 24/7 opening hours (and also use the nearest competitor with 24/7 opening). We provide results for the same specifications for fuel types Super E10 and Diesel in Tables 9 and 10 in Appendix B. As a robustness check, we estimate equivalent models with time-fixed effects instead of region-specific ex-refinery prices (and all covariates, except for weekdays), showing largely similar results.

[32] Exceptions include primarily traffic intensity and distance to the nearest competitor in certain specifications. The latter variable, for many stations, varies only marginally.

[33] In addition, varying coefficient values can, to a limited extent, be associated to diverse opening

Table 3: Regression of Retail Prices (Super E5)

Dependent variable:	Average prices		Point-in-time prices		
Super E5 price	Daily	Daytime	Morning	Evening	Midnight
	(1)	(2)	(3)	(4)	(5)
Station type					
Autobahn station	5.669	6.475	5.690	9.243	3.517
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
24/7 business hours	0.285	0.274	0.113	0.457	-
	(0.00)	(0.00)	(0.01)	(0.00)	
Brand categories					
Oligopoly player brand	2.522	1.139	1.676	1.066	4.180
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Integr. player brand	0.834	0.574	0.977	0.882	1.567
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Station characteristics					
Convenience store	0.261	0.125	0.259	*0.019*	0.802
	(0.00)	(0.00)	(0.00)	*(0.58)*	(0.00)
Kiosk-type store	-0.347	*-0.093*	-0.413	0.150	-1.112
	(0.00)	*(0.20)*	(0.00)	(0.08)	(0.00)
No store	-0.908	-0.320	-1.254	*-0.001*	-1.198
	(0.00)	(0.00)	(0.00)	*(0.99)*	(0.00)
Car wash	0.424	0.172	0.229	0.165	0.264
	(0.00)	(0.00)	(0.00)	(0.00)	(0.04)
Traffic intensity	*0.032*	*-0.012*	*0.012*	*-0.039*	0.195
	(0.18)	*(0.55)*	*(0.64)*	*(0.11)*	(0.00)
Number of pumps	-0.116	-0.097	-0.088	-0.100	-0.063
	(0.00)	(0.00)	(0.00)	(0.00)	(0.09)
Truck pumps	0.202	0.146	0.109	0.177	0.273
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Local competition					
Distance to nearest comp.	0.024	*0.010*	*0.004*	0.045	*0.015*
	(0.02)	*(0.25)*	*(0.71)*	(0.00)	*(0.35)*
# of competitors in 2 km	-0.099	-0.083	-0.113	-0.077	-0.053
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Share of oligopoly brands	0.724	0.561	0.676	0.509	0.717
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
Share of independents	0.423	0.508	0.328	0.630	*-0.023*
	(0.00)	(0.00)	(0.00)	(0.00)	*(0.93)*
Demand-side controls					
School holiday	0.281	0.032	0.240	-0.046	0.697
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Public holiday	0.368	0.672	0.676	0.880	-0.264
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Input costs					
Ex-refinery price	1.104	1.095	1.113	1.084	1.087
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Distance to refinery	0.013	0.016	0.010	0.016	0.007
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Constant	16.939	17.098	17.987	16.405	20.656
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Number of observations	4,989,486	5,001,061	5,003,332	5,000,986	1,955,103
Number of groups	14,005	14,005	14,005	14,005	5,504
R^2	0.875	0.874	0.815	0.838	0.773

Note: Robust p-values in parentheses; non-significance at 10% level denoted in italics.
Included but not shown: Weekday dummies, state dummies, LPG/ CNG pump, ownership type, secondary road, additional distance to 2nd refinery, and open on Sundays dummy.
Omitted variables: Road station, independent brand, standard store.

First of all, ex-refinery prices appear to be a good predictor of (daily) input price changes, with coefficients slightly above one across all specifications. Also, the distance of a station to the nearest refinery has a significant positive impact on prices (e.g., a refinery 100 km further away coincides with an average surplus of 1.3 Eurocents/liter). Secondly, driven by a restricted competitive environment and, potentially, a lower price elasticity of consumers, the Autobahn station dummy variable has the largest coefficient. Everything else being equal, Autobahn stations charge a surcharge of around 6-7 Eurocents/liter during the day, and even close to 10 Eurocents/liter in the evening. For a typical consumer, this price premium at ceteris paribus identical stations is equivalent to extra costs for filling up of around 4-6 Euro per fuel tank or 100-150 Euro in the course of a year.[34] The price difference between Autobahn and road stations is smaller at night, where most stations retain high price levels irrespective of other factors. Third, comparing Bundeskartellamt's brand categories reveals that oligopoly-type players charge significantly more than other stations. While the gap is largest in midnight price specification, it diminishes to around 1 Eurocent/liter in the course of the day. Fourth, regarding station amenities, results are largely in line with the expectation that a wider range of services for the customer, and, therefore, a "one-stop shopping" offering, is associated with higher price levels. Between no shop offering and a convenience store is a range of about 0.4 to 2.2 Eurocents/liter (or 0.2 to 1.3 Euros per fuel tank), while having a car wash facility, ceteris paribus, is associated with a price increase of close to another 0.2 to 0.6 Eurocents/liter. Fifth, for spatial competition-related variables, we find the distance to the nearest competitor to be significant but negligible in magnitude. Furthermore, as expected, an additional station within a local area, on average, slightly decreases price levels. Interestingly, both variables reflecting the share of a brand category in the local market have a positive sign.[35] We infer from this finding that in market areas that comprise a homogenous group of stations, price competition is less intense, while a larger heterogeneity of local competition appears to induce lower prices. Using variables reflecting shares of individual oligopoly-player brands (instead of a single group variable) shows that the effect more than doubles in all specifications for Aral and Shell, suggesting higher price levels in local environments with particularly a higher share of these two brands. Finally, school and public holidays, as relevant demand-side controls, largely have the expected

hours across stations. While we account for such differences with two dummy variables (i.e., 24/7 opening and Sunday opening) in all but the last specification, this might not filter out the entire station- and weekday-specific granular opening hour variety.

[34] Assuming 60 liter per fuel tank and 20,000 km driving distance per year with an average consumption of 8 liter per 100 km.

[35] Except for specification (5), where the share of independents is, however, highly insignificant.

positive impact on price levels. The extent of price effects from school holidays is ambiguous, as coefficient values are either low or even negative in some specifications (especially for Diesel fuel). Also, the price surplus associated with public holidays not necessarily holds true for midnight prices. As the magnitude of both public and school holidays in general is limited, drastic price increases as observed by many customers are, if present, either limited to a subset of stations or limited to specific holiday periods.[36]

As a next step, we specifically investigate the impact of approximately 70 single brand dummies in a model also including all covariates discussed so far. While other coefficients not explicitly shown remain comparable in magnitude, Table 4 shows brand-specific estimates for the same (average, point-in-time) price metrics. On a high-level, significant differences in magnitude across specifications for several brands are obvious, with prices being less dispersed during daytime for most brands. We interpret this as primarily a distinct day- versus nighttime pricing strategy of certain brands (e.g., Aral, Shell, OMV) in light of a higher competition intensity, which is, however, not common to all brands (cf. Agip). Moreover, findings across all specifications support the Federal Cartel Office's (Bundeskartellamt 2011a) classification of "premium brands" (such as Aral, Shell, Esso, Total, OMV, Agip, or Avia), which are able to charge the highest prices. Coefficients on "established brands" (e.g., Star or HEM) are ambiguous in direction. Thus, these brands do not seem to constantly price above the omitted variable of all stations without explicit brand information. Among the independents, remaining associations (e.g., bft or Raiffeisen) show slightly but significantly higher price levels than other independents.

Two further findings are noteworthy: First, Jet's pricing, neither seems to resemble other established brands nor other oligopoly-type player brands. Removing Jet from the group of oligopoly players consequently increases the coefficient for the remaining four-player group considerably. This finding is especially noteworthy because the Federal Cartel Office considers Jet as part of a jointly-dominant oligopoly, while the Düsseldorf Higher Regional Court did not share this view in a recent merger case (see, e.g., Monopolkommission 2014). Secondly, among the brands with most negative coefficients (based on the mean of all Super E5 specifications) and 15 or more active stations are, next to regional Bavarian player Deutscher Brennstoff Ver-

[36]Regressing single, nationwide public holidays and a set of covariates on Super E5 price levels shows, ceteris paribus, significantly higher price levels on Whitmonday (+1.7 Eurocents/liter for daily prices, +1.7 Eurocents/liter for daytime prices), Unity Day (+1.3, +1.4), Labor Day (+1.1, +1.5), and Ascension Day (+0.9, +0.8). Contrary to public opinion, coefficients are ambiguous or even negative (in 2014) on dummy variables for Good Friday (-0.3, +0.4) and Christmas (-1.0, -0.6). Only a few existing studies specifically investigate this question, among them, Hall, Lawson, and Raymer (2007), who find no holiday effect.

Table 4: Regression of Retail Prices (Single Brands, Super E5)

Dependent variable:	Average prices		Point-in-time prices		
Super E5 price	Daily	Daytime	Morning	Evening	Midnight
	(6)	(7)	(8)	(9)	(10)
Oligopoly player brand					
Aral	3.966	1.825	3.340	1.345	6.262
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Shell	4.310	1.480	2.668	1.499	8.103
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Esso	2.861	0.906	2.123	0.301	6.524
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Total	2.560	0.797	2.025	0.174	5.522
	(0.00)	(0.00)	(0.00)	(0.05)	(0.00)
Jet	*-0.063*	-0.377	*0.067*	-0.648	1.687
	(0.40)	(0.00)	*(0.42)*	(0.00)	(0.00)
Other integrated player					
star	0.728	-0.179	1.014	-0.741	3.706
	(0.00)	(0.02)	(0.00)	(0.00)	(0.00)
Agip	1.965	1.922	2.447	1.274	1.572
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
HEM	0.207	-0.236	0.711	-0.725	2.406
	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
OMV	3.998	1.227	3.190	4.090	7.235
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Independent brands (associations)					
AVIA	2.198	0.973	2.182	0.296	4.233
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
bft	0.504	0.171	0.439	0.175	0.674
	(0.00)	(0.02)	(0.00)	(0.06)	(0.05)
Raiffeisen	0.434	0.167	0.582	*-0.090*	1.238
	(0.00)	(0.05)	(0.00)	*(0.38)*	(0.00)
Other selected independent brands					
Mr. Wash	-4.067	-3.131	-4.620	-1.964	no obs.
	(0.00)	(0.00)	(0.00)	(0.00)	
DBV	-2.201	-1.347	-1.499	-1.838	-2.974
	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)
Globus	-1.688	-0.548	-2.273	0.402	-4.144
	(0.00)	(0.01)	(0.00)	(0.08)	(0.00)
ED	-1.624	-1.568	-1.513	-1.803	-3.719
	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)
V-Markt	-1.531	*-0.133*	-3.084	*0.010*	-4.035
	(0.00)	*(0.61)*	(0.00)	*(0.97)*	(0.00)
Input costs					
Ex-refinery price	1.104	1.095	1.113	1.084	1.087
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Constant	16.851	17.259	17.69	16.91	19.478
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Number of observations	4,989,486	5,001,061	5,003,332	5,000,986	1,955,103
Number of groups	14,005	14,005	14,005	14,005	5,504
R^2	0.900	0.882	0.831	0.851	0.816

Note: Robust p-values in parentheses; non-significance at 10% level denoted in italics.
Included but not shown: Other single brands; all station characteristics and demand-side controls.
Omitted variables: "Unbranded" stations and other omitted variables as in previous specifications.

Table 5: Regression of Daily Price Changes (Super E5)

Dependent variable:	GLS	Poisson
# of daily price changes	(11)	(12)
Station type		
Autobahn station	-2.060	-0.532
	(0.00)	(0.00)
24/7 business hours	-0.105	-0.033
	(0.00)	(0.00)
Brand categories		
Oligopoly player brand	0.265	0.061
	(0.00)	(0.00)
Integr. player brand	-0.279	-0.061
	(0.00)	(0.00)
Station characteristics		
Convenience store	0.080	0.021
	(0.01)	(0.04)
Kiosk-type store	-0.445	-0.110
	(0.00)	(0.00)
No store	-0.917	-0.253
	(0.00)	(0.00)
Car wash	0.076	*0.006*
	(0.03)	*(0.59)*
Traffic intensity	0.093	0.022
	(0.00)	(0.00)
Local competition		
Distance to nearest comp.	-0.053	-0.013
	(0.00)	(0.00)
# of competitors in 2 km	0.017	0.004
	(0.00)	(0.03)
Share of oligopoly brands	-0.209	*-0.039*
	(0.00)	*(0.16)*
Share of independents	-0.596	-0.136
	(0.00)	(0.00)
Demand-side controls		
Monday	1.251	0.288
	(0.00)	(0.00)
Saturday	0.619	0.153
	(0.00)	(0.00)
School holiday	0.039	0.008
	(0.00)	(0.00)
Public holiday	-1.239	-0.289
	(0.00)	(0.00)
Constant	8.214	2.220
	(0.00)	(0.00)
Number of observations	4,989,486	4,989,486
Number of groups	14,005	14,005
R^2	0.162	

Note: Robust p-values in parentheses; non-significance at 10% level denoted in italics. Included but not shown: Weekday, state, pumps, ownership, and open on Sundays dummy. Omitted variables: Road station, independent brand, standard store, Sunday.

trieb (DBV) and independent player ED Mineralölhandels KG (ED), three chains, whose primary service offering is different from selling gasoline (namely, Mr. Wash, a car wash chain as well as Globus and V-Markt, two supermarket chains). For these players, selling gasoline can be considered a by-product of car wash or supermarket operations. Common for these stations, however, are in many cases structurally different business hours, matching those of the primary service activity (e.g., "24/7" or Sunday opening is rare). Therefore, next to examining the robustness with regard to daytime, morning, or evening price specifications, which are less prone to a potential opening hour bias, we perform an additional robustness check by estimating a set of specifications including a subset of stations with 24/7 opening hours only (see Table 11 in Appendix B). Results are largely comparable, suggesting not to have a structural difference induced by varying opening hours. Thus, while daytime prices reduce coefficients' negative magnitude, specifically also for the group of other selected independents, significant negative values remain in all specifications.[37]

Finally, we investigate drivers of price volatility to analyze how and why gasoline prices differ across the German market. To approximate volatility, we choose the number of price changes per day as the dependent variable and regress again on a full set of control variables (see Table 5 for estimation results). Given that our dependent variable in this case comprises count data, in addition to a generalized least square estimation, we also estimate a Poisson random-effects model (see Wooldridge 2010, p. 760). Both models indicate a consistent direction of effects.[38] First of all, daily price changes are influenced by the segment, that is, Autobahn stations change prices about two times less often during the day. Secondly, among station-specific characteristics, the type of shop, particularly the absence of a shop, is of relevance. This suggests less volatility in light of less sophisticated operations (e.g., with few employees or automated stations, fewer price changes can be assumed). Third, volatility is also driven by two demand-side factors, namely weekends (specifically Sundays) and public holidays, both inducing one or more price changes less over a typical day.

[37]When interpreting results in Table 11 in Appendix B, please note, however, that for the group of other selected independent brands, a focus on stations with 24/7 opening hours quite dramatically reduces the number of observations, for reasons stated above. Specifically, Mr. Wash has no station (out of 19 or in total), which is always open, while DBV, V-Markt, Globus, and ED operate 10 (of 16), 5 (of 28), 38 (of 41), and 4 (of 106) stations on a 24/7 basis, respectively. Mr. Wash's highly negative coefficients, thus, cannot be tested within a 24/7 opening hour setup.

[38]Coefficients of Poisson model estimations can, however, not be linearly interpreted.

5 Conclusion

In this paper, we have presented a large-scale analysis of price determinants on German retail gasoline and diesel markets, using a census of price quotes of virtually all stations in Germany. Specifically, we have been able to compare pricing at different times of the day (e.g., day- and nighttime), on different market segments (i.e., Autobahn and road stations), and to assess the impact of a rich set of station characteristics and measures of spatial competition on price levels. For this purpose, we have computed average daily and daytime retail prices (based on precise intraday price quotes) as well as daily point-in-time prices (in the morning, evening, and at midnight), which we tested for price distribution and regressed on various supply- and demand-side controls in (station-)random effects models.

We find that a large part of the daily distribution of prices observed "at the pump" can be associated with observable station characteristics as well as price shocks affecting all stations. Among the observable variables, differentiating between the two segments Autobahn and road stations, specific for the German market, is critical. Furthermore, brand recognition has a crucial impact on price levels in line with existing classifications of premium brands, but also with varying strategies regarding day- and nighttime pricing. Interestingly, Jet's position within the group of established brands and oligopoly-type players is rather ambiguous. This is an important finding in the German context, where the role of Jet has been heavily debated between the German Cartel Office on the one hand as well as the market participants and the courts on the other hand. Our findings suggest that Jet's pricing is rather different from the other four so-called oligopoly brands. Moreover, stations that sell gasoline and diesel as a by-product, are among the cheapest gasoline stations, even though structural differences in opening hours need to be accounted for. The type of local competition is found to be more relevant than the sheer number of players. Lower price levels can be expected the more heterogeneous the group of brands within a local area is. Finally, service offerings tend to increase prices, but in some instances also volatility. As an example, the absence of a shop and, thus, likely less sophisticated operations, implies fewer price changes. The results are comparable across fuel types and largely support expectations on price determinants (Eckert 2013), while specific impacts naturally vary.

Our findings are also relevant for the policy debate. Retail gasoline pricing is often poorly understood by policy-makers and, therefore, viewed with great suspicion. In our paper, we have managed to identify a number of factors that affect price levels as well as the frequency of price changes. Parts of the price differences among stations can be explained by factors of product differentiation between stations such

as the type of shop, the presence of a car wash facility, or brand name. Furthermore, competition among stations plays a role, as prices tend to decrease with the number of competitors in the vicinity. Input costs as measured by ex-refinery prices and distance to refineries are also important, so are demand-side factors. Hence, we are able to draw a quite complex picture of the factors driving retail gasoline price levels and price changes. Most important from a policy perspective, however, is the finding that competitive forces are, at least to a measurable degree, working, in contrast to suspicions sometimes voiced in policy circles.

The findings presented in this paper are subject to certain assumptions and limitations. Among others, areas close to the border are subject to cross-border competition, which is not considered in the analysis (see, e.g., Banfi, Filippini, and Hunt 2005). Moreover, the method of calculating average daily and daytime prices might be biased in light of (not fully reflected) varying opening hours and different demand levels across day and night. Further research in the area of retail gasoline pricing in Germany may investigate specific aspects associated with intraday pricing patterns (compare Figure 2), for example, in the context of Edgeworth cycle theory. Furthermore, the impact of opening hours and other competition-related variables on local pricing as well as the price pass-through from refineries to retail gasoline stations (cf. rockets-and-feathers literature) could be interesting aspects for research.

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A Preparation of Raw Data

In this appendix, we will describe the process of data validation including any corrections made to MTS-K raw data with respect to both price and station data.

First, closely following validation rules suggested in Bundeskartellamt (2011b, Appendix p. 3), retail price raw data as submitted to the market transparency unit for fuel is corrected for obvious errors. Broadly speaking, Bundeskartellamt (2011b) proposes to delete inaccurate data entries for one of three reasons: missing entries (i.e., empty price cells), most likely incorrect price levels (i.e., prices below a threshold level of 0.50 Euro per liter or above a threshold level of 2.00 Euro per liter), or most likely incorrect price changes (i.e., zero price change or price change below or above a threshold level of |0.20| Euro per liter). Given that we focus on the standard operation phase ("Regelbetrieb") starting 1 December 2013 and leave out the first month (i.e., December 2013) as several stations are not (yet) submitting prices to MTS-K in this period, necessary adjustments to raw data for the period January to December 2014 are, in total, on an acceptable level (of around 1% of total observations). Table 6 presents an overview of validation rules and affected data records. Please note that deleting a data entry due to an incorrect price change might create a new instances of incorrect price changes. Therefore, we conduct corrections in as many iterations as required to eliminate all errors. Table 6 shows the sum of corrected price changes after all iterations. The empirical analysis presented in this paper relies on "total valid observations".

Table 6: Raw Price Data Preparation

Variable	Super E5	Super E10	Diesel
Total observations	24,284,499	23,636,582	24,816,236
Empty price cell	7,980	46,795	5,101
Price $<$ 0.50 Euro/liter	0	0	0
Price $>$ 2.00 Euro/liter	0	0	0
Change $=$ 0.00 Euro/liter	194,257	182,787	183,823
Change $>$ |0.20| Euro/liter	6,500	4,529	6,021
Total invalid observations	208,737	234,111	194,945
Total valid observations	24,075,762	23,402,471	24,621,291

Source: MTS-K data (Jan-Dec 2014), own calculation.

In a second step, we check MTS-K station data for activity status and submission of price quotes for each fuel type. In total, the MTS-K data set (as of mid-2014) includes 14,838 entries. A number of entries are, however, flagged as no longer active as, for instance, some stations were closed, simple re-entered into the database, or changed their ownership structure and/ or brand name, leading to double entries.

These inactive entries are, therefore, disregarded from the analysis. Some further stations do not submit price quotes at all or not for all three fuel types (e.g., a station does not offer all products). After excluding stations without price quotes, in total, 14,454 stations are considered valid and are used for pricing analysis. For fuel-type specific analysis, (different) subsets of active stations with (valid) price quotes are used. While we explicitly exclude stations without any (fuel-type specific) price quotes, we do not impose further (subjective) threshold levels regarding, for instance, a minimum required number of price quotes per station to be considered. As a consequence, we allow the data set to be unbalanced. Finally, we link various station characteristics from Petrolview to MTS-K station data on the basis of geographic coordinates as well as address information (i.e., street, ZIP code, city). In total, we are able to connect 14,135 or 98% of all valid MTS-K stations with Petrolview data and consequently use this data set to determine price level determinants. Table 7 presents the number of stations along the categories described above. The empirical analysis in this paper relies on "active stations with price quotes" or, more precisely, fuel-type specific sub-groups, as well as "stations with all characteristics" or fuel-type specific sub-groups, respectively.

Table 7: Raw Station Data Preparation

Variable	Count
Total entries (MTS-K)	14,838
Active stations (MTS-K)	14,530
Active stations with price quotes (MTS-K)	14,454
Thereof: Offering Super E5	14,270
Thereof: Offering Super E10	13,673
Thereof: Offering Diesel	14,450
Stations with all characteristics (MTS-K, Petrolview)	14,135
Thereof: Offering Super E5	14,006
Thereof: Offering Super E10	13,436
Thereof: Offering Diesel	14,131

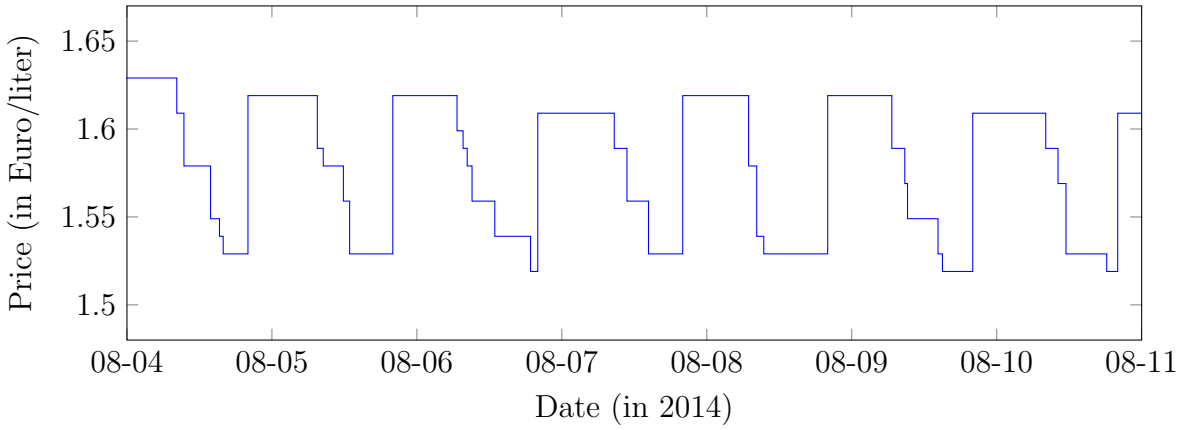
Source: MTS-K data, Petrolview data, own calculation.

B Figures and Tables

Table 8: Overview of Variables

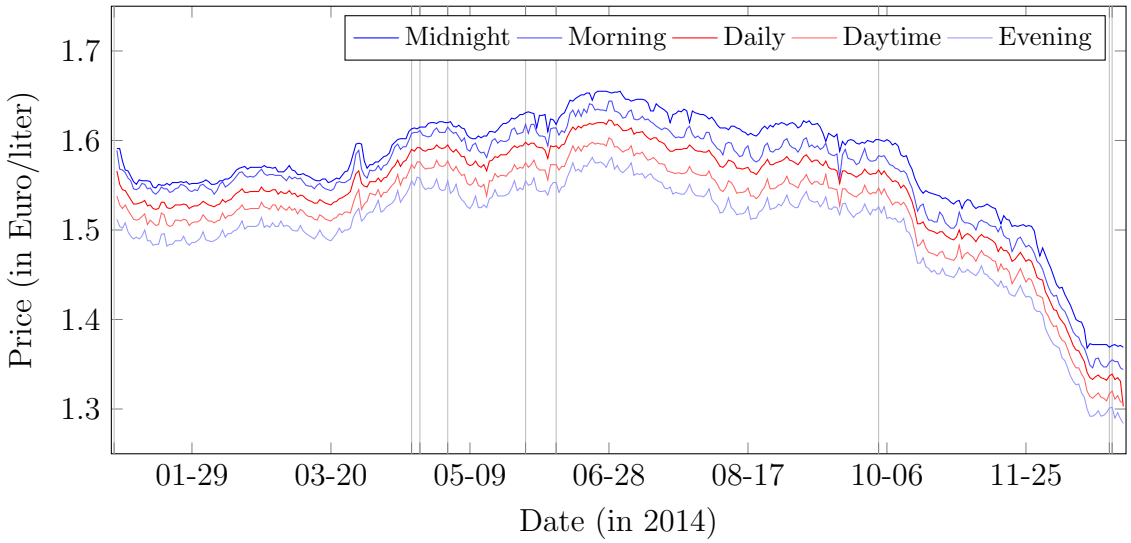
Variable	Type	Source
Station location:		
Station ID	Integer, constant	MTS-K
Latitude	Decimal, constant	MTS-K
Longitude	Decimal, constant	MTS-K
ZIP code	Integer, constant	MTS-K
Federal state	Cluster, constant	OpenGeoDB/ own calc.
Type:		
Brand name	String, constant	MTS-K
Brand category 1	Cluster, constant	Bundeskartellamt/ own calc.
Brand category 2	Cluster, constant	Bundeskartellamt/ own calc.
Ownership type	Cluster, constant	Petrolview
Autobahn station	Binary, constant	Tank & Rast/ own research
Station offering & amenities:		
Offering Super E5	Binary, constant	MTS-K/ own calc.
Offering Super E10	Binary, constant	MTS-K/ own calc.
Offering Diesel	Binary, constant	MTS-K/ own calc.
Shop type	Cluster, constant	Petrolview
Car wash facility	Binary, constant	Petrolview
Gasoline/ diesel pumps	Integer, constant	Petrolview
Truck pumps	Binary, constant	Petrolview
LPG pumps	Binary, constant	Petrolview
CNG pumps	Binary, constant	Petrolview
Traffic intensity	Cluster, constant	Petrolview
Secondary road	Binary, constant	Petrolview
Spatial competition:		
Nearest competitor	Decimal, constant	Own calculation
Competitors in 1/ 2/ 5 km	Integer, constant	Own calculation
Share of oligopoly players	Decimal, constant	Own calculation
Share of independents	Decimal, constant	Own calculation
Business hours:		
Open on Sundays	Binary, constant	MTS-K/ own calc.
Open "24/7"	Binary, constant	MTS-K/ own calc.
Retail prices:		
Fuel type	Integer, constant	MTS-K
Avg. daily/ daytime prices	Decimal, variant	MTS-K/ own calc.
Point-in-time prices	Decimal, variant	MTS-K/ own calc.
Wholesale prices:		
Refinery region	String, constant	O.M.R./ own calc.
Distance to closest refinery	Decimal, constant	O.M.R./ MTS-K/ own calc.
Add'l distance to 2nd refinery	Decimal, constant	O.M.R./ MTS-K/ own calc.
Refinery price	Decimal, variant	O.M.R.
Weekday & holidays:		
Weekday	Integer, variant	Own calculation
Public holiday	Binary, variant	BMI
School holiday	Binary, variant	KMK

Note: BMI = Bundesministerium des Inneren, KMK = Kultusministerkonferenz, MTS-K = Markttransparenzstelle für Kraftstoffe, O.M.R. = Oil Market Report.



Note: Pricing of Aral station in Drolshagen, week commencing 4 August 2014.

Figure 2: Exemplary Weekly Price Pattern of Major-Brand Gasoline Station



Note: Super E5 retail price series (i.e., averages across all German stations' prices) of indicated metric (i.e., point-in-time metrics in blue, average price metrics in red). Vertical lines represent public holidays in majority of states.

Figure 3: Retail Price Series of Different Metrics (Example: Super E5)

Table 9: Regression of Retail Prices (Super E10)

Dependent variable:	Average prices		Point-in-time prices		
Super E10 price	Daily	Daytime	Morning	Evening	Midnight
	(13)	(14)	(15)	(16)	(17)
Station type					
Autobahn station	5.627	6.455	5.649	9.224	3.452
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
24/7 business hours	0.329	0.306	0.155	0.495	–
	(0.00)	(0.00)	(0.00)	(0.00)	
Brand categories					
Oligopoly player brand	2.490	1.140	1.647	1.085	4.063
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Integr. player brand	0.787	0.568	0.934	0.897	1.405
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Station characteristics					
Convenience store	0.255	0.125	0.260	*0.026*	0.780
	(0.00)	(0.00)	(0.00)	*(0.46)*	(0.00)
Kiosk-type store	-0.272	*-0.041*	-0.338	0.210	-0.980
	(0.01)	*(0.60)*	(0.00)	(0.03)	(0.01)
No store	-0.819	-0.243	-1.149	*0.072*	-1.106
	(0.00)	(0.00)	(0.00)	*(0.34)*	(0.00)
Car wash	0.417	0.176	0.215	0.189	*0.212*
	(0.00)	(0.00)	(0.00)	(0.00)	*(0.10)*
Traffic intensity	*0.026*	*-0.011*	*0.006*	*-0.036*	0.187
	(0.27)	*(0.61)*	*(0.81)*	*(0.15)*	(0.00)
Number of pumps	-0.122	-0.096	-0.098	-0.097	*-0.057*
	(0.00)	(0.00)	(0.00)	(0.00)	*(0.13)*
Truck pumps	0.202	0.141	0.098	0.175	0.280
	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)
Local competition					
Distance to nearest comp.	0.026	*0.010*	*0.009*	0.040	*0.026*
	(0.01)	*(0.24)*	*(0.42)*	(0.00)	*(0.13)*
# of competitors in 2 km	-0.099	-0.083	-0.114	-0.075	-0.053
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Share of oligopoly brands	0.691	0.547	0.667	0.472	0.591
	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)
Share of independents	0.389	0.481	0.340	0.549	*-0.104*
	(0.00)	(0.00)	(0.00)	(0.00)	*(0.71)*
Demand-side controls					
School holiday	0.267	0.012	0.231	-0.069	0.697
	(0.00)	(0.02)	(0.00)	(0.00)	(0.00)
Public holiday	0.370	0.683	0.714	0.874	-0.280
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Input costs					
Ex-refinery price	1.107	1.098	1.116	1.086	1.092
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Distance to refinery	0.012	0.016	0.010	0.016	0.006
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Constant	16.254	16.366	17.445	15.584	19.987
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Number of observations	4,781,094	4,792,445	4,794,396	4,792,374	1,863,261
Number of groups	13,435	13,435	13,435	13,435	5,249
R^2	0.876	0.874	0.817	0.839	0.773

Note: Robust p-values in parentheses; non-significance at 10% level denoted in italics.
Included but not shown: Weekday dummies, state dummies, LPG/ CNG pump, ownership type, secondary road, additional distance to 2nd refinery, and open on Sundays dummy.
Omitted variables: Road station, independent brand, standard store.

Table 10: Regression of Retail Prices (Diesel)

Dependent variable:	Average prices		Point-in-time prices		
Diesel price	Daily	Daytime	Morning	Evening	Midnight
	(18)	(19)	(20)	(21)	(22)
Station type					
Autobahn station	5.900	6.723	6.097	9.642	3.527
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
24/7 business hours	0.293	0.262	0.117	0.451	–
	(0.00)	(0.00)	(0.01)	(0.00)	
Brand categories					
Oligopoly player brand	2.706	1.167	1.782	1.108	4.607
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Integr. player brand	0.822	0.534	0.983	0.863	1.630
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Station characteristics					
Convenience store	0.267	0.123	0.274	*0.008*	0.851
	(0.00)	(0.00)	(0.00)	*(0.83)*	(0.00)
Kiosk-type store	-0.447	-0.161	-0.504	*0.073*	-1.233
	(0.00)	(0.03)	(0.00)	*(0.42)*	(0.00)
No store	-0.897	-0.293	-1.245	*0.027*	-1.210
	(0.00)	(0.00)	(0.00)	*(0.70)*	(0.00)
Car wash	0.416	0.154	0.197	0.157	*0.168*
	(0.00)	(0.00)	(0.00)	(0.00)	*(0.21)*
Traffic intensity	*0.041*	*-0.005*	*0.014*	*-0.031*	0.213
	(0.11)	*(0.79)*	*(0.61)*	*(0.21)*	(0.00)
Number of pumps	-0.122	-0.098	-0.087	-0.107	-0.071
	(0.00)	(0.00)	(0.00)	(0.00)	(0.07)
Truck pumps	0.227	0.150	0.130	0.187	0.338
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Local competition					
Distance to nearest comp.	0.022	*0.009*	*0.001*	0.047	*0.008*
	(0.03)	*(0.32)*	*(0.94)*	(0.00)	*(0.64)*
# of competitors in 2 km	-0.108	-0.088	-0.127	-0.082	-0.060
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Share of oligopoly brands	0.839	0.606	0.859	0.526	0.933
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Share of independents	0.498	0.548	0.468	0.643	*0.092*
	(0.00)	(0.00)	(0.00)	(0.00)	*(0.76)*
Demand-side controls					
School holiday	0.068	-0.201	0.024	-0.255	0.493
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Public holiday	0.503	0.882	0.860	1.090	-0.270
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Input costs					
Ex-refinery price	1.075	1.087	1.089	1.072	1.004
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Distance to refinery	0.012	0.016	0.010	0.015	0.006
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Constant	19.690	17.522	20.401	17.086	29.115
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Number of observations	5,034,078	5,045,724	5,048,057	5,045,648	1,996,631
Number of groups	14,130	14,130	14,130	14,130	5,622
R^2	0.815	0.821	0.722	0.771	0.672

Note: Robust p-values in parentheses; non-significance at 10% level denoted in italics.
Included but not shown: Weekday dummies, state dummies, LPG/ CNG pump, ownership type, secondary road, additional distance to 2nd refinery, and open on Sundays dummy.
Omitted variables: Road station, independent brand, standard store.

Table 11: Regression of Retail Prices (Single Brands, Open 24/7, Super E5)

Dependent variable:	Average prices		Point-in-time prices		
Super E5 price	Daily	Daytime	Morning	Evening	Midnight
	(23)	(24)	(25)	(26)	(27)
Oligopoly player brand					
Aral	4.126	1.765	3.463	1.068	6.262
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Shell	4.429	1.376	2.801	1.417	8.103
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Esso	2.909	0.705	2.049	*-0.250*	6.524
	(0.00)	(0.00)	(0.00)	*(0.10)*	(0.00)
Total	2.458	0.409	2.015	-0.735	5.522
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Jet	*-0.189*	-0.882	*0.099*	-1.428	1.687
	(0.24)	(0.00)	*(0.58)*	(0.00)	(0.00)
Other integrated player					
star	0.647	-0.505	0.971	-1.282	3.706
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Agip	2.648	2.239	2.806	1.249	1.572
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
HEM	0.555	*-0.211*	1.012	-0.810	2.406
	(0.00)	*(0.23)*	(0.00)	(0.00)	(0.00)
OMV	4.162	1.169	3.354	3.694	7.235
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Independent brands (associations)					
AVIA	2.070	0.723	2.219	*-0.175*	4.233
	(0.00)	(0.00)	(0.00)	*(0.17)*	(0.00)
bft	*0.258*	*0.114*	*0.221*	*0.014*	0.674
	(0.15)	*(0.42)*	*(0.34)*	*(0.93)*	(0.05)
Raiffeisen	0.446	*0.034*	0.613	-0.351	1.238
	(0.00)	*(0.76)*	(0.00)	(0.01)	(0.00)
Other selected independent brands					
Mr. Wash	no obs.	no obs.	no obs.	no obs.	no obs.
DBV	-2.294	-1.669	-1.203	-2.260	-2.974
	(0.00)	(0.00)	(0.10)	(0.00)	(0.00)
Globus	-1.835	*-0.495*	-2.222	*0.376*	-4.144
	(0.00)	*(0.11)*	(0.00)	*(0.25)*	(0.00)
ED	-2.334	-2.022	-0.663	-2.811	-3.719
	(0.00)	(0.00)	(0.01)	(0.00)	(0.02)
V-Markt	-1.781	*-0.292*	-3.447	*0.082*	-4.035
	(0.00)	*(0.56)*	(0.00)	*(0.90)*	(0.00)
Input costs					
Ex-refinery price	110.58	109.74	111.47	108.75	108.71
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Constant	16.716	17.302	17.361	17.040	19.478
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Number of observations	1,955,127	1,959,479	1,960,544	1,959,454	1,955,103
Number of groups	5,504	5,504	5,504	5,504	5,504
R^2	0.897	0.880	0.825	0.847	0.816

Note: Robust p-values in parentheses; non-significance at 10% level denoted in italics.
Included but not shown: Other single brands; all station characteristics and demand-side controls.
Omitted variables: "Unbranded" stations and other omitted variables as in previous specifications.

C Distribution of Prices

In this appendix, we explore the distribution of prices across gasoline stations in Germany. Generally, price dispersion means that firms charge different prices for selling the same good at the same time (Lewis 2008, p. 654). Despite being fairly homogenous products, dispersed gasoline prices might still be present but induced by station-specific attributes rather than the physical characteristics of the fuel offered.

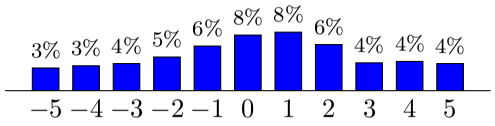
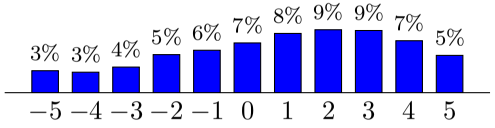
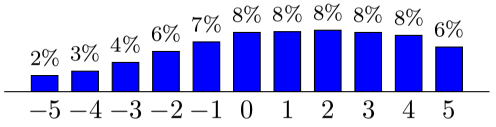
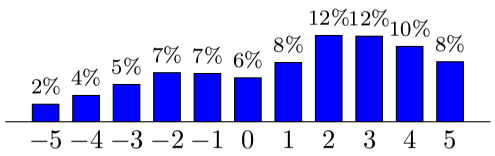
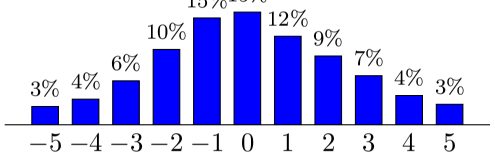
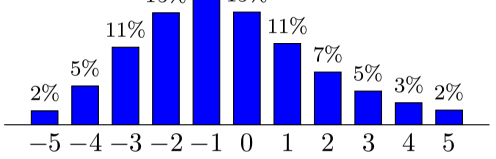
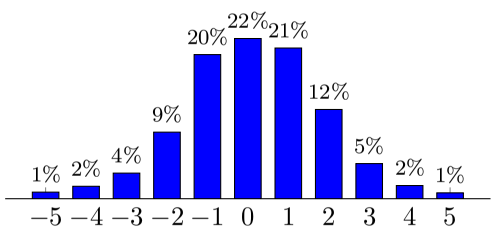
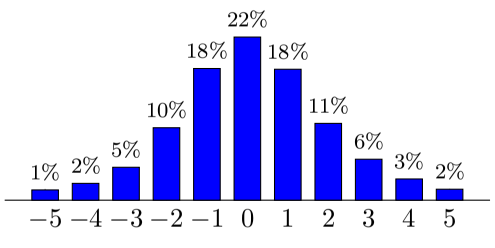
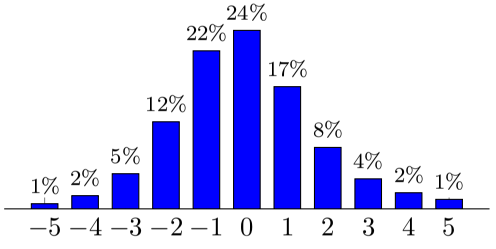
To provide evidence of price dispersion, following Lewis (2008), Hosken, McMillan, and Taylor (2008), and others, we propose a simple model using (time-invariant) station-fixed effects to control for the heterogeneity of stations (irrespective of whether characteristics are observed or unobserved) as well as time-fixed effects (in form of time dummies for all days considered) to account for price changes over time, which are common to all stations. Equation (2) below describes such a two-way fixed effects regression model (see Cameron and Trivedi 2005, p. 738),

$$p_{it} = \alpha + \theta_i + \gamma_t + u_{it} \tag{2}$$

with p_{it} as station i's (point-in-time) retail price at day t, θ_i representing station-fixed effects and γ_t representing time-fixed effects. Residuals u_{it} are considered deviations from the "clean" or "residual" price after controlling for station heterogeneity and (input) price variations equally affecting stations (Pennerstorfer et al. 2014).

Table 12 illustrates the retail price distribution for Super E5 using three point-in-time metrics and three distinct price series, namely (i) retail prices as listed at the pump, (ii) prices corrected for time-fixed effects, and (iii) clean prices as introduced above, estimated by the two-way fixed effects model. The table shows frequency distributions of residuals around the estimated price, rounded to the nearest Eurocent/liter of fuel. The estimated price in the center of the distribution thereby represents either (i) a simple average price across all stations and days, (ii) a day-specific average price across all stations, or (iii) the day-specific average price determined by a specific station's characteristics. Albeit intraday spreads might be considerably larger, distributions around (i) and (ii) represent maximum levels of price differences (at different points in time) a consumer could be exposed to over the year or on a typical day. While prices in (i) are obviously quite dispersed, including time fixed effects in (ii) leads to a higher concentration around the estimated price. Notably, at midnight, numerous stations offer prices slightly above the average, while stations pricing below the average are more dispersed. In (iii), we see evidence of a strong impact of station-specific characteristics on prices. The remaining distribution can be attributed to true price dispersion across all stations in Germany.

Table 12: Distribution of Point-in-Time Prices

Price series	Midnight	Morning	Evening
(i) Distribution of prices around mean: $u_{it} = \overline{p} - p_{it}$			
(ii) Distribution of prices with time-fixed effects: $u_{it} = \hat{p_t} - p_{it}$			
(iii) Distribution of "clean" or residual prices: $u_{it} = \hat{p_{it}} - p_{it}$			

Note: Price distributions for Super E5 in Eurocents/liter (rounded to nearest cent); only illustrated for range of -5 and +5 Eurocents/liter.
Source: MTS-K data, own calculation.