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Manuel Siekmann

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Editor:

Prof. Dr. Hans-Theo Normann
Düsseldorf Institute for Competition Economics (DICE)
Phone: +49(0) 211-81-15125, e-mail: normann@dice.hhu.de

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Characteristics, Causes, and Price Effects: Empirical Evidence of Intraday Edgeworth Cycles*

Manuel Siekmann[†]

May 2017

Abstract

Edgeworth cycles represent the leading concept to explain observed pricing patterns on retail gasoline markets and have been subject to numerous empirical investigations on an interday level. In this paper, I present unique evidence of the presence, causes, and price effects of intraday Edgeworth-type cycles for an entire OECD country, using high-frequency price data from German gasoline stations. I find vast evidence of intraday cycles across municipalities in Germany. Cycle asymmetry and intensity is stronger in more concentrated markets and decreases with a higher share of non-major brands. My analysis suggests that intraday cycles are a sign of competition with a price decreasing effect during evening hours, where consumers conscious of their purchase timing can benefit most.

JEL-Classification: L11, L71

Keywords: Gasoline Markets, Fuel Prices, Edgeworth Cycles, Intraday Pricing

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[†]Heinrich-Heine University Düsseldorf, Düsseldorf Institute for Competition Economics (DICE), Universitätsstr. 1, 40225 Düsseldorf, Germany, Mail: manuel.siekmann@uni-duesseldorf.de

1 Introduction

On retail gasoline markets around the world, price volatility is typically far greater than changes in oil or refinery prices would suggest. Often, retail pricing follows a distinctive pattern with asymmetric cycles, albeit length and amplitude vary. Alternating periods of fast and large price increases and a longer sequence of stepwise price decreases are characteristic features of these recurring cycles. Edgeworth cycles, formalized by Maskin and Tirole (1988), represent the leading theory to explain such pricing patterns. Numerous empirical studies have investigated the presence and characteristics of Edgeworth cycles on retail gasoline markets, primarily for markets in the U.S. (e.g., Doyle, Muehlegger, and Samphantharak 2010; Zimmerman, Yun, and Taylor 2013), Canada (e.g., Atkinson, Eckert, and West 2014; Noel 2007a,b), Australia (e.g., Wang 2008; Wills-Johnson and Bloch 2010c), and a few European countries (e.g., Foros and Steen 2013).

Analyzing price competition on retail gasoline markets is a highly relevant topic as consumers often spend a significant portion of their disposable income at gasoline stations, which are to a large extent operated by just a few integrated players. For this and other reasons, the sector is frequently subject to inquiries from competition authorities (see, e.g., OECD 2013) and direct policy interventions, ranging from price transparency initiatives (e.g., in Germany), price increase notifications or limitations (e.g., in Austria or Australia) to the strict regulation of prices or margins (e.g., in some provinces in Canada). While, from a policy perspective, understanding the welfare effects of price cycles is fundamental, this aspect has received limited attention from authorities and researchers so far (e.g., Noel 2012, 2015; Zimmerman, Yun, and Taylor 2013).

On the German market, motorists frequently observe sharp price fluctuations during the course of a single day, which the competition authority has confirmed for four major cities as part of a fuel sector inquiry (see Bundeskartellamt 2011a,b) and for eight major cities in subsequent analyses (see Bundeskartellamt 2015, 2017). To derive reliable, empirical findings on the characteristics, causes, and price effects of such intraday cycles, it is essential to have access to data of adequate granularity and frequency, which rarely is the case (see discussions in Atkinson, Eckert, and West 2014; Eckert and West 2004). Consequently, price cycles on an intraday level as found on the German market, which are more pronounced than cycles over several days, have not been extensively studied so far. Only recently, enabled by a census of price data, a number of authors have started looking into salient features of intraday pricing (e.g., Eibelshäuser and Wilhelm 2016; Haucap, Heimeshoff, and Siekmann 2016; Neukirch and Wein 2016).

In this paper, I present unique evidence of price competition on an intraday level, investigating the presence, causes, and price effects of intraday Edgeworth cycles, using a novel high-frequency price data set covering virtually all gasoline stations in Germany. With this data, I am able to investigate precise pricing patterns and explore recurring cycles without relying on aggregated observations across time or markets. While, similar to investigations by the German Federal Cartel Office, most existing studies focus on larger metropolitan areas (e.g., Lewis 2012; Noel 2012), I am first to explicitly analyze cycles across an entire country without price regulations, covering numerous municipalities, from urban to rural areas.

I find broad evidence of intraday cycling across municipalities in Germany. Both the asymmetry and the intensity of cycles is driven by a higher density of stations, a higher density of population per station, as well as a lower share of non-major brands. My analysis suggests that intraday cycles are a sign of competition with a price decreasing effect, most pronounced during evening hours. Thereby, consumers can gain from the presence of price cycles and benefit most if they behave less myopic but optimize their intraday purchase timing strategies.

The remainder of this paper is structured as follows: Section 2 discusses the concept of Edgeworth cycles before section 3 presents an overview of relevant empirical literature. In section 4, I explain the data set used before section 5 presents the empirical analysis. The latter includes the identification of price cycles (section 5.1), an analysis of cycle causes (section 5.2), as well as a perspective on price effects (section 5.3) and consumer purchase strategies (section 5.4). Finally, section 6 concludes and provides ideas for further research.

2 Edgeworth Cycles

In light of fast-changing retail gasoline prices, numerous studies focusing on dynamic pricing behavior have been published. Recurring, asymmetric cyclical patterns are often referred to Edgeworth price cycles, which arguably represents the leading theory behind price cycles found on many gasoline retail markets (Noel 2011).¹

¹Some authors doubt the common association of price cycles with Edgeworth theory and propose alternative explanations for pricing dynamics. Hosken, McMillan, and Taylor (2008), for example, discuss both static and dynamic models (including Edgeworth cycles) to explain observed prices in suburban Washington, D.C. The authors state that, using Edgeworth models, it is difficult to determine if stations are in a cycling equilibrium, and conclude that, similar to other discussed models, Edgeworth theory only explains some aspects of gasoline pricing. Noel (2007b, pp. 87-90) investigates – and argues against – a range of competing hypotheses, including fluctuating demand, differences in menu or monitoring costs, the depletion of the inventories in the underground tanks at retail stations, discounts off the posted rack price, and covert collusion. On the Norwegian market, Foros and Steen (2013) find evidence of weekly price cycles but do not associate them

The theoretical foundations of such asymmetric price cycles date back to Francis Ysidro Edgeworth (1925). Formalizing Edgeworth’s ideas, Maskin and Tirole (1988) introduce a Bertrand duopoly model, where two symmetric firms produce homogeneous goods at constant costs and are restricted to using Markov strategies (i.e., a firm’s pricing decision is only dependent on the other firm’s price). The authors show that asymmetric price cycles (called “Edgeworth cycles”) might result as a Markov Perfect Equilibrium (MPE), while an equilibrium with constant “focal prices” over time represents a second possible outcome (for the latter, also see Noel 2007a). In the Edgeworth cycle equilibrium, firms pursue symmetric strategies (Maskin and Tirole 1988, p. 587) with best response functions of the form

$$R(p) = \begin{cases} \bar{p} & \text{for } p > \bar{p} \\ p - k & \text{for } \bar{p} \geq p > \underline{p} \\ c & \text{for } \underline{p} \geq p > c \\ c & \text{with probability } \mu(\delta) \text{ for } p = c \\ \bar{p} + k & \text{with probability } 1 - \mu(\delta) \text{ for } p = c \\ c & \text{for } p < c \end{cases} \quad (1)$$

where \underline{p} and \bar{p} are two prices for which $\underline{p} < \bar{p}$, c represents (constant) marginal costs and k is a single step on a discrete price grid. Edgeworth cycles, with their distinctive “sawtooth” pattern, are, hence, characterized by a longer sequence of small price decreases, down to the level of marginal cost (called “undercutting phase”, with stepwise price reductions $p - k$, eventually, until $p = c$) and a single, large price increase, up to a level slightly above the monopoly price (called “relenting phase”, with a price increase to $\bar{p} + k$). Typically, at the lowest point, a “war of attrition” among competitors starts, where firms play a mixed strategy of maintaining prices at marginal costs c (with probability $\mu(\delta)$) until one of them initiates a cycle restoration (with probability $1 - \mu(\delta)$). This essentially restarts the price cycle with a new series of tit-for-tat price undercuttings. It is important to note that Edgeworth cycles are both independent of input cost movements as well as demand levels but rather a result of firms’ pricing strategies.²

While visual observations indicate strong similarities between the sawtooth pattern of Edgeworth cycles and empirically observed pricing patterns on many retail gasoline markets, formal verifications prove to be challenging given a lack of testable predictions. Over the years, however, the basic model of Maskin and Tirole

with Edgeworth-type cycles. Instead, the authors argue that price controls cause observed patterns (inducing a day-of-the-week effect, with prices regularly jumping up on Mondays).

²For a more detailed, non-technical introduction to Edgeworth cycles, see Noel (2011).

(1988) has been refined, most notably by Eckert (2003), Noel (2008), Wills-Johnson and Bloch (2010a), and – more recently – by Eibelshäuser and Wilhelm (2016), all of them addressing issues with relevance for gasoline markets. First of all, Eckert (2003) introduces supplier heterogeneity (e.g., major and independent brands) and allows for an uneven split of market shares between duopolists even with equal prices. In this setup, the author concludes that, in the presence of asymmetric firms, cycles are more likely to arise. Secondly, Noel (2008) includes fluctuating marginal costs, capacity constraints, and a third player into the model. In his analysis, Noel (2008) shows, among other things, that a triopoly setup might result in anomalies such as delayed price adjustments or “false start” (i.e., reversed) price increases. Third, Wills-Johnson and Bloch (2010a) extend the model by exploring a spatial framework for Edgeworth cycles, showing how cycles might occur in a market characterized by spatial competition. Finally, Eibelshäuser and Wilhelm (2016) take a modified approach, inspired by higher frequency, intraday price cycles documented on German gasoline markets. Given the finite time horizon of these intraday cycles, the authors generalize the two-firm setup presented in Wallner (1999) and test its predictions on the equilibrium price path.

3 Empirical Literature

Castanias and Johnson (1993) are among the first to find similarities between empirical price cycles on U.S. gasoline markets and the Maskin and Tirole (1988) model. Since then, numerous empirical publications have investigated elements of Edgeworth cycles on retail gasoline markets, explored reasons why and where they exist, and described their main features (see Eckert 2013; Noel 2011, 2016 for overviews of empirical studies).³ A typical Edgeworth-type cycle found on many gasoline markets lasts for about a week with a range of eight to ten percent of the price. Cycle length (e.g., from daily to monthly) and amplitudes, however, might vary significantly (Noel 2016). Once they have started, cycles tend to be persistent, with the exception that large shocks such as an unexpected refinery fire (see Atkinson, Eckert, and West 2014 for an example) or substantial regulatory interventions (see Wang 2009 for an example) might temporarily or even permanently stop price cy-

³Edgeworth cycles have also been studied on a few other markets. Closely related to gasoline markets, Isakower and Wang (2014) explore price cycles for a non-gasoline product, namely liquified petroleum gas (LPG), and find that LPG cycles in Western Australia are both longer and more asymmetric than comparable gasoline price cycles. The authors associate their finding to a potentially more elastic aggregate demand for LPG compared with gasoline. In a different context, Zhang (2005), moreover, presents an empirical investigation of Edgeworth cycles in online advertising auctions.

cles. While most studies are able to confirm elements of Edgeworth cycle theory, findings are often limited by data availability and frequency.

Several studies, largely relying on city-level data, are able to document price cycles primarily on markets in the Midwestern U.S. (e.g., Zimmerman, Yun, and Taylor 2013), Canada (e.g., Noel 2007a), and Australia (e.g., Wang 2008). To identify cycling markets, Doyle, Muehlegger, and Samphantharak (2010), Lewis (2009, 2012), and Noel (2015), among others, suggest to use the median value of price changes in a market area to separate cycling from non-cycling markets, assuming to find a negative value in cycling markets with considerably more price decreases than increases, while average price changes should be closer to zero.⁴ Typically, authors also define a cut-off value for the median of price changes to separate cities with low cycle intensity from cities with high cycle intensity.⁵

Next to the identification of cycles, several authors have explored causes of Edgeworth cycles. Among other things, they found that with a higher share of independent retail stations, more markets tend to exhibit cycling behavior (see, e.g., Noel 2007a for Canadian and Lewis 2009 for U.S. cities). Using gasoline station-level data, often gathered from a sample of retail sites, several authors show that large firms tend to initiate the relenting phase, while small firms are more likely to undercut (see, e.g., Atkinson 2009; Noel 2007b for stations in Canada). Lewis (2012), more specifically, associates price cycling (and price restorations) to the presence of two specific independent retail chains, Speedway and QuickTrip, on U.S. markets. With U.S. station-level data, Doyle, Muehlegger, and Samphantharak (2010), moreover, provide evidence that the most and least concentrated markets are less likely to cycle. In their study, the authors also dissent from previous findings that markets are generally more likely to cycle with a higher share of independents. Instead, Doyle, Muehlegger, and Samphantharak (2010) find that markets tend to cycle if independent stations with a large market share have significant convenience store operations. Finally, some studies in this context test for a potential interdependency of Edgeworth cycles with “rockets and feathers” pricing on retail gasoline markets.⁶

⁴More precisely, Lewis (2009) introduces the “median daily change in the city average price” (p. 589) as a proxy metric for the extent of price cycles. This metric has been widely applied by other authors.

⁵For Midwestern U.S. markets, authors suggest to define cities as cycling with a median price change below -0.2 (Lewis 2012, p. 345), -0.3 (Lewis 2009, p. 591), or -0.5 (Doyle, Muehlegger, and Samphantharak 2010, p. 654) US-cents per gallon. As a second approach prevalent in empirical literature to identify Edgeworth cycles, Eckert (2002) and Noel (2007a,b, 2008), for example, apply a Markov-switching regression model (see Hamilton 1989). This approach specifically allows the authors to estimate the length of cycling phases, which, however, is less relevant in a finite time horizon setting.

⁶Empirical studies on rockets and feathers pricing explore the dynamic relationship between input (i.e., oil or wholesale) prices and retail prices. The main hypothesis in this area is that there

While both rockets and feathers pricing and Edgeworth cycles describe asymmetric pricing phenomena, they differ as price changes are either caused by cost shocks or happen independent of costs. Studies combining the two concepts argue that input cost increases might trigger an Edgeworth cycle restoration, while cost decreases allow for additional leeway for price undercuttings (see, e.g., Eckert 2002; Noel 2009). Lewis (2009) and Lewis and Noel (2011), for instance, investigate the speed of response to cost shocks in cities with and without price cycles and find prices in Edgeworth-type markets to fall more quickly after wholesale price spikes (e.g., following Hurricane Rita), so that the presence of Edgeworth cycles might partially mitigate the rockets and feathers phenomenon.

From a competition policy perspective, it is fundamental to understand the welfare consequences of Edgeworth cycles, in addition to its characteristics and potential causes. Nevertheless, this is a largely untapped field of empirical investigations. While some authors have associated price cycles with explicit or implicit collusion (e.g., Erutku and Hildebrand 2010; Wang 2008), recent empirical evidence suggests that cycling markets coincide with lower average price levels (e.g., Doyle, Muehlegger, and Samphantharak 2010; Noel 2011; Zimmerman, Yun, and Taylor 2013). Noel (2015), for instance, finds that the cessation of cycles in three Canadian cities as a result of a refinery fire has led to a price increase and concludes that Edgeworth cycles may be beneficial to consumers. On top, in cycling markets with a higher price spread, informed consumers can benefit from adapting their purchase timing and, therefore, further reduce actual prices vis-à-vis (unweighted) average prices.⁷ Accurately forecasting gasoline price cycles, however, might not be trivial from a consumer's perspective as, for instance, illustrated in Noel (2012), presenting a purchase timing study assuming perfect foresight of consumers, or Noel and Chu (2015), with a discussion on consumer strategies relying on prior and known price data only.⁸

Empirical studies investigating Edgeworth cycles on an intraday level are rare, probably due to a lack of appropriate data sets. On the German market, enabled by

is an asymmetric response, with a quick (rocket-like) increase of retail prices as a reaction to input price increases and a slow (feather-like) decrease as a reaction to input price decreases (see, e.g., Bachmeier and Griffin 2003; Bacon 1991; Borenstein, Cameron, and Gilbert 1997; Verlinda 2008).

⁷This essentially requires consumers to be aware of price cycles and to take advantage of cycles by shifting demand into low-price periods. Based on survey data, the ACCC (2007, p. 178) states that 83% of motorists in Australia are aware of regular price cycles and 74% nominated Tuesday as the cheapest weekday. Survey data for Norway, reported in Foros and Steen (2008, pp. 22-23), shows that a third of surveyed consumers are aware of weekly price patterns. For the German market, Dewenter, Haucap, and Heimeshoff (2012, p. 26) present survey results stating that 54% of respondents refuel either on specific days or as a result of noticed price decreases.

⁸Also see Woods (2014) for a discussion on consumer welfare gains from Edgeworth cycles.

full price transparency (compare section 4), a number of papers recently emerged, which focus on aspects of inter- or intraday price competition (e.g., Frondel, Vance, and Kihm 2016; Haucap, Heimeshoff, and Siekmann 2017; Kihm, Ritter, and Vance 2016). To the best of my knowledge, three of these papers specifically investigate features of intraday price cycles and are, thus, of relevance for my analysis: First, Haucap, Heimeshoff, and Siekmann (2016) present a plausibly causal investigation of the impact of market structure on local prices. The authors use a temporary, intraday variance in market structure – given by exogenously determined opening hours of stations selling gasoline as a by-product – and find a negative price effect of this subset of independent stations on nearby major-brand competitors. Secondly, Neukirch and Wein (2016) focus their analysis on medium-sized German cities (with between 60,000 and 100,000 citizens) and provide evidence of collusive behavior of major brands with regard to upward price movements in evening hours. Third, Eibelshäuser and Wilhelm (2016), who specifically look at Edgeworth-type behavior on an intraday level, test a number of predictions of a finite time horizon model and conclude that intraday cycles are an outcome of intense price competition.⁹ In contrast to the studies described above, I comprehensively investigate intraday price cycle characteristics, potential causes, and price effects. While most empirical studies focus on single cities or a sample of typically larger metropolitan areas (e.g., Wills-Johnson and Bloch 2010b,c analyze cycles in Perth, Noel 2012 looks at stations in Toronto),¹⁰ I contribute an empirical analysis including nationwide municipalities in a major OECD country.

4 Data

Several authors have stressed the importance of data granularity and frequency related to empirical studies on Edgeworth-type cycles on gasoline markets. Atkinson, Eckert, and West (2014) and Eckert and West (2004) highlight issues associated with using data of insufficient frequency or covering only a sample of stations. According to the authors, several studies might not capture cycles well and derive misleading findings subject to the exact time of observation.¹¹ Even in light of recent data sets

⁹Moreover, Boehnke (2014) presents a study on intraday pricing using self-collected data, arguing that price patterns in Germany might be a result of temporary price discrimination.

¹⁰Noteworthy, in this context, are also empirical studies investigating Metropolitan Statistical Areas (MSAs) in the United States. These include Lewis (2009) looking at 85 MSAs, Doyle, Muehlegger, and Samphantharak (2010) with 115 MSAs, Lewis (2012) with 280 MSAs, and Zimmerman, Yun, and Taylor (2013) with 350 MSAs.

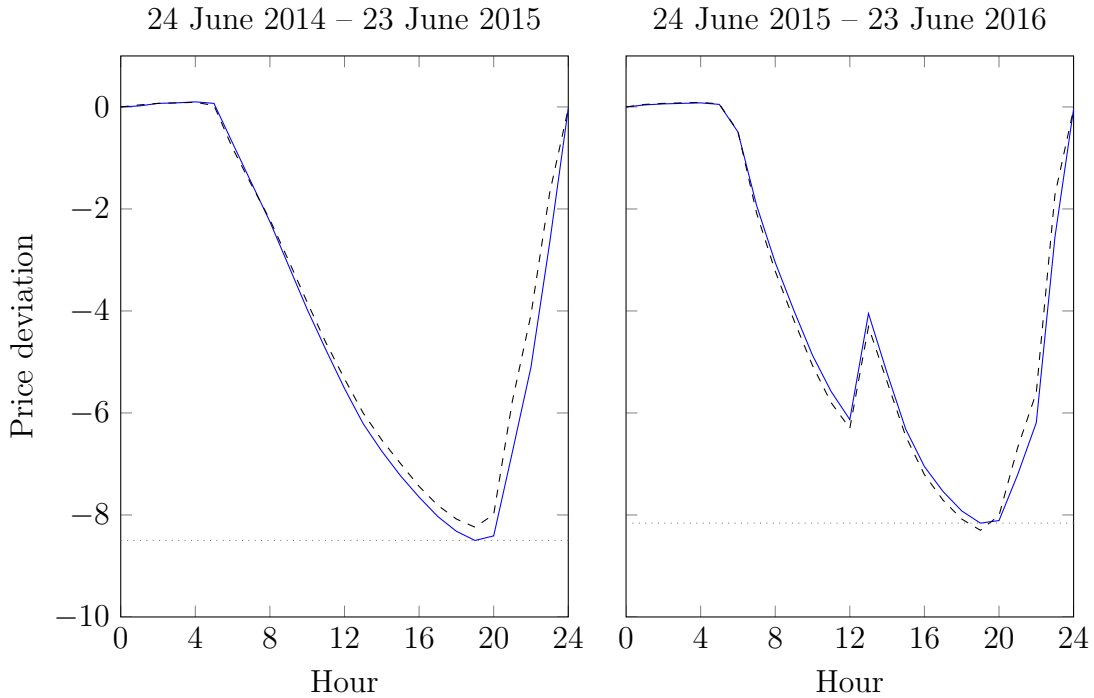
¹¹Similarly, Bettendorf, van der Geest, and Varkevisser (2003) find ambiguous results in a rockets-and-feathers type analysis for the Dutch market. Depending on the weekday on which prices are observed, the authors' estimations suggest either price symmetry or asymmetry.

collected from pricing website, Atkinson (2008) points to sample selection bias issues, for instance, regarding the role of individual brands. Reliable analysis on granular price cycles, thus, requires high-frequency data of a comprehensive set of gasoline stations. In this study, I use a novel data set covering virtually all gasoline stations in Germany with exact time stamps of all price quotes. This data is arguably of higher precision than data used in most other studies on Edgeworth cycles.¹² Established by the German Federal Cartel Office, the so-called market transparency unit for fuel (“Markttransparenzstelle für Kraftstoffe”, MTS-K) centrally collects all fuel prices since the end of 2013 (see Bundeskartellamt 2013, 2014, 2015, 2017).¹³ Retail prices are nominal end-customer prices in Euro(cents) per liter of Super E5 fuel and include all taxes and duties (i.e., value-added tax, energy tax, and a fee for the Petroleum Stockholding Association “EBV”). I investigate a period of observation including two years, from mid-2014 to mid-2016. With this, I reflect a change in the equilibrium pricing pattern first observed on 24th June 2015. Starting from this date, a minor price increase around noon can be found at the majority of gas stations (see Bundeskartellamt 2015, pp. 20-23). I include a full year of data before and after this change (i.e., the period of observation covers 24th June 2014 to 23rd June 2015 and 24th June 2015 to 23rd June 2016, in total 731 days). Figure 1 shows stylized hourly price deviations from daily starting prices, split by respective one-year periods and averaged over all 13,448 stations included in my analysis, with a total of 57.4 million price quotes.¹⁴ Note that, to eliminate cross-sectional variance, I only include gas stations with (i) price quotes for Super E5 in each calendar year, (ii) an initial price quote recorded before the 24th June 2014, and (iii) at least one price quote after the 23rd June 2016. Moreover, to find accurate results, I identify and exclude gas stations with “abnormal” time periods in which no price alteration has been recorded. Specifically, I disregard stations with (i) no price quote for more than a quarter of a year or (ii) no price quote for more than a week if this is atypical for the specific gas station; that is, if the single-longest (or, second-longest) time period between two consecutive price quotes is more than ten times longer than the second-longest (or, third-longest) time period between two price quotes. Thereby, I effectively correct for gas stations subject to a temporary close-down of operations, a change of the service provider responsible for price submissions or similar reasons,

¹²In addition to recent studies on the German market, Atkinson (2009) presents one of the studies using more granular data so far with bi-hourly observations.

¹³Gasoline station operators are obliged to report any price change to the MTS-K within five minutes time, which are then forwarded to authorized consumer information providers in real time. The data set used in this study was kindly provided by consumer information provider “1-2-3 Tanken” (on 2 January 2017).

¹⁴Cycles are comparable across weekdays (see Figure 11 in the Appendix).



Note: Hourly deviation of individual gas station’s price (in Eurocents/liter) from the same station’s daily starting price (at midnight), averaged across all gas stations in Germany (using point-in-time prices at full hours). Dashed line shows hourly deviations only including stations open 24/7.

Figure 1: Average Hourly Price Deviation

causing a erroneously recorded period without new price quotes (see section A in the Appendix for a description of raw data preparation steps and Figure 6 in the Appendix for a distribution of average daily price quotes across stations).

In addition to retail prices, I control for refinery region-specific, daily wholesale prices provided by data provider Oil Market Report (O.M.R.). Wholesale prices “ex-refinery” differ by eight major refinery regions in Germany, I assign each municipality or gasoline station to one of those regions based on minimum linear distance to the region’s market place.¹⁵

Basic MTS-K data on individual gasoline stations includes the geographical position (longitude, latitude), brand affiliation, and details on business hours.¹⁶ I complement these basic station characteristics by including conventional brand clusters

¹⁵Refinery 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). Ex-refinery prices can differ depending on whether they are sold “branded” or “unbranded”, which is not reflected in the data set. Price quotes are, moreover, not available on weekends and public holidays. I assume prices to remain constant on previous-day levels in these cases.

¹⁶Figure 7 in the Appendix provides summary statistics on weekday-specific business hours of gas stations included in this study. Note that <1% of stations have more than one pair of opening and closing times per weekday (e.g., due to closing after midnight for a short period of time); in these instances, stations are treated as if closing at midnight.

(i.e., separating major brands Aral, Shell, Total, and Esso from other, non-major brands) and by including station characteristics such as the presence and size of an associated shop with data collected by data provider “Petrolview”. Moreover, with specific relevance for this study, I conduct reverse geocoding with MTS-K’s geo coordinates to identify the unique municipality identification number (“amtlicher Gemeindeschlüssel”) of each station based on OpenStreetMap data.¹⁷ With the municipality identifier for each gas station, I can analyze price cycles on a municipality level and make use of the categorization of city types applied by the German Federal Office for Building and Regional Planning (“Bundesamt für Bauwesen und Raumordnung”, BBR).¹⁸ Finally, I include official statistics from the so-called Regional Data Base Germany.¹⁹ This includes data on population, area, and the share of commuters on a granular municipality level, as well as disposable household income, GDP per capita, and the number of cars per capita, which are available for cities and administrative districts.

In the following section, I will present empirical evidence on four areas, namely, identifying Edgeworth-type cycles, characterizing cycles’ causes, determining price effects, and consumer purchase strategies. Figure 8 in the Appendix summarizes the development of station-level metrics central to this study (i.e., daily average retail and wholesale price levels, price spreads, size and count of price changes), based on the data sets described above, over the course of the two-year period under observation.

5 Empirical Analysis

5.1 Cycle Identification and Characteristics

Sharp price fluctuations during the day are frequently observed by many motorists. Similar to what Edgeworth theory suggests, intraday price cycles, as depicted in Figure 1, are characterized by a comparably long period of decreasing prices and abrupt price restorations. While price restorations are highly synchronous, price

¹⁷The official municipality identification number (“amtlicher Gemeindeschlüssel”) uniquely identifies each municipality (cities, towns, and rural communities). As an example, the identifier for Berlin is 11000000, for Drolshagen it is 5966008.

¹⁸The BBR classifies municipalities into major cities (with a population of >100k), mid-sized cities (20–100k), larger towns (10–20k), small towns (5–10k), and rural communities (<5k). In addition to population, the BBR classification also considers the degree of available city functions. This may lead to deviations from the pure population-based threshold levels described above (see www.bbsr.bund.de/BBSR/DE/Raumb Beobachtung/Raumabgrenzungen/StadtGemeindetyp/StadtGemeindetyp_node.html). Figure 10 in the Appendix gives an overview of municipality types across Germany.

¹⁹“Regionaldatenbank Deutschland”, see www.regionalstatistik.de.

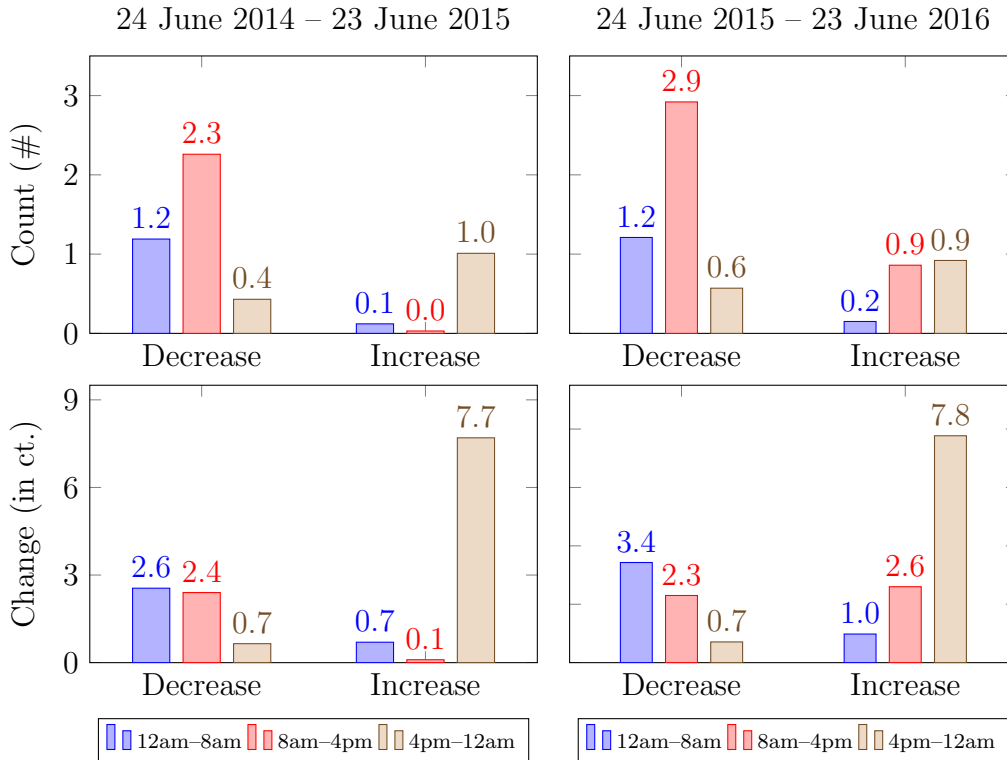
decreases typically happen autonomously on a local level and reflect prevalent competitive dynamics (Eibelshäuser and Wilhelm 2016). Price restorations of intraday cycles in Germany are clearly driven by players with a significant market share, albeit not by independents, in contrast to what Lewis (2012) observed for U.S. cities. Instead, as a common pattern, major-brand Aral (or Shell) initiates daily price restoration rounds with Shell (or Aral) reacting in a short period of time, before other players follow suit (Neukirch and Wein 2016). In this first section of the empirical analysis, I will present descriptive evidence of intraday price cycles along specific metrics to identify and measure price cycles, which I will use in cross-sectional and panel regressions on cycle causes and price effects in the following sections.

To understand timing, quantity, and magnitude of price changes, let me start with dividing the day into three time periods of equal length: from midnight to 8 am, from 8 am to 4 pm, and from 4 pm to midnight. Figure 2 separates price increases from price decreases and illustrates the pure number of price changes next to the average magnitude of changes across all gas stations. I find that price decreases usually happen in the first part (with a count of 1.2) and, predominantly, in the second part of the day (count of 2.3 or 2.9), that is before 4 pm. Afterwards, only occasional price decreases are observable. On average, price decreases have a comparably limited magnitude, in the first two periods of between 2.3 and 3.4 Eurocents/liter. Now, looking at price increases, I again find a pattern resembling Edgeworth-type behavior, with a single, large price increase in the evening hours of a magnitude of 7.7 to 7.8 Eurocents/liter. As discussed before, in June 2015, the equilibrium pattern of intraday pricing changed from one daily cycle to two cycles, with a major increase in the evening and an additional, minor price restoration around noon. Figure 2 confirms this, showing close to a single increase also in the second part of the day, during the second year of observation, with a smaller magnitude of 2.6 Eurocents/liter.²⁰

Let me now turn to statistical indicators to identify price cycles. Similar to Lewis (2009) and other studies, first of all, I use the median of price changes as the key metric to recognize the presence of asymmetric price cycles. However, while Lewis (2009), using daily observations, suggests the “median daily change in the city average price” (p. 589), I take advantage of the census of price quotes at hand and compute the median of all intraday price changes on a station-level, averaged across municipalities.²¹ Indeed, I find distinctly negative median values across the

²⁰Note that this also explains the increase in the number of price changes in the second year of observation, found in Figure 8 in the Appendix. According to Eibelshäuser and Wilhelm (2016), occasional price increases observed in the morning are to be associated to stations with restricted opening hours, adjusting their prices shortly after opening.

²¹Thereby, all price changes are considered for computing the median value, albeit the number



Note: Number and magnitude (in Eurocents/liter) of price changes for the time period shown, averaged across all days and stations.

Figure 2: Average Number and Magnitude of Price Changes by Time Period

country of, on average, -1.2 Eurocents/liter, while the mean of all price changes is marginally positive (with 0.004 Eurocents/liter) and the difference between both metrics is highly significant (t test shows significant difference on the 1% level). This finding suggests a comparable magnitude of the sum of price increases and the sum of price decreases per day in absolute terms, whereas the count of price decreases is higher than the count of price increases. While this underpins the fundamental *asymmetry* of price cycles, I argue that the intraday price spread, which is at a level of 10.0 Eurocents/liter averaged across gas stations, reveals further valuable insights into the *intensity* of price cycles.²²

Next, I will look at cycling patterns through the lens of municipalities. Figure 3 and 4 show hourly price deviations in exemplary municipalities with high and low

of changes and the length of validity of individual prices may vary. This arguably gives smaller values compared with computing the median across fixed time interval (i.e., daily) price changes.

²²Note that intraday price spreads are considerably higher than day-on-day price changes, which are typically not more than 2.0 Eurocents/liter (averaged across gas stations). As intraday price spreads, I report averages across gas station-specific spreads in a municipality, in contrast to municipality-wide price spreads. Naturally, municipality-level price spreads are more pronounced than averages of within-city station-level price spreads. For eight major cities (with numerous gas stations each), the Bundeskartellamt (2015) finds city spreads of at least between 15 and 20 Eurocents/liter or even beyond 20 Eurocents/liter in the cities Berlin, Hamburg, and Cologne.

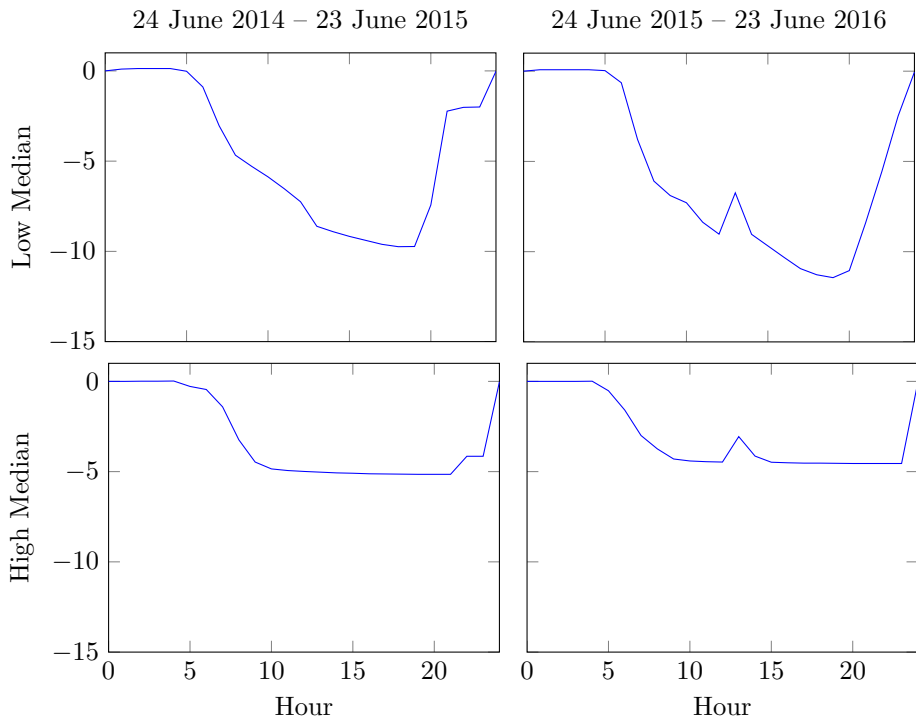
Table 1: Interpretation of Statistical Indicators

Object of investigation		Statistical indicator	
Cycle asymmetry	+	Median of price changes	-
	-		+
Cycle intensity	+	Daily price spread	+
	-		-

values across the metrics median of price changes and daily price spreads defined above. Note that the two statistical indicators used to approximate cycles asymmetry and cycle intensity need to be interpreted differently: While a higher price spread is associated with more intense cycling, a lower median of price changes suggests to find more asymmetric cycles (see Table 1). First, looking at Figure 3, the anecdotal evidence shows that a city with a highly negative median price change (at the top) correlates with an asymmetric, “sawtooth” price pattern. In a city with a median of price changes around zero (at the bottom), in turn, price decreases and increases appear more symmetric, albeit a cycle might still be present. Secondly, while a high price spread per se (as in the top part of Figure 4) is not a sufficient condition for Edgeworth-type cycling, it does give an indication of the intensity of cycles if compared with a city having a lower level of price spreads (at the bottom). In a more systematic way, Figure 9 in the Appendix shows Kernel densities for the two cycle metrics across 4,301 German municipalities.²³ Overall, I find vast evidence of Edgeworth-type cycles across municipalities in Germany. In line with previous studies, I suggest a cut-off value to separate cycling from non-cycling cities. Assuming a value for the median of price changes of -0.3 Eurocents/liter, close to 300 municipalities (or 7%) show rather “sticky” prices, while the majority is considered as cycling. Most of the less cycling municipalities are rural communities or smaller towns, among them, however, are also eight mid-sized cities and one major city (i.e., Trier). While the intensity of cycling, measured by average station-level price spreads, is more distributed, with up to 18 Eurocents/liter at the maximum, a small fraction of close to 200 municipalities show an average daily price spread of less than 2.0 Eurocents/liter.²⁴

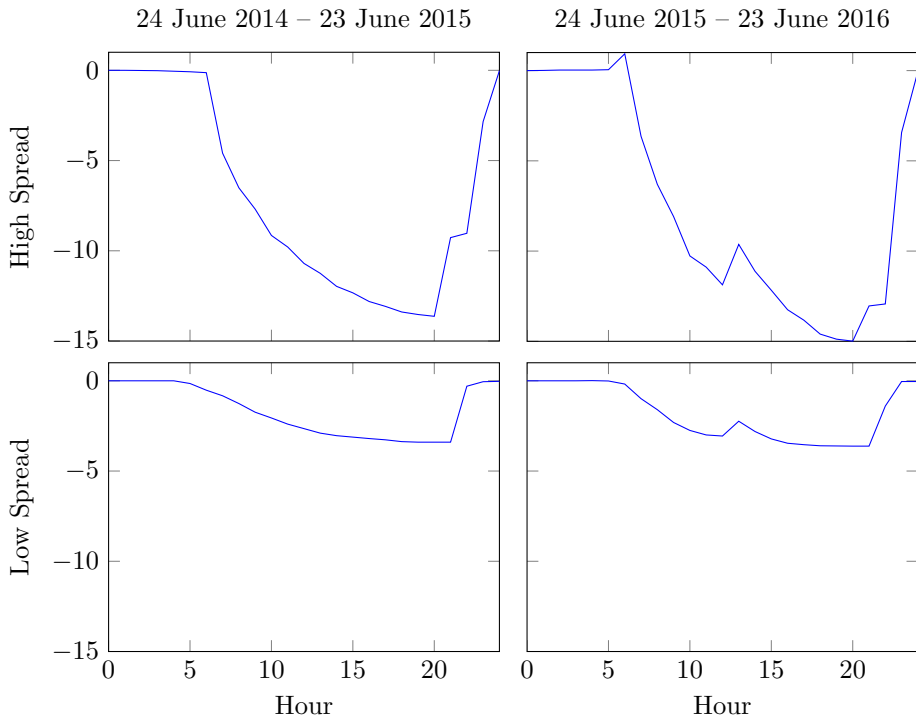
²³See Table 4 in the Appendix for a clustered overview of municipalities in the data set. Comparing municipalities included in my analysis with the last full census of data from BBR (as of Dec 2014), I cover 77 out of 77 (100%) major cities, 682 of 771 (88%) mid-sized cities, 943 of 1,183 (80%) larger towns, 1,376 of 3,430 (40%) small towns, and 1,202 of 5,729 (21%) rural communities. Lower percentages in rural communities are a result of the fact that not every town or rural area has a gas station in its territory.

²⁴Rather “sticky” pricing at individual gas stations was anecdotally validated in random phone calls with gas station operators, conducted in January 2017.



Note: Hourly price deviation for the city of Allersberg at the top (with -2.0 Eurocents/liter median of price changes across three stations) and the city of Ochtrup at the bottom (0.0 Eurocents/liter across four stations).

Figure 3: Exemplary Municipalities with Low and High Median of Price Changes



Note: Hourly price deviation for the city of Schlüchtern at the top (with 16.2 Eurocents/liter average price spread across four stations) and the city of Moosburg at the bottom (4.0 Eurocents/liter across four stations).

Figure 4: Exemplary Municipalities with High and Low Station-level Price Spread

5.2 Cycle Causes

In this part of the empirical analysis, I will focus on identifying reasons for a higher cycle asymmetry and intensity in some municipalities versus lower cycling in others. To explore causes for cycling cities, Lewis (2009), Noel (2007a), and Wills-Johnson and Bloch (2010c), for instance, estimate cross-sectional regressions of their median of price change metric on several supply- and demand-side variables. I will closely resemble their approach to identify municipality-specific characteristics associated with cycling behavior and estimate descriptive regressions of the two metrics determining price cycle asymmetry and intensity introduced in the previous section on local market characteristics. Table 2 shows a number of specifications with either the median of price changes (i.e., in specifications (1) to (3)) or the daily average price spread (i.e., in specifications (4) to (6)) as the dependent variable. In light of regionally observed price differences (see Bundeskartellamt 2015, p. 6), standard errors are clustered by close to 100 ZIP code regions and results are provided with and without federal state fixed effects. As covariates, I include regressors found by Noel (2007a) to be significant, such as the penetration of independent gas stations in a market as well as the density of stations and the population density per station, all of which positively impact on price cycling in Noel’s study. Furthermore, I include similar variables as suggested by Lewis (2009) to be potentially associated with search, travel, or switching costs of consumers (i.e., household income and cars per capita), and complement them with further demographic variables, namely the local GDP per capita and the local share of commuters.²⁵ Finally, I include two regressions (i.e., specifications (3) and (6)) with station-level cycle metrics as dependent variables, to explicitly test for the potential impact of gas station characteristics on price cycles.

Estimation results in Table 2 suggest both a stronger cycle asymmetry and cycle intensity associated with a higher density of stations and a higher population density per station. In contrast to studies on interday cycles in other markets, however, I find indicative evidence that with an increasing share of independent stations, the asymmetry and intensity of cycles is lower.²⁶ With regard to comparable municipalities, the presence of non-major brands can, thereby, imply a price spread reduction of around 4 Eurocents/liter, albeit this finding alone may not be used to draw conclusions on price levels. In their study, Doyle, Muehlegger, and Samphantharak (2010) find that the presence of gas stations with convenience stores impact

²⁵Due to a lack of granular demographic variables for some municipalities, specifications include 3,552 municipalities.

²⁶To eliminate a potential bias caused by restricted business hours, I conduct robustness checks with regressions including gas stations opening 24/7 only, leading to comparable findings.

Table 2: Regression of Retail Price Cycle Metrics

Dependent variable:	Median of price changes			Price spread		
	Municipality		Station	Municipality		Station
	(1)	(2)	(3)	(4)	(5)	(6)
Non-major market share	0.387*** (0.00)	0.379*** (0.00)	0.307*** (0.00)	-4.504*** (0.00)	-4.511*** (0.00)	-3.852*** (0.00)
Stations per km ²	-0.460*** (0.00)	-0.363*** (0.00)	-0.297*** (0.00)	3.670*** (0.00)	3.008*** (0.00)	1.667** (0.01)
Population per station ('000)	-0.014*** (0.00)	-0.013*** (0.00)	-0.009** (0.02)	0.064** (0.03)	0.073** (0.01)	0.017 (0.47)
Commuter share	-0.091 (0.13)	-0.079 (0.15)	-0.138*** (0.00)	0.482 (0.31)	0.603 (0.10)	0.834** (0.01)
Income per capita ('000 EUR)	0.009 (0.16)	-0.001 (0.85)	-0.004 (0.41)	-0.033 (0.57)	-0.018 (0.73)	0.024 (0.46)
GDP per capita ('000 EUR)	0.002** (0.04)	0.001 (0.50)	-0.001 (0.20)	-0.016* (0.06)	-0.005 (0.50)	0.003 (0.39)
Cars per capita	-0.212 (0.50)	-0.712** (0.01)	-0.102 (0.39)	0.285 (0.92)	7.310*** (0.00)	0.344 (0.72)
Convenience store			-0.084*** (0.00)			0.944*** (0.00)
Car wash			-0.159*** (0.00)			1.416*** (0.00)
Constant	-1.390*** (0.00)	-1.056*** (0.00)	-1.084*** (0.00)	12.481*** (0.00)	8.203*** (0.00)	8.644*** (0.00)
State-fixed effects	–	Yes	Yes	–	Yes	Yes
Station-specific characteristics	–	–	Yes	–	–	Yes
Number of observations	3,552	3,552	12,036	3,552	3,552	12,036
R ²	0.140	0.162	0.126	0.287	0.321	0.197

Note: Dependent variable in Eurocents/ liter; robust p-values in parentheses (clustered by ZIP code areas). Asterisks: Statistical significance at 1% (***), 5% (**), or 10% (*) level.

on cycling. In specifications (3) and (6), using station-level data, I indeed find evidence of a positive impact of, in general, more sophisticated station operations (e.g., the presence of a convenience store or a car wash facility) on cycle asymmetry and intensity. On top, only in station-level specifications, an increasing commuter share significantly influences cycling behavior. Findings from descriptive regressions presented in this section may, thus, give guidance on where to find differences in intraday price cycling across municipalities. In the following section, I will comment on the impact that price cycles have on price levels.

5.3 Price Effects

Retail price levels averaged across stations have been fluctuating between 1.15 and 1.48 Euro/liter (daily minimum prices) or 1.27 and 1.67 Euro/liter (daily maximum prices) across the two-year period of observation, with local minima in January 2015 and February 2016 (see Figure 8 in the Appendix). In fact, prices are dispersed across individual stations and across regions. Haucap, Heimeshoff, and Siekmann (2017) show that station heterogeneity determines prices to a considerable extent. On a regional level, the Federal Cartel Office in Germany has recently explained that

price levels vary across ZIP code regions in a “non-uniform way” (Bundeskartellamt 2015, p. 6). While both price dispersion and price cycling are frequently discussed topics, the impact of cycles on price levels and consumer welfare has hardly been explored. In this section, I will test whether price levels in markets with a higher cycle intensity are indeed lower, as suggested by recent literature (e.g., Noel 2015; Zimmerman, Yun, and Taylor 2013). This question is not trivial to answer as, in the absence of volume data, comparing prices relies on the researcher’s choice of the “average price” metric.²⁷ To avoid biases on the selected, non-weighted average price, I will compare the impact of cycling metrics on the minimum and maximum price per day as well as two point-in-time prices (i.e., at 8 am and 6 pm). Therefore, I specify a random-effects model of municipality-level prices on cycling metrics and a set of control variables as shown in equation 2 below

$$p_{it} = \alpha + \beta c_{it} + \gamma * cycle_{it} + \mathbf{x}_i \boldsymbol{\delta} + \mathbf{d}_{it} \boldsymbol{\epsilon} + u_{it} \quad (2)$$

with p_{it} as the point-in-time, minimum, or maximum daily price of municipality i at day t , c_{it} as region-specific input costs “ex-refinery”, $cycle_{it}$ as a (continuous or boolean) price cycle asymmetry or intensity metric, \mathbf{x}_i as a vector of municipality-specific control variables (see section 5.2), and \mathbf{d}_{it} as a vector of dummy variables to control for weekdays and federal states. Table 3 presents results for a number of specifications of the model introduced in equation 2, estimating the impact of the median of price changes and the daily price spread, as well as a dummy variable separating cycling from non-cycling markets defined by a cut-off value applied to the median of price changes (as defined in section 5.1) on retail prices.

Results in Table 3 suggest that neither a higher cycling asymmetry nor a higher intensity lead to lower price levels at all times. However, I find consistent evidence for a stronger price-lowering than price-increasing effect of cycle metrics, both comparing specifications with minimum versus maximum prices and with morning versus evening prices. I interpret this as supporting evidence of the pro-competitive nature of price cycles. While I incorporate both supply- and demand-side effects in my random effects regression, I may still be faced with omitted variable bias. This is true for most empirical studies investigating price cycles as true causal relationships are difficult to obtain in light of typically persisting cycling behavior (Noel 2015). To further validate my findings, I make use of a change in pricing patterns observed in some of the municipalities as a result of the change in the equilibrium price path in the middle of my period of observation: Using the cut-off value of

²⁷Also see the discussion in Bundeskartellamt (2017, pp. 24-25) on the influence of the choice of the “average price” on results.

Table 3: Regression of Retail Price Levels on Price Cycle Metrics

Dependent variable:	Daily minimum price			Daily maximum price			Point-in-time price at 8 am					Point-in-time price at 6 pm				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Median of price change	0.253 (0.00)				-0.224 (0.00)				-0.393 (0.00)				0.402 (0.00)			
(Med. change <-0.3 ct.)		-0.896 (0.00)		-0.686 (0.00)		0.673 (0.00)		0.317 (0.25)		1.076 (0.00)		-0.029 (0.91)		-1.155 (0.00)		-0.776 (0.00)
Price spread			-0.359 (0.00)				0.641 (0.00)				0.083 (0.00)				-0.323 (0.00)	
Ex-refinery price	1.209 (0.00)	1.206 (0.00)	1.207 (0.00)	0.990 (0.00)	1.206 (0.00)	1.209 (0.00)	1.207 (0.00)	1.052 (0.00)	1.249 (0.00)	1.254 (0.00)	1.254 (0.00)	1.037 (0.00)	1.204 (0.00)	1.199 (0.00)	1.200 (0.00)	0.994 (0.00)
Constant	8.846 (0.00)	9.594 (0.00)	11.165 (0.00)	28.013 (0.00)	15.184 (0.00)	14.603 (0.00)	11.166 (0.00)	27.626 (0.00)	7.037 (0.00)	6.089 (0.00)	6.315 (0.00)	26.713 (0.00)	9.944 (0.00)	10.951 (0.00)	12.127 (0.00)	28.218 (0.00)
Weekday dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month dummies	-	-	-	Yes	-	-	-	Yes	-	-	-	Yes	-	-	-	Yes
Year dummies	-	-	-	Yes	-	-	-	Yes	-	-	-	Yes	-	-	-	Yes
Federal state dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality characteristics	Yes	Yes	Yes	-	Yes	Yes	Yes	-	Yes	Yes	Yes	-	Yes	Yes	Yes	-
Municipality fixed effects	-	-	-	Yes	-	-	-	Yes	-	-	-	Yes	-	-	-	Yes
Number of days	731	731	731	731	731	731	731	731	731	731	731	731	731	731	731	731
Number of municipalities	3,552	3,552	3,552	128	3,552	3,552	3,552	128	3,552	3,552	3,552	128	3,552	3,552	3,552	128
Number of observations	2,596,512	2,596,512	2,596,512	93,568	2,596,512	2,596,512	2,596,512	93,568	2,596,512	2,596,512	2,596,512	93,568	2,596,512	2,596,512	2,596,512	93,568
R ²	0.940	0.940	0.946	0.866	0.897	0.897	0.950	0.774	0.913	0.912	0.913	0.786	0.936	0.936	0.940	0.860

Note: Dependent variable in Eurocents/liter; robust p-values in parentheses (clustered by ZIP code areas). Asterisks: Statistical non-significance denoted in italics.

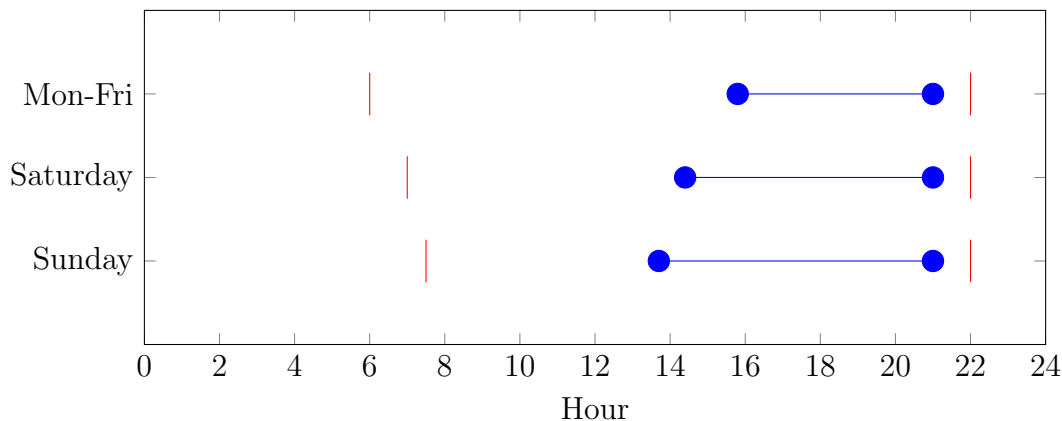
-0.3 Eurocents/liter for the median of price changes identified in section 5.1, I can extract 100 municipalities which change from cycling to non-cycling, while further 28 municipalities change from non-cycling to cycling from the first to the second year of observation. Closely following the model specified in Zimmerman, Yun, and Taylor (2013, p. 312), I estimate a municipality fixed effects regression for the subset of municipalities that have changed from cycling to non-cycling, or vice versa, and further include a full set of month and year dummies. Results for the subset of stations included in this arguably more rigid fixed effects estimation are depicted in specifications (4), (8), (12), and (16) of Table 3. Interestingly, I cannot identify a significant positive impact of cycle metrics on maximum or morning price levels. Price cycles, thus, seem to have an ambiguous influence during higher priced times of the day. However, results confirm the previous evidence of a highly significant, negative impact on minimum or evening price levels.

5.4 Purchase Strategies

Cycling markets offer consumers a menu of prices from which they can choose. In a market with full price transparency and intense price cycles, consumers that have the flexibility to shift consumption can potentially increase their welfare by applying individual purchase timing strategies. Noel (2012) rightly argues that, as a prerequisite, any purchase timing rule needs to not only be effective, but also simple to follow. Thereby, consumers may be encouraged to behave less myopic and, instead, refuel in anticipation of price developments. In a finite time horizon setting, finding a simple rule on an intraday level is much easier to achieve as it is in comparable studies with unpredictably long price cycles (see Noel 2012; Noel and Chu 2015). I will, thus, conclude my empirical analysis with a comment on intraday purchase timing strategies.

Providing advice on purchase timing on a given weekday and in a given municipality essentially relies on investigating *when* and *for how long* prices are on their minimum level. In the extreme, I find that the duration of daily minimum price periods varies from virtually the entire day (in the case of “sticky” prices) to just a few minutes. Figure 5 illustrates start and end times of minimum prices, averaged across municipalities and split by weekday. On a nationwide level, Figure 5 shows that the window of opportunity for consumers to purchase at the lowest price lasts from around 4 pm (on weekdays) or approximately 2 pm (on weekends) until 9 pm.²⁸ Moreover, Table 5 in the Appendix presents descriptive regression

²⁸This is largely in line with findings from the Federal Cartel Office, which says that prices in the eight major cities in scope of their analysis are lowest between approximately 6 pm up to 9



Note: Weekday-specific median of start and end of minimum price per municipality (blue circle) as well as opening and closing times of 8,263 gas stations (61% of total) with restricted business hours (red lines), all other stations with 24/7 opening hours.

Figure 5: Duration of Average Minimum Price Periods by Weekday

results of start and end time of the minimum daily price on certain characteristics an informed consumer might be aware of or could, at least, approximate (such as the population density of the municipality, the non-major market share, or the day of the week). Most notably, estimation results suggest that, in a given market with a higher share of non-major gas stations, consumers have more time flexibility to purchase at the lowest price, which is reached up to two hours earlier. The share of non-major brands, in turn, has a non-significant influence on the end time of the minimum price, as price restorations are less impacted by the market area but largely determined by a predetermined rule set. Moreover, during weekdays and in municipalities with a higher density of stations or population, the length of validity of the minimum price tends to be shorter.

Making a conscious decision on purchase timing assumes flexibility and negligible transaction costs from time and effort to pursue purchase timing strategies (e.g., rearranging consumption patterns in cases where refueling is part of a regular routine). Nonetheless, potential benefits from adhering to simple rules might be substantial in light of station-level price spreads of averagely 10 Eurocents/liter or beyond 20 Eurocents/liter for a given municipality at a given day (see Bundeskartellamt 2015).

6 Conclusion

In this paper, I have presented comprehensive evidence of intraday Edgeworth-type price cycles on retail gasoline markets, a rarely studied field in empirical litera-

pm latest (Bundeskartellamt 2017, p. 2). Note that, by including rural areas, the average length of validity of minimum prices is, thus, widened.

ture. Specifically, I have investigated the characteristics, causes, and price effects of high-frequency cycles – described by statistical indicators for cycle asymmetry (i.e., median of price changes) and cycle intensity (i.e., daily price spreads) – across municipalities in Germany, enabled by a census of price data covering the entire country.

In line with what motorists frequently observe, I find vast evidence of intraday cycling across German municipalities, with only a small fraction of typically rural areas being characterized by less intense cycling. This is a noteworthy difference to several studies on interday cycles, which typically find only occasional evidence of cycling cities (e.g., in a smaller number of contiguous upper Midwestern states in the U.S. as found by Zimmerman, Yun, and Taylor 2013).

With regard to causes of price cycles, my empirical findings suggest to see both more asymmetric and more intense cycles in the presence of a higher density of stations and a higher population density per station. I also find that more sophisticated gas station operations (e.g., stations with a convenience store or a car wash facility) positively impact cycling behavior. In contrast to other studies (e.g., Lewis 2009), however, cycle intensity is found to be lower in markets with a higher share of non-major brands. Especially in market areas with a prevalence of independents and non-existing or limited competition from major brands, the tendency to witness excessive cycling seems to diminish.

From a policy perspective, the impact of cycles on price levels and consumer welfare is a highly relevant topic. In this study, I am first to provide an empirical link between intraday cycling markets and price levels across the day. I find evidence for the pro-competitive nature of price cycles, with a distinct, price-lowering effect, which is most pronounced during evening hours. While the latter is supported by random and fixed effects estimations, the influence of price cycles during higher priced times of the day is ambiguous. Hence, consumers can gain from the presence of price cycles and benefit most if they behave less myopic but optimize their intraday purchase timing strategies, albeit transaction costs might increase (especially if refueling is an integral part of a regular consumption pattern).

This study has certain limitations, most notably with regard to the process of data validation and aggregation (also see section A in the Appendix) and the (indirect) reflection of market structures (e.g., via brand shares). Further research in the area of intraday price cycles on gasoline markets may focus on investigating the impact of cycles on realized prices with the help of volume data (see, e.g., Hashimi and Jeffreys 2016). This could add valuable insights to the discussion whether consumers benefit from a higher cycle intensity or a higher market transparency in

general. In light of full price transparency for consumers and suppliers alike, another interesting aspect could be to examine the effect of emerging price matching schemes, as recently introduced by players like Shell and HEM on the German market, on price cycles and competitive dynamics (see, e.g., Dewenter and Schwalbe 2016).

References

- ACCC (2007). *Petrol Prices and Australian Consumers: Report of the ACCC inquiry into the Price of Unleaded Petrol*. Canberra: ACCC.
- Atkinson, Benjamin (2008). “On Retail Gasoline Pricing Websites: Potential Sample Selection Biases and Their Implications for Empirical Research”. In: *Review of Industrial Organization* 33.2, pp. 161–175.
- (2009). “Retail Gasoline Price Cycles: Evidence from Guelph, Ontario Using Bi-Hourly, Station-Specific Retail Price Data”. In: *The Energy Journal* 30.1, pp. 85–110.
- Atkinson, Benjamin, Andrew Eckert, and Douglas S. West (2014). “Daily Price Cycles and Constant Margins: Recent Events in Canadian Gasoline Retailing”. In: *The Energy Journal* 35.3.
- Bachmeier, Lance J. and James M. Griffin (2003). “New Evidence on Asymmetric Gasoline Price Responses”. In: *Review of Economics and Statistics* 85.3, pp. 772–776.
- Bacon, Robert W. (1991). “Rockets and Feathers: The Asymmetric Speed of Adjustment of UK Retail Gasoline Prices to Cost Changes”. In: *Energy Economics* 13.3, pp. 211–218.
- Bettendorf, Leon, Stéphanie A. van der Geest, and Marco Varkevisser (2003). “Price Asymmetry in the Dutch Retail Gasoline Market”. In: *Energy Economics* 25.6, pp. 669–689.
- Boehnke, Jörn (2014). *Pricing Strategies, Competition, and Consumer Welfare: Evidence from the German and Austrian Retail Gasoline Market*. Working Paper.
- Borenstein, Severin, A. Colin Cameron, and Richard Gilbert (1997). “Do Gasoline Prices Respond Asymmetrically To Crude Oil Price Changes?” In: *Quarterly Journal of Economics* 112.1, pp. 305–339.
- Bundeskartellamt (2011a). *Fuel Sector Inquiry: Final Report May 2011 - Summary*. Bonn: Bundeskartellamt.
- (2011b). *Sektoruntersuchung Kraftstoffe: Abschlussbericht Mai 2011*. Bonn: Bundeskartellamt.
- (2013). *Gesamtkonzept für Aufbau und Betrieb der Markttransparenzstelle für Kraftstoffe (Arbeitsstand)*. Bonn: Bundeskartellamt.
- (2014). *Ein Jahr Markttransparenzstelle für Kraftstoffe (MTS-K): Eine erste Zwischenbilanz*. Bonn: Bundeskartellamt.
- (2015). *Das 2. Jahr Markttransparenzstelle für Kraftstoffe (MTS-K)*. Bonn: Bundeskartellamt.

- Bundeskartellamt (2017). *Das 3. Jahr Markttransparenzstelle für Kraftstoffe (MTS-K)*. Bonn: Bundeskartellamt.
- Castanias, Rick and Herb Johnson (1993). “Gas Wars: Retail Gasoline Price Fluctuations”. In: *The Review of Economics and Statistics* 75.1, pp. 171–174.
- Dewenter, Ralf, Justus Haucap, and Ulrich Heimeshoff (2012). *Maßnahmen zur Steigerung des Wettbewerbs auf den Kraftstoffmärkten in Deutschland: Studie für den Allgemeinen Deutschen Automobil-Club e.V. (ADAC)*. München: ADAC.
- Dewenter, Ralf and Ulrich Schwalbe (2016). “Preisgarantien im Kraftstoffmarkt”. In: *Perspektiven der Wirtschaftspolitik* 17.3, pp. 276–288.
- Doyle, Joseph, Erich Muehlegger, and Krislert Samphantharak (2010). “Edgeworth Cycles Revisited”. In: *Energy Economics* 32.3, pp. 651–660.
- Eckert, Andrew (2002). “Retail Price Cycles and Response Asymmetry”. In: *Canadian Journal of Economics* 35.1, pp. 52–77.
- (2003). “Retail Price Cycles and The Presence of Small Firms”. In: *International Journal of Industrial Organization* 21.2, pp. 151–170.
- (2013). “Empirical Studies of Gasoline Retailing: A Guide to the Literature”. In: *Journal of Economic Surveys* 27.1, pp. 140–166.
- Eckert, Andrew and Douglas S. West (2004). “Retail Gasoline Price Cycles across Spatially Dispersed Gasoline Stations”. In: *Journal of Law & Economics* 47.1, pp. 245–273.
- Edgeworth, Francis Ysidro (1925). “The Pure Theory of Monopoly”. In: *Papers Relating to Political Economy* 1, pp. 111–142.
- Eibelshäuser, Steffen and Sascha Wilhelm (2016). *Price Competition at Work: Intraday Edgeworth Cycles in the German Retail Gasoline Market*. Working Paper.
- Erutku, Can and Vincent A. Hildebrand (2010). “Conspiracy at the Pump”. In: *Journal of Law and Economics* 53.1, pp. 223–237.
- Foros, Øystein and Frode Steen (2008). *Gasoline Prices Jump up on Mondays: An Outcome of Aggressive Competition?* Discussion Paper NHH SAM 04/2008.
- (2013). “Vertical Control and Price Cycles in Gasoline Retailing”. In: *Scandinavian Journal of Economics* 115.3, pp. 640–661.
- Frondel, Manuel, Colin Vance, and Alex Kihm (2016). “Time lags in the pass-through of crude oil prices: big data evidence from the German gasoline market”. In: *Applied Economics Letters* 23.10, pp. 713–717. ISSN: 1350-4851.
- Hamilton, James D. (1989). “A New Approach to the Economic Analysis of Nonstationary Time Series and the Business Cycle”. In: *Econometrica* 57.2, pp. 357–384.

- Hashimi, Hasham and Ian Jeffreys (2016). “The Impact of Lengthening Petrol Price Cycles on Consumer Purchasing Behaviour”. In: *Economic Analysis and Policy* 51, pp. 130–137.
- Haucap, Justus, Ulrich Heimeshoff, and Manuel Siekmann (2016). *Selling Gasoline as a By-Product: The Impact of Market Structure on Local Prices*. DICE Discussion Paper No. 240.
- (2017). “Fuel Prices and Station Heterogeneity on Retail Gasoline Markets”. In: *The Energy Journal* 38.6.
- Hosken, Daniel S., Robert S. McMillan, and Christopher T. Taylor (2008). “Retail Gasoline Pricing: What Do We Know?” In: *International Journal of Industrial Organization* 26.6, pp. 1425–1436.
- Isakower, Sean and Zhongmin Wang (2014). “A Comparison of Regular Price Cycles in Gasoline and Liquefied Petroleum Gas”. In: *Energy Economics* 45, pp. 445–454.
- Kihm, Alex, Nolan Ritter, and Colin Vance (2016). “Is the German Retail Gas Market Competitive? A Spatial-temporal Analysis Using Quantile Regression”. In: *Land Economics* 92.4, pp. 718–736.
- Lewis, Matthew S. (2009). “Temporary Wholesale Gasoline Price Spikes Have Long-Lasting Retail Effects”. In: *Journal of Law & Economics* 52.3, pp. 581–605.
- (2012). “Price Leadership and Coordination in Retail Gasoline Markets with Price Cycles”. In: *International Journal of Industrial Organization* 30.4, pp. 342–351.
- Lewis, Matthew S. and Michael D. Noel (2011). “The Speed of Gasoline Price Response in Markets with and without Edgeworth Cycles”. In: *Review of Economics and Statistics* 93.2, pp. 672–682.
- Maskin, Eric and Jean Tirole (1988). “A Theory of Dynamic Oligopoly, II: Price Competition, Kinked Demand Curves, and Edgeworth Cycles”. In: *Econometrica* 56.3, pp. 571–99.
- Neukirch, Arne and Thomas Wein (2016). *Collusive Upward Gasoline Price Movements in Medium-sized German Cities*. University of Lüneburg Working Paper Series in Economics No. 363.
- Noel, Michael D. (2007a). “Edgeworth Price Cycles, Cost-based Pricing and Sticky Pricing in Retail Gasoline Markets”. In: *Review of Economics and Statistics* 89.2, pp. 324–334.
- (2007b). “Edgeworth Price Cycles: Evidence from the Toronto Retail Gasoline Market”. In: *Journal of Industrial Economics* 55.1, pp. 69–92.

- Noel, Michael D. (2008). “Edgeworth Price Cycles and Focal Prices: Computational Dynamic Markov Equilibria”. In: *Journal of Economics & Management Strategy* 17.2, pp. 345–377.
- (2009). “Do Gasoline Prices Respond Asymmetrically to Cost Shocks? The Effect of Edgeworth Cycles”. In: *RAND Journal of Economics* 40.3, pp. 582–595.
- (2011). “Edgeworth Price Cycles”. In: *The New Palgrave Dictionary of Economics (Online Edition)*. Ed. by Steven N. Durlauf and Lawrence E. Blume. Basingstoke: Nature Publishing Group.
- (2012). “Edgeworth Price Cycles and Intertemporal Price Discrimination”. In: *Energy Economics* 34.4, pp. 942–954.
- (2015). “Do Edgeworth Price Cycles Lead to Higher or Lower Prices?” In: *International Journal of Industrial Organization* 42, pp. 81–93.
- (2016). “Retail Gasoline Markets”. In: *Handbook of the Economics of Retail and Distribution*. Ed. by Emek Basker. Edward Edgar Publishing.
- Noel, Michael D. and Lanlan Chu (2015). “Forecasting Gasoline Prices in the Presence of Edgeworth Price Cycles”. In: *Energy Economics* 51, pp. 204–214.
- OECD (2013). *Policy Roundtables: Competition in Road Fuel 2013*. Paris: OECD.
- Verlinda, Jeremy A. (2008). “Do Rockets Rise Faster and Feathers Fall Slower in an Atmosphere of Local Market Power? Evidence from the Retail Gasoline Market”. In: *Journal of Industrial Economics* 56.3, pp. 581–612.
- Wallner, Klaus (1999). “Sequential Moves and Tacit Collusion: Reaction-Function Cycles in a Finite Pricing Duopoly”. In: *Journal of Economic Theory* 84.2, pp. 251–267.
- Wang, Zhongmin (2008). “Collusive Communication and Pricing Coordination in a Retail Gasoline Market”. In: *Review of Industrial Organization* 32.1, pp. 35–52.
- (2009). “(Mixed) Strategy in Oligopoly Pricing: Evidence from Gasoline Price Cycles Before and Under a Timing Regulation”. In: *Journal of Political Economy* 117.6, pp. 987–1030.
- Wills-Johnson, Nick and Harry Bloch (2010a). “A Simple Spatial Model for Edgeworth Cycles”. In: *Economics Letters* 108.3, pp. 334–336.
- (2010b). *Gasoline Price Cycle Drivers: An Australian Case Study*. Curtin University of Technology Working Paper.
- (2010c). *The Shape and Frequency of Edgeworth Price Cycles in an Australian Retail Gasoline Market*. Curtin University of Technology Working Paper.
- Woods, Jeffrey G. (2014). “An Examination of Edgeworth Price Cycles in the Indianapolis Retail Gasoline Market”. In: *Journal of Research in Industrial Organization*, pp. 1–13.

- Zhang, Xiaoquan (2005). *Finding Edgeworth Cycles in Online Advertising Auctions*. MIT Working Paper.
- Zimmerman, Paul R., John M. Yun, and Christopher T. Taylor (2013). “Edgeworth Price Cycles in Gasoline: Evidence from the United States”. In: *Review of Industrial Organization* 42.3, pp. 297–320.

A Preparation of MTS-K Raw Data

In this appendix, I provide additional information on the main data source used in this paper, the market transparency unit for fuel (“Markttransparenzstelle für Kraftstoffe”, MTS-K) and explain any modifications of the data set prior to using it for my empirical analysis. With the creation of the MTS-K, a novel panel data set including price quotes from virtually all German gasoline stations emerged. Since December 2013, gasoline station owners are obliged to report any price alteration to the MTS-K.

First of all, I correct MTS-K raw price data for obvious errors, closely following validation rules suggested by the Federal Cartel Office (Bundeskartellamt 2011b, Appendix p. 3).²⁹ Secondly, to eliminate cross-sectional variance across the period of observation from mid-2014 to mid-2016, I only consider gas stations actually quoting prices for fuel type Super E5 during each calendar year of my period of observation. Furthermore, each station’s initial price quote needs to be recorded before the 24th June 2014, while I require at least one price quote after 23rd June 2016 to ensure stations are active throughout the entire period.³⁰ Based on these modifications, I have a total of 13,877 gas stations.

Despite the cautious approach chosen to select gas stations, data accuracy might still be a potential concern, especially when conducting analysis on a granular, intraday level. I, therefore, check individual station price data for outliers with regard to longer time periods, in which no Super E5 price quotes have been recorded. From discussions with practitioners, such periods may occur due to

- a temporary close-down of operations (e.g., due to construction work at the gas station),
- technical problems with regard to (own) price submissions, or
- a change of the service provider responsible for price submissions (typically, the provider of the cash register system).

For the reasons stated above, individual gas stations may be subject to one or more “abnormally” long periods without new price quotations, leading to erroneous

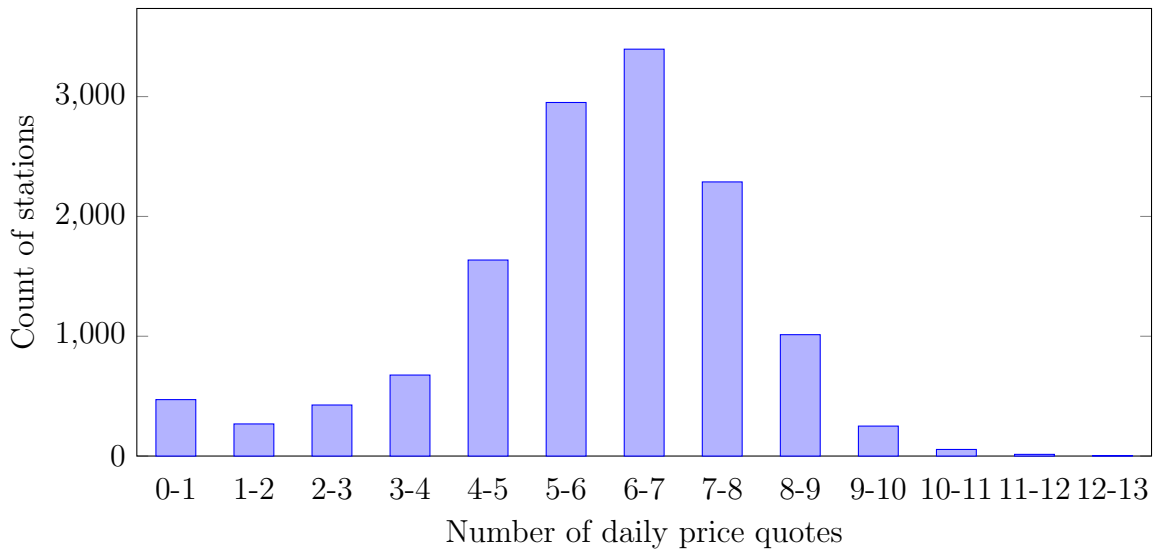
²⁹Also see the online Appendix section 1 of Haucap, Heimeshoff, and Siekmann (2017) for a detailed description of the data set and the method used for raw data preparation.

³⁰Some stations do not quote prices before 24th June 2014 as they either belong to the limited number of smaller stations not required to submit prices to MTS-K from the beginning on or as they have started operations only during my period of observation. Moreover, some stations have stopped quoting prices during my period of observation as they have either closed or changed their branding and, consequently, their entry in the data set.

results if not corrected for. To identify stations with such a pattern, I calculate the exact time period between each pair of consecutive price quotes for all stations and sort them by descending order. I find that 12,093 (87%) gas stations change prices at least once a week throughout the entire period of observation, without any exception.³¹ From the remaining 1,784 (13%) stations, I exclude stations with abnormalities by comparing the relative difference between the single longest time period between two consecutive price quotes to the second longest time period, then the relative difference between the second longest time period to the third longest time period, and so on. I find a number of stations with one or, to a lesser extent, two abnormal periods without price quotes. In total, I exclude 353 stations, where the second longest time period between two price quotes is less than 10% of the single longest time period. Similarly, I exclude 16 further stations, where the third longest time period between two price quotes is less than 10% of the second longest time period (i.e., assuming two outliers). In other words, if the longest (or, second longest) period a station doesn't change its price is more than 10 times higher than the second longest (or, third longest) period, I consider this to be abnormal and invalid. Finally, I exclude 60 stations not quoting prices for more than a quarter of a year (assumed with 90 days). With these adjustments to raw data, I have 13,448 valid stations, which I use for my empirical analysis.

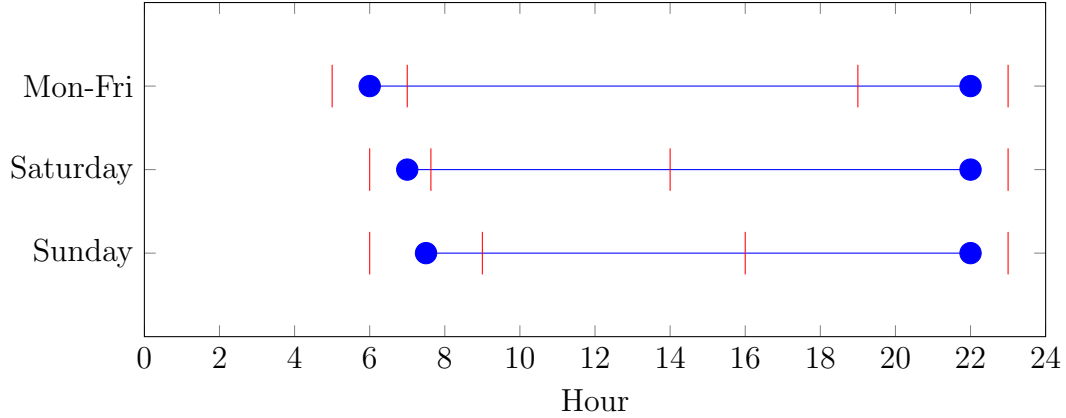
³¹13,179 (95%) stations change prices at least every month (assumed with 30 days).

B Figures and Tables



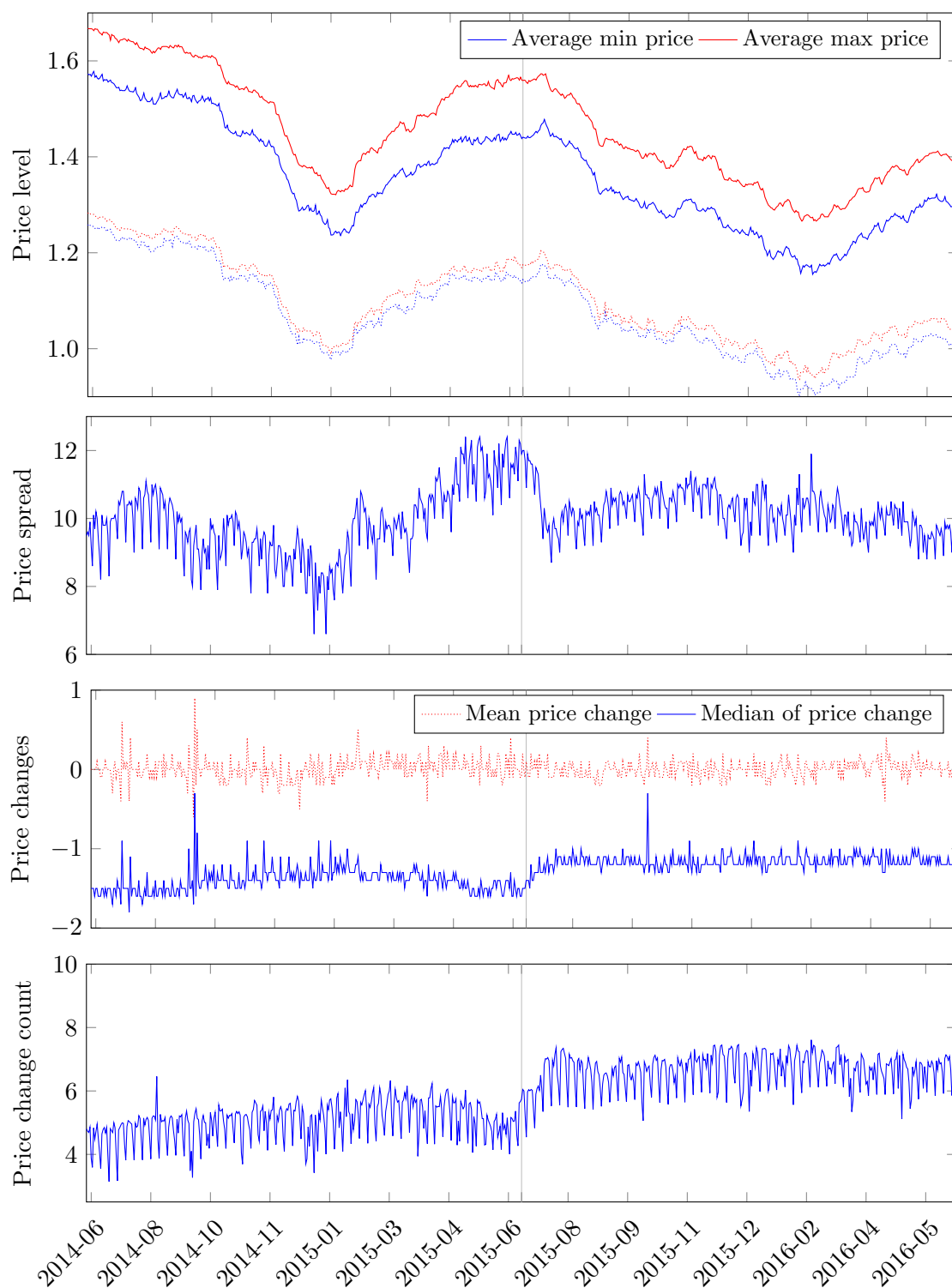
Note: Distribution of number of daily price quotes over two-year period of observation.

Figure 6: Daily Average Price Quote across Gas Stations



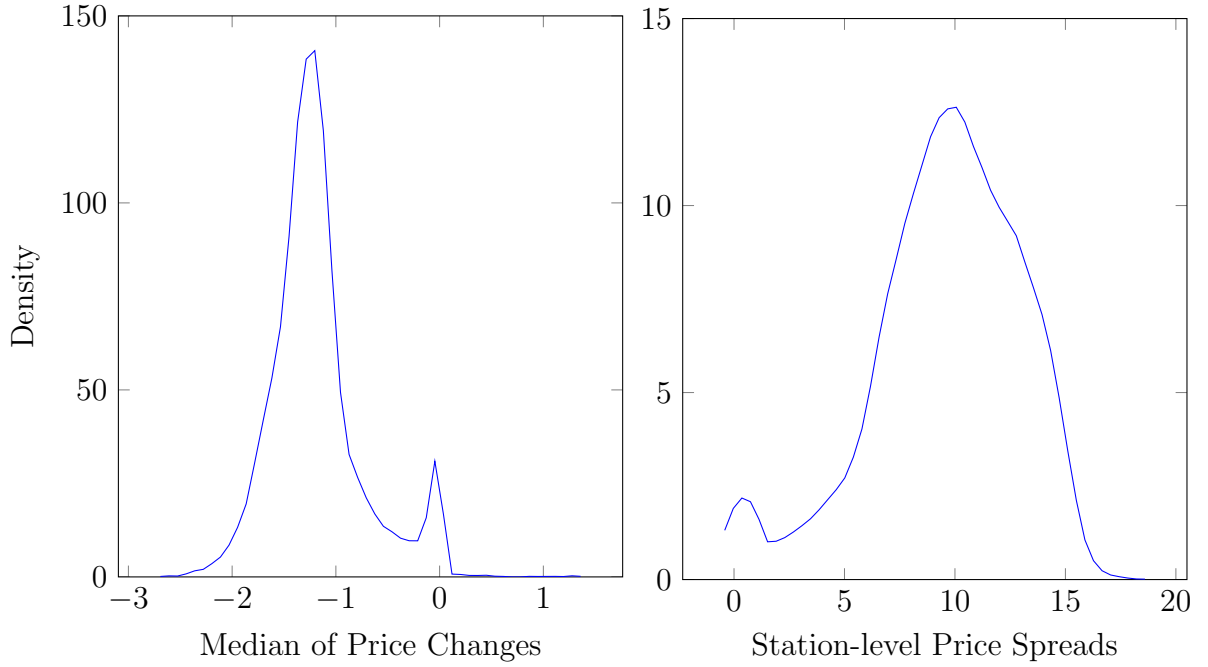
Note: Weekday-specific median (blue circles) as well as 10th and 90th percentiles (red vertical lines) of opening and closing times of all 8,263 gas stations (61% of total) with restricted business hours.

Figure 7: Overview of Business Hours



Note: Average across station-specific daily Super E5 retail min and max price levels (solid) as well as min and max refinery region's prices (dotted, in Euro/liter); daily average price spread (in Eurocents/liter); average of mean and median price changes (in Eurocents/liter); count of daily price changes averaged across all gas stations; vertical line indicates change of equilibrium price pattern (see Bundeskartellamt 2015, pp. 20-23).

Figure 8: Average Daily Station Statistics



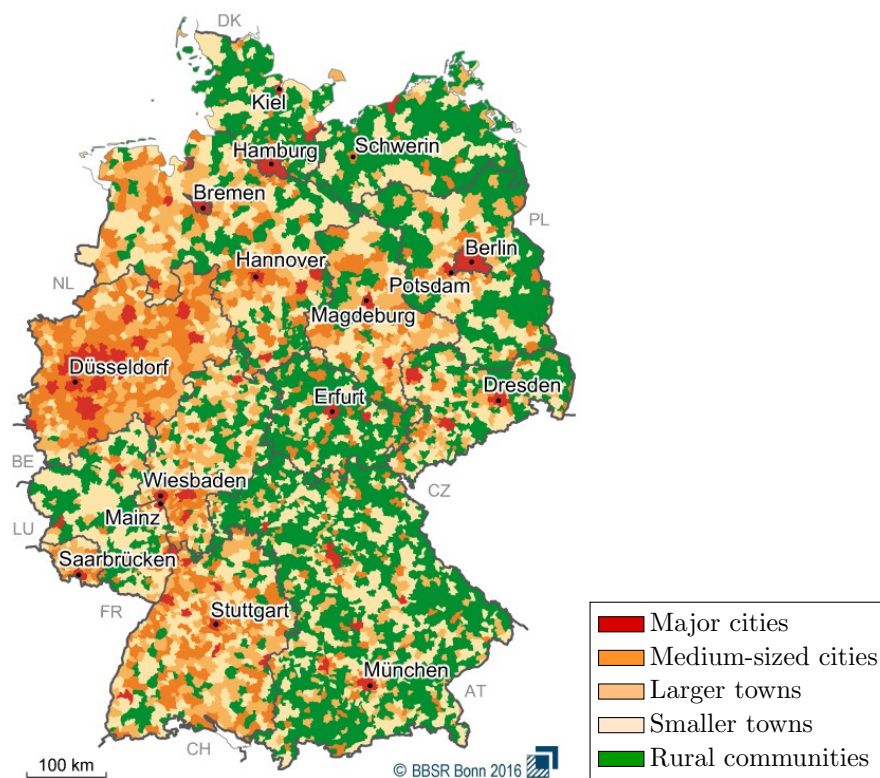
Note: Median of daily price changes and station-level price spreads in Eurocents/liter.

Figure 9: Kernel Densities of Price Cycle Metrics by Municipality

Table 4: Classification of Municipalities

Type	Classification		City count	Stations		Price spread	Price count	Median change
	min	max		total	avg.			
Major cities	100k		77	3,072	39.9	10.6	6.3	-1.29
Mid-sized cities	20k	100k	682	4,160	6.1	10.2	5.9	-1.25
Larger towns	10k	20k	943	2,551	2.7	10.1	5.7	-1.23
Small towns	5k	10k	1,376	2,224	1.6	9.3	5.3	-1.15
Rural areas		5k	1,202	1,441	1.2	9.1	5.3	-1.15

Note: Deviation from purely population-based classification possible based on city functions.
Source: BBR classification with MTS-K price and station data.



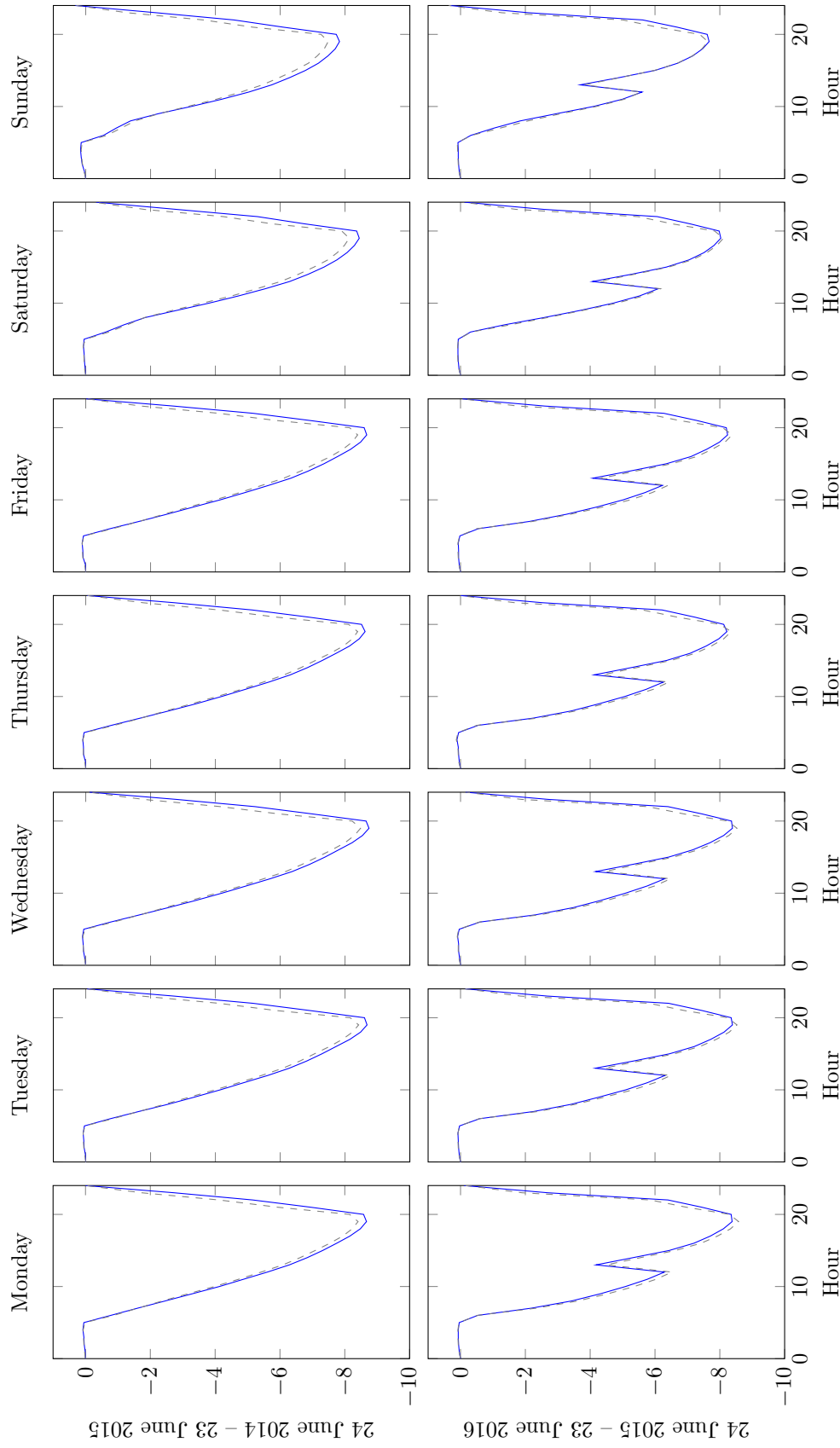
Source: Bundesamt für Bauwesen und Raumordnung (BBR)

Figure 10: Map of Municipality Types in Germany

Table 5: Regression of Minimum Price Start and End Time

Dependent variable:	Start time (1)	End time (2)
Non-major market share	-1.841*** (0.00)	0.071 (0.51)
Stations per km ²	4.367*** (0.00)	1.354*** (0.00)
Population per station ('000)	0.143*** (0.00)	0.087*** (0.00)
Weekday	0.833*** (0.00)	0.188*** (0.00)
Sunday	-0.439*** (0.00)	0.248*** (0.00)
Constant	13.812*** (0.00)	18.439*** (0.00)
State fixed effects	Yes	Yes
Number of observations	2,975,253	2,975,253
R ²	0.081	0.031

Note: Dependent variable in time of day;
robust p-values in parentheses (clustered by ZIP code areas).
Asterisks: Statistical significance at 1% (***), 5% (**), or 10% (*) level.



Note: Average deviation of individual gas station's price from the same station's daily starting price (at midnight) across all valid gas stations in Germany (point-in-time prices at full hour in Eurocents/liter shown). Sunday prices without stations closed on Sundays; deviations from stations open 24/7 dashed.

Figure 11: Average Weekday-specific Hourly Price Deviation

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