11/17

ARBEIDSNOTAT
WORKING PAPER

The Effects of a Day Off from Retail Price Competition: Evidence on Consumer Behavior and Firm Performance in Gasoline Retailing

Øystein Foros
Mai Thi Nguyen
Frode Steen

SNF

Samfunns- og næringslivsforskning AS
Centre for Applied Research at NHH

SNF Working Paper No. 11/17

The Effects of a Day Off from Retail Price Competition: Evidence on Consumer Behavior and Firm Performance in Gasoline Retailing

Øystein Foros
Mai Thi Nguyen
Frode Steen

SNF Project No. 3031: «CenSES 2011-2018»

The project is financed by the Research Council of Norway

CENTRE FOR APPLIED RESEARCH AT NHH
BERGEN, AUGUST 2017
ISSN 1503-2140

The Effects of a Day Off from Retail Price Competition: Evidence on Consumer Behavior and Firm Performance in Gasoline Retailing*

Øystein Foros [†] Mai Nguyen-Ones [‡] Frode Steen [§]

June 2017

Abstract

First, we analyze how regular days off from competition and a time-dependent price pattern affect firm performance. Second, we examine the effects on firms' profitability from consumers' changing search- and timing behavior. We use microdata from gasoline retailing in Norway. Since 2004, firms have practiced an industry-wide day off from competition, starting on Mondays at noon, by increasing prices to a common level given by the recommended prices (decided and published in advance). Hence, firms know when and to what level to raise their price. In areas without local competition, retail prices are always equal to the recommended prices. Hinged on this, we regard recommended prices as the monopoly price level. In turn, a foreseeable low-price window is open before every restoration. During the data period, we observe an additional weekly restoration on Thursdays at noon. We show that an additional day off from competition increases firm performance. As expected, a conventional price search of where to buy reduces firms' profitability. In contrast, consumers who are aware of the cycle and spend effort on when to buy have a positive impact on firms' profitability. If consumers spend effort on when to buy rather than where to buy, price competition might be softened even in the low-price windows.

* We are grateful for financial support from the Centre for Applied Research at NHH (project CenCES 2011-2018). We thank seminar participants at the Norwegian School of Economics, Bergen, December 2016, University in Agder, November 2016, the Annual Meeting of the Norwegian Association of Economists, Oslo, January 2017, FIBE, Bergen, January 2017, MaCCI Annual Conference, Mannheim, March 2017, and RES Annual Conference, Bristol, April 2017, for helpful comments. In particular, we are grateful to Einar Breivik, Gunnar S. Eskeland, Gorm Grønnevet, Daniel Herold, Arnt Ove Hopland, Steffen Juranek and Bjørn A. Reme for very useful insights and suggestions. We thank Silje Scheie Bråthen, Elisabeth Flasnes, Irina Karamushko, Irene Kvernenes, Asgeir Thue, Åse Tiller Vangsnes and Ingrid Kristine Waaler for data collection, and 'DinSide' and Circle K for data access.

[†] Norwegian School of Economics. E-mail: oystein.foros@nhh.no
[‡] Norwegian School of Economics. E-mail: mai.nguyen@nhh.no;
[§] Norwegian School of Economics. E-mail: frode.steen@nhh.no

1 Introduction

Time-dependent price patterns with a saw-tooth shape are observed in various markets. In gasoline retailing, several empirical studies (see Noel, 2016, and Eckert, 2013, for comprehensive surveys) find support for such intertemporal price dispersion as the outcome of a sequential competitive pricing game, known as Edgeworth cycles, as formalized by Maskin & Tirole (1988).[1] Saw-tooth shaped price patterns can also be the outcome of intertemporal price discrimination (e.g. Conlisk et al., 1984). Furthermore, firms may find it profitable to add complexity to their price structure in order to soften price competition (Carlin, 2009, and Ellison & Wolitzky, 2012, among others).

If firms charge uniform prices independently of *when* consumers make their purchases, consumers are harmed if firms manage to reduce or eliminate inter-brand price competition.[2] However, what is the effect of a short but regular period like a weekday off (or a *holiday*) from price competition? Consumers are worse off if they buy on days on which competition is absent, but they now have the option to move their purchases away from these periods. Furthermore, since the pattern is predictable, price competition can be intensified before the weekdays off from competition.

Regular time-dependent price patterns make consumers face an intertemporal menu of prices. If consumers are endowed with a given capacity of effort for search activity, shrinking the time window in which competition is present reduces consumers' ability to search for the where to buy. Complexity also increases since one has to consider both *when* to buy and *where* to buy.[3] Having decided to move one's purchases to a low-price window (e.g. a given day of the week or a happy hour), it becomes more costly to find the seller with the best offer within this time limited low-price window. If the consumer learns that *when* rather than *where* to buy is more effective in terms of savings, she may even reduce her search for the cheapest provider at any given time and instead spend her effort on adapting to the time cycle. Hence, from the consumer's point of view a possible trade-off arises as spending effort on timing purchases to periods with low prices might increase the marginal cost of finding the cheapest provider.

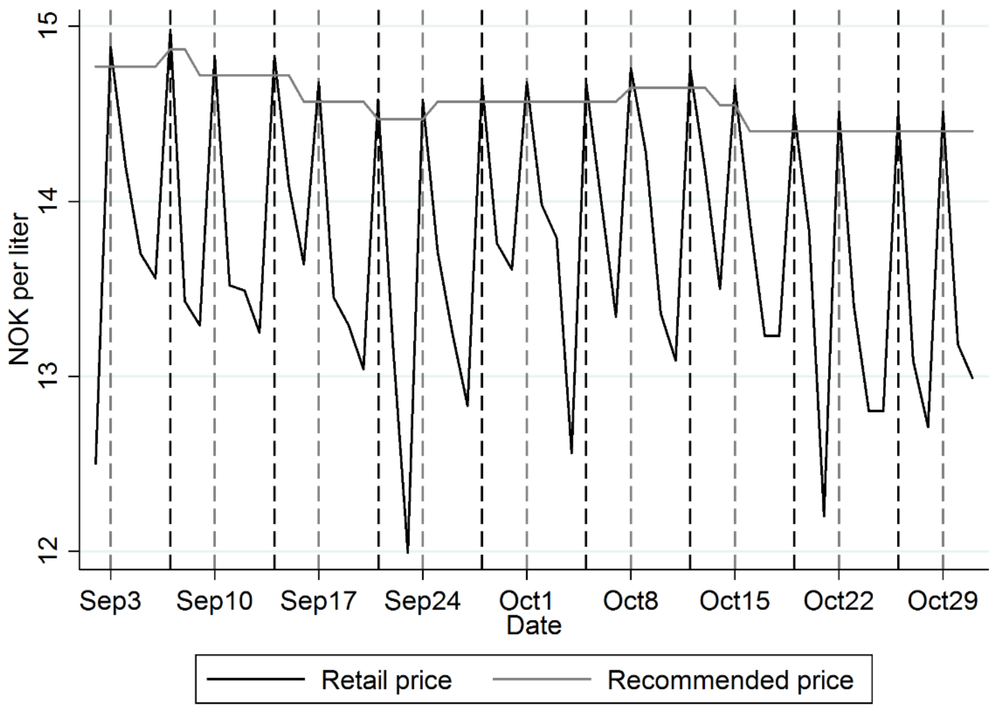
[1] Similar findings are made for search-engine advertising (Zhang & Feng, 2005).

[2] At least if we consider product quality and variety as exogenously given.

[3] General search models (Diamond, 1971, and Stahl, 1989, are seminal papers) predict that prices increase in search costs, and firms may find it optimal to make their own prices more complex for consumers (Ellison & Wolitzky, 2012).

There may be countervailing forces at both sides of the market. If firms expect price wars to end at a given time, they do not need to be concerned about further undercutting in the next period. Consider a time-constrained low-price window such as Black Friday. Firms know that they can lower prices without fear of competitors undercutting on the succeeding days. For consumers, it is more efficient to consider *when* rather than *where* to buy in a Black Friday-regime. They move purchases of e.g. electronic products to Black Friday. However, short low-price windows make comparison of prices between several providers challenging.

Figure 1: Retail prices and recommended prices for one gasoline station. Data period is 2 September to 31 October 2015. Black dashed lines mark Mondays while grey dashed lines mark Thursdays. The figure is constructed by using the last current retail price each day, except from Monday and Thursday in which the highest price is used for illustrative purposes. 1 EUR ≈ 9.50 NOK.



We focus on finite predictable saw-tooth cycles with regular length between restorations. Price increases are predictable and each chain immediately observe if a rival deviates from the established practice. The Norwegian retail gasoline market is a picture perfect application. Since 2004, the four major retail chains have managed to take a day off from competition on Mondays. Every Monday around noon, all retail outlets throughout the country symmetrically raise their pump prices in accordance with the recommended price set by the retail chains' headquarters. Price dispersion is then eliminated throughout the market, and all outlets raise their prices to the same level within approximately an hour. Recommended prices are published on the retail chains' websites, hence they easily detect if a rival deviates from the established practice both with respect to *when* the prices should increase (Monday) and to *which level* the prices should be increased (the recommended price). Prices then gradually decline over the subsequent days of the week when competition is in force. Since 2008 firms have implemented an additional day off from competition on Thursdays.[4] Similar to Mondays, we now observe a countrywide increase of retail prices to the recommended price also on Thursdays around noon. The resulting price cycle is illustrated in Figure 1 for one of the stations included in our sample over a nine-week period in 2015.[5]

Topography leads to geographical isolated local monopolies in some parts of the country. In these locations, we observe that retail prices equal the recommended price throughout the week (Foros & Steen, 2013). As such, we define the recommended price as the monopoly price (Bresnahan & Reiss, 1991). Accordingly, when the price level in geographically competitive locations equals the recommended price, we interpret the situation as a day off from competition.

In Figure 2 we take a closer look at gross margins on the restoration day. The illustration is eye-catching. The figure plots real gross margins at 8 a.m. and 2 p.m. for 43 stations on Monday 21 April 2008 and 44 stations on Monday 24 August 2015 from the same local market (Oslo, the capital and the most populous city in Norway). First, there is a huge difference between morning and afternoon gross margins across all retailers and different companies. Secondly, during an eight-year period (2008-2015), gross margins have increased when prices are at their highest after restoration but, most importantly, also when prices are lowest right before restoration. From the consumer's perspective, Figure 2 shows that spending effort on *when* rather than *where* to buy is more efficient.

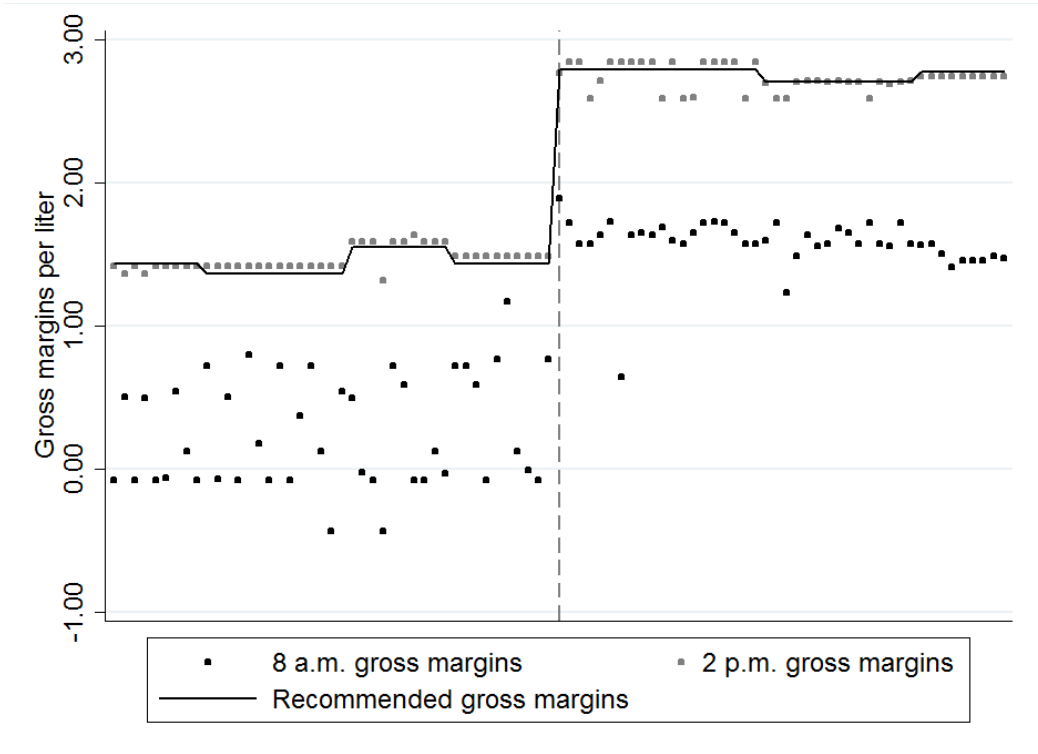
We exploit the established predictable restoration pattern dating back to 2004 together with the new restoration day appearing after 2008. The additional day off from competition

[4] Norwegian Competition Authority (2014).

[5] The four major nationwide gasoline companies are Circle K (market share 33%), Shell (25%), Esso (21%) and Uno-X (17%). See www.np.no for further details. Towards non-integrated retailers, headquarters make use of a maximum resale price maintenance system, recommended prices and a price support arrangement for which the upstream firm decides when to be operative. Symmetric cycles are hence a result of the upstream firms simultaneously deciding to disengage the price support on Mondays, and after 2008 also on Thursdays each week. Retailers are then effectively forced to set their price equal to the recommended price in order to avoid negative margins (Foros & Steen, 2013). A more thorough description is given in Appendix D.

provides us with a scenario close to a natural experiment that allows us to analyze how regular days off from competition influence consumer behavior and firms' profitability (despite the fact that the implementation obviously is endogenously determined by the suppliers).

Figure 2: Gross margins in NOK for gasoline stations in Oslo on Monday 21 April 2008 and Monday 24 August 2015. Margins are in real terms (2015-NOK=1). Each black mark and corresponding grey mark vertically above it are observations for one station. The 2008 observations are to the left of the vertical dashed line, while 2015 observations are to right of the same line. 1 EUR ≈ 9.50 NOK.



We proceed in two steps. First, we study the impact of the time-dependent price pattern on firms' profitability. In particular, we pay attention to the effect of establishing an additional weekly restoration on Thursdays. To the best of our knowledge, our approach is novel.[6]

With the use of a panel dataset of daily gasoline prices covering different periods between 2004 and 2015, we are able to investigate the effect of the development of a second restoration day on profitability over time. We show that the introduction of another day off from competition has increased firms' gross margins throughout the week. This may explain why

[6] Noel (2015) analyzes the effects on prices from a natural experiment (a refinery fire) where price cycles were temporarily eliminated.

firms use a significant amount of effort on continuing to ensure that the system is in use every week.

In the second step, we investigate how consumer behavior influences firms' profitability by matching demand side variables from a survey dataset with the price panel. The survey is constructed to achieve knowledge about consumer awareness and purchasing behavior. It is carried out in four different years between 2005 and 2015 overlapping with the panel in addition to being conducted at retail stations included in the panel. The survey data allow us to scrutinize the interaction between the demand and supply side in a market with next to perfectly predictable prices.

Results show that the Monday restoration increases firms' profitability by 35.6%, while profitability in relation to the Thursday restoration increases by 22.2%. When allowing the Thursday effect to differ before and after the introduction of a second price peak in 2008, estimates suggest that being on a Thursday has an additional positive effect of 9.56% in the post-period, giving a total impact of 27.2%. Now, the Thursday effect is closer to the magnitude of the Monday effect.

Turning to the demand side, we find that increasing the share of consumers searching for the cheapest outlet by 1% decreases firms' profits by 0.5%, indicating that intensified search for where to buy in a market is healthy for competition, as expected. On the other hand, increasing the share of consumers who adapt to the cycle by following a timing rule by 1%, raises firms' profitability by 0.27%. The effect is significant at the 1% level, suggesting that pure adaptation to the cycle independent of station search may be beneficial to sellers. The introduction of an additional day off from competition on Thursdays reduces the competitive time window and likely increases the price complexity for consumers. When separating the effect before and after the establishment of the new Thursday peak, we find that with the new pattern in place, profitability increases by another 0.56%.

In sum, results suggest that when more consumers spend effort on *when* to buy rather than *where* to buy, competition softens. This shift in consumer behavior de-incentivizes firms to compete since competition will not affect consumers' choice of station during the two brief time windows with lower prices. The introduction of a second restoration day reduces the time window with normal price competition and increases profitability.

The rest of the paper proceeds as follows: Section 2 reviews related literature. Section 3 presents the data, while Section 4 provides preliminary results. Section 5 puts forth the methodology. In Section 6, results are presented and discussed. Robustness analyses are found in Section 7. Finally, Section 8 concludes.

2 Literature Review

Our point of departure is the interplay between consumer behavior and supply side profitability in the presence of a time-based pricing pattern. A crucial feature is the time dependency, leading the price pattern to be predictable for both suppliers and consumers. This is in contrast to random sales as analyzed in Stigler (1961), Salop & Stiglitz (1977) and Varian (1980), among others.[7] While our study provides support for that consumers engaging in search for where to buy are unfavorable to firms' profitability, our conjecture is that the cycle may drive consumers' attention away from spending effort on traditional search towards rather considering when to buy.

In the literature on information acquisition, some studies emphasize obfuscation as an explanation for firms' pricing behavior and consumers' response to it. Obfuscation complicates or prevents consumers from gathering price information. Ellison & Wolitzky (2012) show that firms may unilaterally choose to raise consumers' search costs (see also Wilson, 2010). Other papers analyze obfuscation as arising from bounded rationality on the consumer side where consumers for instance follow a rule of thumb. Chioveanu & Zhou (2013) show how firms may use price frames that confuse consumers and thereby affect consumers' ability to compare prices offered. The result is lower price sensitivity and, in turn, lower degree of price competition (see also Piccione & Spiegler, 2012). Carlin (2009) demonstrates that firms might want to add complexity to the price structure, and that the number of consumers who are able to choose the firm with the lowest price decreases in complexity.

De Roos & Smirnov (2015) develop a theory of optimal collusive intertemporal price dispersion. The motivation is the gasoline market, where they show how collusion can generate asymmetric price cycles which resemble Edgeworth cycles. Price dispersion clouds consumers' awareness of prices, which helps firms to coordinate on dispersed prices by decreasing their gains from deviations through price reductions.[8]

---

[7] Stigler (1961) was the first to develop a framework for which price dispersion is an equilibrium outcome due to costly search. Following Stigler (1961), Salop & Stiglitz (1977) show that price dispersion may arise in equilibrium with oligopolistic firms due to consumers who differ in the costs related to information acquisition. Whereas the price dispersion in this framework is persistent in that some sellers always have a higher price than others, Varian (1980) allows the same seller to set different prices over time (temporal price dispersion). In equilibrium, firms randomize prices in order to price discriminate between uninformed and informed consumers. See Tellis (1986) for a survey that makes the distinction between periodic and random sales (discounts). A thorough overview of the literature on search and price dispersion is given in Baye et al. (2006).

[8] Complex price setting is found not only in commodity markets, but also in retail financial markets (Carlin, 2009, and Woodward & Hall, 2012), electricity markets (Waddam & Wilson, 2010) and online markets (Ellison & Ellison, 2009).

In the current application, our conjecture is that firms can make it more costly for consumers in terms of effort to buy from the cheapest provider. The reason is simply that rational consumers that know they need to buy during a brief low price window (Monday morning). Then, at the same time, it then becomes more costly in terms of effort to tank at the outlet with the lowest price. Furthermore, consumers might adapt to a simple rule of thumb saying that they should ensure to tank on Monday morning (Sunday as the second choice). When acting according to a rule of thumb, the attention is devoted to *when* to buy rather than *where* to buy. More attention to *when* to buy may reduce price competition.

Price patterns with a saw-tooth shape, often labeled Edgeworth cycles (Edgeworth, 1925), are widely observed in retail gasoline markets.[9] As formally shown by Maskin & Tirole (1988), this pricing behavior can be the outcome of a sequential competitive pricing game. Firms successively undercut each other in a price-undercutting phase. The process continues until further undercutting becomes too costly. They then run into a war of attrition phase until one of them takes on the burden and raises its prices. The other firms will follow and increase their prices, but not to the same level as the firm that initiated the price increase.[10] Price cycles open up for intensive price undercutting between peaks. The war of attrition phase varies in length. Hence, equilibrium price cycles vary in duration and amplitude. Firms have a common incentive to end the war of attrition game as soon as possible (Wang, 2009). The empirical literature displays that several practices have emerged in order to end the war of attrition phase (see e.g. Wang, 2009, and Foros and Steen, 2013). In the current application, as shown by Foros & Steen (2013), retail chains symmetrically increase prices to the recommended prices on Mondays, and as shown in the present paper, now also on Thursdays. The undercutting phase might be consistent with the predictions from the Edgeworth cycle theory, while the price increases depend on time (day(s) of the week) rather than on a war-of-attrition game when further undercutting becomes too costly.[11]

The vast majority of papers analyzing cycles in retail gasoline markets focus on firms' pricing behavior. As pointed out in the literature surveys of Eckert (2013) and Noel (2016), the empirical literature on retail gasoline pricing is sparse on consumer behavior. Exceptions are

[9] Studies on pricing in gasoline retailing are carried out for markets in numerous European countries, e.g. Haucap et al. (2015) for Germany and Dewenter & Heimeshoff (2012) for Austria. See Eckert (2013) and Noel (2016) for surveys of both theoretical and empirical literature on pricing in retail gasoline markets.

[10] Eckert (2003) and Noel (2007; 2008), provide theoretical extensions of Maskin & Tirole (1988). These extensions show that Edgeworth cycles are not restricted to a symmetric duopoly with homogenous goods.

[11] Sequential undercutting as in Maskin & Tirole (1988) and coordination to end the war-of-attrition phase may be complementary. One example is that one firm takes the role as the price leader (Wang, 2009 and Lewis, 2012). In Norway, Foros & Steen (2013) describe how all firms increase prices at Mondays around noon, giving rise to a regular weekly price cycle.

Noel (2012) and Byrne & De Roos (2015), who examine how consumers respond to retail gasoline price cycles.[12]

An alternative explanation for price patterns with a saw-tooth shape is intertemporal price discrimination (Conlisk et al., 1984 and Sobel, 1984, among others[13]). In contrast to Maskin & Tirole (1988), firms' incentives to reduce prices under intertemporal price discrimination arise from the presence of heterogeneous consumers (they differ in their willingness or ability to wait). Some observations are, however, inconsistent with price discrimination as the main driving force behind cycles. Eckert and West (2004) and Foros & Steen (2013), in the Canadian and Norwegian market, respectively, find that in some regions with high concentration, cycles are absent. Prices are then always equal to the recommended prices. Under intertemporal price discrimination, as in e.g. Conlisk et al. (1984), a monopolist will use price discrimination as well.

A further finding from our survey data is that consumer awareness in terms of learning and adjustment to the simple weekly cycle evolves rather slowly. This implies that intertemporal price discrimination is hardly the driving force behind firms' practice of the price support system and the recommended prices to ensure industry-wide identical retail prices on Mondays (and Thursdays).[14] However, as emphasized by Noel (2012; 2016), even if intertemporal price discrimination is unlikely as the main driving force behind firms' pricing behavior, the fact that competition creates these types of price cycles allows consumers to adapt to the pattern. In particular, this will be the case under regular calendar-based strategies as in Norway.

[12] In contrast to the Norwegian market, cycles are less regular in the Canadian market considered by Noel (2012) and Byrne & De Roos (2015). The latter study finds that consumer responsiveness increases around price restoration periods; forward looking stockpiling behavior is anticipated as a crucial force in generating the cycles. Noel (2012) analyzes four purchase timing strategies consumers can follow to move their consumption. He finds that surprisingly few consumers use such strategies.

[13] In Conlisk et al. (1984) a monopoly firm offers durable goods. The firm uses periodic price reductions to discriminate between low- and high-value consumers. In each period new consumers enter the market. Consumers who do not buy stay in the market, and the residual demand increases until price cuts become profitable. Sobel (1984) extends the former paper to a competitive setting. Dutta et al. (1984) combine repeated game and durable goods models. They demonstrate that the existence of an equilibrium with temporary price reduction requires that firms are more patient than consumers.

[14] Results are in line with the findings of the Norwegian Competition Authority (2914; 2015), which confirms that the increase in the volume purchased in low-price periods only amounts to a small fraction of the total weekly volume.

3 Data

We make use of three different datasets to address our research question.

3.1 Panel data

We use a panel covering different time periods between 3 May 2004 and 31 October 2015.[15] Data constitute daily price observations for unleaded 95-octane gasoline in NOK per liter from 11 local gasoline stations in Bergen (second largest city in Norway). Observations from 2004 and partly from 2005 are from a national website-based (NWB) data set in which consumers reported prices via text messages or e-mails throughout the day. This gives us several observations per station for many dates and sometimes also duplicate observations. Therefore, we take the average of reported prices for each station within each day from noon in order to obtain a unique daily observation per station. The rest of the dataset is collected in the afternoon (after 12 o'clock in the daytime) either by ourselves or provided to us by Circle K Norway.[16,17] In total, we have 2,165 observations. We acknowledge that our panel is highly unbalanced and unequally spaced, especially the observations taken from NWB. However, we have no reason to suspect that unbalancedness is caused by systematic reasons.[18] We measure profitability as real gross margin per liter.[19] We calculate daily gross margins by subtracting the value-added tax (VAT), the gasoline tax, the CO_2 tax and the daily Rotterdam spot price in NOK from the retail price. Taxes are set by the Norwegian Tax Administration.[20]

Finally, all variables are measured in real terms with 2015 as the base year using the yearly Consumer Price Index available at the Statistics Norway's websites.[21]

[15] The Monday peak was first observed after 27 April 2004 (Foros & Steen, 2013). Hence, we limit the data period to after this date.

[16] Prices accessed via Circle K Norway are quoted for each hour in which the price changes. We take the arithmetic average of prices from noon to obtain one price each day. For days without any changes from noon, we use the last applicable price. This concerns mostly Sundays.

[17] Since we are dealing with afternoon prices, Monday and Thursday are regarded as the high price days while Sunday and Wednesday are considered as the low price days.

[18] Rather, it is a consequence of small panels being combined. For the NWB data, incoherence is caused by the fact that prices have not been reported every day and for every station.

[19] A complete overview of local stations and period for which we have data can be found in Table A.1. All stations except Uno-X Kokstaddalen are full-service stations, but we include the station in order to increase sample size and hence preciseness in estimates. We have checked that our main results are robust to excluding this station.

[20] The VAT rate is set to 25% of the sum of the retail price, while the gasoline tax and the CO_2 tax are quantity taxes in NOK per liter and adjusted from year to year. Tax figures are available at the Norwegian Petroleum Industry Association's (NP) websites. The Rotterdam wholesale prices are accessed through Thomson Reuters and provided to us by NP. These are initially quoted in $/ton, but NP gives to us already converted data measured in NOK/liter. Wholesale prices are not quoted for the weekends. We therefore assume Friday prices for Saturdays and Sundays.

[21] See http://www.ssb.no/.

3.2 Survey data

A survey questionnaire constructed to obtain knowledge about cycle awareness and purchasing behavior among consumers was repeatedly carried out in 2005, 2006, 2008 and 2015 at two different gasoline stations in Bergen, giving 867 respondents in total. These data provide us with unique information about how consumer awareness has evolved over an 11-year period. The survey was conducted on two Mondays and two Fridays in 2005, on Monday and one Thursday in 2006 and 2008, respectively, and on two Mondays and two Thursdays in 2015. That is, the interviews were carried out on days of the week on which price restoration takes place.[22] The questionnaire was conducted with in-person interviews, in which costumers were approached and questioned while they were filling their tanks.[23] From this dataset, we measure different demand side factors, which are used in our study.[24]

3.3 Cross-sectional data

In addition, as a supplement to the datasets for Bergen, we use data for retail prices at 8 a.m. and 2 p.m. from 43 stations on Monday 21 April 2008 and 44 stations on Monday 24 August 2015 in Oslo, Norway's capital city.[25] Stations for all the big four companies are included. From the prices, we calculate real gross margins and compare them to recommended gross margins. This dataset let us analyze the development of profitability over time both at the bottom as well as at the top of the price cycles. Hence, it allows us to better understand the price determination scheme in time-dependent markets.

For the sake of examining the establishment of the Thursday restoration, we also consider data from the same sample for two consecutive Thursdays in 2015, namely 27 August with observations from 43 stations and 3 September with observations from 42 stations.

3.4 Combining panel data and survey data

We examine the interaction between demand side factors and firms' profitability by matching the measures constructed from the survey data with the price panel. Specifically, we match survey variables with price variables based on matching year.[26] Since the survey data leave us with a yearly frequency in the variable measures, all observations within a year are

[22] In 2005, Friday was chosen because at that time it was believed that price restoration occurred on this day in addition to Monday.

[23] Interviewers filled out the questionnaire while interviewing costumers. The survey consists of ten closed-ended questions and one open-ended question in addition to requests for personal information.

[24] An overview of station, date and number of respondents each year is given in Table B.2.1. The survey questionnaire is presented in Appendix B.1.

[25] This represent all stations in the two cities.

[26] Since our panel covers 2004, 2005, 2006, 2008 and 2015 while we lack survey data for 2004, we use values for 2005 for 2004.

matched with the same value, independent of station. Ideally, we would have station-specific measures with a daily frequency, but no such data are available. Nonetheless, we bear in mind that we allow for stations to react differently to variation in the demand side measures.

4 Preliminary descriptive results

4.1 Firms' profitability

We start with the cross-sectional data. For the Monday data, we calculate real gross margins at 8 a.m. and 2 p.m. as well as recommended gross margins for each station in 2008 and 2015 (base year 2015). A plot of these data is presented in Figure 2 in the Introduction, while summary statistics are presented in Table 1. We find some striking results. First, the average recommended margins have increased since 2008 by 91.9%. Second, the difference in average real gross margins between these two random Mondays is 86.6% at 2 p.m. and as much as 510.9% at 8 a.m.[27] Third, the Levene's test reveals significantly less dispersed gross margins at 8 a.m. in 2015 compared to 2008. The two-sample t-test shows that the increase in average gross margins at both 8 a.m. and 2 p.m. is significant.[28]

In 2008, the lowest gross margin at 8 a.m. is even negative. From Figure 2, we detect that this is the case for several stations. In contrast, only positive gross margins are observed at 8 a.m. in 2015. Considering the magnitude of the gross margin increase together with the Levene's test, we observe that synchronization of prices has been established even in the low price window. Moreover, there has been an increasing trend in average gross margins as well as in recommended margins in Oslo during the seven-year period.

[27] Our most conservative measure of the increase in 8 a.m. gross margins is 447.7%. This value is achieved by removing 8 a.m. observations for two stations in 2008 and for one station in 2015. These outliers are detected visually. Nonetheless, they are simply due to random variation and should therefore be included in the further analysis.

[28] Tests are reported in Table C.1 and C.2 in the Appendix.

Table 1: Monday summary statistics in NOK per liter.

	Mean	Std.dev.	Min	Max
21.04.2008				
Gross margins 8 a.m.	0.258	0.391	-0.435	1.170
Gross margins 2 p.m.	1.465	0.078	1.316	1.635
Recommended gross margins	1.438	0.071	1.361	1.553
24.08.2015				
Gross margins 8 a.m.	1.576	0.182	0.642	1.890
Gross margins 2 p.m.	2.734	0.089	2.586	2.842
Recommended gross margins	2.760	0.040	2.706	2.794

n=43 for 21.04.2008 and n=44 for 24.08.2015.

Moving to the Thursday data, observations depicted in Figure 3 demonstrate the exact same pattern as detected for Mondays in prices and hence in gross margins on Thursdays too.[29] Further, behavior is similar for two consecutive Thursdays, assuring that predictability in prices is not caused by sampling reasons. On 27 August, gross margins increase on average by 59.4% from 8 a.m. to 2 p.m., while the corresponding increase is 78.1% on 3 September. From the summary statistics in Table 2, we first notice that the mean for the 2 p.m. gross margins is around 1 NOK higher than for the 8 a.m. gross margins. Next, compared to 8 a.m. observations, standard deviations for 2 p.m. observations are three times smaller for 27 August and almost four times smaller for 3 September. From this, we observe that the systematic behavior in prices in 2015 is completely present on Thursdays as well. Around noon, prices increase to the recommended prices for practically all stations. During the morning, there is a higher degree of dispersion. Furthermore, none of the stations has negative gross margins for any of the Thursdays.

[29] We have checked that an analogous pattern exists for Thursday 27 August.

Figure 3: Retail gross margins in NOK for gasoline stations in Oslo on Thursday 3 September 2015. Each black mark and corresponding gray mark vertically above it are observations for one station.

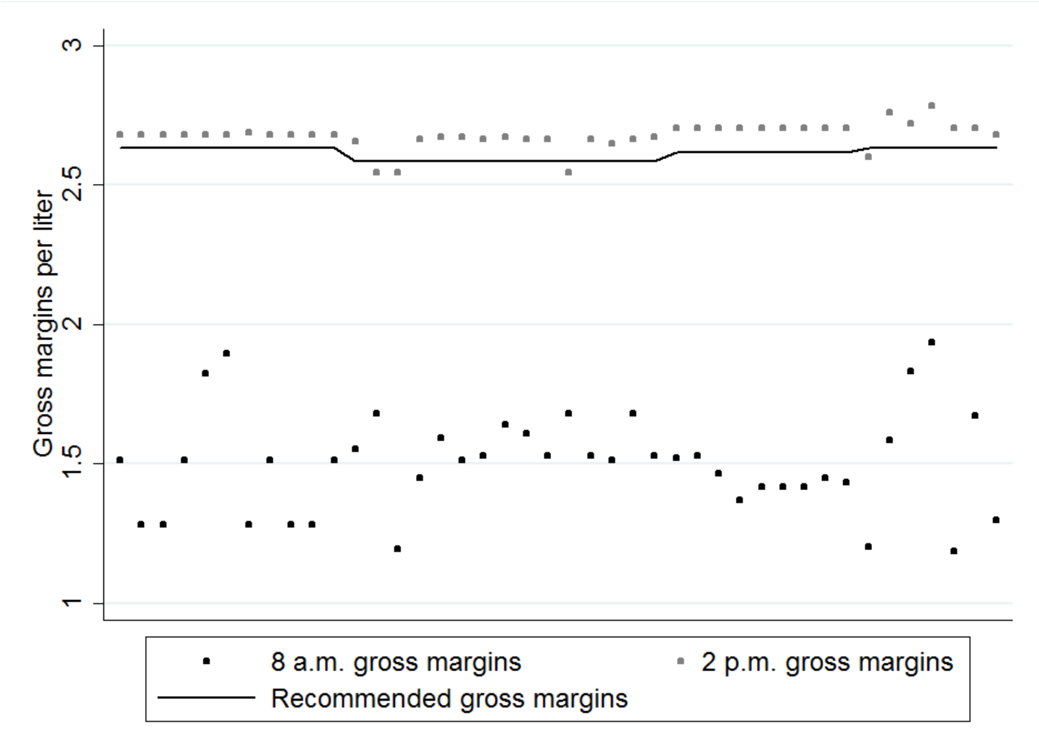
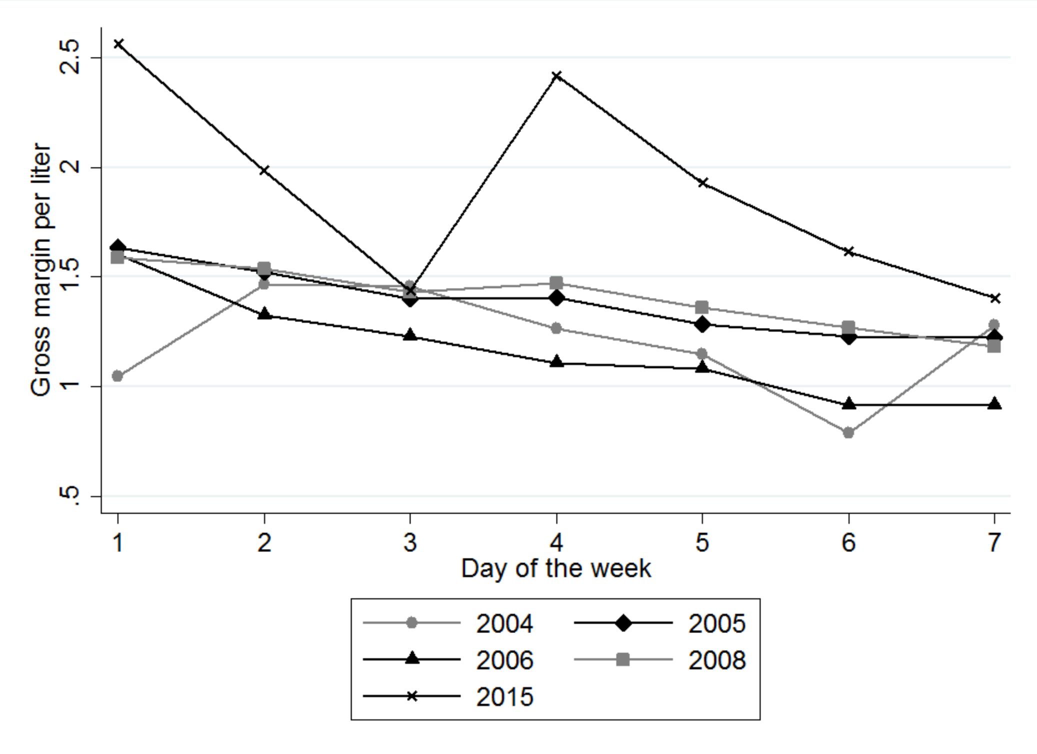


Table 2: Thursday summary statistics in NOK per liter. n=43 for 27.08.2015 and n=42 for 03.09.2015.

	Mean	Std.dev.	Min	Max
21.04.2008				
Gross margins 8 a.m.	0.258	0.391	-0.435	1.170
Gross margins 2 p.m.	1.465	0.078	1.316	1.635
Recommended gross margins	1.438	0.071	1.361	1.553
24.08.2015				
Gross margins 8 a.m.	1.576	0.182	0.642	1.890
Gross margins 2 p.m.	2.734	0.089	2.586	2.842
Recommended gross margins	2.760	0.040	2.706	2.794

Figure 4: Mean gross margin by day of the week and year. Day 1 corresponds to Monday, while day 7 corresponds to Sunday.



We now continue with the panel data. Summary statistics of the price data are reported in Table 3.[30]

Table 3: Summary statistics. Total number of observations is 2,165. All values are in real NOK per liter. Data period is 3 May 2004 to 31 October 2015.

	Mean	Std. dev.	Min	Max
Price	13.455	1.157	10.689	15.980
Wholesale price	3.530	0.821	2.254	5.293
Tax	5.826	0.020	5.806	5.871
VAT	2.691	0.231	2.138	3.196
Gross margin	1.407	0.414	0.078	2.945

[30] More detailed summary statistics can be found in Table A.2 in the Appendix, from which we observe preliminary evidence of increasing real gross margins over the sample period.

Figure 4 depicts the mean gross margin by day of the week and year. We notice that the magnitude of profitability in 2015 clearly stands out compared to previous years. Even the Wednesday margin, just before the new day off from competition (Thursday), has not been reduced. Another insight is that whereas there are signs of a small increase in the Thursday margin in 2005 and 2008, the jump in 2015 is as clear-cut as the Monday peak. Nevertheless, in the following analysis, we rely on the Competition Authority's (2014) observation of 2008 as the start of the establishment of the Thursday restoration.[31]

In sum, we observe that firms' profitability has increased in line with the implementation of a second day off from competition, which is consistent with our conjecture.

4.2 Consumer behavior

From the questionnaire, we create variables based on each respondent's reply to the different questions. Variables are presented as response share of the total number of respondents by year. Table 4 to Table 7 provide descriptive statistics for the most important questions.[32]

Overall, respondents seem to become more aware of the price pattern over time. From Table 4, we see that whereas 35% have the impression that the retail price increases on specific days of the week in 2005, 44% and 53% believe so in 2006 and 2008, respectively, and as many as 81% in 2015. Still, the measure does not tell whether the perceptions are in line with the actual cycle or not. Turning to Table 5, in 2005, 11% of the respondents have the correct impression that Monday is the only restoration day, while 28% give the same answer in 2015. The emergence of a second restoration day has confused consumers further, since only 14% believe correctly that only Monday and Thursday are the only restoration days in 2015.

Question 6, presented in Table 6, concerns whether consumers who are aware of the cycle move their purchases to low-price windows. Of those who are aware of the retail price increasing on specific days of the week, 31% take this information into account very often when making their purchases in 2005, while 39% do so in 2015.[33] At first glance, this observation can be misinterpreted as increasing price sensitivity between 2008 and 2015. However, it might just indicate that more consumers move their attention towards *when* to tank rather than where to tank simply because they follow a rule of thumb, as discussed in the Introduction. If *when* to

[31] A complete overview of retail prices and gross margins by year and day of the week is provided in Table A.3 and A.4 in the Appendix.

[32] Tables B.2.2 to B.2.3 in the Appendix present the remainder. Summary statistics are reported in Table B.2.5.

[33] Note that the shares are decreasing from 2005 to 2006 and 2008. We do not have an explanation for this.

purchase rather than *whe*re to purchase becomes the main factor to act by, it is reasonable to expect that these consumers more often refill at the same station (e.g. the most convenient station to drop by on Monday morning). Provided that consumers have a given capacity of effort, brief low price windows leave little scope for searching between stations.

We are interested in establishing a measure of consumers who are concerned with when to purchase during a week. To follow a rule of purchasing based on timing requires the consumer to know when restorations occur and thereby when low price windows occur. Therefore, we classify a consumer as following a purchasing rule based on when to buy, denoted *timing* , if she is aware that the price increases on specific days during a week (as identified by Question 6 alternative "Very often" or "Fairly often" in Table 6), in addition to making all purchases at the same station (as identified by Question 8 in Table B.2.4). This measure is presented in Table 8. We note that the share of consumers classified as timing consumers increases over time, from 12% in 2005 to 27% in 2015. Intuitively, following for instance a rule of thumb based on when to tank, seems like a rational action as more consumers become aware of the existence of a predictable pattern in prices. As emphasized, our conjecture is that consumers focusing on *when* to buy can soften inter-brand price competition since focus is moved away from where to tank.

In addition, we want a measure of searching consumers as an indication of the consumers concerned with where to find the lowest prices. We assume that a consumer who compares retail prices announced on large signs outside stations during a week drops by the station with the lowest price when she is in need of gasoline. It is reasonable to think that consumers who compare prices on signs are more focused on searching than those who do not check the sign. Intuitively, drivers pass many stations during the week, and while driving can pay attention to the price signs outside stations, which are easily visible from the road.[34] Hence, we define a searching consumer as one who checks the signs outside stations and makes her purchases at more than three different stations. Table B.2.4 shows that 36% of the respondents purchase at more than three different stations compared to 26% in 2005. Moreover, from Table 7 we see that the share of consumers that check the price on signs has almost doubled since 2005. When combining these two requirements, we note from Table 8 that the measure of searching consumers, *search*, has increased from 8% in 2005 to 17% in 2015. This suggests that consumers have become more price conscious with time by attempting to exploit inter-station dispersion.

[34] Our measure of search is motivated by the standard literature in search theory in which consumers' information gathering in prices is costly. One of the classic frameworks is provided by Stigler (1996).

Table 4: Do you think the retail price increases on specific days of the week? Numbers in parentheses are total number of respondents by year. Shares not summing to 100% are due to non-response.

	Yes	No	Do not know
2005 (289)	35 %	63 %	1 %
2006 (151)	44 %	56 %	0 %
2008 (225)	53 %	28 %	19 %
2015 (202)	81 %	9 %	10 %

Table 5: If yes on Question 4, which day of the week does the retail price increase? Numbers in parentheses are total number of respondents by year. Shares not summing to 100% are due to non-response.

	Only Monday	Only Thursday	Only Monday and Thursday
2005 (289)	11 %	0 %	0 %
2006 (151)	23 %	1 %	1 %
2008 (225)	29 %	1 %	1 %
2015 (202)	28 %	0 %	14 %

Table 6: If yes on Question 4, how often do you take this into account when making your purchases? Numbers in parentheses are total number of respondents by year. Shares not summing to 100% are due to non-response. Shares summing to over 100% are due to rounding numbers.

	Very often	Fairly often	Neither	Fairly seldom	Very seldom
2005 (289)	31 %	9 %	7 %	8 %	39 %
2006 (151)	21 %	17 %	12 %	8 %	33 %
2008 (225)	13 %	15 %	18 %	7 %	45 %
2015 (202)	39 %	13 %	12 %	4 %	33 %

Table 7: Where do you check the retail price? Numbers in parentheses are total number of respondents by year. Shares not summing to 100% are due to non-response.

	Do not check the price	Check on the pump	Check on the sign outside of station	Other
2005 (289)	46 %	7 %	31 %	0 %
2006 (151)	35 %	15 %	50 %	0 %
2008 (225)	48 %	13 %	38 %	0 %
2015 (202)	38 %	2 %	60 %	0 %

Table 8: Measure of timing and search by year. Numbers in parentheses are total number of respondents by year.

	Timing	*Search*
2005 (289)	12 %	8 %
2006 (151)	11 %	11 %
2008 (225)	20 %	8 %
2015 (202)	27 %	17 %

5 Methodology

5.1 Measuring the impact of predictable time-dependent price cycles on profitability

We use a fixed effects model for our specification, and our main model is

$$M_{it} = \beta_0 + \sum_{j=1}^{6} \delta_j D_j + \gamma t + \beta_1 D_4 \times post07 + \beta_2 pwhole_t + \mu_i + \epsilon_{it}$$

The dependent variable is the log of gross margin in real NOK per liter for station i on day t. Due to time-dependent cycling prices, the main explanatory variables of interest are a full set of day-of-week dummies D_j, using Sunday as baseline.[35] In order to investigate the development of the Thursday peak over time, we also include an interaction term between the Thursday dummy variable and a dummy variable $post07 = 1$ if the year is 2008 or later. The division in time is chosen based on the Norwegian Competition Authority's (2014) detection of the Thursday restoration for the first time in 2008. As control variables we include the log of wholesale price in real NOK $pwhole_t$ and a daily linear trend t. Finally, μ_i are station-specific fixed effects and ϵ_{it} are idiosyncratic error terms. We use White's robust standard errors.

For the sake of investigating whether the development in trend differs by day of the week, we also estimate a model where a full set of interaction terms between the day-of-week dummy variables and the linear trend is included instead of the interaction term $D_4 \times post07$. This specification is given by

$$M_{it} = \beta_0 + \sum_{j=1}^{6} \delta_j D_j + \gamma t + \sum_{j=1}^{6} (\lambda_j D_j \times t) + \beta_1 pwhole_t + \mu_i + \epsilon_{it}$$

[35] Note that we have defined our days as noon to noon, implying eg., that the Sunday dummy will pick up the lowest prices in the week: Sunday afternoon and Monday morning.

5.2 Measuring the impact of consumer behavior on profitability

We analyze the effect of two different demand side variables.[36] The first model in the investigation of consumer behavior examines the impact of search behavior on gross margin development, according to the specification

$$M_{it} = \alpha_0 + \alpha_1 search_t + \alpha_2 search_t \times post07 + \sum_{j=1}^{6} \delta_j D_j + \gamma t + \alpha_3 D_4 \times post07 + \alpha_4 pwhole_t + \mu_i + \epsilon_{it}$$

The explanatory variable of interest is the log of searching consumers $search_t$. This measure is constructed as the share by year of consumers that check the price on signs outside stations and make purchases at more than three different stations. Identification of α_1 hence stems from changes in the share of searching consumers over time. The inclusion of an interaction term between $search_t$ and the dummy variable $post07 = 1$ if the year is 2008 or later, further allows us to analyze the effect of search behavior on profitability after the establishment of a new weekly peak. In addition, the log of the wholesale price, a full set of day-of-week dummies and a daily trend are included as controls.

We are also interested in the effect of consumers who adapt their purchases to the predictable cycle. The second model therefore includes a measure of the share of consumers who act by timing the cycle, $timing$, as the main explanatory variable:

$$M_{it} = \alpha_0 + \alpha_1 timing_t + \alpha_2 timing_t \times post07 + \sum_{j=1}^{6} \delta_j D_j + \gamma t + \alpha_3 D_4 \times post07 + \alpha_4 pwhole_t + \mu_i + \epsilon_{it}$$

The variable measures the share of consumers who predict when low price windows occur during a week, for instance by following a rule of thumb, and move their purchases to these points in time. These consumers hence do not spend effort on price search because they regard timing purchases as more gainful than exploiting price dispersion across stations.[37]

[36] Data do not permit us to investigate both demand side measures in the same model due to high linear dependency between them and the trend variable. Regressing trend on $search$ and $timing$ gives $R^2 = 0.98$.

[37] In the following, unless it is necessary for avoiding confusion, we will suppress station and time notation.

6 Results

6.1 The impact of predictable time-dependent price cycles on profitability

Table 9 presents our main results on price cycles. From the simplified specification in column (A) in which $D_4 \times post07$ is omitted, all day-of-week dummy coefficients are positive and significant except from the Saturday dummy. Being on Monday increases firms' profitability by 35.6%. The effect then declines when moving to Tuesday and Wednesday, until reaching a new increase on Thursday to 22.2%. Throughout the rest of the week, the effect descends compared to Sunday, which appears to be the day with the lowest profitability during a week (the low price window: noon Sunday to noon Monday). We find no significant difference in gross margins between Saturday and Sunday (2.3% but not significant). Results hence demonstrate the presence of a weekly cycle, with large price increases on Monday and Thursday, which in turn increase firms' profitability. The linear trend coefficient is positive and significant, indicating that gross margins indeed have increased over time. If we calculate the effect of the trend from 3 May 2004 to 31 October 2015, the average margin in real terms has increased by NOK 0.428 - which is a significant amount compared to an average margin in 2004 of NOK 1.22. The average margin increased by more than 35% over the data period.

Model (A) shows the average cycle over the period 2004 to 2015. In model (B), we include the interaction term $D_4 \times post07$ to allow for the new restoration day introduced on Thursdays. The coefficient is positive and significant at the 1% level, suggesting that from 2008, the extra effect of Thursday as the current day of the week is 9.56%. The total effect of being on a Thursday from 2008 is hence 27.2%, which is stronger than the average effect measured in model (A). Of the day-of-week dummies, inclusion of $D_4 \times post07$ only changes the coefficient of the Thursday dummy, which now decreases to 0.176. This suggests that the Thursday peak has not been present during the whole sample period, as coefficients now slowly decline from Monday and throughout the week. The positive average trend effect now suggests an increase in the real margin of NOK 0.441. Thus, model (B) presents very similar results, but also that Thursday emerges as a new restoration day.

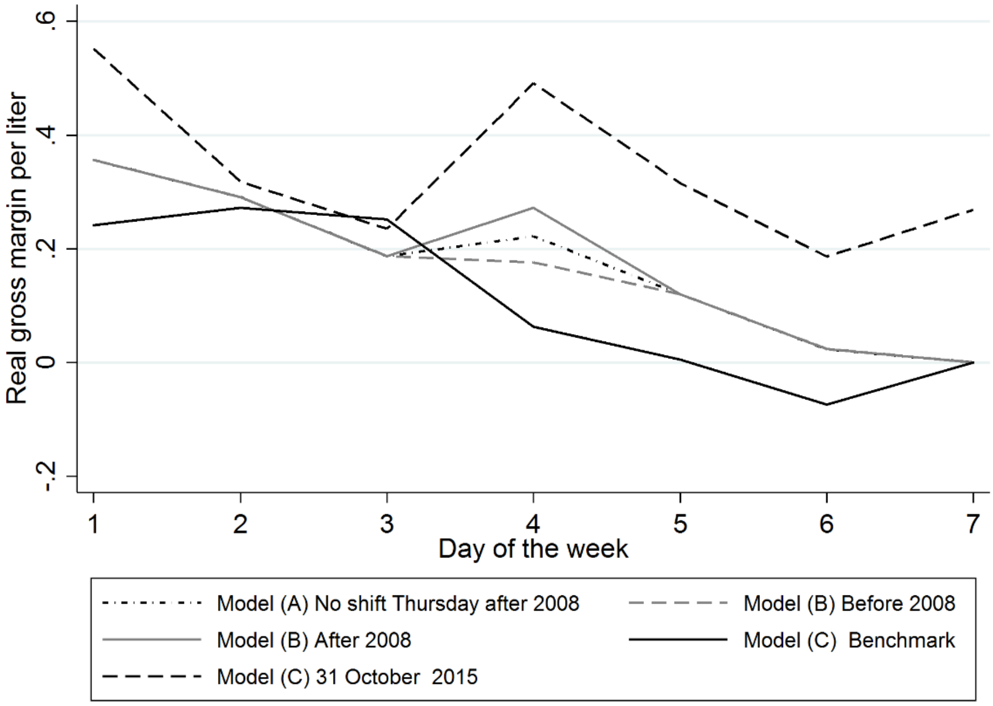
Table 9: Regression results. Dependent variable is log of gross margin in NOK per liter.

	(A)	(B)	(C)
Mon	0.356***	0.356***	0.241***
	(0.026)	(0.026)	(0.051)
Tue	0.291***	0.291***	0.272***
	(0.026)	(0.026)	(0.052)
Wed	0.187***	0.187***	0.252***
	(0.027)	(0.027)	(0.052)
Thu	0.222***	0.176***	0.063
	(0.028)	(0.038)	(0.053)
Fri	0.120***	0.120***	0.005
	(0.030)	(0.030)	(0.057)
Sat	0.023	0.024	-0.074
	(0.031)	(0.031)	(0.059)
Trend	0.000105***	0.000102***	0.000064***
	(0.000008)	(0.000008)	(0.000017)
Trend×Mon			0.000074***
			(0.000021)
Trend×Tue			0.000011
			(0.000026)
Trend×Wed			-0.000040
			(0.000025)
Trend×Thu			0.000102***
			(0.000023)
Trend×Fri			0.000074***
			(0.000024)
Trend×Sat			0.000062**
			(0.000024)
Wholesale price	-0.133***	-0.151***	-0.131***
	(0.033)	(0.034)	(0.032)
Thu×post07		0.096***	
		(0.037)	
Constant	0.116**	0.144***	0.178***
	(0.045)	(0.047)	(0.056)
Observations	2,165	2,165	2,165
R-squared	0.229	0.231	0.246
Station FE	YES	YES	YES

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Data period is 3 May 2004 to 31 October 2015.

In order to analyze the development in trend based on days of the week, model (C) replaces $D_4 \times post07$ in favor of a full set of interaction terms between the trend variable and the day-of-week dummies. We find significant trend effects for four days. These are highest on the new restoration day Thursday, and second highest on Monday and Friday. Monday remains as the day on which firms earn the highest gross margins. To illustrate the development in the margins over time as predicted by model (C), we can calculate the trend effect over the whole data period by adding the trend effect from each day-estimates to the benchmark estimate, e.g., for Thursday; 0.063 + 4198 days × 0.000102 = 0.063 + 0.428 = 0.491. This is illustrated for model (A) to (C) in Figure 5.

Figure 5: Predicted daily gross margins per liter.



Several features become clear from Figure 5. Models (A) and (B) display the same pattern except for Thursday, where model (A) predicts the average effect of the before/after 2008 effects of the introduction of a second restoration day. First, the most flexible model (C) suggests that the Thursday effect has become stronger and very similar to the Monday effect, but that Monday still has the highest margin (0.55 vs 0.49). Second, we observe a marginally small trend-based reduction in the Wednesday margin over the data period (small negative trend coefficient). This is reasonable, since Wednesday (recall that this refers to noon Wednesday to noon Thursday) is now the low price window just before the second restoration on Thursday afternoon, and in the new cycle Wednesday has the same role as Sunday.

Finally, if we compare the estimates to what we saw in Table 1 and Figure 3, model (C) suggests an increase in the Monday afternoon gross margin of 128% (2004-2015). These numbers correspond well with Table 1, where the increase from 2008 to 2015 was more than 90%. The new restoration day increases the Thursday margin by nearly 700%.

In sum, results from models (B) and (C) propose that the introduction of a new weekly day off from competition on Thursdays partly explains the observed increase in profitability. Hence, cycling markets appear to be beneficial for firms. As firms are able to increase markups for most days over time, they will gain in terms of volume-weighted gross margins regardless of when consumers purchase. Thus, another restoration day in the middle of the week shrinks the initial weekly low price window. This is in line with our preliminary findings in Section 5.

Lastly, we briefly pay attention to the effect of the wholesale price. The estimated coefficient on $pwhole$ lies between -0.131 and -0.151. Hence, increasing the wholesale price by 1% decreases gross margins by approximately 0.13%. This suggests that the change in the wholesale price is not perfectly passed through into retail prices. This may indicate that profitability in time-dependent markets is to a certain extent influenced by variable costs. As fluctuations in prices depend on the current day of the week, whereas the development in wholesale prices does not behave in a similar way, prices already more than account for the increase in costs. Hence, firms may trade off passing through the whole cost increase against maintaining the weekly cycle because the weekly price schedule is, overall, more gainful. Furthermore, our results provide indications of weak competition. If competition was aggressive, we would anticipate a full pass through of cost changes into prices and hence no effect on gross margins, as they already are at a restricted level.

6.2 The impact of consumer behavior on profitability

We now consider the impact of demand side variables by including these factors in our specification. First, we examine the measure of search behavior on where to buy. Results of the main model are presented in column (A) in Table 10, whereas the model in column (B) is presented for the sake of comparison.

As expected, the effect of $search$ is negative and significant at the 1% level, suggesting that increasing the share of searching consumers by 1% decreases firms' profitability by 0.5%. Search (where-) activity is hence unfavorable to sellers. An increased amount of search initiated by consumers increases consumers' knowledge about of prices.

Table 10: Regression results: Effect of $search$. Dependent variable is log of gross margin in NOK per liter.

	(A)	(B)	(C)	(D)
Search	-0.499***	-0.510***	-0.922***	-0.922***
	(0.094)	(0.093)	(0.126)	(0.127)
Search×post07			0.114***	0.110***
			(0.015)	(0.015)
Mon	0.354***	0.238***	0.356***	0.240***
	(0.026)	(0.051)	(0.026)	(0.051)
Tue	0.288***	0.268***	0.289***	0.269***
	(0.026)	(0.052)	(0.025)	(0.051)
Wed	0.186***	0.249***	0.186***	0.249***
	(0.026)	(0.052)	(0.026)	(0.051)
Thu	0.191***	0.059	0.178***	0.059
	(0.037)	(0.052)	(0.037)	(0.051)
Fri	0.119***	0.002	0.117***	0.000
	(0.029)	(0.056)	(0.029)	(0.056)
Sat	0.022	-0.076	0.021	-0.079
	(0.031)	(0.058)	(0.030)	(0.057)
Trend	0.000201***	0.000163***	0.000325***	0.000285***
	(0.000022)	(0.000027)	(0.000032)	(0.000036)
Thu×post07	0.060		0.086**	
	(0.037)		(0.037)	
Trend × Mon		0.000075***		0.000074***
		(0.000022)		(0.000021)
Trend × Tue		0.000013		0.000013
		(0.000026)		(0.000026)
Trend × Wed		-0.000039		-0.000039
		(0.000026)		(0.000025)
Trend × Thu		0.000103***		0.000103***
		(0.000023)		(0.000022)
Trend × Fri		0.000075***		0.000075***
		(0.000024)		(0.000024)
Trend × Sat		0.000063***		0.000063***
		(0.000024)		(0.000024)
Wholesale price	-0.369***	-0.361***	-0.125**	-0.123**
	(0.054)	(0.053)	(0.057)	(0.057)
Constant	-0.942***	-0.920***	-2.345***	-2.289***
	(0.216)	(0.217)	(0.339)	(0.342)
Observations	2,165	2,165	2,165	2,165
R-squared	0.252	0.268	0.265	0.280
Station FE	YES	YES	YES	YES

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Data period is 3 May 2004 to 31 October 2015.

Next, we elaborate on the effect of search in relation to the introduction of the Thursday restoration by including the interaction term $search \times post07$. This specification is presented in column (C). The coefficient of the $search$ variable is now almost doubled, indicating that a 1% increase in searching consumers decreases profitability by 0.92%. The effect is significant at the 1% level. However, the coefficient for $search \times post07$ is 0.114, which is positive and significant at the 1% level. This suggests that searching consumers were more unfavorable to retailers before the establishment of another restoration day. In fact, estimates indicate two potential features: In a situation with only Monday as a restoration day, increased consumer search activity is even worse for retailers. However, after the introduction of a second restoration day, which seems to suggest that consumers are exposed to more noise, search activity has less negative influence on retailers because they manage to confuse consumers with their price setting schedule. Hence, the Thursday restoration acts as obfuscation which makes consumers less informed.

Further, from model (D), which replaces $D_4 \times post07$ with a full set of interaction terms between the trend variable and the day-of-week dummies, we can confirm that gross margins have increased for most days of the week over time. The coefficients on $search$ and $search \times post07$ are similar to the former specification.

We now move on to examine the effect of consumers who follow a rule of thumb and make purchases close to the restoration, $timing$. The measure serves as a proxy for consumers who have learned the behavior of the present cycle and move their purchases to points in time with the lowest prices, regardless of station. Hence, when a consumer drops by a station it is due to convenience and not due to the particular station itself. Results are presented in Table 11 column (A). Column (B) includes interaction terms between the trend variable and day-of-week dummies instead of $D_4 \times post07$ for comparability.

The coefficient of $timing$ is 0.269 and significant at the 1% level, meaning that increasing the share of consumers who purchase close to the restoration by 1% increases profitability by 0.27%. One interpretation is that a sole adaptation to the cycle without participating in search is beneficial for sellers. Intuitively, consumer adjustment to predictable low price windows (more when-behavior) also makes consumers' purchasing behavior easily foreseeable for firms. Thus, sellers have less incentives to undercut each other as harsh price competition will not have a large impact on consumers' choice of station in the brief low price window since consumers' marginal cost of searching across stations has increased. In turn, competition is weakened and makes firms better off. Hence, this may explain the positive coefficient on $timing$. The effect is quite similar when including a full set of interaction terms between the trend variable and day-of-week dummies in column (B).

Table 11: Regression results: Effect of *timing*. Dependent variable is log of gross margin in NOK per liter.

	(A)	(B)	(C)	(D)
Timing	0.269***	0.289***	2.094***	2.117***
	(0.086)	(0.085)	(0.320)	(0.320)
Timing×post07			0.564***	0.563***
			(0.081)	(0.081)
Mon	0.355***	0.239***	0.356***	0.242***
	(0.026)	(0.052)	(0.026)	(0.051)
Tue	0.290***	0.271***	0.293***	0.278***
	(0.026)	(0.052)	(0.026)	(0.051)
Wed	0.187***	0.251***	0.189***	0.258***
	(0.027)	(0.053)	(0.026)	(0.051)
Thu	0.186***	0.062	0.178***	0.061
	(0.038)	(0.053)	(0.037)	(0.052)
Fri	0.120***	0.004	0.119***	0.004
	(0.030)	(0.057)	(0.029)	(0.056)
Sat	0.024	-0.073	0.023	-0.073
	(0.031)	(0.059)	(0.030)	(0.058)
Trend	0.000045**	0.000003	-0.000180***	-0.000222***
	(0.000019)	(0.000023)	(0.000044)	(0.000046)
Thu×post07	0.072*		0.088**	
	(0.038)		(0.037)	
Trend × Mon		0.000074***		0.000073***
		(0.000021)		(0.000021)
Trend × Tue		0.000012		0.000009
		(0.000026)		(0.000026)
Trend × Wed		-0.000040		-0.000043*
		(0.000025)		(0.000025)
Trend × Thu		0.000102***		0.000102***
		(0.000023)		(0.000023)
Trend × Fri		0.000074***		0.000074***
		(0.000024)		(0.000024)
Trend × Sat		0.000062**		0.000062**
		(0.000024)		(0.000024)
Wholesale price	-0.291***	-0.286***	0.058	0.063
	(0.058)	(0.058)	(0.058)	(0.057)
Constant	0.914***	1.012***	4.649***	4.750***
	(0.249)	(0.246)	(0.703)	(0.702)
Observations	2,165	2,165	2,165	2,165
R-squared	0.236	0.252	0.257	0.273
Station FE	YES	YES	YES	YES

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Data period is 3 May 2004 to 31 October 2015.

We now include the interaction term $timing \times post07$ for the sake of investigating the impact of the introduction of the Thursday peak. The coefficient of $timing$ is increased to a significant 2.094, and the coefficient for $timing \times post07$ is 0.564 and significant at the 1% level, meaning that the effect of consumers who adapt to the cycle is larger in magnitude after the introduction of another weekly peak. One interpretation is that the new pattern allows consumers to purchase cheaply in two periods rather than one during a week. Hence, there is now an additional window in which firms see no point in competing with each other. The total effect of timing may therefore increase due to impaired price dispersion twice a week.[38]

7 Robustness analysis and supplementary examination

This section presents additional results in the interest of investigating the robustness of our main findings.

7.1 Newey-West standard errors

One concern when working with long panels is that residuals are likely to be autocorrelated. Therefore, we begin by reporting Newey-West standard errors, allowing for seven lags due to the weekly pattern in prices.[39]

Overall, results presented in Table 12 show that the significance of coefficients is similar to the main results. Generally, standard errors of demand side coefficients are almost doubled. However, conclusions regarding significance remain unchanged. Standard errors of the day-of-week dummies are mostly slightly smaller. Major conclusions are unchanged.

7.2 Inclusion of $pwhole_{t-7}$ as explanatory variable

Whereas the wholesale price typically changes on a daily basis, the recommended price changes around once a week.[40] Recommended prices serve to represent the correct retail price when taking costs into account. As such, the wholesale price affects recommended prices and, in turn, retail prices with a fall-back over several periods. In this regard, we add dynamics to

[38] In models (C) and (D), the effect of trend becomes negative and significant, while the effect of the wholesale price becomes positive and insignificant. We do not have a proper explanation for this.

[39] The number of lags coincides with a rule-of-thumb given by the integer of $\sqrt[4]{n}$, for which n is the total number of observations (Baum, 2006, p.140).

[40] For one of the brands, during a nine week period in 2015, the recommended price changed ten times.

our specification by including the seventh lag of the wholesale price, $pwhole_{t-7}$, in favor of allowing the retail price and hence gross margins to adjust slowly to changes in costs.

Table 12: Regression results: Newey-West standard errors. Dependent variable is log of gross margin in NOK per liter.

	(A)	(B)	(C)	(D)	(E)	(F)
Search			-0.922***	-0.922***		
			(0.241)	(0.241)		
Search×post07			0.114***	0.110***		
			(0.027)	(0.027)		
Timing					2.094***	2.117***
					(0.604)	(0.606)
Timing×post07					0.564***	0.563***
					(0.151)	(0.152)
Mon	0.356***	0.241***	0.356***	0.240***	0.356***	0.242***
	(0.025)	(0.050)	(0.025)	(0.050)	(0.025)	(0.050)
Tue	0.291***	0.272***	0.289***	0.269***	0.293***	0.278***
	(0.024)	(0.049)	(0.024)	(0.048)	(0.024)	(0.049)
Wed	0.187***	0.252***	0.186***	0.249***	0.189***	0.258***
	(0.023)	(0.044)	(0.022)	(0.044)	(0.023)	(0.044)
Thu	0.176***	0.063	0.178***	0.059	0.178***	0.061
	(0.027)	(0.039)	(0.027)	(0.039)	(0.027)	(0.039)
Fri	0.120***	0.005	0.117***	0.000	0.119***	0.004
	(0.020)	(0.039)	(0.019)	(0.039)	(0.019)	(0.039)
Sat	0.024	-0.074**	0.021	-0.079**	0.023	-0.073**
	(0.015)	(0.032)	(0.015)	(0.031)	(0.015)	(0.031)
Trend	0.000102***	0.000064***	0.000325***	0.000285***	-0.000180**	-0.000222***
	(0.000012)	(0.000018)	(0.000060)	(0.000063)	(0.000083)	(0.000083)
Wholesale price	-0.151***	-0.131**	-0.125	-0.123	0.058	0.063
	(0.057)	(0.057)	(0.097)	(0.097)	(0.098)	(0.098)
Thu×post07	0.096***		0.086***		0.088***	
	(0.030)		(0.028)		(0.028)	
Constant	0.144*	0.178**	-2.345***	-2.289***	4.649***	4.750***
	(0.077)	(0.085)	(0.640)	(0.644)	(1.332)	(1.333)
Observations	2,165	2,165	2,165	2,165	2,165	2,165
Station FE	YES	YES	YES	YES	YES	YES
Interaction trend and day of week	NO	YES	NO	YES	NO	YES

Newey-West standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Data period is 3 May 2004 to 31 October 2015.

Table 13: Regression results: Inclusion of $pwhole_{t-7}$. Dependent variable is log of gross margin in NOK per liter.

	(A)	(B)	(C)	(D)	(E)	(F)
Search			-0.904***	-0.907***		
			(0.125)	(0.125)		
Search×post07			0.102***	0.097***		
			(0.014)	(0.014)		
Timing					2.203***	2.224***
					(0.301)	(0.301)
Timing×post07					0.580***	0.577***
					(0.075)	(0.074)
Mon	0.390***	0.333***	0.389***	0.331***	0.389***	0.333***
	(0.025)	(0.049)	(0.025)	(0.049)	(0.025)	(0.049)
Tue	0.311***	0.333***	0.311***	0.331***	0.312***	0.334***
	(0.027)	(0.056)	(0.026)	(0.054)	(0.026)	(0.054)
Wed	0.205***	0.301***	0.204***	0.300***	0.205***	0.302***
	(0.028)	(0.057)	(0.027)	(0.055)	(0.027)	(0.056)
Thu	0.165***	0.078	0.170***	0.073	0.171***	0.073
	(0.040)	(0.058)	(0.039)	(0.056)	(0.039)	(0.057)
Fri	0.138***	0.042	0.135***	0.037	0.136***	0.037
	(0.031)	(0.061)	(0.030)	(0.059)	(0.030)	(0.060)
Sat	0.051	-0.011	0.048	-0.016	0.049	-0.015
	(0.032)	(0.063)	(0.031)	(0.061)	(0.031)	(0.061)
Trend	0.000094***	0.000076***	0.000309***	0.000288***	-0.000208***	-0.000232***
	(0.000009)	(0.000019)	(0.000033)	(0.000038)	(0.000042)	(0.000043)
Thu×post07	0.128***		0.113***		0.113***	
	(0.038)		(0.038)		(0.038)	
Wholesale price t	-1.289***	-1.261***	-1.270***	-1.258***	-1.211***	-1.197***
	(0.163)	(0.162)	(0.157)	(0.156)	(0.160)	(0.158)
Wholesale price t-7	1.145***	1.144***	1.113***	1.105***	1.254***	1.248***
	(0.168)	(0.167)	(0.169)	(0.168)	(0.164)	(0.162)
Constant	0.146***	0.139**	-2.247***	-2.233***	4.929***	4.995***
	(0.048)	(0.059)	(0.330)	(0.334)	(0.669)	(0.667)
Long run effect of Wholesale price	-0.144***	-0.117***	-0.158***	-0.153**	0.043	0.050
	(0.035)	(0.034)	(0.061)	(0.061)	(0.059)	(0.058)
Observations	1,951	1,951	1,951	1,951	1,951	1,951
R-squared	0.267	0.281	0.307	0.322	0.301	0.316
Station FE	YES	YES	YES	YES	YES	YES
Interaction, trend and day of week	NO	YES	NO	YES	NO	YES

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Data period is 3 May 2004 to 31 October 2015.

Results are reported in Table 13. We will pay attention to the model in column (A), keeping in mind that estimates are quite similar for all models. The coefficient on $pwhole_t$ is -1.289, while the coefficient on $pwhole_{t-7}$ is 1.145. The instant effect of the wholesale price on firms' profitability is negative, as 1% increase lowers gross margins by 1.27%. However, taking slow adjustment into account, the long-run effect is reduced to -0.14%. By comparing the estimates with the coefficient of -0.15 in Table 9 column (B), the long-run effect corresponds well to our main findings.[41] From columns (C) and (D), we note that adding $pwhole_{t-7}$ to the specification lowers the magnitude of $search$ and $search \times post07$ slightly. On the other hand, the coefficients of $timing$ and $timing \times post07$ in columns (E) and (F) increase slightly. In sum, results do not differ much from the main models. The size of the coefficient on $D_4 \times post07$ is 0.128 in column (B) compared to 0.096 in the leading results. Overall, estimates are much the same as in the main models.[42]

8 Concluding remarks

We empirically examine the impact of time-dependent price patterns on consumer behavior and firms' profitability. The Norwegian retail gasoline market is a picture perfect application. Since 2004, we have observed a regular weekly price pattern with a saw-tooth shape. On Mondays around noon all the four major retail chains increase their retail prices to the recommended price. The retail chains decide their recommended prices in advance, and publish recommended prices on their websites. Consequently, each retail chain knows when to raise the price, and to what level. Moreover, they are immediately able to observe should a rival deviate from the established practice.

In local markets with high concentration (long distance between competing outlets), retail prices are equal to the recommended prices throughout the week. Therefore, we consider the level of recommended prices as a measure of the monopoly price. In less concentrated areas, firms undercut each other during the rest of the week, such that the price level is regularly at its lowest on Monday morning. Since 2008, retail chains have managed to introduce another day off from competition on Thursdays. Like on Mondays, there is now an industry-wide synchronization of retail prices to the level of the recommended prices on Thursdays.

We combine panel data on supply side measures and survey data containing information on consumer behavior with a time span between 2004 and 2015. This allows us to scrutinize the interplay between firms' and consumers behavior. Consumers face a menu of prices depending on when they buy. With a given capacity of effort, there are typically larger savings

[41] An F-test rejects the null hypothesis of the long run effect being equal to 0.

[42] To account for potential inertia of profitability we also estimated models where we allowed for an AR(1) process, including yesterday's gross margin. The AR(1) term is significant, and the weekly pattern is still present with highest margins on Monday and Thursday in our preferred model. The trend is still positive and significant. The wholesale price is negative and in the same range as before in the models without demand controls.

to gain by using effort on timing of when to buy rather than on where to buy. As expected, we find that conventional price search on where to buy reduces firms' profitability. In contrast, consumers who are aware of the cycle and act by when to make their purchases have a positive impact on firms' profitability. For consumers in a market with a predictable cycle, it might be rational to adopt to a simple rule of thumb: tank on Sunday or on Monday morning. However, competition among sellers are highly driven by price search. Consequently, if consumers (rationally) spend their effort on when to buy rather than on where to buy, price competition might be softened (even in the in low-price windows). For policy makers and consumer associations this creates a difficult trade-off when advising consumers. On the one hand, there are huge savings for consumers if they adapt to the pattern and tank gasoline in the weekly low-price windows. On the other hand, if more consumers, by for instance adapting to a rule of thumb, pay less attention to where to buy, retailers lose incentives to compete aggressively. In this respect, the weekly price pattern has been given a great deal of media coverage since it was initiated in 2004.

References

Baum, C. F. (2006). *An Introduction to Modern Econometrics Using Stata*. Stata press.

Baye, M. R., Morgan, J., & Scholten, P. (2006). Information, Search, and Price Dispersion. *Handbook on Economics and Information Systems*, 1, 323-375.

Bresnahan, T. F. & Reiss, P. C. (1991). Entry and Competition in Concentrated Markets. *Journal of Political Economy*, 99(5), 977-1009.

Byrne, D. P. & De Roos, N. (2015). Consumer search in retail gasoline markets. *Available at SSRN 2427556.*

Carlin, B. I. (2009). Strategic price complexity in retail financial markets. *Journal of financial Economics*, 91(3), 278-287.

Chioveanu, I. & Zhou, J. (2013). Price Competition with Consumer Confusion. *Management Science*, 59(11), 2450-2469.

Conlisk, J., Gerstner, E., & Sobel, J. (1984). Cyclic Pricing by a Durable Goods Monopolist. *The Quarterly Journal of Economics*, 99(3), 489-505.

De Roos, N. & Smirnov, V. (2015). Collusion with Intertemporal Price Dispersion. *Available at SSRN: http://ssrn.com/abstract=2575947*.

Dewenter, R. & Heimeshoff, U. (2012). Less Pain at the Pump? The Effects of Regulatory Interventions in Retail Gasoline Markets. *DICE Discussion paper, NO. 51.*

Diamond, P. A. (1971). A model of price adjustment. *Journal of Economic Theory*, 3(2), 156-168.

Dutta, P., Matros, A., & Weibull, J. W. (2007). Long-run price competition. *The RAND Journal of Economics*, 38(2), 291-313.

Eckert, A. (2003). Retail price cycles and the presence of small firms. *International Journal of Industrial Organization*, 21(2), 151-170.

Eckert, A. (2013). Empirical studies of gasoline retailing: A guide to the literature. *Journal of Economic Surveys*, 27(1), 140-166.

Eckert, A. & West, D. S. (2004). Retail Gasoline Price Cycles across Spatially Dispersed Gasoline Stations. *The Journal of Law and Economics*, 47(1), 245-273.

Edgeworth, F. (1925). The Pure Theory of Monopoly. *Papers Relating to Political Economy*, 1, 111-142.

Ellison, G. & Ellison, S. F. (2009). Search, Obfuscation, and Price Elasticities on the Internet. *Econometrica*, 77(2), 427-452.

Ellison, G. & Wolitzky, A. (2012). A search cost model of obfuscation. *The RAND Journal of Economics*, 43(3), 417-441.

Foros, Ø. & Steen, F. (2013). Vertical Control and Price Cycles in Gasoline Retailing. *The Scandinavian Journal of Economics*, 115(3), 640-661.

Haucap, J., Heimeshoff, U. & Siekmann, M. (2015). Price Dispersion and Station Heterogeneity on German Retail Gasoline Markets. *DICE Discussion Paper, No. 171*.

Judson, R. A. & Owen, A. L. (1999). Estimating dynamic panel data models: a guide for macroeconomists. *Economics Letters*, 65(1), 9-15.

Lewis, M. S. (2012). Price leadership and coordination in retail gasoline markets with price cycles. *International Journal of Industrial Organization*, 30(4), 342-351.

Maskin, E. & Tirole, J. (1988). A Theory of Dynamic Oligopoly, ii: Price Competition, Kinked Demand Curves, and Edgeworth Cycles. *Econometrica*, 56(3), 571-599.

Noel, M.D. (2016). Retail Gasoline Markets. In E. Basker (Ed.), *Handbook on the Economics of Retailing and Distribution*. Edward Elgar Publishing.

Noel, M. D. (2007). Edgeworth Price Cycles, Cost-Based Pricing, and Sticky Pricing in Retail Gasoline Markets. *The Review of Economics and Statistics*, 89(2), 324-334.

Noel, M. D. (2008). Edgeworth Price Cycles and Focal Prices: Computational Dynamic Markov Equilibria. *Journal of Economics & Management Strategy*, 17(2), 345-377.

Noel, M. D. (2012). Edgeworth price cycles and intertemporal price discrimination. *Energy Economics*, 34(4), 942-954.

Norwegian Competition Authority (2014). The Retail Gasoline Market in Norway - Increase in Margin and New Price Peak.

Norwegian Competition Authority (2015). Decision Spring 2015 - St1 Nordic OY - Smart Fuel AS.

Piccione, M. & Spiegler, R. (2012). Price Competition Under Limited Comparability. *The Quarterly Journal of Economics*, 127(1), 97-135.

Salop, S. & Stiglitz, J. (1977). Bargains and Ripos: A Model of Monopolistically Competitive Price Dispersion. *The Review of Economic Studies*, 44493-510.

Sobel, J. (1984). The Timing of Sales. *The Review of Economic Studies*, 51(3), 353-368.

Stahl, D. O. (1989). Oligopolistic Pricing with Sequential Consumer Search. *The American Economic Review*, 79(4), 700-712.

Stigler, G. J. (1961). The Economics of Information. *Journal of Political Economy*, 69(3), 213-225.

Tellis, G. J. (1986). Beyond the Many Faces of Price: An Integration of Pricing Strategies. *The Journal of Marketing*, 50(4), 146-160.

Varian, H. R. (1980). A Model of Sales. *The American Economic Review*, 70(4), 651-659.

Waddams, C. & Wilson, C. (2010). Do consumers switch to the best supplier? *Oxford Economic Papers*, 62(4), 647-668.

Wang, Z. (2009). (Mixed) Strategy in Oligopoly Pricing: Evidence from Gasoline Price Cycles Before and Under a Timing Regulation. *Journal of Political Economy*, 117(6), 987-1030.

Wilson, C. M. (2010). Ordered search and equilibrium obfuscation. *International Journal of Industrial Organization*, 28(5), 496-506.

Woodward, S. E. & Hall, R. E. (2012). Diagnosing Consumer Confusion and Sub-Optimal Shopping Effort: Theory and Mortgage-Market Evidence. *The American Economic Review*, 102(7), 3249-3276.

Zhang, X. & Feng, J. (2005). Price Cycles in Online Advertising Auctions. *ICIS 2005 Proceedings*, 61, 769-781.

Appendices

A Panel data

Table A.1: Overview of gasoline stations and data periods.

Station	Brand	Data periods
1	Esso	03.05.2004-30.11.2004*
		12.02.2005-23.03.2005*
2	Hydro Texaco	23.01.2005-01.05.2005
		13.05.2005-17.05.2005
3	Hydro Texaco	03.05.2004-30.11.2004*
		10.02.2005-23.03.2005*
4	Hydro Texaco	31.01.2005-03.07.2005
		28.01.2008-21.07.2008
5	Statoil	23.01.2005-01.05.2005
		13.05.2005-26.06.2005
		28.01.2008-21.07.2008
6	Statoil	23.01.2005-03.07.2005
		17.10.2005-15.03.2006
		28.01.2008-21.07.2008
		22.06.2015-16.08.2015
		02.09.2015-31.10.2015
7	Statoil	20.06.2004-30.11.2004*
		15.02.2005-17.02.2005*
		17.10.2005-15.03.2006
		28.01.2008-21.07.2008
		02.09.2015-31.10.2015
8	Statoil	16.05.2004-30.11.2004*
		22.03.2005
9	Shell	08.05.2004-20.10.2004*
		09.03.2005-23.03.2005*
10	Shell	17.10.2005-15.03.2006
		28.01.2008-21.07.2008
11	Hydro Texaco	02.07.2004-16.11.2004*

Periods with the asterisk * are non-consecutive.

Table A.2: Summary statistics. Data period is 3 May 2004 to 31 October 2015.

	Mean	Std. dev.	Min	Max
2004				
Price	12.079	0.541	10.689	12.718
Wholesale price	2.639	0.173	2.289	2.930
Tax	5.806	0.000	5.806	5.806
VAT	2.416	0.108	2.138	2.544
Gross margin	1.218	0.423	0.171	1.952
2005				
Price	12.543	0.650	10.830	14.000
Wholesale price	2.812	0.306	2.254	3.450
Tax	5.837	0.023	5.820	5.869
VAT	2.509	0.130	2.166	2.800
Gross margin	1.386	0.388	0.380	2.051
2006				
Price	12.839	0.506	11.603	13.745
Wholesale price	3.276	0.152	2.917	3.555
Tax	5.819	0.000	5.819	5.819
VAT	2.568	0.101	2.321	2.749
Gross margin	1.176	0.442	0.078	1.982
2008				
Price	14.487	0.696	12.517	15.869
Wholesale price	4.362	0.516	3.533	5.293
Tax	5.821	0.018	5.814	5.871
VAT	2.897	0.139	2.503	3.174
Gross margin	1.407	0.291	0.539	2.109
2015				
Price	14.006	0.915	11.990	15.980
Wholesale price	3.484	0.476	2.818	4.612
Tax	5.820	0.000	5.820	5.820
VAT	2.801	0.183	2.398	3.196
Gross margin	1.901	0.578	0.486	2.945
Total				
Price	13.455	1.157	10.689	15.980
Wholesale price	3.530	0.821	2.254	5.293
Tax	5.826	0.020	5.806	5.871
VAT	2.691	0.231	2.138	3.196
Gross margin	1.407	0.414	0.078	2.945

All values are in real NOK per liter.

Table A.3: Mean retail price by day of the week and year. Data period is 3 May 2004 to 31 October 2015.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
2004							
Mean	11.780	12.265	12.501	12.167	11.983	11.608	12.260
Std.dev.	0.715	0.237	0.141	0.505	0.593	0.647	0.273
Min	10.812	11.931	12.288	11.058	10.689	10.812	11.956
Max	12.558	12.718	12.718	12.583	12.558	12.288	12.718
2005							
Mean	12.846	12.701	12.549	12.572	12.434	12.366	12.335
Std.dev.	0.492	0.568	0.680	0.645	0.636	0.671	0.689
Min	11.084	11.072	11.120	11.120	11.120	10.830	10.830
Max	14.000	13.564	13.782	13.782	13.600	13.661	13.661
2006							
Mean	13.393	13.028	12.883	12.718	12.744	12.534	12.525
Std.dev.	0.290	0.378	0.347	0.474	0.506	0.484	0.454
Min	12.293	12.174	12.174	11.722	11.662	11.603	11.603
Max	13.745	13.518	13.316	13.602	13.685	13.447	13.447
2008							
Mean	14.713	14.623	14.527	14.561	14.441	14.325	14.216
Std.dev.	0.643	0.608	0.608	0.653	0.714	0.762	0.750
Min	13.395	13.532	13.418	12.950	12.517	12.517	12.517
Max	15.846	15.812	15.869	15.869	15.869	15.846	15.846
2015							
Mean	14.846	14.130	13.431	14.632	14.028	13.635	13.394
Std.dev.	0.602	0.990	0.859	0.681	0.719	0.694	0.720
Min	14.010	12.115	11.990	13.290	12.020	11.990	11.990
Max	15.830	15.880	14.680	15.980	15.780	15.220	14.780

All values are in real NOK per liter.

Table A.4: Mean gross margin by day of the week and year. Data period is 3 May 2004 to 31 October 2015.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
2004							
Mean	1.048	1.465	1.459	1.263	1.151	0.790	1.280
Std.dev.	0.545	0.170	0.274	0.370	0.540	0.417	0.098
Min	0.299	1.139	1.197	0.442	0.171	0.274	1.113
Max	1.588	1.717	1.952	1.607	1.896	1.294	1.439
2005							
Mean	1.636	1.521	1.403	1.406	1.283	1.228	1.223
Std.dev.	0.285	0.349	0.361	0.382	0.377	0.384	0.386
Min	0.486	0.380	0.606	0.525	0.525	0.501	0.501
Max	2.051	1.997	1.968	2.029	1.956	1.956	1.939
2006							
Mean	1.604	1.327	1.232	1.110	1.085	0.918	0.917
Std.dev.	0.289	0.351	0.289	0.423	0.468	0.434	0.410
Min	0.594	0.449	0.717	0.315	0.126	0.078	0.078
Max	1.961	1.822	1.613	1.982	1.924	1.734	1.734
2008							
Mean	1.590	1.539	1.433	1.471	1.363	1.269	1.182
Std.dev.	0.220	0.214	0.245	0.261	0.277	0.289	0.293
Min	0.673	0.624	0.708	0.605	0.635	0.635	0.539
Max	2.048	1.999	1.999	1.950	2.109	1.991	1.991
2015							
Mean	2.560	1.985	1.436	2.416	1.929	1.615	1.405
Std.dev.	0.255	0.531	0.434	0.424	0.417	0.333	0.365
Min	1.874	0.486	0.582	0.869	0.900	0.876	0.876
Max	2.893	2.714	2.169	2.945	2.481	2.194	2.554

All values are in real NOK per liter.

B Survey data

B.1 Survey Questionnaire

1. Type of fuel

1. Unleaded gasoline 95: ___________
2. Unleaded gasoline 98: ___________
3. Diesel: ___________
4. Other: ___________

2. How often do you purchase gasoline?

1. 4 times or more per month: ___________
2. 2-4 times per month: ___________
3. Once per month or less: ___________

3. How often do you think that the retail price changes?

1. Several times per day: ___________
2. Once per day: ___________
3. Every 2nd or 3rd day: ___________
4. Every 7th day or less: ___________
5. Do not know: ___________

4. Do you think the retail price increases on specific days of the week?

1. Yes: ___________
2. No: ___________ (Go to Question 7)
3. Do not know: ___________

5. If yes on Question 4, which days?

Sunday : ___________

Monday: ___________

Tuesday: ___________

Wednesday: ___________

Thursday: ___________

Friday : ___________

Saturday: ___________

Sunday: ___________

6. If yes on Question 4, how often do you take this into account when making purchases?

(Very often) 1 2 3 4 5 (Very seldom)

7. How often do you fill full tank?

(Very often) 1 2 3 4 5 (Very seldom)

8. Where do you purchase gasoline?

1. At the same station every time: ___________
2. At 2 or 3 different stations: ___________
3. At more than 3 different stations: ___________

9. How far do you drive per year?_______ km

10. Where do you check the retail price?

1. Do not check the price: ___________
2. Check on the pump: ___________
3. Check on the sign outside station: ___________
4. Other: ___________

11. Do you observe a weekly price pattern – if so, which? ___________

Gender:

Male: ___________

Female: ___________

Age:

18-24: ___________

25-34: ___________

35-45: ___________

45-66: ___________

Over 66: ___________

B.2 Questionnaire Overview

Table B.1: Overview of station, date of survey and number of respondents.

Name	Brand	Date of survey	Day of week	Number of respondents
Hydro Texaco Tertnes	Hydro Texaco	29.04.2005	Friday	39
		06.06.2005	Monday	29
		10.06.2005	Friday	49
		30.03.2006	Thursday	30
		03.04.2006	Monday	33
		04.02.2008	Monday	50
		07.02.2008	Thursday	39
Statoil Helleveien	Statoil	25.04.2005	Monday	47
		29.04.2005	Friday	44
		06.06.2005	Monday	42
		10.06.2005	Friday	39
		30.03.2006	Thursday	50
		03.04.2006	Monday	38
		04.02.2008	Monday	78
		07.02.2008	Thursday	58
		21.09.2015	Monday	58
		24.09.2015	Thursday	49
		28.09.2015	Monday	48
		01.10.2015	Thursday	47
Sum				867

Table B.2: How often do you think the retail price changes?

	Several times during a day	Once a day	Every 2nd or 3rd day	Every 7th day or Less	Do not know
2005 (289)	18 %	31 %	31 %	10 %	0 %
2006 (151)	24 %	22 %	30 %	18 %	0 %
2008 (225)	13 %	27 %	20 %	16 %	24 %
2015 (202)	23 %	19 %	32 %	8 %	18 %

Numbers in parentheses are total number of respondents by year. Shares not summing to 100% are due to non-response.

Table B.3: How often do you fill full tank?

	Very often	Fairly often	Neither	Fairly seldom	Very seldom
2005 (289)	44 %	13 %	11 %	8 %	11 %
2006 (151)	56 %	9 %	14 %	9 %	11 %
2008 (225)	59 %	8 %	8 %	8 %	16 %
2015 (202)	65 %	9 %	13 %	2 %	11 %

Numbers in parentheses are total number of respondents by year. Shares not summing to 100% are due to non-response.

Table B.4: Where do you purchase gasoline?

	Same station every time	2 or 3 different stations	More than 3 different stations
2005 (289)	37 %	31 %	26 %
2006 (151)	30 %	42 %	27 %
2008 (225)	44 %	34 %	22 %
2015 (202)	29 %	36 %	36 %

Numbers in parentheses are total number of respondents by year. Shares not summing to 100% are due to non-response.

Table B.5: Summary statistics.

	Mean	Std.dev	Min	Max
Timing	0.163	0.050	0.110	0.270
Search	0.090	0.025	0.080	0.170
Purchase at the same station	0.385	0.053	0.290	0.440
Purchase at more than 3 stations	0.253	0.038	0.220	0.360
Check price on the sign outside station	0.381	0.086	0.310	0.600
Retail price increases on specific days of the week	0.469	0.130	0.350	0.810
Fill full tank very often	0.530	0.078	0.440	0.650

C Cross-sectional data

Table C.1: Levene's test and Brown-Forsythe test for the equality of variances for real gross margins in 2008 and 2015.

	Levene	Brown-Forsythe
8 a.m.	55.353***	31.303***
2 p.m.	0.226	0.557

H_0: Population variances are equal. H_1: Populations variances are different. Values are test statistics. Degrees of freedom are (1, 85). *** p<0.01, ** p<0.05, * p<0.1.

Table C.2: Two-sample t test with for real gross margins in 2008 and 2015.

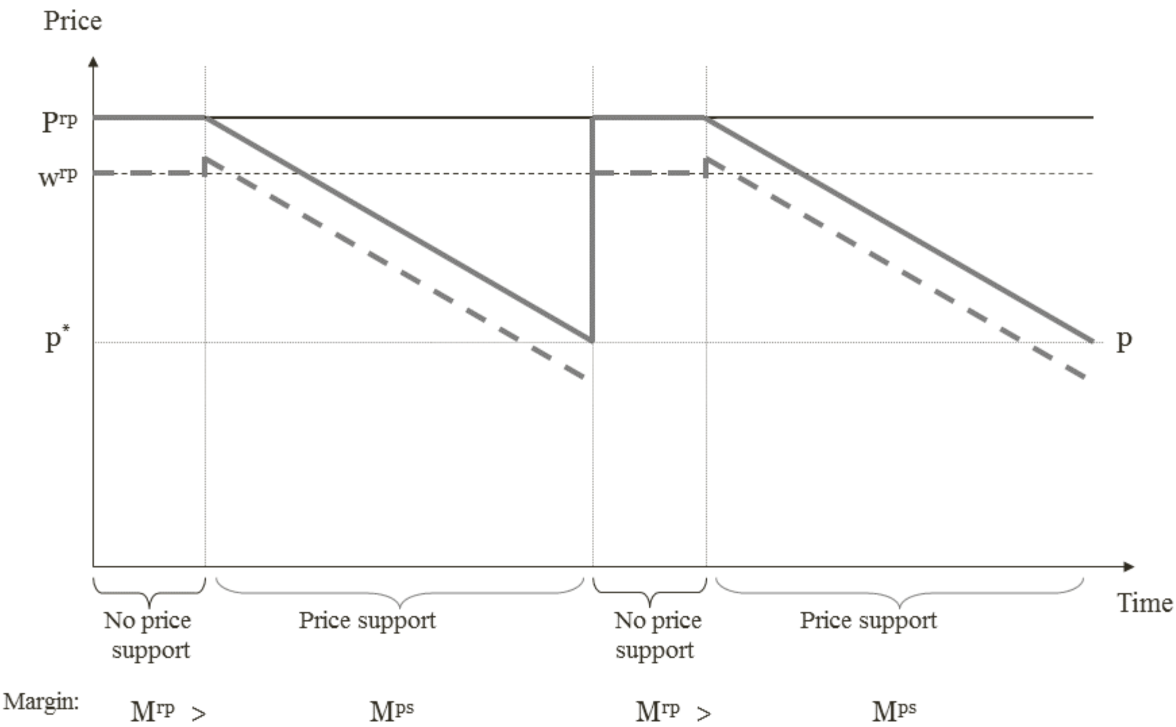
	Variance assumption	Test statistics	Degrees of freedom
8 a.m.	Unequal	-20.090***	59.086 1
2 p.m.	Equal	-71.160***	85

H_0: Population means are equal. H_1: Populations means are different. Values are test statistics. [1]Degrees of freedom are of Satterthwaite's type. *** p<0.01, ** p<0.05, * p<0.1.

D Retail price determination

Our research question heavily relies on the calendar based price cycle recognized in the Norwegian market. A theoretical framework illustrating the observed price behavior is given in Foros & Steen (2013), which suggests an explanation to how headquarters of gasoline companies manage to simultaneously increase retail prices to the recommended prices published online even for vertically separated outlets. This arrangement is depicted in Figure D.1.

Figure D.1 Price support arrangements in the retail gasoline market.



The upstream firm establishes a profit-sharing scheme consisting of two parts, dividing the margin $p - c$ per liter of gasoline between itself and the downstream firm, where p is the retail price and c is the upstream firm's input price, respectively.

A maximum retail price maintenance (RPM hereafter) equal to the recommended price p^{rp} is introduced in the first part of the agreement. If the retailer sets his price equal to the maximum RPM, the upstream firm charges him a wholesale price w^{rp} where $w^{rp} < p^{rp}$, leaving the retailer with a margin $M^{rp} = p^{rp} - w^{rp}$ per liter sold. The wholesale price exceeds the cost per liter of gasoline c, such that the upstream firm also receives a strictly positive profit. This part of the agreement is at disposal during the entire week.

The second part is called price support, in which the retailer receives a margin $M^{ps} < M^{rp}$ if he sets the retail price below the maximum RPM. In contrast to the first part of the scheme, the upstream firm decides when the price support is in force.

Therefore, if the upstream firm chooses w^{rp} so as to induce the retailer to set $p = p^{rp}$ when the price support is inoperative, the profit sharing scheme essentially induces falling prices due to competition during the price support interrupted by immediate restorations when the support is withdrawn. Hence, theory suggests that symmetric cycles may be a result of the four upstream firms simultaneously deciding to disengage the price support on Mondays and Thursdays each week. Retailers are then effectively forced to set price equal to the recommended price in order to avoid negative margins. Price competition among sellers are thus only possible when the price support is in force, unless they want to operate with losses. Since the recommended prices across companies are close to identical, a deviation of a firm from the pricing rule will immediately be discovered by its rivals. Consequently, the arrangement entails an effective commitment to having identical prices as the rivals twice a week.

11/17

ARBEIDSNOTAT
WORKING PAPER

The Effects of a Day Off from Retail Price Competition: Evidence on Consumer Behavior and Firm Performance in Gasoline Retailing

Øystein Foros
Mai Thi Nguyen
Frode Steen

SNF

Samfunns- og næringslivsforskning AS
Centre for Applied Research at NHH