Joint Discussion Paper Series in Economics

by the Universities of

Aachen · Gießen · Göttingen
Kassel · Marburg · Siegen

ISSN 1867-3678

No. 13-2019

Samuel de Haas

Do pump prices really follow Edgeworth cycles? Evidence from the German retail fuel market

Coordination: Bernd Hayo • Philipps-University Marburg
School of Business and Economics • Universitätsstraße 24, D-35032 Marburg
Tel: +49-6421-2823091, Fax: +49-6421-2823088, e-mail: hayo@wiwi.uni-marburg.de

Do pump prices really follow Edgeworth cycles? Evidence from the German retail fuel market

Samuel de Haas*

March 21, 2019

Abstract

Most of the literature on retail fuel markets find high-frequency and asymmetric price cycles. This is typically explained by the model of Edgeworth price cycles. A key element of this model is that prices fall to marginal costs during a cycle. It seems challenging to address this assumption empirically. However, I use a natural experiment in the German fuel market to analyze the effects of an external cost shock. I find strong evidence that prices do not fall to marginal costs. This is not in line with Edgeworth cycles and thus, should be taken into account when analyzing fuel markets.

JEL codes: L11, L81, L91, K21, Q41
Keywords: Edgeworth price cycles, Retail gasoline, Price effects, Natural experiment, Coordination

*Chair for Industrial Organization, Regulation and Antitrust, Department of Economics, Justus-Liebig-University Giessen - Licher Strasse 62, 35394 Giessen, Germany. E-mail: samuel.de-haas@wirtschaft.uni-giessen.de, Phone: +49-641-9922057.

1 Introduction

In many countries retail fuel prices follow high-frequency and asymmetric cycles. During these recurring cycles, prices can rise and fall about 5% - 10% within hours. The cycles repeat over and over even in the absence of any changes in wholesale prices. (Noel, 2015) There are only a few markets with similar price patterns.[1] Thus, retail fuel markets and their prices have been subject to public discussion for decades.

Most of the related literature tries to explain these typical price developments by the theory of Edgeworth price cycles.[2] The baseline model of this theory assumes a dynamic oligopoly game where firms compete in prices when selling homogeneous goods. The described price cycle is a possible Nash equilibrium when firms play Markov strategies. (Maskin and Tirole, 1988)

The standard model assumes that firms, starting from prices relatively high above marginal cost, alternately and repeatedly take turns in undercutting one anothers price by the smallest possible amount. Assuming homogeneous goods, this is sufficient to steal total market demand. A key result of the standard model is that undercutting continues until prices equal marginal costs. Given that there is no gain to lowering prices further, firms play a war of attrition. Each firm mixing between a higher price and maintaining the price equal to marginal costs. When one firm increases its price to a much higher level, the other follows, and a new round of undercutting begins.(Noel et al., 2011) Thereby, the theoretical results are robust to varying and uncertain marginal costs as well as to demand fluctuations.(Noel, 2008) These kind of price cycles are often found in retail fuel markets as discussed e.g. by Eckert and West (2004) and Noel (2007).

Former research also analyzed the effects of cost shocks on fuel prices.(e.g. Noel (2009) and Noel (2015)) However, these analyses mainly focused on potentially asymmetric passthrough of increasing and decreasing costs, respectively: While fuel prices increase

[1] E.g. Zhang and Feng (2005) found similar price cycles in keyword advertising auctions.

[2] A good overview of related literature is given by Noel et al. (2011).

promptly whenever prices of inputs increase, they decrease slowly after input price decreases. ('rockets and feathers').

Byrne and De Roos (2019) and Foros and Steen (2013) also analyzed retail fuel markets. In contrast to the literature mentioned above, however, they find evidence for collusion in the underlying markets. While the former analysis was using Australian data and is based on descriptive statistics only, the latter one used Norwegian data. Note that the four big gasoline companies in Norway use a vertical restraint that is adopted industry-wide (labeled price support). Therefore, the analysis of this market cannot readily be generalized to other markets.

Siekmann (2017), Linder et al. (2018) and Haucap et al. (2017) analyzed the German retail fuel market. They find a oligopoly of five members dominating the market.[3] Price patterns in Germany are similar to the ones mentioned above for other countries. Particular, they explain their findings by Edgeworth cycles (at least for most of the time). However, they find that the cycles are of a higher frequency as assumed in former literature. The typical price cycle in Germany is within one day rather than within the order of a week or similar.

In the present analysis a natural experiment is used to address the question if price patterns in retail fuel markets really can be explained by the standard model of Edgeworth cycles. I analyze hourly pump prices of stations in Cologne and Hamburg during the period of June 1, 2018 until December 31, 2018. During the observation period the water of the Rhine river fell to historically low levels. Given that tank farm logistics in the Cologne area are dependent on shipment via the Rhine, transport costs increased significantly during the low water period. In contrast, tank farms surrounding Hamburg were not affected by this cost shock. By using a difference-in-differences analysis, effects are isolated. The results suggest that observed price cycles in retail fuel markets are not in line with the standard theory of Edgeworth cycles. This should be taken into account when analyzing fuel markets.

[3] Shell, BP/Aral, Esso, Total and Jet (Conoco) have together market shares of about two thirds.

2 Data and Methodology

The analysis is based on data from the 'Markttransparenzstelle für Kraftstoffe' (market transparency unit for fuels, MTS-K). The MTS-K is an independent unit of the German competition authority and was established in 2013. Since then, all petrol stations in Germany are legally bound to inform the MTS-K about price changes in real time.[4] The data set includes hourly data on prices of all petrol stations in Cologne (115) and Hamburg (214) during the period from June 1 to December 31, 2018. Additionally, I use daily data on the average water level of the Rhine and the prices for Brent crude oil during this period.[5]

As described above, I use a natural experiment to analyze a cost shock on pump prices, i.e., the extreme low water levels of the Rhine river in late autumn of 2018. While the two refineries in Cologne are supplied with crude oil by a pipeline from Rotterdam, the further transport to surrounding tank farms is mainly processed by ship. Due to the limited inland navigation on the Rhine, this further transport had to switch to railroad and trucks during the low water period. These adjustments in the logistic chain corresponded to higher transport costs.[6] In contrast, the two refineries in Hamburg and surrounding tank farms are located at the Elbe river, that was not affected by low water levels because it is not far from the Baltic Sea. Thus, transport costs of petrol stations in Hamburg should not be affected by the low water levels of the Rhine river.

In the following analysis the low water level period is defined by a Rhine water level below one meter at station Cologne.[7] Thus, the observation period can be divided into three parts:

1. June 1, 2018 - October 11, 2018: Control period (normal water levels)

2. October 12, 2018 - December 2, 2018: Treatment period (low water levels, 'LW')

[4]For more information see MTS-K website: https://goo.gl/hF3niN (last accessed on March 11, 2019)

[5]These data are publicly available by the German administration for waterways (WSV): https://goo.gl/uUVN5u (last accessed on March 11, 2019.)

[6]For more information see press release of the German petroleum association (MWV e.V.): https://goo.gl/D5AAF6 (last accessed on March 11, 2019.)

[7]Such water levels are very rare as discussed in more detail in de Haas et al. (2019).

3. December 3, 2018 - December 31, 2018: After treatment period (after low water levels, possible adjustments, 'ALW')

For the empirical analysis I use a difference-in-differences approach: Beside the treatment periods the petrol stations are divided by their locations into two groups. If a petrol station is located in Cologne it belongs to the treatment group ('CG'), if it is located in Hamburg it belongs to the control group ('HH'). As described above, I include the logarithm of the daily Brent crude oil price in the regression.[8] Thus, I can control for the main cost driver beside the transport costs. To control for the well known price cycles during a day and a week, respectively, I include dummies for each day of the week and each hour. I also include brand dummies[9] to control for corresponding effects.(Siekmann, 2017) Additionally I control for possible effects due to holidays by including an appropriate dummy.

When other exogenous effects are controlled for, one would expect increasing fuel prices in Cologne during the low water period, but no direct effects on prices in Hamburg. This is based on the fact, that filling stations in Cologne purchase their fuels from tank farms located at the Rhine river and thus, are probably affected by higher transport costs. Filling stations in Hamburg, instead, purchase from tank farms located in Hamburg that are not affected by the low water levels. The price developments are illustrated in figure 1.[10] To test this hypothesis empirically a difference-in-differences regression is performed. The structural equation of the baseline model takes the following form:

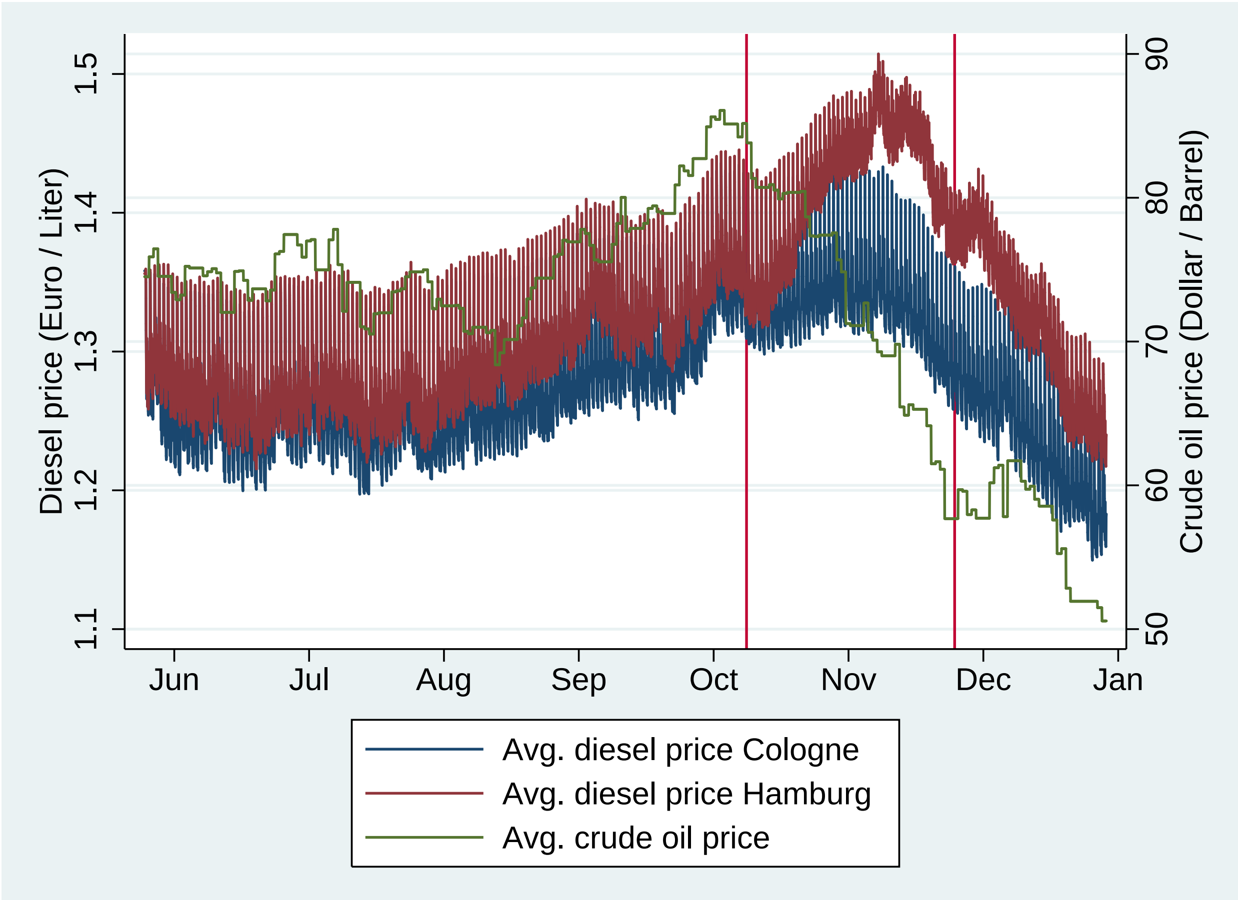
$$\begin{aligned} p_{i,t} = c + \beta_1 \ln Oil_t + \beta_2 D_{CG,i} + \beta_3 D_{LW,t} + \beta_4 D_{ALW,t} + \beta_5 D_{CG,i} D_{LW,t} + \beta_6 D_{CG,i} D_{ALW,t} \\ + \beta_7 D_{Holiday,t} + X_{Brand,i}\gamma_1 + X_{Day,t}\gamma_2 + X_{Hour,t}\gamma_3 + \epsilon_{i,t} \end{aligned} \quad (1)$$

[8]Former research showed that crude oil prices effect pump prices with a certain delay. (e.g. Bacon (1991)) Thus, I use the daily average crude oil price three days before the respective pump price observations in the analyses. However, the results of the present analyses are robust when varying the period of delay (0, 1, 5 or 10 days).

[9]All petrol stations not operated by one of the above mentioned oligopoly members are summarized by "Others".

[10]All figures and regressions in this analysis use prices of diesel. However, corresponding results for petrol showed no significant differences.

Figure 1: Price developments



3 Results and Discussion

Results of the baseline model are summarized in table 1.[11]

Overall, prices in Cologne are about 2.5 Cents higher than in Hamburg. This indicates a structural difference between the two regional markets (e.g. demand). During the low water level period, this difference increases about 6.5 Cents (about 5.5 Cents after this period). As discussed above, this observation can be at least partially explained by increased transport costs (and potential adjustments, afterwards). However, prices in Hamburg are also increasing by *ceteris paribus* about 6.5 Cents during the low water level period (1.75

[11]For reasons of clarity results for the constant and the dummies of each day of the week, each hour and holidays are skipped. The corresponding coefficients are in line with former research (e.g. Siekmann (2017)) and not of interest for these analyses.

Table 1: Baseline model - Difference-in-differences regression results

	(1)	
	Diesel	
$\ln Oil$	0.202***	(0.00483)
D_{CG}	0.0248***	(0.00296)
D_{LW}	0.0655***	(0.00108)
D_{ALW}	0.0175***	(0.00170)
$D_{CG} * D_{LW}$	0.0638***	(0.00168)
$D_{CG} * D_{ALW}$	0.0543***	(0.00198)
D_{Shell}	-0.00525	(0.00505)
D_{Esso}	-0.0196**	(0.00690)
D_{Total}	0.000980	(0.0126)
D_{Jet}	-0.0438***	(0.00396)
D_{Others}	-0.0478***	(0.00398)
Observations	1,685,976	
R^2	0.6624	

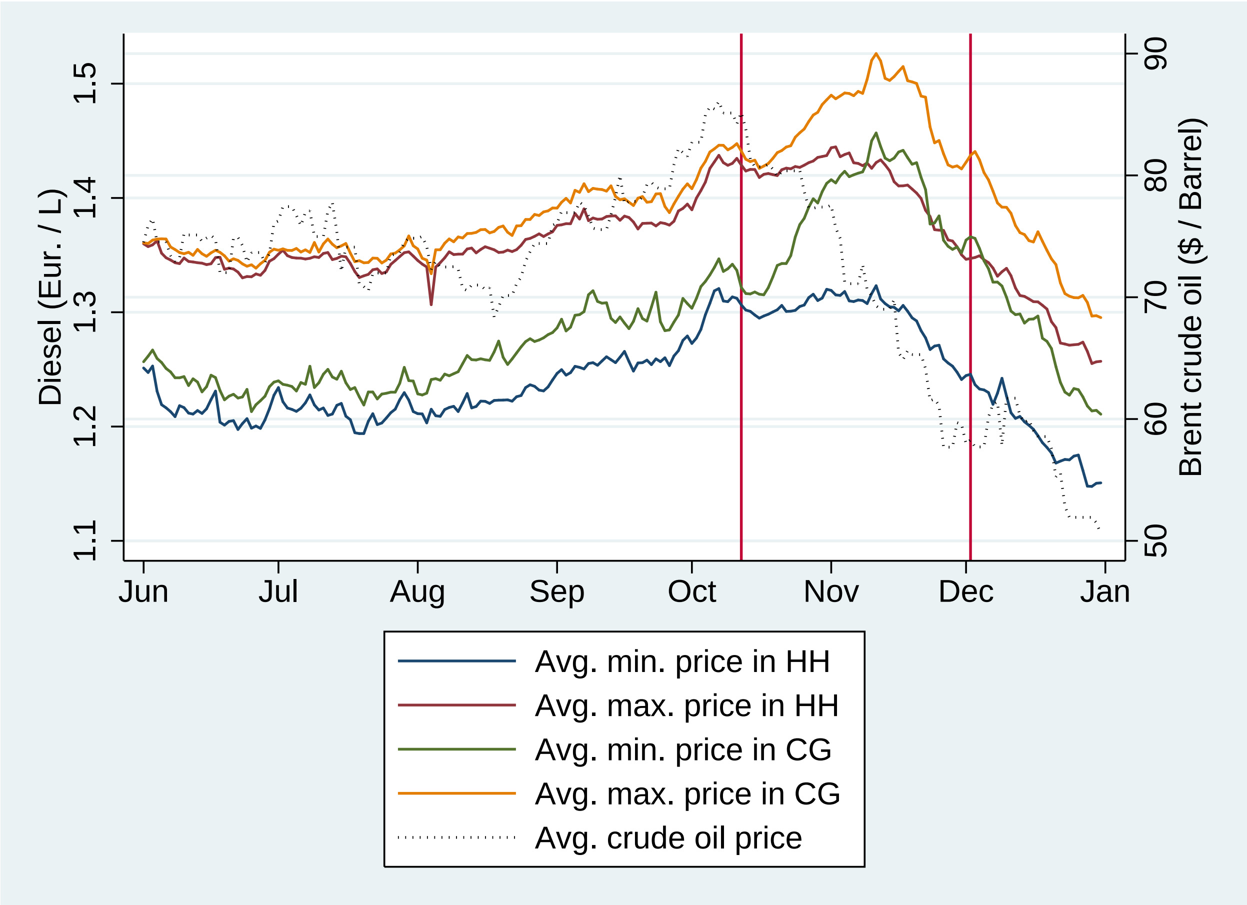
The estimation is performed using GLS. Cluster-robust standard errors (clustered on station level) are presented in parentheses. Statistics are significant for * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Cents, afterwards). This observation cannot be explained by higher transport costs, as for Cologne.

As described above, one has to distinguish two phases in the model of Edgeworth cycles: On the one hand, firms undercut each other until prices equal marginal costs. On the other hand, when prices equal marginal costs, firms play a war of attrition until one firm will increase its price to a much higher level and the cycle starts again. The specific level of the high price depends (among others) on consumers willingness to pay. Thus, the above mentioned observation might be in line with the model of Edgeworth cycles, if consumers price sensitiveness decreased during the period of low water levels. Firms than would increase prices after the war or attrition to higher levels as before. This increase in the maximum prices can lead to higher prices on average. As described in de Haas et al. (2019), it is plausible to assume a decrease in consumers price sensitiveness caused by public reporting during this time.

However, as discussed above, a key element of the model is that firms undercut each other until price equals marginal costs. As shown by Noel (2008), this result holds for fluctuating marginal cost.[12] Thus, while increasing average and maximum prices in Hamburg might be in line with the model, the minimum prices should *ceteris paribus* not increase due to the low water level of the Rhine river. Instead, the spread between maximum and minimum prices should increase. Developments of the average minimum and maximum prices are illustrated in figure 2.

Figure 2: Minimum and maximum price developments



To test these hypotheses, daily minimum and maximum prices as well as the spread between them (instead of hourly prices) are regressed on the explanatory variables given in (1).[13] As discussed in Siekmann (2017) and Linder et al. (2018), the German retail fuel

[12]Even for with uncertainty about marginal costs, firms undercut each other until prices are 'near the band of marginal costs'.

[13]Given these are daily prices, there is no need to control for the time of the day.

market is characterized by intraday cycles. Thus, daily minimum and maximum prices are appropriate measurements of corresponding prices of the model of Edgeworth cycles. Results of the regressions are stated in table 2.

Table 2: Minimum and maximum prices - Difference-in-differences regression results

	(1) Min. price	(2) Max. price	(3) Spread
$\ln Oil$	0.206***	0.226***	0.0206***
	(0.00508)	(0.00444)	(0.00272)
D_{CG}	0.0284***	0.00967***	-0.0187***
	(0.00300)	(0.00256)	(0.00269)
D_{LW}	0.0688***	0.0604***	-0.00840***
	(0.00119)	(0.00105)	(0.00120)
D_{ALW}	0.0186***	0.00660***	-0.0120***
	(0.00179)	(0.00178)	(0.00167)
$D_{CG} * D_{LW}$	0.0663***	0.0464***	-0.0199***
	(0.00169)	(0.00293)	(0.00272)
$D_{CG} * D_{ALW}$	0.0553***	0.0417***	-0.0136***
	(0.00185)	(0.00373)	(0.00357)
D_{Shell}	-0.00283	-0.000656	0.00218
	(0.00514)	(0.00309)	(0.00360)
D_{Esso}	-0.0106	-0.0554***	-0.0448***
	(0.00654)	(0.00546)	(0.00247)
D_{Total}	-0.00145	-0.00236	-0.000910
	(0.0119)	(0.00892)	(0.00569)
D_{Jet}	-0.0253***	-0.0797***	-0.0544***
	(0.00365)	(0.00305)	(0.00237)
D_{Others}	-0.0281***	-0.0848***	-0.0567***
	(0.00366)	(0.00313)	(0.00243)
Observations	70,245	70,245	70,245
R^2	0.6510	0.7349	0.5642

The estimation is performed using GLS. Cluster-robust standard errors (clustered on station level) are presented in parentheses. Statistics are significant for * p < 0.05, ** p < 0.01, *** p < 0.001.

While minimum and maximum prices in Cologne are overall slightly higher than in Hamburg, the spread is a little bit smaller. During the low water level period, these differences increase further. However, the spread is decreasing about 2 Cents relative to that observed for Hamburg. Unexpectedly, not only maximum prices but also minimum prices are increasing in Hamburg by *ceteris paribus* about 7 Cents and 6 Cents, respectively. As discussed above, these findings are not in line with standard Edgeworth cycles.

As robustness checks all regressions are performed with daytime prices (between 7 a.m. and 9 p.m.) only. Additionally, regressions are performed by excluding stations that do not belong to one of the oligopoly members and by excluding all stations that belong to one of the oligopoly members, respectively. The results are robust to these variations. I further run regression on the number of price adjustments (overall, price decreases and price increases, respectively). While the number of adjustments significantly decreased in Cologne due to the cost shock, the cycle movements are stable in Hamburg.[14]

The results indicate a strong shock in Cologne. Not only price levels, but also patterns of daily price cycles are disrupted by the low water levels of the Rhine and corresponding cost shocks. The effects of this shock persisted after water levels rose again. It seems, that firms appeared on an adjustment path towards a new equilibrium in December, 2018. In contrast, patterns of price cycles in Hamburg are stable. Only the level of prices increased. While increasing maximum prices might be in line with the model of Edgeworth cycles, increasing minimum prices and decreasing spreads cannot be explained by the standard model.

4 Conclusion

I use a natural experiment to analyze cost shocks on fuel prices: In late autumn of 2018 the water levels of the Rhine river had fall to historically low levels. This resulted in an interruption of the logistic chain of tank farms around Cologne. The transport costs increased and thus, pump prices increased. Surprisingly, pump prices in Hamburg also increased even though tank farms in Hamburg were not affected by low water levels.

While an increase of daily maximum prices in Hamburg might be in line with the model of Edgeworth cycles, an increase of daily minimum prices are not. The former one can be explained by lower price sensitivity of the customers due to public reporting. The latter

[14] Results of these regressions are available upon request from the author.

could only be explained by increasing marginal costs within the model. Given that I control for the main cost driver, i.e., crude oil prices, it seems questionable that marginal costs increased so much, that an increase of *ceteris paribus* 7 Cents could be explained by omitted variables.

Hence, I find strong evidence that the standard model of Edgeworth cycles is not appropriate to explain pump prices. Future research should address whether the model of Edgeworth cycles has to be extended, other ways to model the present cycles have to be used or collusion in the retail fuel market has to be assumed.[15] However, the present results caution against reliance on the standard model of Edgeworth cycles when analyzing retail fuel markets.

References

Bacon, R. W., 1991. Rockets and feathers: the asymmetric speed of adjustment of uk retail gasoline prices to cost changes. Energy economics 13 (3), 211–218.

Byrne, D. P., De Roos, N., 2019. Learning to coordinate: A study in retail gasoline. American Economic Review 109 (2), 591–619.

de Haas, S., Herold, D., Schaefer, J. T., 2019. Low water level, high prices how the water level of the rhine increases the price at the pump in hamburg. Wirtschaftsdienst 99 (4), forthcoming.

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.

Foros, Ø., Steen, F., 2013. Vertical control and price cycles in gasoline retailing. The Scandinavian Journal of Economics 115 (3), 640–661.

[15]While Byrne and De Roos (2019) and Foros and Steen (2013) assume collusion on retail fuel markets, it might be worthwhile to think of an intertemporal extension of the 'model of sales' (Varian, 1980).

Haucap, J., Heimeshoff, U., Kehder, C., Odenkirchen, J., Thorwarth, S., 2017. Auswirkungen der markttransparenzstelle für kraftstoffe. Wirtschaftsdienst 97 (10), 721–726.

Linder, M., et al., 2018. Price cycles in the german retail gasoline market-competition or collusion. Economics Bulletin 38 (1), 593–602.

Maskin, E., Tirole, J., 1988. A theory of dynamic oligopoly, ii: Price competition, kinked demand curves, and edgeworth cycles. Econometrica: Journal of the Econometric Society, 571–599.

Noel, M., 2009. Do retail gasoline prices respond asymmetrically to cost shocks? the influence of edgeworth cycles. The RAND Journal of Economics 40 (3), 582–595.

Noel, M. D., 2007. Edgeworth price cycles: Evidence from the toronto retail gasoline market. The Journal of Industrial Economics 55 (1), 69–92.

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., 2015. Do edgeworth price cycles lead to higher or lower prices? International Journal of Industrial Organization 42, 81–93.

Noel, M. D., et al., 2011. Edgeworth price cycles. New Palgrave Dictionary of Economics. Palgrave Macmillan.

Siekmann, M., 2017. Characteristics, causes, and price effects: Empirical evidence of intraday Edgeworth cycles. No. 252. DICE Discussion Paper.

Varian, H. R., 1980. A model of sales. The American Economic Review 70 (4), 651–659.

Zhang, X., Feng, J., 2005. Finding edgeworth cycles in online advertising auctions. Unpublished paper.