Station Heterogeneity and Asymmetric Gasoline Price Responses

Emmanuel Asane-Otoo and **Bernhard C. Dannemann**

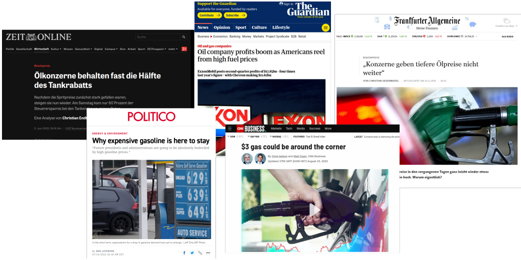
Department of Business Administration, Economics and Law

Institute of Economics — Carl von Ossietzky University Oldenburg

August 22, 2022

Current Situation

- Public perception that retail fuel prices are higher than necessary; oil companies are suspected of collusion and asymmetric pricing strategies



'Exxon made more money than God last year' — Joe Biden

Carl von Ossietzky Universität Oldenburg

Asymmetric Pricing in the Retail Fuel Market

- Aforementioned findings and perceptions are partly confirmed by the empirical literature, however, mixed results are found – even for the same market **(Asane-Otoo and Schneider, 2015; Verlinda, 2008)**
- Asymmetric gasoline price responses at the pump in reaction to input cost fluctuations are well-documented, with two prevalent explanations for non-competitive pricing: **(Eckert, 2013; Periguero-Garía, 2013; Cook and Fosten, 2019; Asane-Otoo and Dannemann, 2022)**
  1. Market power **(Borenstein et al., 1997; Balke et al., 1998)**
     - A higher number of competitors is thought to ensure competitive pricing behavior **(Barron et al., 2004; Lewis, 2008; Bergantino et al., 2020)**
  2. Search costs **(Tappata, 2009; Johnson, 2002; Lewis, 2011)**
     - With price comparison being costly for consumers, retailers can charge higher prices

Aggregation Issues

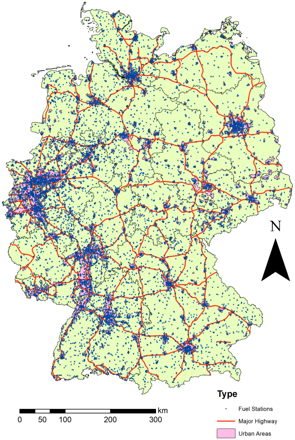
- The issue of data aggregation receives increasing attention, with focus on disaggregated data sets **(Asane-Otoo and Dannemann, 2022; Frondel et al., 2020)**
- Temporal aggregation inadequately reflects station level pricing decisions and masks pricing patterns ´
- Spatial aggregation ignores heterogeneity across stations or regions, and masks patterns in the spatial distribution of pricing strategies **(Haucap et al., 2017; Balaguer and Ripollés, 2016)**

Research Contribution

- However, the majority of studies relies on panel regression techniques and presents parameter estimates as averages across stations
- Panel aggregation bias receives little to no attention
- **This paper:**
  - Estimation of asymmetric error correction model for 12,613 individual station daily time series
  - Focus on parameter heterogeneity
  - Station-specific input costs (wholesale price)
  - Analysis of drivers of pricing patterns in local markets

Retail Price Data

- By law, fuel station operators are obliged to publicly disclose all price changes in real-time **(German Federal Cartel Office, 2011)**
  - Georeferenced station-level data available since 2014 for 15,227 stations
  - 12,613 stations ($\approx$ 83%) part of the regression sample
  - Daily price averages 2014–2018

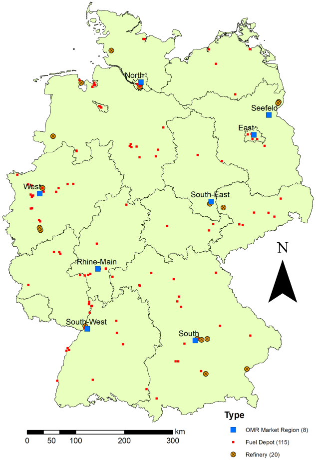


Carl von Ossietzky Universität Oldenburg

Input Cost Data

- Wholesale rather than international crude oil prices might be relevant for retailers **(Delpachitra, 2002)**
  - Currently 18 active refineries, with 8 at least partly owned by vertically integrated companies
  - Refined products stored in 117 fuel depots

⇒ Both types supply fuels to stations
  - Refineries and depots are assigned to 8 distinct wholesale market regions identified by an external data provider
  - Supply **depot** → **station** is typically done by road transport
  - Openstreetmap driving distance used as a proxy for transport costs



Further Variables

- Further demand-side fluctuations are proxied for by considering relevant factors that affect motorists' behavior
- Neighborhood retail price of adjacent fuel stations to account for competition **(Haucap et al., 2017; Atkinson, 2009)**
- Ambient temperature and precipitation capture transportation mode choice based on weather conditions **(Koetse and Rietveld, 2009; Klein Tank et al., 2002)**
- Public holidays and school holiday start proxy for phenomena such as wave of vacationers **(Cools et al., 2007; Jun, 2010)**

Cointegration Equation

1. Test for cointegration follows Engle-Granger two-step procedure **(Granger and Engle, 1987)**
2. Long-run relationship between retail fuel price and input cost is estimated:

$$r_t = \sigma + \theta w_t + \gamma' \boldsymbol{H} + \delta' \boldsymbol{D} + \xi_t \quad (1)$$

3. Test for stationarity of residual (ξ_t)
    - With cointegration, θ is long-run cost pass-through
    - Residual corresponds to deviations from long-run equilibrium

Regression Equation

- Asymmetric Error Correction Model (AECM) estimated separately for 12,613 fuel stations and different input cost measures **(Granger and Lee, 1989)**
- Test for Symmetric pricing, that is, $|\phi^+| = |\phi^-|$

$$
\begin{aligned}
\triangle r_t = {} & \alpha + \phi^+ \xi^+_{t-1} + \phi^- \xi^-_{t-1} \\
& + \sum_{l=1}^{L} \left(\beta^+_l \triangle r^+_{t-l} + \beta^-_l \triangle r^-_{t-l} \right) \\
& + \sum_{m=0}^{M} \left(\lambda^+_m \triangle w^+_{t-m} + \lambda^-_m \triangle w^-_{t-m} \right) + \sum_{n=0}^{N} \left(\sigma^+_n \triangle c^+_{t-n} + \sigma^-_n c^-_{t-n} \right) \\
& + \psi \triangle \bar{r}_{(-i)t-1} + \pi' \triangle \boldsymbol{W} + \gamma' \boldsymbol{H} + \delta' \boldsymbol{D} + \tau t + \varepsilon_t
\end{aligned} \tag{2}
$$

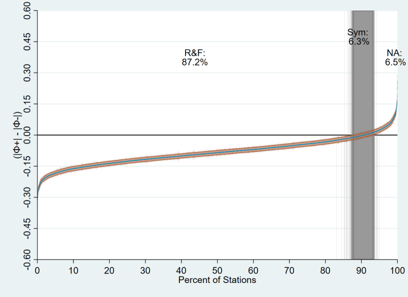
with r retail, w wholesale and c crude oil price, and $\boldsymbol{W}$ weather, $\boldsymbol{H}$ holidays, $\boldsymbol{D}$ day-of-the-week and month/year FE

Carl von Ossietzky Universität Oldenburg

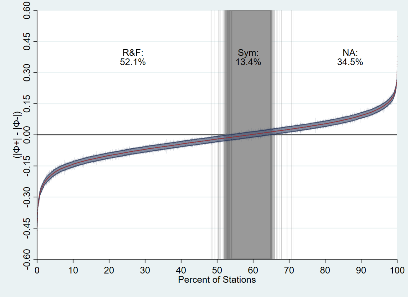
Part 1a: Input Cost Measure and Pricing Pattern

- Comparison of long-run adjustment parameters for individuals stations reveals drastic change in pricing patterns

Input Cost: Crude Oil Price

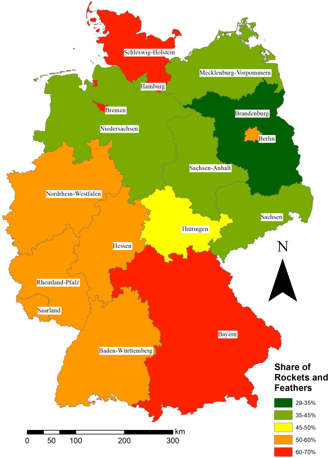


Input Cost: Wholesale Price



Part 1b: Spatial Distribution of Pricing Patterns

- Large geographic differences of prevailing pricing patterns across federal states, for example, for rockets and feathers
- States with higher population densities and more refinery / fuel depot infrastructure have high share of rockets and feathers stations



Carl von Ossietzky Universität Oldenburg

Part 2: Local Market Characteristics

- Magnitude of pricing asymmetry from the prior regression is employed as the dependent variable in a cross-section of stations

	(1)	(2)	(3)	(4)	(5)
	Dependent Variable: $(\vert\phi^{+}\vert - \vert\phi^{-}\vert)/\sqrt{SE_{\phi^{+}}/N + SE_{\phi^{-}}/N}$				
Total Number of Neighbors	-0.103***	-0.096**	-0.175***	-0.175***	-0.073*
	(0.028)	(0.029)	(0.039)	(0.039)	(0.035)
Total Number of Neighbors ^{2}	0.003***	0.003***	0.004***	0.004***	0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
No Neighbors		0.319	0.465	-0.587	-2.767***
		(0.441)	(0.444)	(0.559)	(0.634)
ln(Population Density)			0.466**	0.504**	0.111
			(0.153)	(0.154)	(0.136)
Share of Major Brand				-1.322**	-1.868***
				(0.460)	(0.406)
Share of Same Brand				-1.276*	-0.930
				(0.540)	(0.476)
Share showing Rockets and Feathers					-10.035***
					(0.496)
Share showing Negative Asymmetry					8.334***
					(0.528)
Number of Stations	12,613	12,613	12,613	12,613	12,613
Federal State Fixed Effects?	Yes	Yes	Yes	Yes	Yes
Brand Fixed Effects?	Yes	Yes	Yes	Yes	Yes
$R^2_{Adj.}$	0.078	0.078	0.079	0.079	0.285

Carl von Ossietzky Universität Oldenburg

Part 3a: Pooled-Panel Estimation

- Estimation of a pooled-panel of all fuel stations

	(1) Crude Oil Price	(2) Wholesale Price	(3) Both
	Dependent Variable: $\triangle$ Retail Price of E5 Fuel		
Input Cost Decrease (ϕ^+)	-0.021***	-0.024***	-0.024***
	(0.000)	(0.000)	(0.000)
Input Cost Increase (ϕ^-)	-0.056***	-0.042***	-0.042***
	(0.000)	(0.000)	(0.000)
	F-Tests for Symmetry		
$\phi^+ = \phi^-$	20,022.02***	3,210.96***	3,146.30***
$\beta_l^+ = \beta_l^-, \quad l \in [1,7]$	6,292.55***	5,150.56***	5,145.28***
$\lambda_m^+ = \lambda_m^-, \quad m \in [0,7]$		390.63***	429.67***
$\sigma_n^+ = \sigma_n^-, \quad n \in [0,7]$	4,522.24***		766.80***
Cointegration based on	c_t	w_t	w_t
N	21,621,581	21,621,581	21,621,581
$R^2_{Adj.}$	0.286	0.332	0.332
Number of Stations	12,613	12,613	12,613
Month/Year Fixed Effects ($\boldsymbol{Y}$)	Yes	Yes	Yes
Controls ($\boldsymbol{W}$, $\boldsymbol{H}$, $\boldsymbol{T}$, $\triangle\bar{r}_{(-i)t-1}$)	Yes	Yes	Yes

Part 3b: Pooling by Pricing Pattern

- Fuel stations are pooled by the pricing pattern obtained from individual time series regression

	(1) Rockets and Feathers	(2) Symmetric Adjustment	(3) Negative Asymmetry
	Dependent Variable: $\triangle$ Retail Price of E5 Fuel		
Input Cost Decrease (ϕ^+)	-0.019***	-0.028***	-0.031***
	(0.000)	(0.001)	(0.000)
Input Cost Increase (ϕ^-)	-0.049***	-0.040***	-0.032***
	(0.000)	(0.001)	(0.000)
	F-Test for Symmetry		
$\phi^+ = \phi^-$	4,887.60***	179.18***	1.89
$\beta_l^+ = \beta_l^-, \quad l \in [1,7]$	2,115.47***	618.19***	2,527.68***
$\lambda_m^+ = \lambda_m^-, \quad m \in [0,7]$	230.27***	45.84***	177.30***
$\sigma_n^+ = \sigma_n^-, \quad n \in [0,7]$	425.37***	87.40***	267.95***
Cointegration based on	w_t	w_t	w_t
N	11,480,801	2,428,496	7,712,284
$R^2_{Adj.}$	0.328	0.336	0.339
Number of Stations	6,718	1,421	4,474
Month/Year Fixed Effects ($\boldsymbol{D}$)	Yes	Yes	Yes
Controls ($\boldsymbol{W}$, $\boldsymbol{H}$, $\boldsymbol{T}$, $\triangle\bar{r}_{(-i)t-1}$)	Yes	Yes	Yes

Summary of Main Results

- Individual station time series reveal wide scope of pricing patterns upon switching to wholesale prices as input costs
  - Findings masked by pooled-panel analysis
  - Controversially, individual price patterns deviate from pooled-panel results
- Brand structure and station density affect pricing pattern in local markets
- Geographical differences in prevailing pricing patterns
  - Access to refinery infrastructure as a possible explanation
  - States with many depots/refineries show higher prevalence of asymmetric pricing

Carl von Ossietzky Universität Oldenburg

Conclusion

- In spite of full market transparency in Germany facilitating consumer serach, asymmetric pricing patterns still prevail
- Use of crude oil rather than wholesale price seems to overstate prevalence of non-competitive pricing
- Market transparency unit makes price comparison possible, but could be a double-edged sword
  - Firms can also track competitors prices
  - Leads to tacit collusion and algorithmic pricing **(Calvano et al., 2020)**

Carl von Ossietzky Universität Oldenburg

Thank you!

References I

Asane-Otoo, E. and Dannemann, B. C. (2022). Rockets and Feathers Revisited: Asymmetric Retail Gasoline Pricing in the Era of Market Transparency. *The Energy Journal*, 43(6).

Asane-Otoo, E. and Schneider, J. (2015). Retail Fuel Price Adjustment in Germany: A Threshold Cointegration Approach. *Energy Policy*, 78:1–10.

Atkinson, B. (2009). Retail Gasoline Price Cycles: Evidence from Guelph, Ontario using Bi-Hourly Station Specific Retail Price Data. *The Energy Journal*, 30:85–109.

Balaguer, J. and Ripollés, J. (2016). Asymmetric Fuel Price Responses Under Heterogeneity. *Energy Economics*, 54:281–290.

Balke, N. S., Brown, S. P., and Yücel, M. (1998). Crude Oil and Gasoline Prices: An Asymmetric Relationship? *Economic and Financial Policy Review*, Q1:2–11.

Barron, J. M., Taylor, B. A., and Umbeck, J. R. (2004). Number of Sellers, Average Prices, and Price Dispersion. *International Journal of Industrial Organization*, 22(8-9):1041–1066.

Bergantino, A. S., Capozza, C., and Intini, M. (2020). Empirical Investigation of Retail Fuel Pricing: The Impact of Spatial Interaction, Competition and Territorial Factors. *Energy Economics*, 90:104876.

Borenstein, S., Cameron, A. C., and Gilbert, R. (1997). Do Gasoline Prices Respond Asymmetrically to Crude Oil Price Changes? *Quarterly Journal of Economics*, 112:305–339.

Calvano, E., Calzolari, G., Denicolò, V., and Pastorello, S. (2020). Artificial Intelligence, Algorithmic Pricing, and Collusion. *American Economic Review*, 110(10):3267–3297.

Cook, S. and Fosten, J. (2019). Replicating Rockets and Feathers. *Energy Economics*, 82:139–151.

Cools, M., Moons, E., and Wets, G. (2007). Investigating Effect of Holidays on Daily Traffic Counts: Time Series Approach. *Transportation Research Record: Journal of the Transportation Research Board*, 2019:22–31.

Delpachitra, S. B. (2002). Price Rigidity in the Downstream Petroleum Industry in New Zealand: Where Does It Happen? *Energy economics*, 24(6):597–613.

Eckert, A. (2013). Empirical Studies of Gasoline Retailing: A Guide to the Literature. *Journal of Economic Surveys*, 27:140–166.

References II

Frondel, M., Horvath, M., Vance, C., and Kihm, A. (2020). Increased Market Transparency in Germany's Gasoline Market. *Journal of Transport Economics and Policy*, 54(2):102–120.

German Federal Cartel Office (2011). Fuel Sector Inquiry. *Final Report in Accordance with §32e GWB – May 2011 – Summary*. https://www.bundeskartellamt.de/SharedDocs/Publikation/EN/Sector%20Inquiries/Fuel%20Sector%20Inquiry%20-%20Final%20Report.pdf?__blob=publicationFile&v=14 (last accessed: 17 January 2020).

Granger, C. W. and Engle, R. F. (1987). Co-Integration and Error Correction: Representation, Estimation, and Testing. *Econometrica*, 55(2):251–276.

Granger, C. W. and Lee, T. H. (1989). Investigation of Production, Sales and Inventory Relationships using Multicointegration and Non-Symmetric Error Correction Models. *Journal of Applied Econometrics*, 4:145–159.

Haucap, J., Heimeshoff, U., and Siekmann, M. (2017). Fuel Prices and Station Heterogeneity on Retail Gasoline Markets. *The Energy Journal*, 38(6):81–103.

Johnson, R. N. (2002). Search costs, lags and prices at the pump. *Review of Industrial Organization*, 20:33–50.

Jun, J. (2010). Understanding the Variability of Speed Distributions Under Mixed Traffic Conditions Caused by Holiday Traffic. *Transportation Research Part C*, 18:599–610.

Klein Tank, A. M. G., Wijngaard, J. B., Können, G. P., Böhm, R., and others (2002). Daily Dataset of 20th-Century Surface Air Temperature and Precipitation Series for the European Climate Assessment. *International Journal of Climatology*, 22:1441–1453. Data and metadata available at https://www.ecad.eu//dailydata/predefinedseries.php (last accessed: 9 October 2019).

Koetse, M. J. and Rietveld, P. (2009). The Impact of Climate Change and Weather on Transport: An Overview of Empirical Findings. *Transportation Research Part D*, 14:205–221.

Lewis, M. (2008). Price Dispersion and Competition with Differentiated Sellers. *The Journal of Industrial Economics*, 56(3):654–678.

Lewis, M. S. (2011). Asymmetric Price Adjustment and Consumer Search: An Examination of the Retail Gasoline Market. *Journal of Economics & Management Strategy*, 20:409–449.

References III

Periguero-Garía, J. (2013). Symmetric or Asymmetric Oil Prices? A Meta-Analysis Approach. *Energy Policy*, 57:389–397.

Tappata, M. (2009). Rockets and Feathers: Understanding Asymmetric Pricing. *RAND Journal of Economics*, 40(4):673–687.

Verlinda, J. A. (2008). Do Rockets Rise Faster and Feathers Fall Slower in an Atmosphere of Local Market Power? Evidence From the Retail Gasoline Market. *The Journal of Industrial Economics*, 57:581–612.