

Fuel Prices and Station Heterogeneity on Retail Gasoline Markets

– Appendix

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1. PREPARATION OF RAW DATA

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

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

In a second step, we check MTS-K station data for activity status and submission of price quotes for each fuel type. In total, the MTS-K data set (as of mid-2014) includes 14,838 entries. A number of entries are, however, flagged as no longer active as, for instance, some stations were closed or changed their ownership structure and/ or brand name, leading to double entries. These inactive entries are, therefore, disregarded from the analysis. Some further stations do not submit price quotes at all or not for all three fuel types (e.g., a station does not offer all products). After excluding stations without price quotes, in total, 14,454 stations are considered valid and are used for pricing analysis. For fuel-type specific analysis, (different) subsets of active stations are used. While we explicitly exclude stations without any (fuel-type specific) price quotes, we do not impose further (subjective) threshold levels regarding, for instance, a minimum required number of price quotes per station to be considered. As a consequence, we allow the data set to be unbalanced. Finally, we link various station characteristics from Petrolview to MTS-K station data on the basis of geographic coordinates as well as address information (i.e., street, ZIP code, city). In total, we are able to connect 14,135 or 98% of all valid MTS-K stations with Petrolview data and consequently use this data set to specify price level determinants. Table 7 presents the number of stations along the categories described above. The empirical analysis in this paper relies on "stations with all characteristics" or, more precisely, fuel-type specific sub-groups.

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Table 6: Raw Price Data Preparation

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

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

Table 7: Raw Station Data Preparation

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

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

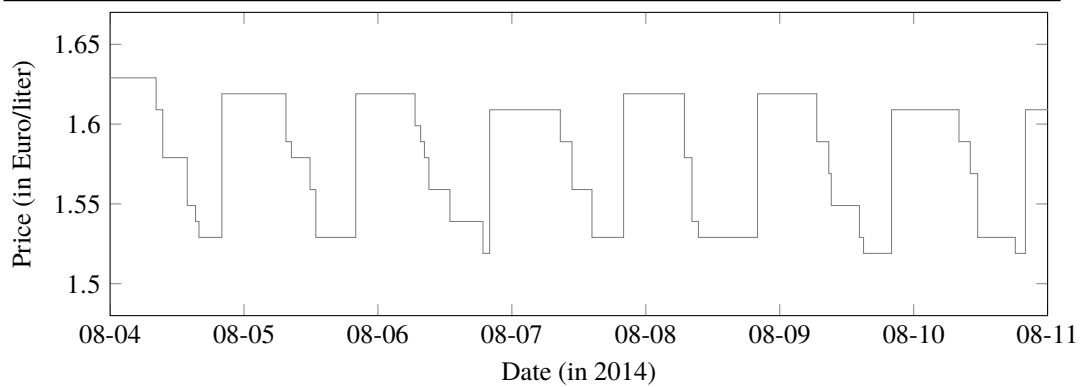
2. FIGURES AND TABLES

Table 8: Overview of Variables

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

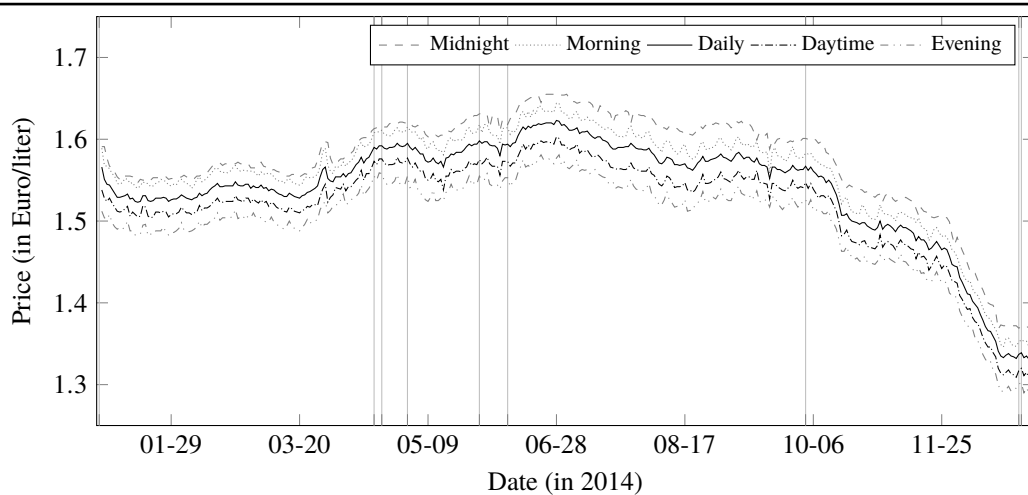
Note: BMI = Bundesministerium des Inneren, KMK = Kultusministerkonferenz, MTS-K = Markttransparenzstelle für Kraftstoffe, O.M.R. = Oil Market Report.

Figure 4: Exemplary Weekly Price Pattern of Major-Brand Gasoline Station



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

Figure 5: Retail Price Series of Different Metrics (Example: Super E5)



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

Table 9: Regression of Retail Prices (Super E10)

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

Note: Robust p-values in parentheses; non-significance at 10% level denoted in italics.

Included but not shown: Weekday dummies, state dummies, LPG/ CNG pump, ownership type, secondary road, additional distance to 2nd refinery, and open on Sundays dummy.

Omitted variables: Road station, independent brand, standard store.

Table 10: Regression of Retail Prices (Diesel)

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

Note: Robust p-values in parentheses; non-significance at 10% level denoted in italics.

Included but not shown: Weekday dummies, state dummies, LPG/ CNG pump, ownership type, secondary road, additional distance to 2nd refinery, and open on Sundays dummy.

Omitted variables: Road station, independent brand, standard store.

Table 11: Regression of Retail Prices (Super E5) – Further Variables

| Dependent variable: Super E5 price | Average prices | | Point-in-time prices | | |
|--|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|
| | Daily (1) | Daytime (2) | Morning (3) | Evening (4) | Midnight (5) |
| <i>Station-specific variables</i> | | | | | |
| Open on Sundays | 0.309 (0.00) | <i>0.033</i> (<i>0.65</i>) | 0.548 (0.00) | -0.367 (0.00) | - |
| Company ownership | 0.104 (0.00) | <i>-0.013</i> (<i>0.69</i>) | 0.094 (0.02) | 0.007 (0.86) | 0.682 (0.00) |
| Other ownership | -0.225 (0.06) | -0.509 (0.00) | -0.468 (0.00) | -0.660 (0.00) | <i>-0.478</i> (<i>0.22</i>) |
| Secondary road | 0.188 (0.00) | 0.095 (0.00) | 0.122 (0.00) | 0.109 (0.00) | 0.245 (0.00) |
| LPG pumps | -0.177 (0.00) | -0.130 (0.00) | -0.080 (0.03) | -0.142 (0.00) | -0.349 (0.00) |
| CNG pumps | <i>0.055</i> (<i>0.38</i>) | 0.200 (0.00) | <i>0.108</i> (<i>0.13</i>) | 0.166 (0.01) | <i>-0.051</i> (<i>0.70</i>) |
| Add'l distance to 2 nd refinery | 0.004 (0.00) | 0.005 (0.00) | 0.004 (0.00) | 0.005 (0.00) | <i>-0.001</i> (<i>0.57</i>) |
| <i>Demand-side controls (weekdays)</i> | | | | | |
| Monday | -0.332 (0.00) | -0.583 (0.00) | -0.669 (0.00) | -0.929 (0.00) | 0.160 (0.00) |
| Tuesday | -0.194 (0.00) | -0.450 (0.00) | -0.638 (0.00) | -0.782 (0.00) | 0.303 (0.00) |
| Wednesday | -0.177 (0.00) | -0.440 (0.00) | -0.591 (0.00) | -0.756 (0.00) | 0.363 (0.00) |
| Thursday | -0.256 (0.00) | -0.544 (0.00) | -0.713 (0.00) | -0.787 (0.00) | 0.339 (0.00) |
| Friday | -0.297 (0.00) | -0.557 (0.00) | -0.758 (0.00) | -0.865 (0.00) | 0.241 (0.00) |
| Saturday | -0.201 (0.00) | -0.388 (0.00) | -0.114 (0.00) | -0.562 (0.00) | 0.192 (0.00) |
| <i>Demand-side controls (states)</i> | | | | | |
| Baden-Württemberg | 2.219 (0.00) | 2.109 (0.00) | 2.338 (0.00) | 2.190 (0.00) | 2.564 (0.00) |
| Bayern | 1.677 (0.00) | 1.699 (0.00) | 1.515 (0.00) | 2.286 (0.00) | 1.195 (0.00) |
| Berlin | -0.419 (0.00) | -0.437 (0.00) | -0.518 (0.00) | -0.302 (0.03) | <i>-0.305</i> (<i>0.27</i>) |
| Brandenburg | 0.299 (0.02) | 0.403 (0.00) | 0.458 (0.00) | <i>0.240</i> (<i>0.12</i>) | <i>0.370</i> (<i>0.14</i>) |
| Bremen | <i>-0.201</i> (<i>0.30</i>) | -1.030 (0.00) | <i>-0.145</i> (<i>0.46</i>) | -0.819 (0.00) | 1.792 (0.00) |
| Hamburg | <i>0.221</i> (<i>0.17</i>) | -0.271 (0.03) | 0.334 (0.04) | <i>-0.213</i> (<i>0.16</i>) | 1.111 (0.00) |
| Hessen | 1.227 (0.00) | 1.254 (0.00) | 1.444 (0.00) | 1.187 (0.00) | 1.152 (0.00) |
| Mecklenburg-Vorpommern | -0.355 (0.01) | -0.538 (0.00) | <i>0.010</i> (<i>0.94</i>) | -1.086 (0.00) | 0.764 (0.01) |
| Niedersachsen | 0.839 (0.00) | 0.594 (0.00) | 1.202 (0.00) | 0.314 (0.01) | 1.372 (0.00) |
| Nordrhein-Westfalen | 0.869 (0.00) | 0.555 (0.00) | 1.251 (0.00) | 0.313 (0.00) | 1.657 (0.00) |
| Rheinland-Pfalz | 1.245 (0.00) | 1.374 (0.00) | 1.219 (0.00) | 1.615 (0.00) | 1.007 (0.00) |
| Saarland | 1.907 (0.00) | 1.613 (0.00) | 2.677 (0.00) | 1.735 (0.00) | 1.929 (0.00) |
| Sachsen | <i>-0.157</i> (<i>0.16</i>) | <i>-0.021</i> (<i>0.83</i>) | -0.247 (0.03) | <i>-0.041</i> (<i>0.75</i>) | <i>-0.065</i> (<i>0.79</i>) |
| Sachsen-Anhalt | <i>-0.174</i> (<i>0.16</i>) | <i>-0.016</i> (<i>0.88</i>) | -0.351 (0.00) | <i>-0.147</i> (<i>0.28</i>) | <i>-0.127</i> (<i>0.63</i>) |
| Schleswig-Holstein | 0.710 (0.00) | 0.338 (0.00) | 1.003 (0.00) | -0.192 (0.17) | 1.414 (0.00) |
| Constant | 16.939 (0.00) | 17.098 (0.00) | 17.987 (0.00) | 16.405 (0.00) | 20.656 (0.00) |
| Number of observations | 4,989,486 | 5,001,061 | 5,003,332 | 5,000,986 | 1,955,103 |
| Number of groups | 14,005 | 14,005 | 14,005 | 14,005 | 5,504 |
| R ² | 0.875 | 0.874 | 0.815 | 0.838 | 0.773 |

Note: Robust p-values in parentheses; non-significance at 10% level denoted in italics.

Only variables not included in Table 3 shown.

Omitted variables: Sunday (weekday), Thüringen (state), dealer ownership.

Table 12: Regression of Retail Prices (Single Brands, Open 24/7, Super E5)

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

Note: Robust p-values in parentheses; non-significance at 10% level denoted in italics.

Included but not shown: Other single brands; all station characteristics and demand-side controls.

Omitted variables: "Unbranded" stations and other omitted variables as in previous specifications.

3. DISTRIBUTION OF PRICES

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

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

$$p_{it} = \alpha + \theta_i + \gamma_t + u_{it} \quad (2)$$

with p_{it} as station i 's (point-in-time) retail price at day t , θ_i representing station-fixed effects and γ_t representing time-fixed effects. Residuals u_{it} are considered deviations from the "clean" or "residual" price after controlling for station heterogeneity and (input) price variations equally affecting stations (Pennerstorfer et al., 2015).

Table 13 illustrates the retail price distribution for Super E5 using three point-in-time metrics and three distinct price series, namely (i) retail prices as listed at the pump, (ii) prices corrected for time-fixed effects, and (iii) clean prices as introduced above, estimated by the two-way fixed effects model. The table shows frequency distributions of residuals around the estimated price, rounded to the nearest Eurocent/liter of fuel. The estimated price in the center of the distribution thereby represents either (i) a simple average price across all stations and days, (ii) a day-specific average price across all stations, or (iii) the day-specific average price determined by a specific station's characteristics. Albeit intraday spreads might be considerably larger, distributions around (i) and (ii) represent maximum levels of price differences (at different points in time) a consumer could be exposed to over the year or on a typical day. While prices in (i) are obviously quite dispersed, including time fixed effects in (ii) leads to a higher concentration around the estimated price. Notably, at midnight, numerous stations offer prices slightly above the average, while stations pricing below the average are more dispersed. In (iii), we see evidence of a strong impact of station-specific characteristics on prices. The remaining distribution can be attributed to true price dispersion across all stations in Germany.

Table 13: Distribution of Point-in-Time Prices

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

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

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