Does tax policy work when consumers have imperfect price information? Theory and evidence

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Motivation

Design of optimal tax policy requires understanding of tax pass-through

Tax incidence determines

▷ corrective effect of Pigouvian taxes
▷ effectiveness of unconventional fiscal policy to stimulate the economy
▷ excess burden and distributional consequences of any commodity tax
Research Question

Oftentimes: oligopolistic markets with imperfect information

- Little theoretical evidence on how lack of price transparency affects pass-through
- In general, scarce empirical evidence on what determines commodity tax pass-through
  - data-intensive task: requires granular information on prices

Understand the pass-through of commodity taxes in markets where consumers have imperfect information about prices
This project: commodity tax pass-through with imperfect information

1. Develop a theoretical search model, in which some consumers know all available prices and others need to sequentially acquire price information at a cost

   ▶ Novel notion of price sensitivity: The larger the share of informed consumers, the higher is the price sensitivity of demand, as experienced by sellers

   ▶ Derive predictions on the effects of price sensitivity and number of firms in a market on commodity tax pass-through
This project: commodity tax pass-through with imperfect information

2. Test theoretical predictions by studying pass-through of two tax changes in Germany

- Exploit rich data on fuel prices & use France as a control
- Analyse tax increase and decrease, as well as ad-valorem and per unit taxes
- Explore heterogeneity in pass-through for fuel types with differently price sensitive consumer groups
- Estimate how pass-through varies with the number of rival fuel stations
Related Literature

Theory

▶ consumer search model (Stahl 1989); tax pass-through with imperfect competition and complete information (Weyl & Fabinger 2013)

Cost and tax pass-through

▶ higher cost or tax pass-through for competitive tariffs or more visible services (Duso et al. 2017; Kosonen 2015)

▶ heterogeneity in pass-through with intensity of competition (Genakos & Pagliero 2019; Miller et al. 2017)

Pass-through of value-added taxes

▶ under-shifting (Benzarti et al. 2019; Carbonnier 2007), over-shifting (Besley & Rosen 1999), full pass-through (Buettner et al. 2020; Fuest et al. 2020)

▶ asymmetric pass-through for tax increases and decreases (Benzarti et al. 2020)
1. Introduction
2. Theory
3. Data & descriptive evidence
4. Empirical strategy & results
5. Conclusion
Setup

Demand
- Each consumer has valuation $v$ for homogenous good; demand inelastic
- Fraction $\phi$ shoppers: fully informed and buy from the lowest price seller
- $(1 - \phi)$ non-shoppers: sequentially draw prices at a search cost $s$

Supply
- Infinite number of symmetric firms that can potentially enter
- Fixed entry cost $F$; marginal cost $c$; ad-valorem tax $\tau$

Two-stage game:
1. Firms decide whether to enter the market
2. Firms choose prices. Consumers make search and purchase decisions

Price equilibrium in mixed strategies
Tax pass-through & price elasticity

Common wisdom from theoretical setup with perfect information:

The higher the price elasticity of aggregate demand, the lower the commodity tax pass-through.
Tax pass-through & price sensitivity

In this model:

- aggregate demand fixed for prices below reservation price
- residual demand per seller depends on price sensitivity of consumers, reflected by the share of shoppers & search cost of non-shoppers
- higher price sensitivity intensifies competition

⇒ The more price sensitive consumers are on average, the higher is the pass-through rate

Intuition The more price sensitive consumers are on average, the closer is the expected price to marginal cost
Tax pass-through & number of firms in a market

Pass-through of $\tau$ to $E[p]$  

Parameter values: $\nu = 2.5$, $c = 0.4$, $\tau = 0.2$ and $\hat{\tau} = 0.22$. 

Pass-through of $\tau$ to $E[p_{\min}]$  

Parameter values: $\nu = 2.5$, $c = 0.4$, $\tau = 0.2$ and $\hat{\tau} = 0.22$. 

Share of shoppers  

- 0.10  
- 0.25  
- 0.50  
- 0.75  
- 0.90
Outline

1. Introduction
2. Theory
3. Data & descriptive evidence
4. Empirical strategy & results
5. Conclusion
Tax changes in Germany

Tax decrease

- Temporary decline in the value-added tax from 19 to 16 percent between 1 July and 31 December 2020 (2020 Coronavirus Tax Assistance Act)

Tax increase

- Increase in the value-added tax back to 19 percent on 1 January 2021
- Simultaneous introduction of the carbon price of 25 Euro per emitted tonne of CO$_2$ on oil, gas and fuel (2020 Fuel Emissions Trading Act)

Theoretical predictions on the determinants of pass-through are qualitatively the same for ad-valorem taxes and per unit taxes
Data sources & fuel products

Data sources

administrative data on E5, E10 and diesel prices and fuel stations in Germany and France

Gasoline: E5

ethanol share of 5%
81.7% of the gasoline market in Germany (2019)

Gasoline: E10

ethanol share of 10%, introduced in Germany in 2011
13.7% of the gasoline market (2019)

Diesel

used in ca. 32% of passenger cars in Germany (2018)
annual mileage about two times higher than for gasoline vehicles
(Federal Ministry of Transportation)
More diesel drivers search for a fuel price than gasoline drivers

Number of distinct users by fuel type

Number of distinct users per 1,000 vehicles
More E10 drivers search for a fuel price than E5 drivers

Number of distinct users by fuel type
Tax decrease: price change as share of total tax change

[Graph showing share of total tax change from May to August 2020 for different fuel types: E5, E10, and Diesel.]
Tax increase: price change as share of total tax change

![Graph showing the share of total tax change over time for different fuels (E5, E10, Diesel). The graph illustrates the percentage change in retail margins for each fuel from 1 Nov 2020 to 1 Feb 2021.]
Outline

1. Introduction
2. Theory
3. Data & descriptive evidence
4. Empirical strategy & results
5. Conclusion
Empirical strategy

Synthetic difference-in-differences design (SDiD) [Arkhangelsky et al. 2020]:

\[
(\hat{\tau}_{sdid}, \hat{\mu}, \hat{\alpha}, \hat{\beta}) = \arg\min_{\tau, \mu, \alpha, \beta} \left\{ \sum_{i=1}^{N} \sum_{t=1}^{T} (Y_{it} - \mu - \alpha_i - \beta_t - Tax_{it}\tau)^2 \hat{w}_i^{sdid} \hat{\lambda}_t^{sdid} \right\}
\] (1)

- \(\hat{\tau}_{sdid}\): estimated effect of the tax change
- \(\hat{w}_i^{sdid}\) and \(\hat{\lambda}_t^{sdid}\): SDiD unit and time weights
- \(Y_{it}\): log weighted average price at a station \(i\) and in a day \(t\)
- \(Tax_{it}\): dummy that equals one for German stations after 1 July 2020 or 1 January 2021
- \(\alpha_i\) and \(\beta_t\): station and day fixed effects

SDiD algorithm  Station weights
## Effect of the tax change on log prices (SDiD)

<table>
<thead>
<tr>
<th></th>
<th>E5</th>
<th>E10</th>
<th>Diesel</th>
<th>E5</th>
<th>E10</th>
<th>Diesel</th>
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<tr>
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<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
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<td><strong>Tax change</strong></td>
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<td>-.0130***</td>
<td>-.0199***</td>
<td>.0554***</td>
<td>.0627***</td>
<td>.0872***</td>
</tr>
<tr>
<td></td>
<td>(.0013)</td>
<td>(.0013)</td>
<td>(.0015)</td>
<td>(.0012)</td>
<td>(.0019)</td>
<td>(.0013)</td>
</tr>
<tr>
<td><strong>Pass-through rate</strong></td>
<td>34% [24%, 43%]</td>
<td>52% [42%, 62%]</td>
<td>79% [67%, 91%]</td>
<td>68% [65%, 71%]</td>
<td>75% [70%, 79%]</td>
<td>90% [88%, 93%]</td>
</tr>
<tr>
<td><strong>Date fixed effects</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Station fixed effects</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td><strong>Observations</strong></td>
<td>1,736,145</td>
<td>1,968,984</td>
<td>2,176,362</td>
<td>1,218,168</td>
<td>1,399,776</td>
<td>1,594,320</td>
</tr>
</tbody>
</table>

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Dynamic effects of the tax change on log fuel prices

Tax decrease

Tax increase

Retail margins
Average pass-through by number of competitor stations, E5

**Tax decrease**

**Tax increase**
Conclusion

1. Theoretical prediction: Higher pass-through for more price sensitive consumers


2. Empirical finding: Pass-through increases in price sensitivity of consumers; hump-shaped relationship between pass-through and number of sellers

Implications for public policy

The extent to which commodity taxes are passed through depends on

▶ the price sensitivity of consumers
▶ as well as the price elasticity of aggregate demand

How should this affect different policy areas?

▶ Use unconventional fiscal policy targeted at markets with high degree of price transparency
▶ Account for incomplete pass-through when estimating optimal Pigouvian taxes
▶ Account for how imperfect information affects tax incidence to assess distributional consequences
Comments welcome!
Stage 2: equilibrium price distribution

The lowest price firms may draw in equilibrium:

\[ p = \frac{p_r}{\phi_N} + c \frac{1 + \tau}{1 + \frac{1-\phi}{\phi_N}} \]  \hspace{1cm} (2)

The CDF of the equilibrium pricing strategy:

\[ F(p_i) = 1 - \left( \frac{p_r - p_i}{p_i - c(1 + \tau) \frac{1 - \phi}{N\phi}} \right)^{\frac{1}{N-1}} \]  \hspace{1cm} (3)
Stage 2: expected price & expected minimum price

The expected price:

\[ E[p] = p + \left( \frac{1 - \phi}{N \phi} \right)^{\frac{1}{N-1}} \int_{\underline{p}}^{p_r} \left( \frac{p_r - p}{p - c(1 + \tau)} \right)^{\frac{1}{N-1}} dp \quad (4) \]

The expected minimum price:

\[ E[p_{\text{min}}] = \frac{1 - \phi}{\phi} \left[ p_r - E[p] + (p_r - c(1 + \tau))c(1 + \tau) \int_{\underline{p}}^{p_r} \frac{1}{(p - c(1 + \tau))^2} F(p) dp \right] \quad (5) \]
The equilibrium number of entrants $N^*$:

$$
\left( \frac{p_r}{1 + \tau} - c \right) \frac{1 - \phi}{F} M - 1 < N^* \leq \left( \frac{p_r}{1 + \tau} - c \right) \frac{1 - \phi}{F} M. \tag{6}
$$

This study: assume that there is no entry, since six-month temporary VAT reduction is unlikely to result in entry.
## Summary statistics

<table>
<thead>
<tr>
<th></th>
<th>Germany pre-treatment</th>
<th>Germany post-treatment</th>
<th>France pre-treatment</th>
<th>France post-treatment</th>
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<tr>
<td><strong>A. Station characteristics</strong></td>
<td></td>
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<td>Number of stations</td>
<td>14,554</td>
<td>14,490</td>
<td>8,832</td>
<td>9,104</td>
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<td>Median comp. nr. (5km markets)</td>
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<td>4</td>
<td>2</td>
<td>2</td>
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<td>Share of local monopolists</td>
<td>13%</td>
<td>13%</td>
<td>19%</td>
<td>19%</td>
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<td><strong>B. Prices, E5</strong></td>
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<td>Mean price</td>
<td>1.23</td>
<td>1.39</td>
<td>1.35</td>
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<td>Mean price net of taxes and duties</td>
<td>.41</td>
<td>.45</td>
<td>.44</td>
<td>.51</td>
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<tr>
<td>Mean retail margin</td>
<td>.13</td>
<td>.11</td>
<td>.16</td>
<td>.17</td>
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<td><strong>C. Prices, E10</strong></td>
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<tr>
<td>Mean price net of taxes and duties</td>
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<td>.41</td>
<td>.43</td>
<td>.49</td>
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<tr>
<td>Mean retail margin</td>
<td>.09</td>
<td>.07</td>
<td>.15</td>
<td>.16</td>
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<td>.48</td>
<td>.42</td>
<td>.49</td>
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<tr>
<td>Mean retail margin</td>
<td>.16</td>
<td>.15</td>
<td>.14</td>
<td>.15</td>
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<td><strong>E. Mobility data</strong></td>
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<tr>
<td>Retail &amp; recreation</td>
<td>-28.8%</td>
<td>-60.1%</td>
<td>-40.7%</td>
<td>-39.3%</td>
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<tr>
<td>Workplaces</td>
<td>-16.1%</td>
<td>-31.4%</td>
<td>-25.1%</td>
<td>-23.1%</td>
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</tbody>
</table>
Tax decrease: margin change as share of total tax change
Tax increase: margin change as share of total tax change

-40 %
-20 %
0
20 %
40 %

Share of total tax change

1 Nov 2020
1 Dec 2020
15 Dec 2020
1 Jan 2021
1 Feb 2021

E5
E10
Diesel
SDiD algorithm

1. Compute the regularization parameter;
2. Compute the unit weights \( \hat{w}_{i}^{sdid} \);
3. Compute the time weights \( \hat{\lambda}_{t}^{sdid} \);
4. Compute the SDID estimator \( \hat{\tau}^{sdid} \) via

\[
(\hat{\tau}^{sdid}, \hat{\mu}, \hat{\alpha}, \hat{\beta}, \hat{\gamma}) = \arg \min_{\tau, \mu, \alpha, \beta, \gamma} \left\{ \sum_{i=1}^{N} \sum_{t=1}^{T} (Y_{it} - \mu - \alpha_{i} - \beta_{t} - X_{it}\gamma - W_{it}\tau)^2 \hat{w}_{i}^{sdid} \hat{\lambda}_{t}^{sdid} \right\}
\]
Unit weights:

\[
(\hat{w}_0, \hat{w}^{sdid}) = \arg \min_{w_0 \in \mathbb{R}, w \in \Omega} l_{\text{unit}}(w_0, w), \quad \text{where}
\]

\[
l_{\text{unit}}(w_0, w) = \frac{T_{\text{pre}}}{N_{tr}} \left( w_0 + \sum_{i=1}^{N_{co}} w_i Y_{it} - \frac{1}{N_{tr}} \sum_{i=N_{co}+1}^{N} Y_{it} \right)^2 + \zeta^2 T_{\text{pre}} \| w \|_2^2,
\]

\[
\Omega = \left\{ w \in \mathbb{R}_+^N : \sum_{i=1}^{N_{co}} w_i = 1, w_i = N_{tr}^{-1} \text{ for all } i = N_{co} + 1, \ldots, N \right\}.
\]
Regularization parameter:

\[
\bar{\xi}^2 = \frac{1}{N_{co}T_{pre}} \sum_{i=1}^{N_{co}} \sum_{t=1}^{T_{pre}} (\Delta_{it} - \bar{\Delta})^2, \text{ where}
\]

\[
\Delta_{it} = Y_{i,(t+1)} - Y_{it}, \text{ and } \bar{\Delta} = \frac{1}{N_{co}(T_{pre} - 1)} \sum_{i=1}^{N_{co}} \sum_{t=1}^{T_{pre}-1} \Delta_{it}.
\]
SDiD algorithm

Time weights:

\[
(\hat{\lambda}_0, \hat{\lambda}^{sdid}) = \arg \min_{\lambda_0 \in \mathbb{R}, \lambda \in \Lambda} l_{time}(\lambda_0, \lambda), \quad \text{where}
\]

\[
l_{time}(\lambda_0, \lambda) = \sum_{i=1}^{N_{co}} \left( \lambda_0 + \sum_{t=1}^{T_{pre}} \lambda_t Y_{it} - \frac{1}{T_{post}} \sum_{t=T_{pre}+1}^{T} Y_{it} \right)^2,
\]

\[
\Lambda = \left\{ \lambda \in \mathbb{R}_+^T : \sum_{t=1}^{T_{pre}} \lambda_t = 1, \lambda_t = T^{-1}_{post} \text{ for all } t = T_{pre} + 1, .., T \right\}.
\]
(a) Summer 2020

(b) Winter 2020/21
Dynamic effects of the tax change on retail margins

**Tax decrease**

- Diesel
- E5
- E10

**Tax increase**

- Diesel
- E5
- E10
### Effect of the tax decrease on log prices (DiD)

<table>
<thead>
<tr>
<th></th>
<th>E5</th>
<th>E10</th>
<th>Diesel</th>
<th>E5</th>
<th>E10</th>
<th>Diesel</th>
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<tbody>
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<td>-.0115***</td>
<td>-.0237***</td>
<td>-.0079***</td>
<td>-.0123***</td>
<td>-.0233***</td>
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<tr>
<td></td>
<td>(.0003)</td>
<td>(.0002)</td>
<td>(.0002)</td>
<td>(.0003)</td>
<td>(.0002)</td>
<td>(.0002)</td>
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<tr>
<td>Retail &amp; recreation</td>
<td>.0016***</td>
<td>.0033***</td>
<td>.0039***</td>
<td>(.0005)</td>
<td>(.0004)</td>
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<td>.0115***</td>
<td>-.0017***</td>
<td>(.0004)</td>
<td>(.0004)</td>
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<td>(.0003)</td>
<td></td>
<td></td>
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<tr>
<td>DE × oil price</td>
<td>.1952***</td>
<td>.1624***</td>
<td>.0394***</td>
<td>.2245***</td>
<td>.1919***</td>
<td>.0451***</td>
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<tr>
<td></td>
<td>(.0053)</td>
<td>(.0033)</td>
<td>(.0030)</td>
<td>(.0053)</td>
<td>(.0033)</td>
<td>(.0031)</td>
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<tr>
<td>Pass-through rate</td>
<td>27%</td>
<td>46%</td>
<td>94%</td>
<td>31%</td>
<td>49%</td>
<td>93%</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>2,329,576</td>
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<td>Adjusted $R^2$</td>
<td>0.889</td>
<td>0.887</td>
<td>0.952</td>
<td>0.890</td>
<td>0.887</td>
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<td>Mean price</td>
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<td>1.06</td>
<td>1.24</td>
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### Effect of the tax increase on log prices (DiD)

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<td>0.0581***</td>
<td>0.0613***</td>
<td>0.0824***</td>
<td>0.0576***</td>
<td>0.0606***</td>
<td>0.0810***</td>
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<td></td>
<td>(0.0004)</td>
<td>(0.0003)</td>
<td>(0.0002)</td>
<td>(0.0004)</td>
<td>(0.0003)</td>
<td>(0.0002)</td>
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<td>-0.0054***</td>
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<td>-0.0051***</td>
<td>-0.0054***</td>
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<tr>
<td></td>
<td>(0.0004)</td>
<td>(0.0003)</td>
<td>(0.0003)</td>
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<td>-0.0068***</td>
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<tr>
<td></td>
<td>(0.0004)</td>
<td>(0.0004)</td>
<td>(0.0004)</td>
<td>(0.0004)</td>
<td>(0.0004)</td>
<td>(0.0004)</td>
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<tr>
<td>DE × oil price</td>
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<td>0.0258***</td>
<td>0.0963***</td>
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<td>0.0085***</td>
<td>0.0708***</td>
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<tr>
<td></td>
<td>(0.0068)</td>
<td>(0.0041)</td>
<td>(0.0030)</td>
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<td>Pass-through rate</td>
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<td>73%</td>
<td>85%</td>
<td>71%</td>
<td>72%</td>
<td>84%</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Observations</td>
<td>1,456,883</td>
<td>1,600,333</td>
<td>1,871,204</td>
<td>1,455,899</td>
<td>1,598,098</td>
<td>1,868,287</td>
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<tr>
<td>Adjusted $R^2$</td>
<td>0.942</td>
<td>0.948</td>
<td>0.970</td>
<td>0.942</td>
<td>0.948</td>
<td>0.971</td>
</tr>
<tr>
<td>Mean price</td>
<td>1.30</td>
<td>1.26</td>
<td>1.13</td>
<td>1.30</td>
<td>1.26</td>
<td>1.13</td>
</tr>
</tbody>
</table>
Average pass-through by number of competitor stations, E5

![Graph showing the relationship between average pass-through rate and number of competitor stations within a 3km radius. The graph indicates a downward trend as the number of competitor stations increases.]
Average pass-through by number of competitor stations, E10
Average pass-through by number of competitor stations, E5
Average pass-through by number of competitor stations, E10
Average pass-through by number of competitor stations, diesel
Average pass-through by number of competitor stations, diesel