Colluding Against Environmental Regulation: The Case of German Automakers

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Tech Adoption in an Oligopolistic Industry

- Regulation often necessitates technology adoption
- Firms may find it feasible to coordinate tech adoption
  - E.g., through R&D joint ventures, industry consortia, business meetings
- Such coordination can turn into foot-dragging
  - High-profile cases: automobile emissions control, seat belt and airbag, electric vehicle, e-SIM card

Kenneth Hahn, Los Angeles County supervisor, 1964:

> *I have tried to tell [the auto executives] ... that they have a responsibility on air pollution and they have not met it ... [T]hey know about the problem ... They have been here; there are devices manufactured that have been proven ... [A]nd it is strange why they have not put it on all their cars.*

Donald Schaffer, general counsel to Allstate Insurance, 1972:

> *[T]he installation of airbags is not being delayed because the technology is not ready or because the cost outweighs the benefits. Rather their installation is resisted for politico - economic and philosophic reasons unrelated to the technical merits or their ability to save lives and prevent injuries.*

John Casesa, Group Vice President of Global Strategy at Ford, 1999:

> *The government wants clean air, the people want clean air, and all manufacturers want to get there. Why should we compete with ourselves to develop a new technology?*

Substantial Policy Interest

- United States v. Motor Vehicle Mfrs. Association Inc. (1969)
  - "A conspiracy to eliminate competition among themselves in the research, development, manufacture, and installation of pollution control equipment"
- Justice Department: AT&T, Verizon, and a telecommunications standards organization (2018)
  - Apple and a wireless carrier complained about the resistance to switch from SIM cards to eSIM
  - Antitrust chief vowed to scrutinize industry standards that could hurt competition
- EU: five premium German automakers (Daimler, BMW, Audi, Porsche, and Volkswagen) (2019)
  - Breached EU antitrust rules from 2006 to 2014 by colluding to restrict competition on the development of technology to clean vehicle emissions
  - "European consumers may have been denied the opportunity to buy cars with the best available technology "

This Paper

- Research Questions
  1. What makes firms collude on technology adoption?
  2. What are the welfare consequences of such collusion?
  3. What should regulators do about it?
- Context
  - German automakers' collusion in adopting ineffective NO_x control technology (small AdBlue tanks) in diesel passenger vehicles in EU since 2006

Methodology

- A structural model of technology collusion
  - in each period, colluding automakers
    - first choose AdBlue tank size in a potentially coordinated way
    - then choose price competitively
    - subject to probabilistic government detection
  - whereas non-colluding automakers choose both competitively
- Data:
  - vehicles sales from JATO, vehicle specifications from a German consumers' auto club website, demographics
- Policy simulations:
  - competitive vs. collusive vs. socially optimal outcomes and likelihoods, in various market conditions, under the following government interventions:
    - status quo
    - changes in detection probability and punishment severity
    - technology mandate vs. performance standards vs. market-based regulation

Policy Implications

1. Antitrust in technical development
   - EU competition rules prohibit cartel agreements to "limit or control ... technical development"
   - Distinguish collusion from "forms of cooperation between companies aimed at improving product quality and innovation which do not raise concerns under EU competition law"
   - DoJ recently vowed to scrutinize industry standards
2. Environmental regulation with imperfect competition
   - Performance of technology mandate vs. performance standards vs. market-based regulation when technology collusion is possible
   - Important industries: electricity generation, automobiles, air transport, resource extraction

Literature

1. Non-price collusion
   - Hackner (1995), Xu and Coatney (2015), Sullivan (2017), Ale-Chilet and Atal (2019)
   - Our contribution: externality and government detection
2. Technology adoption with imperfect competition
   - E.g., Baker and Phibbs (2002), Schmidt-Dengler (2006), Milliou and Petrakis (2011)
   - Our contribution: go beyond static competition to collusion
3. Technical standards
   - E.g., Shapiro (2001), Basker and Simcoe (2019), Li (2019)
   - Our contribution: endogenize standards to market competition
4. Environmental regulation in the automotive sector
   - E.g., Klier and Linn (2016), Reynaert (2017), Reynaert and Sallee (2018), Tanaka (2019), Li (2019), Leard et al. (2019)

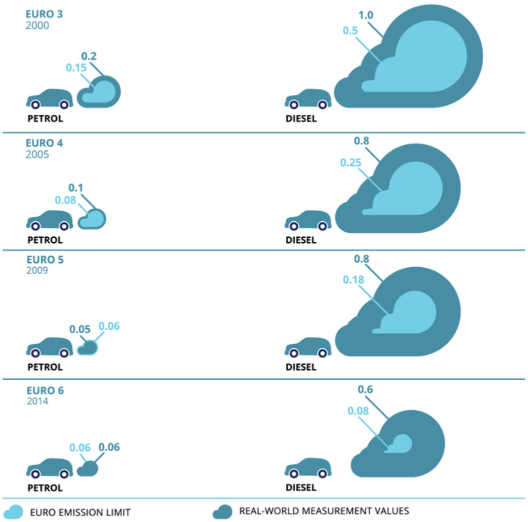
Rest of Talk

1. Background
2. Conceptual framework
3. Data
4. Model sketch
5. Conclusion

Background

- Adverse effects of NO_x
  - NO_x + atmospheric chemicals = PM 2.5 -> 4.2 million premature deaths worldwide in 2015
  - NO_x + VOC + sunlight = ozone -> 254,000 premature deaths worldwide in 2015
  - NO_x reduces crop and forest productivity -> more CO_2
- Road transport = ~40% of NO_x emissions in both EU and US
  - NO_x in diesel exhaust is a particularly hard problem
- NO_x control technologies for diesel vehicles
  1. Exhaust Gas Recirculation: in-chamber, widely installed, ↑ PM emissions & fuel consumption
  2. Aftertreatments:
     - 2.1 Lean NO_x trap: ↑ fuel consumption, good for small vehicles
     - 2.2 Selective Catalytic Reduction (SCR): minimal impact on fuel consumption, attractive for big vehicles, need extra tank and refills for the AdBlue fluid
     - 2.3 Combination of SCR and trap

Comparison of NO_x emission standards for different Euro classes



Adapted from: ICCT, 2014a; Emisia, 2015

Nitrogen oxide (NO_x) emissions (in g/km)

"Circle of Five"

- Members: BMW, Daimler, VW, Porsche and Audi (both owned by VW)
- 2006: used different tank sizes for AdBlue; "this was absurd", needed a "coordinated approach", "target size of 17 to 23 liters"
- 2007: still installed "between 17 and 35 liters", "urgent need for cooperation among the companies"
- 2008: agreed on tanks as small as 8-liter. "It was lightweight", "didn't cost much", "left enough space for golf bags in the trunk"
- 2011: preparing for Euro 6, Audi warned against any company going it alone; to avoid "at all costs" "an arms race with regard to tank sizes"
  - Der Spiegel: "If one manufacturer had installed larger AdBlue tanks, ... authorities would probably have become suspicious. The obvious question would have been why that one company's vehicles needed so much more urea to clean the exhaust gases, while the other manufacturers' cars supposedly managed with significantly less AdBlue."
- 2017: European Commission inspected firms' premises unannounced
- 2018: EC began an formal investigation into whether they "colluded, in breach of EU antitrust rules, to avoid competition on ... the roll-out of emissions control technologies from 2006-2014"
- 2019: EC concluded investigation, sent Statement of Objections

Conceptual Framework

If:

- Firms $i = 1, 2$
- Decide between S (small tank) vs. L (large)
- Cost $c(L) > c(S) > 0$
- Sell product at a common price $P > c(L)$, split the market

Then (S, S) is the competitive outcome -> no need to collude

What would make firms collude on (S,S)?

- Need regulation
  - Suppose only L is compliant
  - Once detected, firm with S not allowed to produce
  - Imperfect detection: $0 \leq \alpha_{SS} < \alpha_{SL} = \alpha_{LS} < 1$

Conceptual Framework (cont'd)

	S	L
S	$\frac{1}{2}(1-\alpha_{SS})\pi(S), \frac{1}{2}(1-\alpha_{SS})\pi(S)$	$\frac{1}{2}(1-\alpha_{SL})\pi(S), (\alpha_{SL}+\frac{1}{2}(1-\alpha_{SL}))\pi(L)$
L	$(\alpha_{SL}+\frac{1}{2}(1-\alpha_{SL}))\pi(L), \frac{1}{2}(1-\alpha_{SL})\pi(S)$	$\frac{1}{2}\pi(L), \frac{1}{2}\pi(L)$

Conditions for (S, S) to be collusive given competitive (L, L):

1. (S, S) be more efficient than (L, L): need small enough α_{SS}
2. (S, S) be not competitive/Nash: need big enough α_{SS} or α_{SL}
3. (S, S) be enforceable by inter-temporal incentives: need small enough α_{SS} or α_{SL}
4. (L, L) be static Nash: need big enough α_{SL}

Data

- Vehicle registrations
  - JATO
  - Monthly new registrations, trim-level, 1998-2018, 9 largest EU markets (Germany, UK, France, Netherlands, Belgium, Spain, Italy, Portugal, Greece)
  - Includes country-specific MSRP and tax for each trim
- Vehicle specifications
  - A German consumers' auto club website
  - All trims available to German consumers, 1960-present, >200 variables
  - JATO: Model-level crossover across major EU countries close to 100%, variations are merely trim-level
- Demographics and general market information
- Unless otherwise noted, using all trims from 2005-2018 below...

Table 1: Choice of NO_x Technology in Euro 5 - 6 Diesels

	DPF only	NOx Trap	SCR	NOx Trap + SCR
Horsepower	148.43	147.69	165.27	244.32
	(52.62)	(56.03)	(60.81)	(96.51)
CC	2037.91	1850.19	2115.86	2393.17
	(523.05)	(437.43)	(525.39)	(610.86)
Footprint	8.59	8.29	9.26	9.18
	(0.99)	(0.74)	(0.91)	(0.64)
Weight	1727.87	1578.25	1884.91	1905.54
	(321.78)	(259.01)	(318.68)	(278.30)
Convertible	0.03	0.02	0.01	0.00
	(0.16)	(0.16)	(0.10)	(0.00)
Coupe	0.03	0.03	0.02	0.03
	(0.17)	(0.18)	(0.14)	(0.17)
SUV	0.28	0.33	0.25	0.54
	(0.45)	(0.47)	(0.43)	(0.50)
Sedan	0.21	0.23	0.14	0.20
	(0.41)	(0.42)	(0.34)	(0.40)
Wagon	0.18	0.26	0.17	0.22
	(0.38)	(0.44)	(0.38)	(0.42)
Van	0.27	0.12	0.41	0.00
	(0.44)	(0.33)	(0.49)	(0.00)
Circle of Five	0.23	0.11	0.36	0.52
	(0.42)	(0.31)	(0.48)	(0.50)
N	2181	689	1095	103

Standard deviation in parentheses. All technologies have DPF.

Table 2: Circle of Five Installed Smaller AdBlue Tanks

	(1) log_AdBlue	(2) log_AdBlue	(3) log_AdBlue	(4) log_AdBlue
Circle of Five	−0.016	−0.065***	−0.039*	−0.050**
	(0.019)	(0.021)	(0.022)	(0.023)
Horsepower		0.000**	0.002***	0.001***
		(0.000)	(0.000)	(0.000)
CC		0.000**	0.000	0.000
		(0.000)	(0.000)	(0.000)
Constant	2.848***	2.645***	2.876***	3.174***
	(0.008)	(0.035)	(0.115)	(0.320)
Body FE			X	X
Emission Control FE			X	X
Drive Type FE			X	X
Year FE				X
N	1152	1152	1152	1152
Adjusted R^2	-0.000	0.042	0.161	0.206

Standard errors in parentheses. *: $p < 0.10$, **: $p < 0.05$, ***: $p < 0.01$.

Table 3: AdBlue Tank Increases Vehicle Weight

	(1) Weight	(2) Weight	(3) Weight	(4) Weight
AdBlue tank size	10.14***	15.40***	0.82***	1.74***
	(0.53)	(0.60)	(0.28)	(0.44)
Fuel tank size				0.69*
				(0.39)
Footprint				69.22***
				(5.81)
Height				0.11***
				(0.03)
# of seats				12.14***
				(2.02)
# of doors				53.14***
				(8.55)
# of gears				7.13***
				(1.75)
Horsepower				0.46***
				(0.05)
CC				0.09***
				(0.01)
Year FE		X	X	X
Series FE			X	X
All Other FE				X
N	5898	5898	5898	5898
Adjusted R^2	0.046	0.096	0.979	0.989

Standard errors in parentheses. *: $p < 0.10$, **: $p < 0.05$, ***: $p < 0.01$. Diesel vehicles only. All other fixed effects include transmission, drive, engine layout, and emission control technology fixed effects.

Table 4: AdBlue Tank Takes Up Cargo Room

	(1) Convertible	(2) Coupe	(3) SUV	(4) Sedan	(5) Van	(6) Wagon
AdBlue tank size	−1.54	−2.27*	−0.92**	−0.22	22.19**	−2.22*
	(0.96)	(1.31)	(0.41)	(0.29)	(10.43)	(1.22)
Fuel tank size	−2.71***	−0.18*	−2.31***	0.92***	−1.95	−0.19
	(0.25)	(0.11)	(0.48)	(0.11)	(1.61)	(0.23)
volume	0.04***	−0.03***	0.01	0.02***	0.40***	0.10***
	(0.00)	(0.01)	(0.01)	(0.00)	(0.02)	(0.01)
Horsepower	0.12***	0.02	0.04	0.04**	−0.81*	−0.04
	(0.04)	(0.06)	(0.08)	(0.02)	(0.49)	(0.05)
CC	−0.01***	0.00	0.00	0.00***	0.13***	0.00
	(0.00)	(0.00)	(0.01)	(0.00)	(0.03)	(0.00)
Torque	0.03	−0.02	−0.01	−0.02*	0.34	0.07**
	(0.03)	(0.02)	(0.04)	(0.01)	(0.28)	(0.03)
Weight	−0.10***	−0.00	−0.04	−0.09***	−1.74***	−0.01
	(0.02)	(0.01)	(0.03)	(0.01)	(0.20)	(0.02)
N	2025	1679	4523	9626	3117	4249
Adjusted R^2	0.988	0.990	0.898	0.977	0.979	0.904

Standard errors in parentheses. *: $p < 0.10$, **: $p < 0.05$, ***: $p < 0.01$. Fixed effects include series name, series start year, transmission, drive, engine layout, fuel type, and emission control technology fixed effects. Other controls include number of seats/doors/gears and a constant.

Table 5: AdBlue Tank Takes Up Cargo Room with Rear Seats Folded Down

	(1) SUV	(2) Sedan	(3) Wagon	(4) Van
AdBlue tank size	−1.24**	−8.68*	−5.27***	3.88
	(0.60)	(4.95)	(0.98)	(10.96)
Fuel tank size	−2.74***	−0.28	−2.54***	13.77***
	(0.71)	(0.41)	(0.64)	(2.70)
volume	−0.02	0.04***	0.18***	0.27***
	(0.01)	(0.01)	(0.01)	(0.04)
Horsepower	−0.40***	0.57***	−0.39***	−1.08***
	(0.07)	(0.10)	(0.11)	(0.33)
CC	0.00	−0.01	0.02***	0.09***
	(0.01)	(0.00)	(0.01)	(0.02)
Torque	0.22***	−0.27***	0.24***	−0.29
	(0.04)	(0.07)	(0.06)	(0.22)
Weight	0.13***	−0.10***	−0.04	0.36***
	(0.03)	(0.02)	(0.04)	(0.14)
N	4350	6104	4216	2493
Adjusted R^2	0.948	0.971	0.949	0.972

Standard errors in parentheses. *: $p < 0.10$, **: $p < 0.05$, ***: $p < 0.01$. Fixed effects include series name, series start year, transmission, drive, engine layout, fuel type, and emission control technology fixed effects. Other controls include number of seats/doors/gears and a constant.

Model Sketch

In each period, colluding firms:

Stage 1. jointly choose AdBlue tank sizes

Stage 2. competitively choose price

while non-colluding firms choose both competitively.

i.e. add technology collusion to a basic model similar to Fan (2013)'s where newspapers choose product characteristics and then prices

We take predetermined:

1. cartel membership
2. NO_x technology adopted
3. other vehicle characteristics

Identification

1. Estimate demand
   - Willingness to pay for cargo space and fuel economy
   - Combine demand estimates with tradeoff estimates
     $\implies$ how AdBlue tank size affects demand
2. Estimate supply
   - Competitive pricing stage allows us to recover marginal cost
     $\implies$ how AdBlue tank size affects supply
3. Estimate detection probabilities
   - Steps 1 and 2 will have given us supply and demand as functions of AdBlue tank size
   - Level of AdBlue tank sizes identifies the symmetric part of detection probabilities
   - Dispersion of AdBlue tank sizes identifies the asymmetric part of detection probabilities

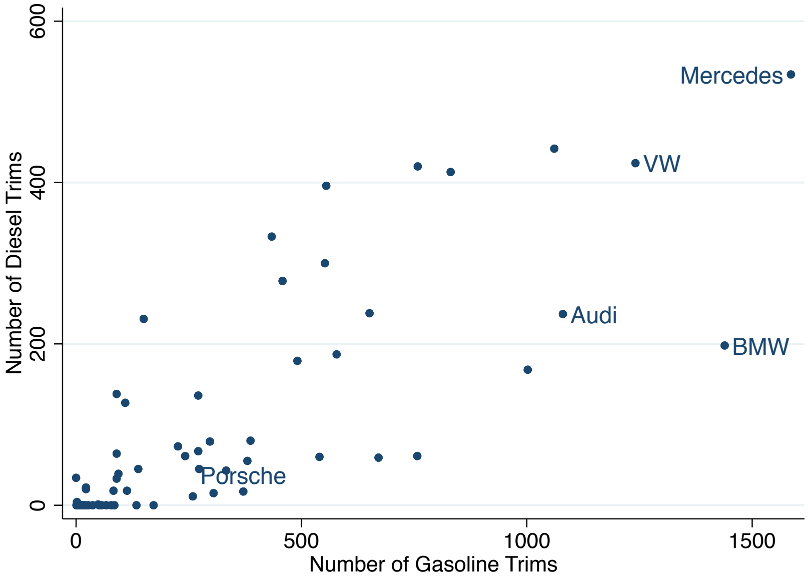
What Do We Do with the Estimated Model?

1. Simulate consumer welfare in various environments
    1.1 Market variations in e.g. cargo space value, economy of scale
    1.2 Regulation variations in e.g. detection probabilities, punishment severity, technology mandates, attribute-based regulation
2. Understand firms' conduct
    2.1 When technology collusion may occur
    2.2 How far those outcomes are from social optima
    2.3 What regulatory intervention can get us closer to social optima

Conclusion

- Firms may find it feasible and desirable to coordinate technology adoption in response to environmental regulation
- We use a structural model to study market and regulatory conditions conducive to technology collusion and the welfare consequences in the context of the German automakers' collusion in limiting vehicle emissions control technologies
- Our model is informed by the following quantitative evidence (as well as press articles and engineering knowledge):
  1. German automakers installed smaller AdBlue tanks
  2. AdBlue tank increases vehicle weight
  3. AdBlue tank takes up cargo room
- Next steps: structural estimation and policy simulation

Supplementary Slides



Number of Diesel Trims
0
200
400
600
Number of Gasoline Trims
0
500
1000
1500
Mercedes
VW
Audi
BMW
Porsche

Table 6: Adblue tanks do not add to the increasing trend in vehicle size

	(1) Log(Footprint)	(2) Log(Height)	(3) Log(Volume)
Series Year	0.41***	0.23***	0.64***
	(0.15)	(0.08)	(0.18)
Series Year Sq	−0.00***	−0.00***	−0.00***
	(0.00)	(0.00)	(0.00)
1(AdBlue)	−0.31	−0.08	−0.39
	(0.80)	(0.72)	(1.18)
1(AdBlue) X Series Year	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)
CC	−0.00***	−0.00	−0.00**
	(0.00)	(0.00)	(0.00)
N	4182	4182	4182
Adjusted R^2	0.980	0.989	0.982

Standard errors in parentheses. *: $p < 0.10$, **: $p < 0.05$, ***: $p < 0.01$. Diesel vehicles only.