The Effects of Heavy-Duty Vehicle Fuel Economy Standards

Stephanie M. Weber

Yale School of the Environment

Motivation

- The transportation sector is the largest contributor to US greenhouse gas emissions (28% as of 2018)
- Trucks are < 10% of vehicles on the road, 20% of transport CO_2 emissions
- Fuel efficiency regulations were only imposed recently (announced in 2011, implemented in 2014), virtually no ex post research exists on truck policies

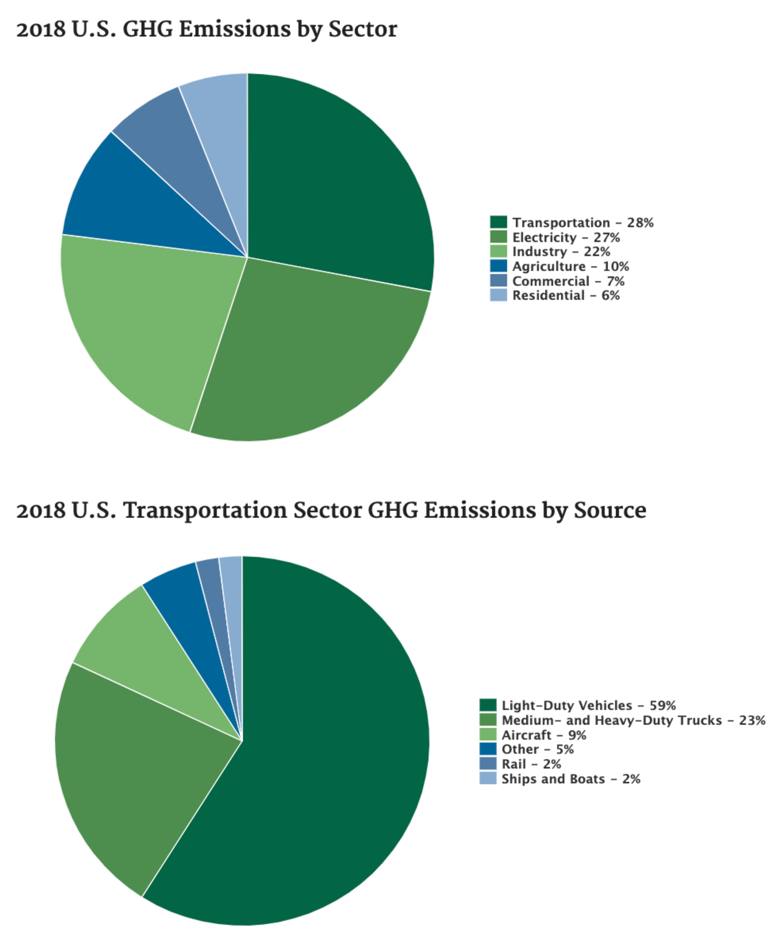


Figure 1. 2018 GHG emissions by sector, transport emissions by source. Source: EPA

Research Questions

- What is the effect of recent truck fuel economy standards on consumer welfare, manufacturer profits, fleet attributes and safety, environmental damages?
- Are there heterogeneous consequences for different buyers or manufacturers?

Empirical Setting

Truck Characteristics

- Vehicles characterized by gross vehicle weight rating
- Heavy duty trucks (class 7 and 8) can be combination tractors or vocational vehicles
- Buyers also care about: presence of sleeper cab, roof height, axle configuration, fuel intensity…

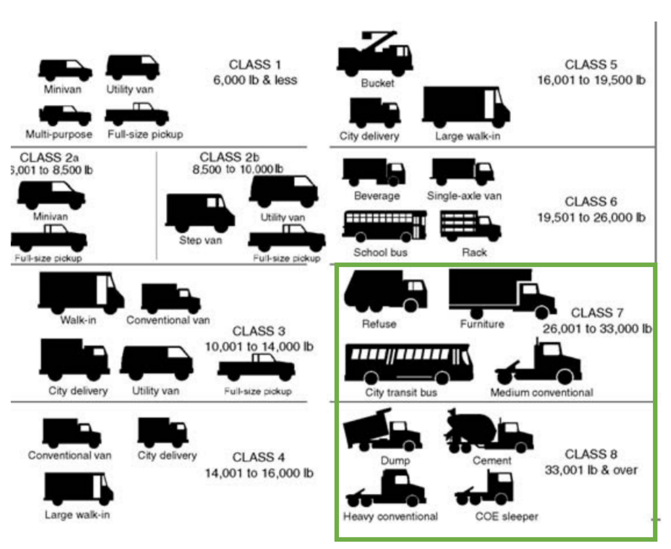


Figure 2. Examples of trucks by class Source: Commercial Carrier Journal

Market

- Truck manufacturers: 8 firms, producing 11 brands in the data
- Truck buyers: use trucks for widely varying commercial purposes (especially freight)

Policy: Heavy-Duty National Program Phase I (2014-2018)

	EPA Emissions Standards ($g\ CO_2$/ton-mile)			NHTSA Fuel Consumption Standards (gal/1,000 ton-mile)		
	Low Roof	Mid Roof	High Roof	Low Roof	Mid Roof	High Roof
Day Cab Class 7	104	115	120	10.2	11.3	11.8
Day Cab Class 8	80	86	89	7.8	8.4	8.7
Sleeper Cab Class 8	66	73	72	6.5	7.2	7.1

Figure 3. Standards by category for 2017.

Data

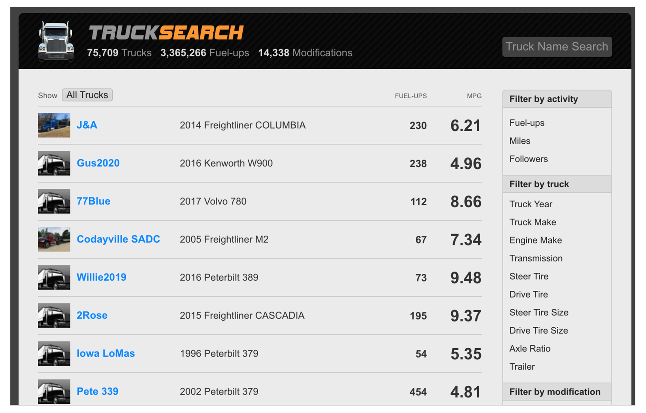
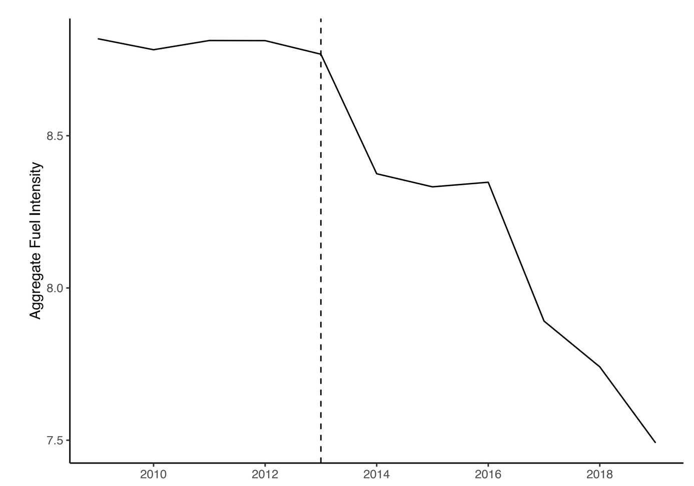


Figure 4. Fuel efficiency data source.



- Annual sales data by model, 2009-2019
- Truck model attributes
- Fuel efficiency from fuel tracking website
- State-level manufacturing wages from BLS, plant assembly location from VINs
- Industry-level employment from County Business Patterns

Figure 5 (left). Aggregate fuel intensity of non-vocational trucks sold, 2009-2019.

Model/Estimation

Demand Model 2009-2019 data

Buyer *i* chooses truck *j* to maximize utility

$$U_{i,j} = x_j\left(\beta_x + \sum_{ind} 1(i \text{ in } ind)\, \beta_x^{ind} + \beta_x^u\right) + p_j\beta_p + \xi_j + \varepsilon_{i,j}$$

- x_j : truck attributes
- $1(i \text{ in } ind)$: indicator that buyer *i* is in industry *ind*
- p_j: truck price
- ξ_j: unobs. truck attributes

Supply Model Pre-policy (2009-2013) and Policy Phase I (2014-2018) data

Firm *f* chooses prices to maximize profits and comply with policy

$$max_p \sum_{j \epsilon J_f} \left[(p_j - mc_j)q_j(p) + \sum_r \lambda_r q_j(p) L_{j,r}\right]$$

- mc_j: marginal cost
- q_j: quantity
- λ_r: shadow cost of policy on regulatory group *r*
- $L_{j,r}$: truck *j*'s distance from group *r* standard

→ Derive marginal cost function using FOCs

$$mc_{j,t} = \alpha + \gamma X_{j,t} + \omega_{j,t} + g_{f,r,t}(e_j)$$

- $\omega_{j,t}$: time-truck specific error term
- $g_{f,r,t}(e_j)$: firm-group-specific shadow cost that depends on vehicle fuel intensity, policy timing

Counterfactual Simulations

Re-solve for market equilibrium in the absence of policy

Results

Supply and demand estimates:

	logit	random coeffs
Mean parameters		
Prices	-0.02	-0.015
	(0.004)	(0.004)
GVW	0.888	0.568
	(0.457)	(0.45)
Class 7 day cab	2.729	3.258
	(0.54)	(0.531)
Class 8 day cab	1.385	1.744
	(0.444)	(0.435)
Sleeper cab	2.131	2.492
	(0.631)	(0.619)
4×2 axle config.	0.265	0.304
	(0.099)	(0.099)
6×4 axle config.	2.403	2.475
	(0.096)	(0.094)
8×4, 8×6 axle config.	0.192	0.125
	(0.142)	(0.14)
Medium conventional cab	-0.217	-0.133
	(0.12)	(0.118)
Non-conventional cab	0.139	0.278
	(0.166)	(0.163)
Fuel Intensity (FI)	0.114	0.166
	(0.046)	(0.045)
Day × FI	-0.162	-0.261
	(0.056)	(0.055)
Sleeper × FI	-0.189	-0.302
	(0.084)	(0.082)
Constant	-5.786	-6.272
	(0.943)	(0.92)
Buyer attribute interactions		
Vocational × Construction	–	0.531
	–	(0.011)
Vocational × General Freight	–	-2.176
	–	(0.002)
Vocational × Sanitation	–	0.493
	–	(0.013)
Vocational × Specialized Hauling	–	-0.106
	–	(0.019)

Table 1. Demand model estimated with and without industry preferences.

	(1)	(2)	(3)	(4)	(5)
Post-standard	13.04	40.92	4.03	26.31	-16.61
	(8.19)	(8.2)	(8.52)	(14.57)	(12.84)
Post-standard × fuel intensity	-0.7	0.83	0.85	2.23	2.97
	(0.77)	(0.73)	(0.72)	(1.51)	(1.32)
Post-standard × sleeper	-30.09	-51.05	-48.16	-41.4	-38.33
	(13.86)	(12.25)	(12.07)	(12.09)	(11.95)
Post-standard × sleeper × fuel intensity	3.81	5.45	5.11	4.37	4.02
	(1.49)	(1.31)	(1.3)	(1.3)	(1.28)
PACCAR × Post-standard		-52.28	-5.74	-26.17	25.56
		(3.21)	(5.35)	(17.59)	(16.64)
Navistar × Post-standard		-22.42	10.82	0.2	39.73
		(3.8)	(6.94)	(18.61)	(17.61)
Daimler × Post-standard		-58.77	-7.21	-76.43	-15.97
		(3.25)	(5.79)	(16.24)	(15.16)
PACCAR × fuel intensity × Post-standard				-2.57	-3.23
				(1.85)	(1.7)
Navistar × fuel intensity × Post-standard				-2.43	-3.08
				(2.03)	(1.88)
Daimler × fuel intensity × Post-standard				2.06	0.98
				(1.73)	(1.55)
Average Policy Cost					
PACCAR Day Cab	4.98	-1.82	8.01	-3.67	5.97
PACCAR Sleeper	10.56	-6.50	3.16	-5.30	4.11
Navistar Day Cab	6.60	26.12	22.61	24.69	22.13
Navistar Sleeper	8.83	19.86	16.40	19.92	17.45
Daimler Day Cab	6.45	-10.06	4.76	-9.88	4.41
Daimler Sleeper	8.06	-18.04	-3.10	-21.35	-6.38
Volvo Day Cab	6.31	48.88	12.14	47.68	11.79
Volvo Sleeper	8.98	42.57	5.86	40.32	3.70
Firm FE	✓	✓	✓	✓	✓
Firm × fuel intensity				✓	✓
Firm × time			✓		✓

Table 2. Estimates of the policy-induced components of marginal cost for non-vocational vehicles.

Counterfactual results:

- Under policy, consumers worse off and manufacturer profits increase
  - Compensating variation: $27 -$47M
  - Increased profit: $4-$6B

	% Change Profit
PACCAR	+4 to 10%
International	+1 to 7%
Daimler	+3 to 13%
Volvo	-8 to +4%

Table 3. Change in profits by manufacturer of non-vocational vehicles.

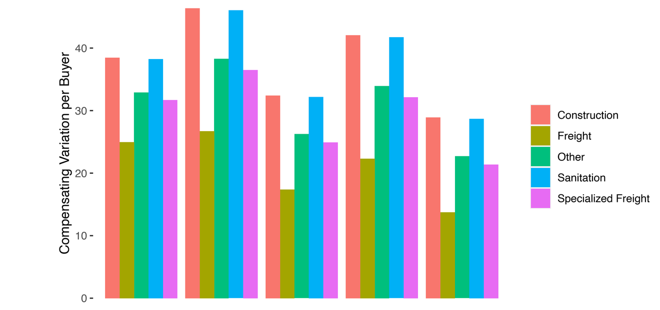


Figure 6. Compensating variation by industry across model specifications.

- Characteristics of vehicles sold change:
  - Fuel intensity improved by .5-1.5%
  - GVW of day and sleeper cabs increased .3-2%
  - Sales-weighted average prices fell, but average price increased up to 7%

Findings and Next Steps

- Truck fuel economy standards benefited many manufacturers
- Consumers, esp. sanitation and construction buyers, were made worse off because it was harder for these buyers to switch to alternative vehicles
- Policy had indirect effects on safety, road damage via GVW
- Future work:
  - Additional counterfactual simulations of alternative policy specifications (uniform policy, mpg-based policy)
  - Environmental damages