Are There Environmental Benefits from Driving Electric Vehicles? The importance of Local Factors

Holland et.al. (2015)

Enviromental Reading Group session 1

July 7, 2023

Research Question

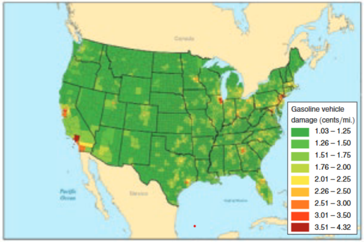
- Are electric vehicles more green than gasoline vehicles?
- What is the efficient policy for electric vehicle? Tax vs. Subsidy? National vs. local? Is full damage priced in current subsidy?

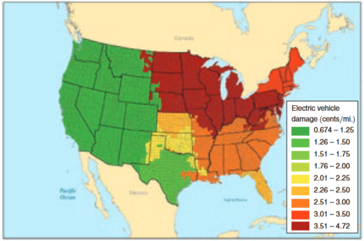
Calculation of Damages

Pollutants: $CO_2, SO_2, NO_X, PM_{2.5}, VOC_s$

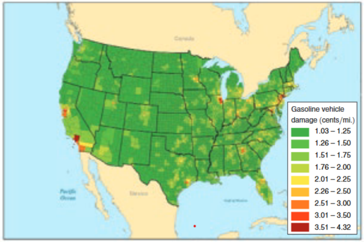
1. Emissions from Gasoline vehicles (gasoline conversion to pullutants) vs Electric Vehicle (electricity production)
2. Emissions to damages in \$

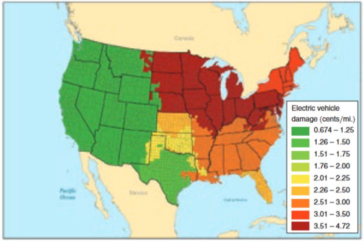
Damage for Gas and Electric Vehicle





Damage for Gas and Electric Vehicle





- On average, Gasoline vehicle has a lower damage than electric ones;
- Great geographic variation.

Electric Vehicle damage

Global vs Local?

TABLE 2—SUMMARY STATISTICS OF DAMAGES AND ENVIRONMENTAL BENEFITS IN CENTS PER MILE FOR 2014 ELECTRIC VEHICLES AND SUBSTITUTE 2014 GASOLINE VEHICLES ACROSS COUNTIES

	Electric vehicle			Gasoline vehicle			Environmental benefits		
Vehicle	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Panel A. Damages and environmental benefits									
Chevy Spark	2.28	0.59	4.17	1.69	0.95	4.30	−0.60	−3.15	3.08
Honda Fit	2.30	0.60	4.20	1.93	1.13	4.83	−0.37	−3.00	3.60
Fiat 500e	2.34	0.61	4.27	1.74	0.93	4.62	−0.60	−3.26	3.33
Nissan Leaf	2.38	0.62	4.35	1.23	0.74	3.53	−1.16	−3.52	2.22
Mitsubishi i-Miev	2.42	0.63	4.41	1.69	0.95	4.30	−0.73	−3.40	3.05
Smart fortwo	2.54	0.66	4.63	1.67	0.98	4.50	−0.87	−3.57	3.13
Ford Focus	2.59	0.67	4.72	1.86	1.03	4.32	−0.73	−3.63	3.16
Tesla S (60 kWh)	2.82	0.73	5.15	2.44	1.28	5.48	−0.38	−3.78	4.28
Tesla S (85 kWh)	3.06	0.80	5.59	2.67	1.48	5.74	−0.39	−4.02	4.55
Toyota Rav4	3.58	0.93	6.52	2.09	1.20	5.02	−1.49	−5.23	3.50
BYD e6	4.35	1.13	7.94	2.09	1.20	5.02	−2.27	−6.64	3.30

	Environmental benefits			Global environmental benefits			Local environmental benefits		
Vehicle	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Panel B. Decomposition of environmental benefits into global and local environmental benefits									
Chevy Spark	−0.60	−3.15	3.08	0.35	−0.14	0.72	−0.95	−3.01	2.37
Honda Fit	−0.37	−3.00	3.60	0.52	0.02	0.89	−0.89	−3.02	2.71
Fiat 500e	−0.60	−3.26	3.33	0.32	−0.19	0.71	−0.92	−3.08	2.63
Nissan Leaf	−1.16	−3.52	2.22	−0.09	−0.40	0.28	−1.07	−3.16	1.99
Mitsubishi i-Miev	−0.73	−3.40	3.05	0.30	−0.21	0.69	−1.04	−3.20	2.36
Smart fortwo	−0.87	−3.57	3.13	0.18	−0.24	0.57	−1.06	−3.34	2.57
Ford Focus	−0.73	−3.63	3.16	0.44	−0.21	0.89	−1.17	−3.43	2.28
Tesla S (60 kWh)	−0.38	−3.78	4.28	0.83	-0.07	1.36	−1.21	−3.72	2.93
Tesla S (85 kWh)	−0.39	−4.02	4.55	0.96	0.01	1.54	−1.36	−4.04	3.02
Toyota Rav4	−1.49	−5.23	3.50	0.23	−0.51	0.81	−1.72	−4.73	2.71
BYD e6	−2.27	−6.64	3.30	−0.04	−0.88	0.65	−2.23	−5.78	2.66

Environmental Benefits of Electric Vehicle by State: 2014 Ford Focus

TABLE 4—ENVIRONMENTAL BENEFITS IN CENTS PER MILE BY STATE FOR A 2014 FORD FOCUS
(Electric versus Gasoline)

State	Environmental benefits per mile	VMT (percent)	Damage per mile (gasoline)	Damage per mile (electric)	Purchase subsidy
Highest benefit states					
California	1.86	11	2.55	0.69	$2,785
Utah	0.73	1	1.77	1.04	$1,089
Colorado	0.60	2	1.63	1.03	$902
Arizona	0.59	2	1.62	1.02	$889
Washington	0.58	2	1.59	1.02	$865
Other high VMT states					
Texas	0.34	8	1.75	1.41	$505
Florida	−0.70	7	1.80	2.49	−$1,049
Georgia	−0.78	4	1.96	2.74	−$1,166
New York	−0.91	5	2.19	3.10	−$1,371
North Carolina	−1.07	4	1.67	2.74	−$1,611
Virginia	−1.20	3	1.72	2.93	−$1,807
Illinois	−1.56	3	2.31	3.87	−$2,345
Ohio	−1.76	4	1.89	3.65	−$2,640
Pennsylvania	−1.78	3	1.86	3.64	−$2,675
Michigan	−2.48	3	1.76	4.24	−$3,720
Lowest benefit states					
South Dakota	−2.66	0	1.27	3.93	−$3,992
Minnesota	−2.76	2	1.72	4.48	−$4,145
Wisconsin	−2.79	2	1.59	4.37	−$4,180
Iowa	−2.93	1	1.37	4.30	−$4,394
North Dakota	−3.31	0	1.27	4.58	−$4,964
US average	−0.73	100	1.86	2.59	−$1,095

Notes: The environmental benefits are the difference in damages between the gasoline-powered Ford Focus and the electric Ford Focus. Environmental benefits are weighted by gasoline-vehicle VMT within each state. The purchase subsidy assumes the vehicle is driven 150,000 miles.

- Great variation;
- Negative environmental benefits of electric vehicle for US average.

Externality

TABLE 5—NATIVE DAMAGES IN CENTS PER MILE BY STATE AND COUNTY AND EXPORT PERCENTAGES

Vehicle	Damages	Mean	Med.	SD	Min	Max
Electric	All	2.59	2.74	1.18	0.67	4.72
	Non-GHG	1.70	1.86	1.02	0.16	3.50
	State	0.15	0.16	0.07	0.04	0.33
	Export percent	91	91			91
	County	0.02	0.02	0.01	0.00	0.06
	Export percent	99	99			98
Gasoline	All	1.86	1.76	0.59	1.03	4.32
	Non-GHG	0.53	0.36	0.52	0.01	2.92
	State	0.43	0.26	0.51	0.00	2.76
	Export percent	19	28			5
	County	0.23	0.10	0.37	0.00	2.03
	Export percent	57	72			30
Environmental benefits	All	−0.73	−1.01	1.39	−3.63	3.16
	Non-GHG	−1.17	−1.48	1.19	−3.43	2.28
	State	0.28	0.12	0.51	−0.32	2.46
	County	0.21	0.08	0.37	−0.06	2.00

- Larger externality of electric vehicle;
- Electric vehicle has lower native damage

Optimal Policy

Discret Choice Model:

$$U_g = V_g + \varepsilon_g, U_e = V_e + \varepsilon_e$$
$$V_g = \max_{x,g} x + f(g) \quad s.t. x + (p_g + t_g)g = I - p_\Psi$$
$$V_e = \max_{x,e} x + f(e) \quad s.t. x + (p_e + t_e)g = I - (p_\Omega - s)$$

Hence, a consumer selects gasoline if

$$\pi = P(U_g > V_g) = \frac{exp(V_g/\mu)}{exp(V_g/\mu) + exp(V_e/\mu)} \tag{1}$$

and the expected utility becomes:

$$E(\max[U_e, U_g]) = \mu \ln(exp(V_e/\mu)) + exp(V_g/\mu)) \tag{2}$$

Model Cont.

consider each location as an independent agent, the welfare maximization function is:

$$\max W_i = \mu \ln(exp(V_e/\mu)) + exp(V_g/\mu)) + R_i - (\pi \delta_{gi} g_i + (1-\pi)\delta_{ei} e_i) \quad (3)$$

Optimal regional subsidy:

$$s_i^* = \delta_{gi} g_i - \delta_{ei} e_i \quad (4)$$

Optimal uniform subsidy:

$$s = (\sum_{\alpha_i} \delta_{gi}) g - (\sum_{\alpha_i} \delta_{ei}) e \quad (5)$$

Deadweight Loss of Differentiated Policys

TABLE 6—DEADWEIGHT LOSSES OF DIFFERENTIATED VMT TAXES AND DIFFERENTIATED PURCHASE SUBSIDIES

Panel A. Deadweight losses of differentiated VMT taxes	Gas and electric tax BAU EV share percent			Gas tax only BAU EV share percent			Electric tax only BAU EV share percent		
	1	2	5	1	2	5	1	2	5
County policies	0	0	0	201	391	905	1,709	1,717	1,740
State policies	89	92	102	289	482	1,005	1,712	1,721	1,752
Federal policies	162	191	277	343	542	1,095	1,736	1,770	1,874
County (native)	989	1,073	1,325						
State (native)	1,067	1,153	1,412						
Federal (native)	778	809	903						

Panel B. Deadweight losses of differentiated electric vehicle purchase subsidies	BAU EV share percent		
	1	2	5
County policies	1,754	1,806	1,960
State policies	1,758	1,815	1,983
Federal policies (−$1,095 subsidy)	1,783	1,864	2,107
County policies (native damages)	1,788	1,874	2,134
State policies (native damages)	1,792	1,881	2,152
Federal policies (native damages)	1,785	1,868	2,188
Current federal policy ($7,500 subsidy)	2,581	3,459	6,079
BAU federal policy (zero subsidy)	1,791	1,880	2,148

Conclusion

1. in US average level, Short term benefits of electric vehicle is negative; so taxes should be charged instead of subsidies if applying uniform policy.
2. There is big difference among different states and counties. Region-specific tax can reduce deadweight loss.
3. Externality is nonnegligible. Full damage instead of native damage should b considered. Otherwise, greater ddl from differentiated policies.

Reference

Holland, Stephen P., Erin T. Mansur, Nicholas Z. Muller, and Andrew J. Yates. 2016. "Are There Environmental Benefits from Driving Electric Vehicles? The Importance of Local Factors." American Economic Review, 106 (12): 3700-3729.