Emissions Standards and Electric Vehicle Targets for Passenger Vehicles

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Electric vehicles are the main strategy for decarbonizing passenger vehicles

Government and industry goals (US)

• Biden: 50% plug-in vehicle market share by 2030

• Automakers: phase out internal combustion engines by 2030s, with major investments in technology and manufacturing

Supporting policies

• Federal fuel economy and GHG emissions standards (i.e., CAFE)

• Zero emission vehicle (ZEV) program

• Purchase and charging subsidies, infrastructure investments, education ...
How do fuel economy/GHG and ZEV standards fit together?

Distinct but related objectives

• CAFE: average fuel consumption and emissions rates
• ZEV: (essentially) minimum market share for plug-ins

Different regulators and timelines

• Federal agencies, with restrictions on lead time and horizon
• California and other states, setting standards up to a decade in advance
Regulatory timeline

2011/2: DOT and EPA finalize standards through 2021 (2025)

2012: California sets ZEV standards through 2025

2016/7: DOT and EPA confirm standards through 2025

2020: DOT and EPA weaken 2022-2026 standards

2021: DOT and EPA strengthen 2023-2026 standards

2022: California prepares ZEV standards through 2035
Research questions

How did the 2012-2022 CAFE standards affect social welfare?

How did the choice of ZEV standards affect net benefits of CAFE?

How have the welfare effects of these programs varied across income groups?
Data

MartizCX

• Survey of recent new vehicle buyers, 1 percent sample (1.5 million observations 2010 – 2018)
• Vehicle identifying information and transaction price, consumer demographics

IHSMarkit, Consumer Expenditure Survey

• Weight Maritz observations to match registrations by vehicle and demographic group
• Used vehicle purchases by demographic group and year

Main data set

• Observations by vehicle (~1,000) demographic group (20), and year (2010 – 2018)
• Sales, transaction prices, attributes
Vehicle attributes by demographic group

Transaction price (2018 $)

Fuel cost per mile

Log (horsepower / weight)

Share of hybrids in new sales

Share of electrics in new sales

Share of used in total sales
Overview of equilibrium model

Structure

• Consumers choose vehicles to maximize subjective utility

• Manufacturers choose vehicle prices annually and redesign vehicles every 5 years, choosing fuel economy and horsepower

Demand

• Utility is linear in price and attributes

• Preferences vary across demographic groups (income, age, urbanization) and region

• Estimate parameters accounting for endogeneity of price, fuel economy, and horsepower
Supply

Price and attribute choices

• Each year, manufacturers choose prices for each vehicle and region

• Every five years, manufacturers choose fuel economy and horsepower given expected profits

• Adopting fuel-saving technology incurs fixed costs and raises marginal costs

Policies

• Competitive credit markets for ZEV and CAFE

• Equilibrium credit price balances credit demand and supply

• Federal and state plug-in subsidies
Preference parameter estimates

Own-price elasticity of demand

Willingness to pay for 1 percent fuel economy increase

Willingness to pay for 1 percent performance increase

Valuation ratio
How has CAFE affected social welfare?

Compare 2012 and 2022 levels of standards

• Counterfactual: given 2022 ZEV standards, what if DOT and EPA had kept standards frozen at 2012 levels?

• Simulate market equilibrium in 2022, representing steady state (two full redesigns)

Key assumptions

• Gasoline prices and aggregate vehicle demand are exogenous

• Vehicle entry and exit are exogenous

• Estimate fuel consumption and emissions over vehicle lifetimes (scrappage exogenous)
### Welfare effects of fuel economy standards (preliminary estimates)

<table>
<thead>
<tr>
<th>ZEV requirement (percent)</th>
<th>0</th>
<th>14.5</th>
<th>14.5</th>
<th>19.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year of standards</td>
<td>2012</td>
<td>2012</td>
<td>2022</td>
<td>2022</td>
</tr>
<tr>
<td>ZEV ($/credit)</td>
<td>0</td>
<td>5,594</td>
<td>118</td>
<td>1,424</td>
</tr>
<tr>
<td>Fuel economy ($/1% mpg improvement)</td>
<td>60</td>
<td>59</td>
<td>302</td>
<td>281</td>
</tr>
<tr>
<td>Consumer welfare (billion $)</td>
<td>494</td>
<td>489</td>
<td>544</td>
<td>543</td>
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<tr>
<td>Profits (billion $)</td>
<td>128</td>
<td>129</td>
<td>121</td>
<td>121</td>
</tr>
<tr>
<td>Subsidy expenditure (billion $)</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Emissions (million metric tons)</td>
<td>785</td>
<td>782</td>
<td>638</td>
<td>639</td>
</tr>
<tr>
<td>Damages (billion $)</td>
<td>39</td>
<td>39</td>
<td>31</td>
<td>32</td>
</tr>
<tr>
<td>Sales</td>
<td>208,337</td>
<td>343,650</td>
<td>576,738</td>
<td>594,657</td>
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<tr>
<td>Market share</td>
<td>0.014</td>
<td>0.024</td>
<td>0.040</td>
<td>0.041</td>
</tr>
<tr>
<td>Total welfare (billion $)</td>
<td>581</td>
<td>577</td>
<td>628</td>
<td>626</td>
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</tbody>
</table>
How do ZEV standards affect CAFE?

Vary levels of 2022 ZEV and CAFE standards

• California choose ZEV first

• Given ZEV, DOT and EPA choose CAFE standards

• Simulate equilibriums in 2022

Hypothesis

• Assumption: EPA and DOT choose welfare-maximizing level of standards, conditional on ZEV

• Stricter ZEV standards make stronger CAFE standards more likely
Without ZEV standards, agencies maximize welfare by choosing CAFE standard corresponding to A and B.

If California sets ZEV standard at C, agencies still choose B, resulting in greater emissions reductions.

Note: This analysis includes many simplifications that are relaxed in simulations.
### Social welfare and emissions by level of ZEV and CAFE standards (preliminary estimates)

#### Panel A: Social welfare (billion $)

<table>
<thead>
<tr>
<th>ZEV standard (percent)</th>
<th>2016</th>
<th>2018</th>
<th>2020</th>
<th>2022</th>
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<tbody>
<tr>
<td>17</td>
<td>617</td>
<td>630</td>
<td>629</td>
<td>628</td>
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<td>22</td>
<td>612</td>
<td>625</td>
<td>619</td>
<td>626</td>
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#### Panel B: CO2 emissions (million metric tons)

<table>
<thead>
<tr>
<th>ZEV standard (percent)</th>
<th>2016</th>
<th>2018</th>
<th>2020</th>
<th>2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>710</td>
<td>676</td>
<td>681</td>
<td>638</td>
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<td>22</td>
<td>711</td>
<td>678</td>
<td>682</td>
<td>641</td>
</tr>
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Conclusions

2012-2022 fuel economy standards increased social welfare

• Annual welfare gains of about $50 billion
• Fuel economy market failure explains majority of benefits

Tighter ZEV standards strengthens case for tighter CAFE standards

• Increasing ZEV requirement from 17 to 22 percent raises net benefits of tighter standards by ~3$ billion
• Doesn’t include dynamics of EV adoption or battery costs

ZEV program is regressive, CAFE progressive across new vehicle buyers (not shown)

• ZEV program benefits high-income consumers, who are more likely to buy plug-ins
• CAFE is progressive because low-income consumers have larger undervaluation
• Combined, ZEV and CAFE have been progressive