Problem Set: The Welfare Effects of Electric Vehicle Subsidies

Overview

What we'll do
In this problem set, you'll estimate the welfare effects of electric vehicle subsidies that were extended under the Inflation Reduction Act in 2022 and eliminated under the One Big Beautiful Bill Act in 2025.

Please submit the following on Canvas:
1. Your code in .R format
2. Your written answers (i.e., the tables and figures you create plus additional text in response to the questions) in PDF format.

Why we're doing this
1. Corrective subsidies are a key component of current US climate policy, so it is crucial to evaluate the benefits and costs.
2. We'll have a chance to work with the multinomial logit model, which allows us to estimate demand in differentiated product markets. The logit model is widely used. For example, many companies use logit models to decide how low to set their prices, and government antitrust authorities use it to decide whether to allow or block mergers between large companies.

Dataset codebook

Download vehicle_data.csv.

vehicle_data.csv has prices, quantities, and characteristics for the best-selling 10 electric vehicles and best-selling 25 vehicles overall in 2022 in the US, plus two high-end luxury vehicles. Price, fuel cost, and CO2 emissions (for gasoline vehicles) are from fueleconomy.gov. CO2 emissions for electric vehicles are from the Alternative Fuels Data Center. Weight and horsepower are from Edmunds. Clean Vehicle Credit eligibility is from the Department of Energy.

Key: model

Variables are defined below:

- make
- model
- quantity: 2022 units sold (000s)
- price: Manufacturer's Suggested Retail Price ($000s)
- class: vehicle class (e.g., sedan, suv, pickup)
- weight: curb weight (tons)
- hp: horsepower (100s)
- fuel_cost: annual fuel cost ($)
- ev: indicator for whether the model is electric
- co2: lifetime CO2 emissions from driving (metric tons CO2), assuming driven 200,000 miles. For electric vehicles, this uses the national average emissions from electricity.
- eligible: indicator for whether the model is eligible for the full $7500 Clean Vehicle Credit

Assumptions

- Assume the total annual market size is 250 million, which is approximately the total number of potential US vehicle buyers.

1. Descriptive correlations

A. Make a scatterplot of price vs. quantity for these vehicle models.
B. Is this relationship plausibly causal? Explain why or why not.
C. Generate a variable for lifetime CO2 damages: co2cost = lifetime CO2 emissions × $190, where $190 is the social cost of carbon. Report the averages for electric vehicles and non-electric vehicles.
D. Make a histogram of lifetime CO2 damages for all mass-market gasoline vehicles (i.e., all non-electric vehicles with price under $50,000).

2. Logit model estimation

The representative consumer logit model implies the following equation:

$$\ln s_j/s_0 = \beta_{price} p_j + \beta X_j + \xi_j, \qquad (1)$$

where s_j is the market share of vehicle j, $j = 0$ refers to the outside option, p_j is the price, X_j is the vector of observed non-price characteristics {weight, hp, fuel_cost, ev}, and ξ_j is the unobserved characteristic, which becomes the regression error term. As usual, we suggest using [fixest](#) for estimation, with robust standard errors.

A. Estimate equation (1) using OLS.
B. Interpret the coefficients on the price variable and the electric vehicle indicator. (This should be a sentence like, "one additional gram of sugar per serving is associated with a 3 percent increase in market share.")
C. Do you think the estimated β_{price} is unbiased, biased toward zero, or biased away from zero, relative to the true effect of price on quantity sold? Explain why.

3. Counterfactual policy analysis

In the class slides, we derived the formulas for changes in consumer surplus and total surplus from a price change. We assume:
- Vehicle utilization (the amount that consumers drive) is fully inelastic.
- Vehicles are produced in a perfectly competitive market at constant marginal costs, so each vehicle's supply is perfectly elastic.

We compare three scenarios:
    B. Baseline: no taxes or subsidies
    T. "Optimal" vehicle tax to internalize CO2 externality
    S. Clean Vehicle Credits ($7500 subsidy for EVs with eligible==1)
We'll use superscripts to index these three scenarios.

A. In this model, will the incidence of the vehicle taxes and subsidies be on producers or consumers? Explain the intuition.
B. In this model, the optimal (i.e., total surplus maximizing) CO2 tax for each vehicle is equal to its lifetime CO2 damages, which you computed above. Report the (unweighted) average across all vehicles.
C. Create three new columns containing each vehicle's representative utility V_j, one with V_j^B (at baseline), one with V_j^T (with the tax), and one with V_j^S (with the Clean Vehicle Credit subsidy). Report the (unweighted) averages across all vehicles.
D. Create two new columns for counterfactual market shares, s_j^T and s_j^S. Write the intuition for why the outside option market share differs between these two

columns. Also describe how the market shares change with the tax compared to baseline for high vs. low emission vehicles.

E. Create a table that reports the changes in total surplus and its components in the two counterfactuals. Specifically, the table should have six rows:
- Consumer surplus change
- Producer surplus change
- Government revenue change
- Externality change
- Total surplus change
- Cost per ton of carbon abated
  - This is (Consumer surplus change + Producer surplus change + government revenue change) / (tons of CO_2 abated)

The units for the first five rows should be \$/consumer per year, where there are 250,000,000 consumers in the market. The table should have two columns: column (1) is for scenario T compared to B, and (2) is for scenario S compared to B.

4. Summary

Write a short summary of what we've found. Make sure to cover each of the following things:
- Using the figure from 1D and our discussion in class, give at least two reasons why in our model, EV subsidies will generate lower total surplus gains than CO_2 taxes.
- Using your table from part 3E, compare the economic efficiency (i.e. effects on total surplus) and distributional implications (i.e. effects on consumer surplus, producer surplus, and government revenues) for CO_2 taxes vs. EV subsidies. Comment on how these distributional implications might impact political feasibility.
- You may have found that EV subsidies actually increase negative externalities relative to baseline. Do you think this is realistic? If not, what *specific* modeling simplifications generated this unrealistic result?
- What modeling simplifications have we made that might bias the results?
- Which modeling simplification do you think causes the *largest* bias in the results? Explain your reasoning.

5. Reading responses

A. Explain the equimarginal principle.
B. A policy is *economically efficient* if it maximizes total surplus. A policy is *cost-effective* if it minimizes the cost of achieving some goal. For example, a pollution tax equal to marginal damages is both economically efficient and cost effective in standard economic models, while a pollution tax set above or below marginal damages would not be economically efficient but would be a cost effective way to achieve pollution goals that were above or below the optimum. Describe why emission standards and technology-based regulations are unlikely to be cost effective, while pollution taxes and cap-and-trade programs are more likely to be cost effective.
C. Explain why we might be worried about "hot spots" under pollution taxes or cap-and-trade programs.
D. One of the markets that RTOs run is called the "Energy Market." Briefly describe how Energy Markets work.