CASCADING DIFFUSION AND THE HETEROGENEITY IN ELECTRIC VEHICLE ECONOMICS

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Overview

The field of transportation is one the largest greenhouse gas emitter sector in developed countries. Hence, it is essential to find a viable alternative to internal combustion vehicles. Electrified vehicles are a good alternative as they emit little to no greenhouse gasses locally. Vehicle users have two main fears regarding electrified vehicles: range anxiety and vehicle price. It is true that electrified vehicles have a higher purchase cost compared to internal combustion vehicles but lower operating cost. Therefore, applying an economic model such as the total cost of ownership (TCO) is essential to study the economic viability of electrified vehicles [1]. This study assesses the economic and carbon benefits of electric technology vehicles (electric, plug-in hybrid, and hybrid) in the U.S., accounting for household-by-household behavioral variability and geographical differences in fuel and electricity prices. This finer resolution provides insight into subsets of the population for whom adoption is economically or environmentally favorable, allowing us to construct Marginal Abatement Cost Curves for CO2 that account for geographic, behavioral and stock heterogeneities. We then explore the interaction between future cost reductions and economically motivated adoption of ETVs. We construct a model of the U.S. personal vehicle market accounting for heterogenous use and vehicle preferences, in which adoption induces cost reductions that increase future market share.

Methods

The National Household Travel Survey (NHTS) sample vehicle fleet is used as the main input for the vehicle-level analysis. NHTS reports the households' state of residence, used in modeling geographical heterogeneity with state-specific electricity emissions, fuel and electricity prices. The NHTS dataset also reports make, model and type of the vehicle (used to estimate the initial capital cost and mileage), number of months the vehicle is currently owned (used to estimate the expected duration of ownership of the vehicle), and number of miles driven annually (behavioral heterogeneity) for each household vehicle. In evaluating purchase of an electric technology vehicle, we assume consumers keep the same make, model and type as their previous vehicle. Four technology options are considered: 1. Updated Conventional Vehicle, 2. Hybrid Electric Vehicle, 3. Battery Electric Vehicle and 4. Plug-in Hybrid Electric Vehicle. The economic and carbon implications of purchasing an ETV by comparing the ETV with the updated conventional vehicle are then assessed [2].

The Financial Model described above is coupled with a Market Allocation Model, and a Technology Progress Model. The Total Cost of Ownership data from the Financial Model is sent to the Market Allocation Model, essentially a diffusion model in which consumers choose a conventional vehicle or an ETV. Starting with the year 2018, U.S. drivers expected to purchase a vehicle that year are "sent to the market", where their vehicle choice is determined by the Market Allocation Model. This results in cumulative sales of ETVs that is used in a technological progress model. An experience curve model forecasts cost reductions of ETVs and potential cost increases in conventional vehicles due to fuel efficiency rules such as CAFE standards. This system of modules is repeated year by year, generating annual vehicle costs and market shares of conventional vehicles and ETVs from 2018-2040, where later ETV adoption results from adoption-drive price declines in earlier years.

Results

One significant result is that accounting for heterogeneity affects results; the resulting ETV market share is 23% higher than treating consumers using their average parameters. A second result is that future outcomes depend on uncertainty in the current price of ETVs and the trajectory in conventional vehicle cost: The projected market share of ETVs in 2040 can vary from 18% to 100%, depending on these two assumptions. Resolving cost uncertainties is essential in deciding ETV subsidy polices.

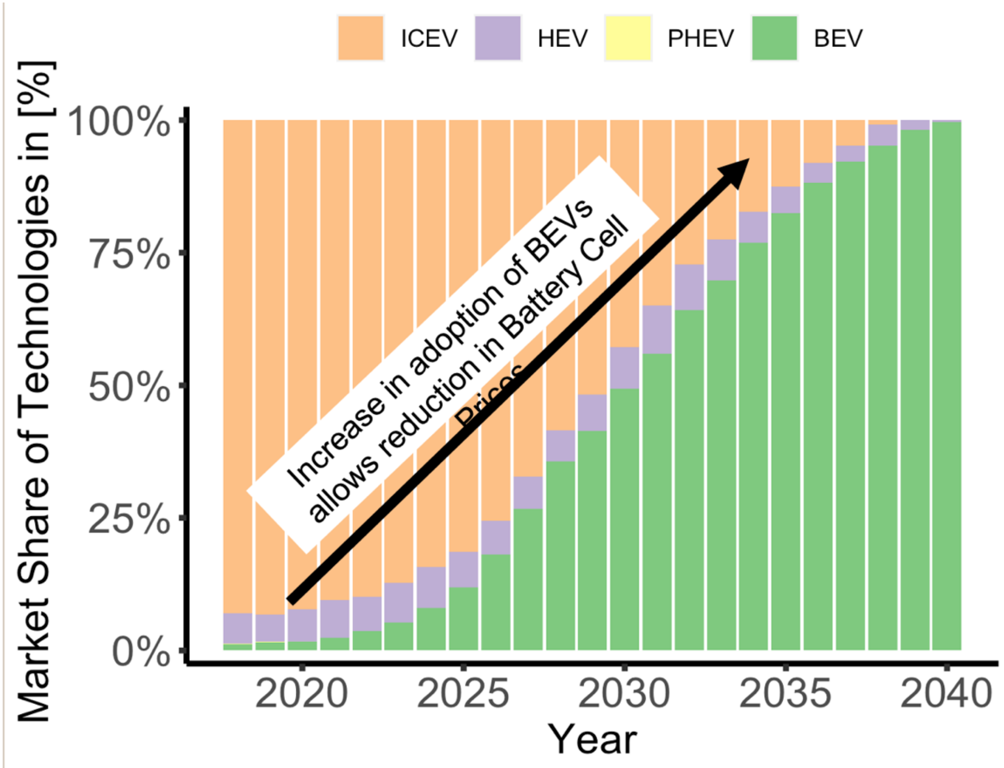

Figure 1. Projected annual market share of vehicle technologies for the base case, with heterogenous consumers (HEV=Hybrid Electric Vehicle, BEV= Battery Electric Vehicle (BEV), PHEV= Plug-in Hybrid Electric Vehicle, ICEV = Internal Combustion Engine Vehicle)

Conclusions

The first key takeaway from our model is that heterogeneity matters for technology diffusion of ETVs. We only treated two extreme cases: detailed heterogeneity and a national average. It is an important question, which we leave for future research, of what level of heterogeneity is needed to achieve a desired degree of accuracy. We consider 350,000 different drivers, but perhaps similar results are achieved with significantly fewer. The second key takeaway is that very little can reliably be said about the future of ETVs without resolution on key inputs that are normally of little importance in most analyses, specifically current non-battery costs, future prices of internal combustion vehicles, and future gasoline prices.

References

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