VALUING PLUG-IN HYBRID ELECTRIC VEHICLES' BATTERY CAPACITY USING A REAL OPTIONS FRAMEWORK

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Overview

Plug-in hybrid electric vehicles (PHEVs) allow their drivers to choose whether to use electricity or gasoline, but this fuel flexibility benefit requires the purchase of additional battery capacity relative to most other vehicles. We value this fuel flexibility by representing the purchase of the battery as the purchase of a strip of call options on the price of transportation. We find that using a real options approach instead of a discounted cash flow analysis can substantially raise the retail battery price at which the battery pays for itself. Unless battery prices fall or expected long-term average U.S. gasoline prices rise to $5 per gallon or greater, the PHEV's battery may still not pay for itself, and greenhouse gas abatement via PHEVs may cost over $100/t CO_2-eq. However, the value of subsidizing PHEVs as an abatement strategy is greater than represented by their direct reductions in emissions because the vehicles reduce the cost of adopting more stringent climate policies in the future.

Methods

We represent the purchase of each mile of PHEV battery capacity as the purchase of a strip of European call options in which the payoffs are the fuel savings in dollars per mile from powering the vehicle with grid-supplied electricity instead of gasoline. Each option corresponds to the decision on some day *d* about whether to use grid electricity for some mile *m* of PHEV travel. We value each call option under different assumptions about the form of the mean-reverting stochastic process used to represent the evolution of gasoline prices, and we also consider a case in which PHEV owners participate in real-time electricity pricing and so see electricity prices which follow a mean-reverting stochastic process. We also correct and extend the formula for the valuation of a spread call option when both underlying assets follow mean-reverting price processes, as in our real-time electricity pricing case.

Results

Adopting a real options approach instead of a disconted cash flow analysis can raise the price at which batteries pay for themselves via fuel savings andfuel flexibility by $100-$200/kWh, but batteries are nonetheless unlikely to be economical (as defined by this metric of fuel savings payback) at near-term battery and fuel prices. In addition, subsidizing PHEVs to achieve greenhouse gas emission reductions may still be a costly abatement strategy unless we also value the more indirect effects of PHEVs on abatement costs.

Conclusions

Our real options approach increases the battery price at which a PHEV's additional battery capacity may pay for itself, but our valuation example shows that for the battery to actually pay for itself, long-term gasoline prices may need to rise above $5/gallon (without a corresponding rise in electricity prices) or battery prices may need to fall by more than some predict mass production alone will achieve. Further work could combine this real options approach with better modeling of vehicle characteristics, costs, and usage patterns and with better estimation of price process parameters. It would be interesting to see how the break-even battery cost varies with energy management strategy as well as with charge-depleting or all-electric range. Future analyses could also assess the influence of climate policies on the incentives to purchase PHEVs by representing these policies' effects in the fuel price processes. Most importantly, they should also consider PHEVs' larger role in greenhouse gas abatement efforts by using a real options framework to value the abatement flexibility that would be gained from widespread adoption of PHEVs.

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