Are Electric Vehicle Driving Costs Too High? The Implicit Cost of Range Anxiety

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Overview

The fight against climate change has led policymakers to pursue new strategies in an effort to reduce carbon emissions from the transportation sector. These climate policies have increasingly focused on transforming the vehicle fleet from one heavily dependent on fossil fuels to a predominantly electric one. Often referred to as zero emissions vehicles due to the absence of tailpipe emissions, under a clean energy grid, electric vehicles (EVs) represent one of the most promising methods of reducing pollution from light duty vehicles.

Critics argue that government subsidies on EV purchases are not enough to reduce prices to levels on par with those of conventional vehicles. However, sticker price is likely not the only deterrent of EV adoption. This paper studies an additional, behavioral, cost specific to the use of EVs: range anxiety. The idea behind range anxiety is that consumers will experience distress from driving EVs due to fear of meeting the mileage capacity of a battery, when refueling costs are high due to both an insufficient charging infrastructure and the opportunity cost of time. Thus, range anxiety is particularly relevant for EVs, as refueling an internal combustion engine (ICE) vehicle is less time imposing, and the gasoline infrastructure is vast. In comparison, charging times for most EVs can exceed 5 hours using a standard Level 2 power source.

Methods

We estimate and monetize the disutility a consumer expects to receive through range anxiety by formalizing the manner in which range and travel demand enters consumer utility for a vehicle. To explain, consider a low range EV, which, all else equal, imposes significant costs on its drivers through range anxiety. Assuming that this is the consumer's primary vehicle, now consider that electricity prices are high. By the law of demand, when fuel prices are high, a consumer's latent demand for vehicle miles traveled (VMT) will adjust to lower levels. Given lower VMT demand, the constraint a low range vehicle imposes may not be binding. That is, when a consumer expects to drive the vehicle less, the range limit of a vehicle is less imposing. However, when both fuel prices and range are low, the converse is true. This illustration suggests that the costs imposed on consumers through an EV's limited range enters their utility through an implicit interaction between fuel prices and the vehicle's range.

In this paper, we leverage within city variation in electricity prices in Texas, paired with within vehicle model variation in range to pin down the cost of expected range anxiety, revealed through new vehicle purchases. Evidence of expected range anxiety is provided through a reduced form framework that simply allows fuel prices to enter vehicle choice through its baseline price-per-mile, and through an interaction with the vehicle's range. Our specification allows us to control for granular, city-by-time fixed effects---absorbing baseline variation in fuel prices---and unique model-by-model year fixed effects---absorbing baseline variation in range and other vehicle characteristics. Results produce the theoretically predicted outcomes: While consumers will be more likely to purchase EVs that have higher range, the marginal effects of range diminish when the price-per-mile of a vehicle is high.

To translate these interaction effects into an economically meaningful cost, we estimate a structural model of range anxiety. We assume that the disutility of range anxiety is proportional to the mileage gap between latent miles demanded and the range constraint, if latent mileage demand exceeds range. This introduces the interaction between range and fuel costs in a formalized manner. The distribution of demand shocks around the estimated VMT demand generate estimates for the frequency that a consumer wishes to drive beyond this range. A consumer's expectation of these frequencies directly influences their vehicle choice.

Results

Following the joint estimation of travel expectations and choice parameters, we calculate the implied value consumers place on the gap between latent mileage demand and battery range. This is the welfare cost of range anxiety; variation in fuel prices allow us to monetize these estimates. Our main findings suggest that the average prospective EV driver anticipates range anxiety costs equivalent to a $1.3-1.8 daily driving tax ($475-660, annually). This applies to the majority of EVs with ranges between 200 and 300 miles, while this cost increases for lower range vehicles. The estimates are on par with daily gasoline expenditures paid by Toyota Corolla consumers driving 15 miles per day at $3 per gallon. Importantly, our estimates illustrate large reductions in these costs as range increases. The marginal effect of a 100-mile increase in range amounts to a $0.20-1.20 increase in daily welfare, with marginal increases highest at lower range vehicles. Finally, the average driver generates range anxiety of only $0.90 per day when ranges are as high as 500.

Conclusions

Achieving 100 percent EV ownership is an ambitious policy goal. However, the cost to own EVs represents a major hurdle in successfully achieving this switch. While the higher sticker price is the most obvious direct cost, high driving costs are also a concern. In this paper, we present evidence that consumers exhibit high range anxiety costs associated with driving EVs. As these costs exist when driving a vehicle, they play a large role in a household's decision to replace their ICE vehicle as a primary commuter vehicle. When consumers internalize these future costs at the point of purchase, our results indicate that expected range anxiety significantly reduces the likelihood that they will purchase an EV.

The results in this paper present the primary demand mechanism driving an interdependence between EV adoption and charging infrastructure (Li and Zhou, 2018). Investment in EV charging infrastructure depends on the extent to which consumers adopt EVs and, because of range anxiety, EV adoption depends heavily on the available charging infrastructure. A higher density of charging stations relieves range anxiety and, thus, increases EV adoption. This suggests a means in which policy may reduce these high costs of EV consumption.

Excessive charging times also contribute to the estimates we uncover. Results from this paper suggest that consumers place high disutility on an anticipated mileage gap between VMT demanded and the range constraint. Secondary results illustrate that this mileage gap does not play a significant role for the adoption of plug-in hybrid vehicles, which have the option of being fueled by gasoline.

We hypothesize that the main driver is the costly allocation of time when charging a battery EV. We consider this a component of the range anxiety mechanism, implying that a large portion of these costs are tied to technology. Both innovations in charging speed and innovations in range may reduce the burden. On the range side, our model illustrates the importance of fuel efficiency, as a technology that not only reduces the direct cost of driving an EV, but also simultaneously increases its range.

In order to increase EV ownership, policy makers must consider the cost of range anxiety, and the various policy levers that may be used to reduce the cost of driving EVs. Our results suggest that expanded charging networks and innovations in both charging speeds and EV range would produce the desired outcomes. Fuel efficiency standards for EVs may additionally lead to advances in vehicle range. This paper demonstrates that, without such advances, an all-EV fleet is a very costly fleet.

References

Li, Shanjun and Yiyi Zhou. 2018. "Technology Adoption and Critical Mass: The Case of the U.S. Electric Vehicle Market." *The Journal of Industrial Economics*, LXVI (2): 423-480.