Charging Infrastructure, Income, and Electric Vehicle Adoption: Evidence from Washington State

Research Problem

Globally, the transportation sector accounts for roughly 14% of greenhouse gas (GHG) emissions (UN Environment Programme 2023). In the U.S., transportation is the largest emitting sector at about 28% of total GHG emissions (U.S. EPA 2024). Despite federal and state incentives, electric vehicles (EVs) represented only 16% of U.S. light-duty vehicle sales in 2023 (U.S. DOE 2024, U.S. EIA 2024). The gap between climate goals and realized adoption underscores the importance of understanding the drivers of EV adoption.

The availability of public charging infrastructure and local socioeconomic conditions, especially income, are key correlates of EV adoption. Prior work argues that incremental expansions of charging networks can measurably increase EV uptake, particularly in earlier stages of market development when range anxiety and perceived charging scarcity are most salient (van Dijk 2022, White et al. 2022). However, comparatively little is known about how the influence of charging availability varies by facility type, such as entertainment and shopping districts, parking facilities, and other destination-oriented venues. Existing evidence on public charging behavior suggests that charging type and location can meaningfully shape usage patterns, implying that the adoption response to new chargers may depend on where chargers are sited as well as their types (Zhang et al. 2025). Apart from these, higher income is widely documented as a strong predictor of EV uptake, but this conclusion is often based on descriptive evidence (Bauer et al. 2021, Lou et al. 2024). Understanding the true effects of both public charging infrastructure and income is increasingly important as policy emphasis shifts away from purchase incentives, making adoption increasingly reliant on the rollout of public charging infrastructure.

Motivated by these considerations, we empirically study three main research questions. First, we examine how public charging infrastructure, including charger type and facility placement, shapes EV adoption. Second, we investigate how the spatial distribution of EV chargers influences adoption patterns. Third, we characterize the true relationship between income and EV adoption.

Data & Methodology

Washington State provides a strong empirical setting for our research questions because it exhibits substantial variation in EV adoption, income, and charging infrastructure across its 457 ZIP codes.

We compile data from multiple sources and construct a quarterly panel for all 457 Washington ZIP codes from 2010 to 2023. Our outcome variable is EV adoption, measured as the number of newly registered EVs per ZIP code in each quarter. We also assemble socioeconomic covariates, such

as population, housing composition, and transit score, which captures multimodal accessibility and helps control for broader transportation infrastructure differences across ZIP codes. In addition, we build a rich dataset on public charging infrastructure in Washington, including station coordinates, installation dates, charger type (Level 2 vs. DC fast), accessibility, and facility type. Using a GIS workflow, we assign charging stations to ZIP codes and compute charger availability within each ZIP code as well as in nearby areas. Specifically, we construct a 14-mile buffer around each ZIP code boundary to capture chargers located just outside the ZIP code that may still be relevant for daily travel (consistent with an average commute distance of roughly 14 miles). This approach measures the number of chargers by type and facility category while accounting for cross-boundary travel. To characterize the spatial distribution of chargers beyond simple counts, we construct additional measures using two complementary machine-learning–based approaches. First, we use k-nearest-neighbor distances to quantify local charger density. Second, we compute HDBSCAN-based clustering metrics that capture network coherence and spatial separation, distinguishing compact, well-organized clusters from sparse, fragmented networks. Together, these measures provide a richer description of spatial distribution of chargers.

For estimation, we use dynamic panel models with Blundell–Bond system GMM (Blundell and Bond 1998) to address three challenges: strong persistence in EV adoption, endogenous charger deployment that may respond to prior adoption trends, and unobserved ZIP-specific heterogeneity. System GMM leverages lagged levels and differences of potentially endogenous variables as internal instruments, reducing simultaneity bias. All specifications include ZIP and time fixed effects, with standard errors clustered at the ZIP level. We assess robustness using alternative buffer distances, fixed-effects-only models, and urban–rural subsamples.

Main Results and Insights

We find that public charging infrastructure significantly increases EV adoption, and that both charger type and siting location play an important role. EV adoption increases following the installation of both Level 2 and DC fast chargers, with DC fast chargers delivering substantially larger marginal effects. We show that charger siting also plays a first-order role. Chargers installed at entertainment and shopping destinations generate the strongest adoption response, followed by parking facilities. Overall, these results suggest that when expanding public charging infrastructure, installing DC fast chargers in entertainment and shopping districts yields particularly strong returns.

Our analysis shows that spatial sparsity has a significant negative effect on EV adoption. When charging stations within a ZIP code and its surrounding 14-mile radius are more widely spaced, indicating greater sparsity, EV adoption declines. Conversely, when chargers are located closer

together and form tighter, more coherent spatial clusters, adoption increases. This means that, contrary to intuition, placing chargers closer together rather than spreading them out leads to higher EV adoption.

Finally, we identify a significant non-monotonic relationship between EV adoption and income. Specifically, we find that in contrast to the common understanding in the literature, EV adoption increases with income up to a threshold, but beyond that point it strictly decreases as income rises further.

References

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