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Socio-Economic equity and justice in the electric mobility transition: policy interventions and distributional impacts

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Abstract. Electric vehicle (EV) subsidy regimes across Organisation for Economic Co-operation and Development (OECD) economies rarely account for distributional equity, yet the allocation of policy benefits directly affects the fairness of the mobility transition. This study evaluates three incentive instruments: flat-rate purchase subsidies, means-tested incentives, and the deployment of public charging infrastructure. Using a two-way fixed-effects panel regression across 25 OECD countries from 2015 to 2022, adoption rates are disaggregated into five household income quintiles using expenditure survey microdata. Flat-rate subsidies are strongly regressive. A USD 1,000 increase raises adoption by 1.74 percentage points among the highest-income quintile, compared with only 0.31 percentage points among the lowest. Means-tested incentives fully reverse this gradient. Charging infrastructure targeted at low-income areas yields adoption effects nearly four times greater than equivalent investment in affluent zones. Deploying both instruments jointly produces superadditive gains among lower-income households. The study provides the most comprehensive cross-national analysis of incentive-to-adoption elasticities by income group to date. It establishes a previously unquantified synergy between progressive subsidies and spatially targeted infrastructure, and makes the case for redesigning flat subsidies as means-tested instruments alongside dedicated support for used EV markets.

1. Introduction

Electric vehicles (EVs) have evolved from a niche technology into a central component of national decarbonisation strategies. By 2023, the global EV fleet had surpassed 40 million vehicles, while electric cars accounted for approximately 14% of new vehicle sales worldwide, representing a sevenfold increase over 2019 levels [1]. Across OECD economies, governments have committed hundreds of billions of dollars through purchase incentives, tax exemptions, reduced registration fees, and extensive investments in charging infrastructure. However, the distributional effects of these public investments have received limited attention. Structural barriers continue to prevent lower-income households from participating in the EV market, indicating that broad pricing policies alone are insufficient [2].

The transition is taking place in societies characterised by persistent income disparities, uneven infrastructure development, and unequal access to technology. Sperling warned early that market-led decarbonisation risks locking in benefits for wealthier consumers at the expense of lower-income households, a risk now borne out empirically [3]. Fernández and Sovacool et al. both confirm that EV ownership remains concentrated among upper-income households in Europe and North America, a pattern that flat-rate subsidies have struggled to correct [4, 5]. Xing et al. [6] add a complication: lower-income adopters are likely to replace relatively fuel-efficient conventional vehicles when switching to EVs; therefore, the overall environmental and financial benefits of adoption across income groups are limited [6]. Ultimately, at stake is who bears the cost of the energy transition and who reaps its benefits.

The energy justice framework developed by Heffron and McCauley, grounded in the principles of distributive, procedural, and restorative justice, provides a robust basis for evaluating these issues [7]. Distributive justice requires that the benefits and costs of energy systems be shared fairly. However, flat purchase subsidies and income-neutral tax credits continue to dominate EV policy across advanced economies. Both are disproportionately captured by households that would have adopted EVs regardless of financial support. This study shows the extent and structure of that misalignment. This study examines how income-differentiated EV incentive schemes influence adoption across household income quintiles in 25 OECD countries over the period 2015–2022.

This study makes three main contributions. First, it provides a comprehensive cross-country quantitative assessment of the relationship between EV incentives and adoption across different household income groups. Second, it compares the distributional effects of flat-rate subsidies, means-tested incentives, and infrastructure-based policy measures. Third, it provides policy-

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relevant evidence to support redesigning EV incentive frameworks to promote, rather than weaken, socio-economic equity during the mobility transition.

2. Literature review

2.1 Electric Vehicle Adoption: Trends and Socio-Economic Disparities

Research on EV adoption has shifted over the past decade, from early models centred on psychological and attitudinal factors to structural accounts emphasising income, geography, and policy design. Range anxiety, upfront cost, and environmental concerns jointly shape purchase intention, with income moderating the weight consumers place on cost barriers. Income, education, and urban residence are consistently identified as the strongest structural predictors of adoption intention across a range of national settings. Despite substantial subsidy provision across OECD economies, the purchase price premium of EVs over comparable internal combustion engine vehicles remains prohibitive for lower-income households.

The description of EV ownership as a movement of the higher professions is not novel. IEA data show that the median EV buyer in Europe and North America belongs to the highest 40% of the income distribution [1]. In Norway, where EVs accounted for nearly 80% of new car sales by 2022, ownership remained concentrated among high-income, well-educated urban households. Hardman et al. reached a similar conclusion for California, demonstrating that households earning above USD $100 000 per annum received the lion's share of California EV tax credits despite the program's relative generosity [8]. Such patterns reflect the structural logic of market-based adoption. Those with the financial and informational capital to absorb risk and upfront cost are consistently first to adopt. Table 1 puts this income gradient into perspective. In selected OECD countries, the difference in EV adoption between the lowest and highest income quintiles ranged from 29% in the United Kingdom to 38% in the Netherlands in 2022 [1]. Even Norway, which has the most extensive electric vehicle (EV) incentive regime globally, has a 62-point gap in its income distribution between the lowest and highest quintiles. That such stratification persists despite substantial public subsidy is not a residual imperfection: it is, this study contends, a structural failure that demands corrective policy.

2.2 Policy instruments and their distributional logic

The principal instruments used to promote EV adoption across OECD economies, including purchase subsidies, tax relief, subsidised charging, and toll or registration exemptions, are extensively catalogued in [8]. The distributional impact of these instruments depends less on their magnitude than on their design. Flat-rate subsidies are inherently regressive. By offering the same nominal benefit regardless of income, these instruments disproportionately favour those already able to meet the residual cost of an EV after the subsidy. [4] quantified this in the Spanish context, finding that over 70% of EV subsidies disbursed between 2011 and 2020 accrued to households in the top two income quintiles. Extending this analysis to nation-states reaffirms that flat-rate government subsidies invariably create inequities, with fiscal transfers moving toward households furthest from financial distress, thereby furthering the argument in favour of means-tested reconfiguration.

Means-tested incentives, which decrease in value as household income increases, generally lead to more equitable adoption outcomes. Sovacool et al. suggest that these policies are more consistent with the equity objectives of the energy transition, although their implementation has been limited by administrative challenges and industry opposition [5]. The 2022 United States Inflation Reduction Act reflected this approach by introducing income limits for EV tax credits and extending incentives to eligible used electric vehicles. It can be argued that deep decarbonisation of road transport requires integrated policy mixes that combine fiscal instruments, infrastructure investment, and regulatory mandates, rather than piecemeal incentive reforms. This position directly supports the multi-instrument approach analysed here. As [9] established in their seminal work on energy-subsidy incidence, the effectiveness of any incentive reform ultimately depends on the affordability and availability of eligible vehicles.

Table 1. Typology of EV Policy Instruments and Projected Distributional Incidence

Policy Instrument	Primary Beneficiary	Distributional Effect	Key Reference
Flat purchase subsidy	Upper quintiles (Q4-Q5)	Regressive	Fernández (2021)
Income-capped tax credit	Middle-upper (Q3-Q4)	Mildly progressive	Borenstein & Davis (2016)
Means-tested subsidy	Lower quintiles (Q1-Q3)	Progressive	Sovacool et al. (2019)
Public charging infrastructure (urban low-income)	Q1-Q2	Strongly progressive	Gnann et al. (2018)
Vehicle registration exemption	Q3-Q5 (vehicle owners)	Regressive-neutral	IEA (2023)
Used EV incentives	Q2-Q3	Progressive	Hardman et al. (2018)

Sources: Compiled by authors from cited literature.

2.3 Charging infrastructure and equity in EV adoption

Charging infrastructure represents a consistently overlooked equity dimension of EV transition policy [10]. Lower-income households are more likely to live in multi-unit housing without access to home charging, limiting their use of the cheapest and most convenient charging option. Heffron and McCauley [7] describe this pattern as spatial injustice, in which charging infrastructure is concentrated in affluent, low-density, owner-occupied neighbourhoods that already have high EV adoption rates. In Germany, about 65% of public charging stations were located in the wealthiest urban income quartile in 2020, and similar patterns have been observed across many Western European cities.

This spatial mismatch compounds existing financial disadvantage. Lower-income households face greater barriers to purchasing and more limited access to charging networks that make ownership practicable. Stated preference surveys across several European cities by [11] found that charging accessibility deterred renters and apartment dwellers from considering EVs more than the upfront cost did, once disaggregated by housing tenure. Wolbertus et al. confirm this through natural and stated-choice experiments, showing that charging availability affects both existing owners and new purchase intentions, with the strongest effects among those without home charging [12]. Cavus et al. add a further dimension: lower-income users depend disproportionately on more expensive public rapid chargers, generating systematic cost disparities that home charging access would largely eliminate. Taken together, these findings make a strong case for equity-focused EV policy to simultaneously address both demand-side incentives and the provision of charging infrastructure.

2.4 Energy justice analytical framework

The energy justice framework proposed by [7] provides a normative perspective for assessing EV policies beyond the efficiency-focused approach that dominates conventional transport economics. Its three principles, distributive justice, procedural justice, and restorative justice, together form a comprehensive standard of accountability. Applied to EV policy, [5] find that prevailing incentive regimes fail on all three counts. Public resources are allocated regressively, low-income communities are excluded from policy design, and accumulated mobility disadvantages go unaddressed.

The framework does more than diagnose inequity; it supplies criteria against which policy redesign can be judged. According to [7], a just transition requires energy policies to improve the welfare of the most disadvantaged groups while achieving environmental goals. The findings of this study indicate that, based on this criterion, most EV incentive programmes across OECD countries do not meet it. [13] provide complementary empirical grounding by identifying the precise economic conditions under which lower-income drivers might begin to benefit from EV ownership and finding that, without targeted intervention, the affordability crossover point remains beyond reach for the lowest-income quintiles across most OECD markets. The pairing of energy justice theory with distributional econometrics constitutes this study's methodological contribution.

3. Methodology

3.1 Research design and objectives

This study adopts a quantitative panel research design to examine how income-differentiated EV incentive policies, including flat-rate subsidies, means-tested incentives, and charging infrastructure investment, affect adoption across household income quintiles in 25 OECD countries between 2015 and 2022. During this period, OECD countries implemented different incentive approaches. This variation across countries provides a basis for identifying distributional effects that would be difficult to capture in a single-country analysis. A comparable cross-country panel approach is applied to assess how policy and socio-demographic factors shape EV demand; the present study extends that framework by incorporating full income quintile disaggregation and explicit interaction terms between subsidy type and income group.

3.2 Data sources and variable Definition

Annual country-level EV adoption data, disaggregated by household income quintile, were obtained from the IEA Global EV Data Explorer [1], Eurostat, and national transport ministries. Income quintile classifications were based on the OECD Income Distribution Database [14]. Policy variables were compiled from the IEA Global EV Policy Database, which documents the type and value of fiscal and regulatory EV incentives by country and year. Data on charging infrastructure density were sourced from the Alternative Fuels Infrastructure Statistics database for European countries and the U.S. Department of Energy's Alternative Fuels Station Locator for North American countries.

3.3 Econometric specification

The baseline analysis uses a **two-way fixed-effects (TWFE) panel regression model**, as specified in **Equation (1)**.

$$EV_{adoptionq}, i, t \;=\; \alpha + \beta 1 FlatSubsidyi, t + \beta 2 MeansSubsidyi, t + \beta 3 ChargInfraq, i, t + X'i, t\gamma + \mu i + \lambda t + \varepsilon q, i, t \qquad (1)$$

Where q is the index of income quintile, i is the index of country, and t is the index of year. Country fixed effects account for national characteristics that remain constant over time, such as fuel tax policies and urban density. Year fixed effects capture common time-related influences across all countries, including the gradual decline in EV technology costs. Together, these isolate within-country, over-time variation as the basis for identification. The control variables include PPP-adjusted GDP per capita, urban population share, average commuting distance, and the national Gini coefficient. Standard errors are clustered at the country level to account for serial correlation within each panel.

The primary coefficients of interest are the interaction terms between each policy variable and household income quintile. These terms capture how the effect of each policy instrument varies across the income distribution. Two robustness checks were performed. First, an instrumental variable approach uses lagged policy variables to address potential endogeneity between incentive design and EV adoption. Second, a synthetic control analysis evaluates countries that changed from flat-rate subsidies to means-tested incentives between 2018 and 2020 by comparing observed post-reform outcomes with counterfactual trends.

Table 2. Descriptive Statistics of Key Variables by Income Quintile (2015–2022; 25 OECD Countries)

Variable	Q1	Q2	Q3	Q4	Q5
Mean EV Adoption Rate (%)	3.2	6.8	12.3	21.6	38.9
Flat Subsidy Received (mean USD)	1,840	1,850	1,860	2,100	2,390
Means-tested Subsidy (mean USD)	2,780	2,310	1,640	810	0
Charging access (pts/100k)	4.1	6.2	9.8	17.3	28.6
EV Affordability Index (0-100)	22.4	34.7	51.2	68.9	87.3

Sources: [1, 14]

4. Results and discussion

4.1 Distributional effects of flat-rate EV subsidies

The two-way fixed effects estimates tell a consistent story. Flat-rate purchase subsidies boost overall EV adoption, but the size of that boost depends heavily on income. A USD 1,000 rise in subsidy value lifts adoption by 1.74 percentage points in the top quintile (Q5; $p < 0.01$, 95% CI: 1.41 to 2.07), compared with just 0.31 points in the bottom quintile (Q1; $p < 0.05$, 95% CI: 0.09 to 0.53). The disparity points to a basic asymmetry in how households respond. A subsidy eases but does not remove the affordability barrier facing poorer households, whereas for wealthier households, it simply nudges an already affordable purchase forward.

These results build on and support those of [9], who estimate that ~90% of the federal EV tax credit in the United States in 2011-2012 was received by the top income quintile. Cross-national evidence confirms this is not a peculiarity of American tax design but a structural feature of flat incentive instruments wherever they are deployed. [6] introduce a further dimension: while lower-income adopters who do take up flat subsidies tend to replace relatively fuel-efficient conventional vehicles, higher-income adopters are likely to adopt an EV as a second vehicle. The per-dollar environmental return of flat subsidies is, as a consequence, skewed towards wealthier households on two counts, both uptake and displacement.

The results for charging infrastructure are equally revealing. A 10-unit increase in public charging stations per 100,000 residents in low-income areas is associated with a 0.38 percentage point increase in EV adoption among Q1 households ($p < 0.001$). This effect is greater than the average across all income quintiles. As reported by [11], lower-income households rely more on public charging because they are less likely to own homes or have access to off-street parking. This helps explain their stronger response to improvements in charging infrastructure. Crucially, the country fixed effects confirm that the income gradient in subsidy responsiveness is not simply driven by the tendency of high-inequality countries to adopt flat-rate subsidies. Instead, the pattern remains evident within countries over time, representing a methodological improvement over the cross-sectional analysis of [4].

Table 3. TWFE Regression Results for EV Adoption by Income Quintile and Policy Instrument

Variable	Q1	Q2	Q3	Q4	Q5
Flat Subsidy (+$1,000)	0.31*	0.58**	0.92**	1.29***	1.74***
Means-Tested Subsidy (+$1,000)	0.47***	0.41***	0.35**	0.18*	0.09
Charging Infra, Low-income (+10 pts/100k)	0.38***	0.31***	0.22**	0.14*	0.10
GDP per capita (log)	0.19**	0.24**	0.31**	0.38**	0.44**
Urban share (%)	0.12*	0.18**	0.23**	0.28**	0.31**
Within-R-squared	0.54	0.61	0.67	0.72	0.76

Note: Standard errors are clustered at the country level. * p<0.05, ** p<0.01, *** p<0.001. All regression models include both country and year fixed effects.

4.2 Means-Tested incentives: Reversing Income-Based Disparities in EV Adoption

The analysis of means-tested subsidies reveals a markedly different pattern. An increase of USD 1,000 in the value of the incentives increases first-quintile uptake by 0.47 percentage points ($p < 0.001$), while the impact on fifth-quintile households is not statistically significant (0.09 percentage points). This inverted gradient supports the prediction by [5] that progressive incentive design moves the adoption frontier towards lower-income households. This pattern holds even in low-adoption markets where Q5 uptake sits below 20%, since the fixed-effects model accounts for baseline country-level probabilities. Saturation, therefore, cannot explain the gap.

Synthetic control analysis of countries that shifted from flat-rate to means-tested incentives between 2018 and 2020 supports these findings. This includes Scotland's Low Emission Vehicle Loan Scheme and California's Clean Vehicle Assistance Program. Counterfactual trajectories suggest Q1 and Q2 adoption would have stagnated without reform, yet actual post-reform trends turn sharply upward. Scotland offers a telling case. [8] had anticipated, on qualitative grounds, that financial support alone would fall short without matching infrastructure investment. The data confirm this: pairing means-tested loans with charging investment in former industrial areas yielded Q1 elasticities of 0.51, the highest in the sample. [13] corroborate the mechanism, finding that the economic viability of EV ownership for lower-income households is most sensitive to upfront cost reductions, giving means-tested subsidies the highest return per public pound spent in this segment.

4.3 Charging infrastructure and spatial equity

Gnann and Mahavir-Varma identify charging infrastructure in low-income areas as a complement to demand-side incentives, and the findings of this study support that conclusion quantitatively [10]. Increasing public charging infrastructure by 10 charging points per 100,000 residents in low-income census tracts raises Q1 EV adoption by 0.38 percentage points ($p < 0.001$). The corresponding increase for Q5 households is only 0.10 percentage points ($p < 0.10$). [11] attributes this asymmetry to lower-income households' structural reliance on public charging, while [12] shows that charging availability most strongly shapes purchase decisions among those without home charging access, a group weighted towards lower incomes.

What prior literature has not provided is a quantified interaction between charging infrastructure and means-tested subsidies. Deploying both instruments together lifts Q1 adoption by 0.73 percentage points per USD 1,000 of equivalent spending, which is about 2.3 times the effect of either instrument alone. This superadditive result points to a genuine complementarity: charging infrastructure in low-income areas does not merely add to progressive subsidies but amplifies their effect, functioning as a synergistic accelerator. The finding aligns with the integrated policy mix argument, which holds that deep decarbonisation in road transport requires the concurrent deployment of complementary instruments rather than a single lever applied in isolation.

4.4 The EV Adoption Gap: Quantifying Socio-Economic Inequities

Under flat-rate subsidy regimes, the adoption gap between the richest and poorest quintiles widened from 28.4 percentage points in 2015 to 42.7 points in 2022, an increase of roughly 50%. Rather than narrowing the gap, these policy investments appear to have widened it, directing public funds towards households with the least need. [7] classifies outcomes that worsen the position of the most disadvantaged as unjust within energy policy, a standard that flat-rate EV subsidies across most OECD economies clearly meet.

The contrast with means-tested regimes is instructive. This is the case for the small subset of countries that continued means-tested programmes throughout the study period, namely Norway from 2019 and California's programme, for which the Q5-Q1 adoption gap increased by just 11.2 percentage points and, in two cases, decreased. A two-way fixed effects design cannot establish causation with certainty. Even so, the consistent findings from the instrumental variable and placebo analyses suggest that policy design is the main driver of distributional outcomes in the EV transition. As [9] notes, these outcomes reflect policy choices rather than market inevitability.

5. Policy implications

The findings point to a clear policy direction. Most importantly, flat-rate purchase subsidies should be replaced with means-tested incentives that incorporate progressive tapering. Evidence from this study, supported by [4, 9], and the cross-national comparison establishes the regressive nature of uniform transfers (in their fiscal incidence), channeling the major share of public resources to the households least in need. A means-tested subsidy structure provides the highest incentives to lower-income households and gradually reduces support above a defined income threshold. This approach improves distributional equity while directing public resources to households where the impact on EV adoption is greatest.

Charging infrastructure investment should be targeted to underserved locations. Deployment policies and financial incentives should prioritise low-income neighbourhoods, social housing, and multi-unit residential buildings. As noted by [7], spatial inequities cannot be addressed solely through demand-side incentives. [10] propose a charging equity index that compares charging-point density with the proportion of non-homeowner households in an area, providing a useful tool for infrastructure planning and policy. The present results support this approach: targeted infrastructure investment in low-income areas generates adoption effects in the lowest quintile that are nearly four times those of equivalent spending in affluent zones.

Used EV markets warrant considerably more policy attention than they have received to date. Resale value is a principal determinant of the long-run affordability trajectory for lower-income consumers [13], and a well-supplied used market can substantially extend EV access without requiring those households to absorb new-vehicle price premiums. The used-vehicle credit introduced under the United States Inflation Reduction Act is a step in the right direction. However, its income eligibility threshold and vehicle price cap remain misaligned with current market conditions. [13] shows that the EV depreciation curve positions secondhand buyers so close to total cost of ownership parity with internal combustion engine vehicles that internal combustion engines become a greater competitor to EVs several years before new vehicle buyers, an insight for which there are direct implications for a thoughtfully designed subsidy as well as in fleet renewal policy.

The procedural dimension of energy justice demands that low-income communities and environmental justice organisations participate in EV policy design from the outset, rather than after decisions have been made. [5] document how the lack of such representation has led to programmes that are formally open to all but which are effectively closed to those at the bottom, due to barriers to information, lack of credit, and geographical targeting of incentive administration. [2] extends this argument to emerging-economy contexts, identifying participation barriers, information asymmetries, and restricted access to credit as structural preconditions for equitable adoption that policy must address directly rather than treat as residual problems. The design of access matters as much as the financial instrument.

6. Conclusion

This study examined the effects of income-differentiated EV incentive structures on adoption across household income quintiles in 25 OECD countries between 2015 and 2022. Three findings are the most significant. Flat-rate subsidies are highly regressive, with the adoption elasticities for the highest-income quintile exceeding those for the poorest quintile by more than fivefold, extending the single-country evidence in [9] and [4] to a cross-country context. Means-test-based incentives reverse this gradient, and we find the largest adoption responses among lower-income households, who current policy targets least, with elasticities in the first quintile ranging from 0.31 to 0.47, compared with near-zero effects in the fifth quintile. Targeted charging infrastructure in low-income areas complements demand-side incentives, yielding adoption gains nearly four times those observed with comparable investments in higher-income areas.

Taken together, these findings show that the distributional outcomes of the EV transition are shaped by policy design rather than technology alone. Under current policy approaches, the adoption gap widened by an estimated 18–24 percentage points over the study period. Flat subsidies and infrastructure concentrated in wealthier areas reproduced the structural inequities of the fossil fuel system rather than correcting them. By the standard of [7], this is a simultaneous failure of the distributive and procedural justice.

The findings point to a clear, though politically challenging, policy direction: progressive, means-tested incentives, targeted charging infrastructure, support for used-EV markets, and more inclusive policy design. These are not marginal adjustments to equity; they are (given the reported elasticity estimates) the most cost-efficient use of public funds to reach those households currently out of the transition. Future research should extend this framework to non-OECD economies, where the equity stakes are higher, and the evidence base is thinner. The work of [2] on EV adoption prospects in developing-country contexts points the way, and the income-quintile disaggregation methodology developed here provides a transferable tool. The intersection of energy justice and mobility equity remains one of the most important, yet least explored, areas of sustainable energy research.

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