How Cost-effective are Electric Vehicle Subsidies in Reducing Tailpipe-CO_2 Emissions? An Analysis of Major Electric Vehicle Markets

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Global transport was the fourth largest source of greenhouse gas (GHG) emissions in 2018, producing about 24% of global energy-related CO_2 emissions. About 75% of transport emissions come from road vehicles including cars and trucks. The majority of GHG emission reductions in the transport sector are projected to come from electrification of light-duty vehicles (LDVs), where technology is already commercial.

Governments globally have adopted various policies to support electrification of LDVs. Demand-side fiscal policies - in particular, incentives to reduce the upfront price of plug-in electric vehicles (PEVs), represent one of the most commonly used policy levers. This paper explores the PEV subsidy impact and cost-effectiveness in reducing CO_2 emissions across a range of major PEV markets. In particular, we utilize detailed micro-level data from 2010 to 2017 for 11 countries including China, the U.S. and nine major European countries. These countries have a wide range of PEV market shares, ranging from 1 to 40%, and subsidy percentages (government-subsidized portion of PEV pricing) ranging from 0% to 55%. By contrasting these countries, the paper aims to gain a better understanding of how trends and measures such as tailpipe-CO_2 avoided and subsidy cost-effectiveness may change as subsidy levels, PEV prices, and PEV market shares change. Overall, this study attempts to provide the most comprehensive set of cost-effectiveness estimates available in the literature for multiple countries. It also discusses some of the factors that contribute to cost-effectiveness disparities between countries, as well as the lessons that can be learned from them.

To estimate the tailpipe-CO_2 emissions avoided by PEV adoption, we assume that a PEV buyer would have bought an average ICEV of the same body type as the PEV in the counterfactual case of no PEVs. We couple this counterfactual vehicle assumption with insights from the choice modeling literature to allow for more realistic substitution patterns and more realistic estimates for tailpipe-CO_2 savings.

To estimate the cost per tonne of tailpipe-CO_2 avoided, we divide the total subsidy cost by the total tailpipe-CO_2 avoided over the lifetime of the vehicle. To estimate the cost-effectiveness of the subsidy, we account for the fact that taking away the subsidy would not result in zero PEV sales. In other words, we account for the fact that some consumers would have bought a PEV even in the absence of the subsidy. We do so by incorporating values from the literature on the extent of PEV sales induced by the subsidy. Finally, we also incorporate the CO_2 emissions from the combustion of fuels associated with the generation and distribution of electricity used for PEV charging. This gives us the actual cost per tonne of CO_2 avoided from subsidizing PEVs.

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The analysis yielded four major sets of results. First, the average non-PEV fleet is less efficient than the replacement fleet based on the body-type equivalency assumption. This means that if we had not employed the body-type equivalency assumption, we would have exaggerated the tailpipe-CO_2 reductions while underestimating the cost per tonne of tailpipe-CO_2 saved. In other words, the usual use of the standard counterfactual technique in the literature, which does not contain the body-type equivalency assumption, overestimates the cost-effectiveness of PEV subsidies.

Second, we discover that the percentage of tailpipe-CO_2 avoided as a result of PEV substitution varies linearly with PEV market share. This finding suggests that, in the absence of detailed data on new vehicle fleets, the country‘s PEV market share could be used as a proxy to estimate the percentage of tailpipe-CO_2 avoided through PEV substitution. Two factors contribute to deviations from this linear variation: (i) a higher proportion of PHEVs in a country‘s PEV mix, and (ii) PEVs replacing relatively cleaner vehicles.

Third, we found that the subsidy cost per tonne of tailpipe-CO_2 avoided varies according to the percentage of PEV pricing subsidized by the government. The Netherlands and Denmark, which subsidized high-priced PEVs including plug-in hybrid electric vehicles, lie above the trend, while the U.S., where PEVs replaced higher-emission vehicles, is below the trend. China is paying the most to decrease carbon emissions through PEV subsidies, costing as high as $1,600 per tonne in the short-run, an order of magnitude more than the social cost of carbon. The high costs suggest that PEV subsidies are more a part of China‘s industrial policy rather than its carbon policy.

Fourth, the estimated cost per tonne of CO_2 avoided rises even more when the actual extent of electric vehicle sales induced by subsidies and the emissions associated with electricity generation are considered. Accounting for these additional CO_2 emissions results in a PEV sales-weighted average short-run static cost of $1441 per *additional* net tonne of CO_2 avoided for U.S. and Europe combined. Even after accounting for subsidy-induced sales and power generating emissions, a linear link between subsidy costs and government-subsidized PEV pricing remains, with the Netherlands and Denmark staying above the linear variation. Also, Germany seems to be above the variation, whilst the U.S. no longer appears to be significantly below it. This is because power generation in the U.S. and Germany is not as clean as in the other European countries in this study.

The high tailpipe-CO_2 emissions reduction costs of PEV subsidy policies warrants research into and adoption of innovative subsidy designs to improve their cost-effectiveness. Innovative targeted PEV subsidy designs could be incorporated in the COVID-19 economic stimulus packages that are being currently considered in different parts of the world for promoting PEV adoption. Targeted designs based on either consumer income or vehicle price represent viable cost-effective alternatives.