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Peer Review

# Review of: "Electric Vehicle Fleet Penetration and Air Pollution Mortality in Europe"

**Zoran Cekerevac**[1]

1. Independent researcher

## *Summary and Key Findings*

**Short summary:**

The manuscript examines the relationship between electric vehicle fleet penetration and PM2.5-attributable mortality across 35 European countries using cross-sectional 2023–2024 data. The reported Pearson correlation is moderately negative (r = -0.465, p = 0.013). The author concludes that higher BEV fleet shares are associated with lower PM2.5 mortality but correctly emphasizes that electrification is necessary but not sufficient: fleet turnover lag, multiple PM2.5 sources, meteorology, and comprehensive policy packages all mediate the relationship.

## *Methodology and Data Strengths and Weaknesses*

**Strengths**

- Fleet stock rather than sales data is used, which better reflects current exposure.
- Public sources (EEA, ACEA) are cited, improving transparency and reproducibility.
- The manuscript explicitly discusses contextual factors (turnover lag, emission source mix, geography), showing a systems perspective.

**Weaknesses and ambiguities**

- Cross-sectional design prevents causal inference; some language in conclusions risks implying causality.
- EV penetration estimates for some countries rely on inferred values; the magnitude of measurement error is not quantified.



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- Outcome aggregation: national PM2.5 mortality aggregates urban and rural exposures and does not isolate urban vehicle-related effects.
- Lack of multivariate controls: the analysis appears to rely on bivariate correlation without controlling for key confounders (GDP per capita, governance, share of solid-fuel heating, industrial emissions, VKT, population density, electricity carbon intensity).
- The manuscript relies on a rather limited set of literature sources to substantiate its claims. The review of prior research should be broadened to incorporate studies conducted in the countries included in the analysis, thereby ensuring that the evidentiary base is both comprehensive and contextually relevant.

## *Statistical Validity and Recommended Additional Analyses*

**Issues to address**

- *Confounding*: Countries with high EV shares often have higher socioeconomic status and stronger environmental governance; without controls, the correlation may reflect these factors rather than a direct EV effect.
- *Spatial dependence:* Neighboring countries may share pollution patterns; spatial autocorrelation should be tested and accounted for.
- *Influential observations:* Nordic and Balkan extremes may disproportionately drive the correlation; test robustness to outliers.
- *Nonlinearity and heteroskedasticity:* Consider transformations or nonlinear specifications if residual diagnostics indicate them.
- *Temporal lag:* Fleet composition changes slowly; use lagged EV shares or panel data if available.
- *Source attribution:* Decomposing PM2.5 by source (transport vs heating vs industry) would allow a more direct assessment of the potential impact of vehicle electrification.

**Recommended additional analyses**

1. Multivariate regression with comprehensive controls: Estimate multivariate models that include plausible confounders (GDP per capita, governance or institutional quality index, share of household heating from solid fuels, industrial emission indicators, vehicle-kilometers travelled, population density, and electricity carbon intensity). Report full model diagnostics ($R^2$, adjusted $R^2$, coefficient

standard errors, 95% confidence intervals, and exact p-values) and assess model specification sensitivity.

2. Spatial dependence and clustering: Test for spatial autocorrelation in residuals (e.g., Moran's I) and, if present, apply spatial econometric techniques (spatial lag or spatial error models) or use cluster-robust standard errors to account for geographic dependence among neighboring countries.
3. Robustness and influence diagnostics: Conduct robustness checks excluding influential observations and outliers (e.g., Nordic and Balkan extremes), compare results across alternative outcome transformations (e.g., log mortality), and evaluate heteroskedasticity and nonlinearity (e.g., via White tests and spline or polynomial specifications).
4. Temporal and panel analyses: Where data permit, exploit multi-year panel data or lagged EV penetration measures to account for fleet turnover dynamics and to reduce simultaneity bias. Fixed-effects or difference-in-differences designs should be considered to control for unobserved time-invariant heterogeneity.
5. Endogeneity and instrumental variable strategies: Explore instrumental variable approaches to address potential endogeneity of EV penetration (for example, historical timing of subsidy programs, early charging infrastructure rollout, or exogenous policy shocks). Provide validity tests for instruments (relevance and exclusion restrictions) and report IV estimates alongside OLS for comparison.
6. Source-attribution analysis: Decompose PM2.5 concentrations and attributable mortality by source (transport, residential heating, industry, agriculture, transboundary transport) using available emission inventories or receptor/source-apportionment studies. This will clarify the maximum plausible contribution of vehicle electrification to observed mortality differences.
7. Uncertainty quantification for estimated inputs: Quantify and propagate uncertainty arising from estimated EV fleet shares (where ACEA data were incomplete) and from PM2.5 mortality estimates (confidence intervals from EEA/WHO). Perform sensitivity analyses to show how measurement error in key inputs affects the main correlation and regression results.
8. Comparative historical analysis of pre-EV era versus present: Perform a comparative analysis contrasting the present cross-sectional relationship with the situation approximately a decade earlier, when EV adoption was rare. This should include: (a) assembling comparable historical data on fleet composition and PM2.5 mortality (or concentration proxies) for the earlier period; (b) estimating the same statistical models for the historical snapshot and formally testing whether the EV–mortality relationship has changed over time (e.g., interaction terms between period indicators

and EV share, or pooled panel models with period fixed effects); and (c) interpreting changes in light of concurrent policy, economic, and energy-system developments. Such a comparative exercise would help distinguish structural differences across countries from emergent effects associated with recent EV diffusion and would provide stronger contextual evidence on temporal dynamics and potential causal pathways.

## *Interpretation and Policy Implications*

**Correct interpretation**

- The reported correlation is informative but *does not prove causation*. The manuscript correctly stresses that electrification must be combined with other measures.
- Distinguish *urban health effects* (where vehicle tailpipe emissions matter most) from *national aggregate mortality*, which depends heavily on non-transport sources and regional transport of pollution.
- Recognize that electrification can *displace* emissions to power plants; health benefits depend on grid cleanliness.

**Policy messages**

- Rapid fleet electrification is desirable but must be regionally tailored: in countries where residential heating dominates PM2.5 (e.g., Poland), policies targeting heating will yield larger near-term benefits.
- Manage public expectations about timing: fleet turnover implies multi-decadal realization of full benefits unless complemented by targeted short-term measures.

## *Recommendations for Authors and for the Journal*

**For the authors**

- *Add multivariate models* with the controls listed above and present full statistical output ($R^2$, CI, SE).
- *Test spatial dependence* and report robustness to outliers and alternative specifications.
- *Use lagged or panel data* where available; consider an IV strategy to address endogeneity.
- *Quantify uncertainty* in EV penetration estimates and PM2.5 mortality and include sensitivity analyses.
- *Disaggregate* where possible (urban vs national) or explicitly discuss limitations of national aggregation.
- *Soften causal language* throughout and emphasize the correlational nature of findings.

- *Document data treatment* and provide code and data as supplementary materials to enable reproducibility.
- *Declare AI assistance* is used for figure preparation and ensure figures are reproducible from provided code and data.

**For the editorial office**

Personally, I believe it is premature to draw conclusions about the magnitude of any positive effect of electric vehicles on human health and longevity, particularly considering the varied methods of EV production and the upstream activities associated with their manufacture. Given that electric vehicles have only recently begun to be adopted at scale, it is difficult to expect that their impact on life expectancy can yet be reliably assessed. Even in Norway — which objectively represents an outlier — EVs still constitute a minority of the fleet. Moreover, when we consider countries such as Finland (approximately 2.5% EV fleet share) and Denmark (approximately 1.5% EV fleet share), which show lower mortality than countries with higher EV shares, it is hard to accept the claim that EVs are a significant determinant of reduced mortality.

- I advise either **rejecting** the article or **requesting major revisions**: although the topic is potentially engaging for readers and the manuscript demonstrates clear motivation, further in-depth analysis and improved methodological clarity are necessary prior to acceptance.

## Declarations

**Potential competing interests:** No potential competing interests to declare.