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Literature and Institutional Review (2015–2024)

Air pollution and premature deaths: A panel analysis of $PM_{2.5}$ effects in Europe (Tümay, 2025)

- **Authors:** Muhammed Tümay
- **Year:** 2025 (early view)
- **Region:** 27 EU countries (2007–2019 panel data)
- **Key Findings:** Using a fixed-effects (FE) panel regression with country and time effects, this study found that a 1% increase in fine particulate matter ($PM_{2.5}$) concentrations is associated with about a **1.9% increase in premature mortality** [1] [2]. The $PM_{2.5}$ coefficient was highly significant across model specifications. Control variables included healthcare expenditure (% GDP), income inequality, healthy life expectancy, fertility, and total deaths. Notably, higher healthcare spending was linked to significantly lower premature death rates (negative coefficient) [3]. Diagnostic tests (Hausman test, etc.) indicated that a FE model with year-fixed effects and Driscoll–Kraay robust standard errors (to address heteroskedasticity and serial correlation) was most appropriate [4] [5]. No severe multicollinearity was detected (all VIFs < 10) [6], and the final model had good fit (≈78% within R^2). The results reinforce that **air pollution poses a grave public health risk**, echoing prior findings that $PM_{2.5}$ exposure elevates mortality [2].
- **Relevance to Thesis:** This source provides a **methodological benchmark** for linking air quality to health outcomes in a longitudinal EU context. It validates the use of FE panel models (with lags and robust SE) to control for unobserved heterogeneity and temporal effects. The significant elasticity (~1.9) of mortality with respect to $PM_{2.5}$ offers a concrete literature anchor for the magnitude of pollution's impact on public health [2]. Moreover, Tümay's inclusion of socio-economic controls and extensive diagnostics (VIF for multicollinearity, Hausman test, etc.) exemplifies best practices in **model specification and validation** for environmental health economics research [6] [5]. This supports the thesis by showing that a rigorous, reproducible panel-data approach can quantify the health benefits of pollution reduction in line with policy targets.

Air pollution and life expectancy in Europe: Does investment in renewable energy matter? (Rodríguez-Álvarez, 2021)

- **Authors:** Ana Rodríguez-Álvarez (and colleagues)
- **Year:** 2021
- **Region:** 29 European countries (panel data covering 2005 and 2018)
- **Key Findings:** This study took a novel approach using panel data and a stochastic frontier analysis to distinguish between **potential vs. observed health**. It examined how air pollution and clean energy investment affect life expectancy at birth. Results show that major air pollutants – **NO_x, PM_{10}, and $PM_{2.5}$ – each had significant negative impacts on life expectancy** across Europe [7] [8]. In practical terms, countries with higher levels of those pollutants tend to have lower life expectancy. By contrast, greater **investment in renewable energy** was associated with **improvements in life expectancy** [9]. Among pollutants, nitrogen oxides (NO_x) and fine particulates ($PM_{2.5}$) exhibited the

strongest adverse effects on population health, with $PM_{2.5}$ having the most detrimental impact (more so than coarse PM_{10}) [10]. The study concludes that shifting energy investments toward renewables and away from fossil fuels would mitigate pollution's harm and increase the "potential" lifespan of European citizens [9] [11].

- **Relevance to Thesis:** Rodríguez-Álvarez (2021) provides **cross-country econometric evidence** linking air quality to health outcomes in Europe. It supports the thesis by demonstrating that even at relatively low pollution levels (common in Europe), variations in $PM_{2.5}$ and NO_x translate into meaningful differences in life expectancy [7] [8]. The inclusion of renewable energy investment as an explanatory variable highlights the importance of **policy interventions**: cleaner energy not only reduces emissions but measurably improves public health. This aligns with the thesis focus on environment-health-economic links, reinforcing that panel data models can capture long-term health benefits of emissions reductions. The methodological detail (using a two-period panel and a frontier approach to estimate "health efficiency") also underscores innovative ways to handle **unobserved heterogeneity** and **potential outcomes** in public health economics.

Associations of air pollution and greenness with mortality in Greece: An ecological study (Kasdagli *et al.*, 2021)

- **Authors:** Maria-Iosifina Kasdagli; Klea Katsouyanni; Kees de Hoogh; Pagona Lagiou; Evangelia Samoli
- **Year:** 2021 (Env. Research)
- **Region:** Greece – 1,035 municipal units (nationwide cross-sectional dataset, exposure year ~2010)
- **Key Findings:** This study assessed long-term air quality impacts on mortality across Greek municipalities, incorporating **multiple pollutants and greenness exposure**. Using Poisson regression (age-standardized mortality as outcome) with spatial adjustments, it found that higher chronic exposure to **$PM_{2.5}$, NO_2, and black carbon (BC)** each corresponded to **significant increases in all-cause mortality rates** [12] [13]. For example, an interquartile range increase in $PM_{2.5}$ was associated with ~9% higher natural-cause mortality (RR≈1.09) [14], and NO_2 with ~3% higher mortality (RR≈1.03). In contrast, greater vegetative **greenness (NDVI)** had a protective effect, with an IQR increase in greenness linked to ~5% lower all-cause mortality (RR≈0.95) [15]. Notably, ozone (O_3) showed an unexpected negative association with mortality (possibly reflecting its rural spatial pattern) [16]. Effects were stronger in urban areas, and two-pollutant models as well as pollutant–greenness interaction terms suggested that greenness can buffer some respiratory mortality risk of pollution (negative interaction), whereas cardiovascular mortality showed positive pollution–greenness interaction [17] [18]. All associations were robust to co-exposure adjustments.
- **Relevance to Thesis:** Although cross-sectional, this Greek study provides granular, **city-level evidence** linking air pollutants to mortality, reinforcing the thesis at a sub-national scale. It underscores the importance of controlling for confounders like socio-economic status and incorporating **lagged environmental factors** (here, long-term greenness) to capture interactions. The finding that $PM_{2.5}$ and NO_2 drive mortality even in a mid-income EU country aligns with broader panel results, while the **greenness benefit** highlights how urban planning can mitigate health risks. Methodologically, Kasdagli *et al.* demonstrate rigorous data harmonization: exposures were derived from high-resolution models (100×100 m grids) and health data from national registries [19]. This speaks to best practices in **data harmonization and reproducibility** – using standardized exposure models and adjusting for spatial autocorrelation to ensure valid, comparable results. The study's explicit consideration of multi-pollutant models and interactions provides a methodological template for handling correlated environmental variables in panel/longitudinal analyses.

Greenhouse Gas Emissions and Health in the Countries of the European Union (Gavurová *et al.*, 2021)

- **Authors:** Beáta Gavurová; Martin Rigelský; Viera Ivanková
- **Year:** 2021 (Frontiers in Public Health)
- **Region:** 27 EU countries (annual data, **2009–2018** panel)
- **Key Findings:** This study explicitly linked **GHG emissions** to population health by examining five major greenhouse gases (CO_2, CH_4, N_2O, HFCs, SF_6) and health outcomes measured as Disability-Adjusted Life Years (**DALYs** lost). Using correlation, clustering, and panel regression analyses, the authors found CO_2 to be the **dominant driver** among GHGs affecting health [20]. In particular, **higher CO_2 emissions are associated with higher DALYs (i.e. worse health)** in EU populations [21]. The panel regression (with tests confirming the need for panel estimators) showed a positive link: a decrease in CO_2 tended to accompany a decrease in DALYs [20]. By one cited estimate, a 1% rise in carbon emissions leads to ~0.3% rise in adverse health outcomes [22]. The analysis also noted that while all GHGs matter, **reducing CO_2** would yield the most health co-benefits, though other co-emitted pollutants must drop concurrently for full benefit [20]. Countries like Luxembourg and Estonia (with very high per-capita CO_2) had the most elevated health burden, whereas Germany exhibited the lowest DALYs rate (best health outcome) among the set [20]. Breusch–Pagan and Wooldridge tests were applied to validate model assumptions (heteroskedasticity, panel effects) [23], ensuring a statistically sound model.
- **Relevance to Thesis:** Gavurová et al. (2021) connects **climate-related emissions with health metrics** in a comprehensive EU-wide panel, underscoring that environmental quality (even in terms of GHGs) has tangible public health repercussions. This supports the thesis' inclusion of **GHG emissions alongside air pollutants**: while CO_2 itself is not directly toxic, it proxies fossil fuel combustion and correlates with co-pollutants. The study's finding of a quantifiable CO_2–DALY relationship [20] provides a literature-backed justification for incorporating GHG reductions into health benefit models. Methodologically, the paper exemplifies **data harmonization**: it leverages EU-wide emissions inventories (e.g. UNFCCC submissions) and health data from the Global Burden of Disease (IHME/WHO) [24]. It also emphasizes reproducibility and rigor, using standard tests and noting limitations (e.g. potential unobserved country differences) [25] [26]. This aligns with best practices in public health economics – ensuring that multi-country data are comparable and results are robust to statistical assumptions – thereby strengthening the thesis's methodological foundation.

The impact of financial development, health expenditure, CO_2 emissions, institutional quality, and energy mix on life expectancy in Eastern Europe: CS-ARDL and quantile regression approaches (Nica *et al.*, 2023)

- **Authors:** Elvira Nica; Adela Poliakovă; Gheorghe H. Popescu; Katarina Valášková; Ștefan G. Burcea; Andreea-Ligia D. Constantin
- **Year:** 2023 (Heliyon, Vol. 9, No. 11)
- **Region:** Eastern European countries (panel data **1990–2021**)
- **Key Findings:** Focusing on Eastern Europe, this study investigated how economic and environmental factors jointly affect longevity. The authors employed advanced panel techniques – **Cross-Sectional**

Autoregressive Distributed Lag (CS-ARDL) to account for non-stationarity and cross-country dependence, plus Quantile Regression for robustness [27] [28]. Key findings include: **higher CO_2 emissions and greater fossil fuel consumption significantly reduce life expectancy**, whereas increased health expenditures and a shift to renewable energy significantly improve life expectancy [29]. Quantitatively, the estimates suggest that for Eastern Europe, a rise in CO_2 emissions correlates with a small but detectable decline in life expectancy (e.g. every additional metric ton per capita of CO_2 might lower life expectancy by a few hundredths of a year, and heavy reliance on fossil fuel energy lowers it by over a year in aggregate) [30]. These results held consistently across mean and quantile-based analyses. Other factors: financial development had a positive but insignificant effect on life expectancy, while better institutional quality (governance) and higher healthcare spending were strongly beneficial to health outcomes [31]. The study took care to verify cross-sectional dependence and heterogeneity (applying Pesaran CSD tests and slope tests) and used second-generation panel unit root and cointegration tests before estimating the long-run CS-ARDL model [32].

- **Relevance to Thesis:** This source provides a **state-of-the-art panel econometric analysis** that closely aligns with the thesis scope. It demonstrates how to handle long panels (32 years) with potential non-stationarity, offering a template for including **lag structures and long-run relationships** between pollution and health. Empirically, Nica et al. confirm that environmental degradation (CO_2 emissions, fossil fuel use) impairs public health even when controlling for socio-economic developments [30]. This reinforces the thesis argument that climate mitigation and air quality improvements yield health dividends. Moreover, the emphasis on **institutional quality and economic controls** speaks to best practices: it highlights that robust inference on environmental health effects requires accounting for governance and economic context. The thorough testing for unit roots, cointegration, and use of CS-ARDL reflect a high standard of **reproducibility and rigor**, ensuring that conclusions (e.g. the need to pivot from fossil fuels to renewables for health gains [33]) are on solid statistical ground. Incorporating such advanced methodological insights will strengthen the thesis's credibility in addressing longitudinal data and complex dynamics.

A panel data study on the effect of climate change on life expectancy (Roy, 2024)

- **Authors:** Amit Roy
- **Year:** 2024 (PLOS Climate)
- **Region:** Global – 191 countries (1940–2020 panel)
- **Key Findings:** Roy (2024) examined how **long-term climate change** (especially rising temperatures and changing rainfall patterns) affects life expectancy at birth. Using a fixed-effects panel model over an exceptionally long period, the study found a pronounced **negative effect of warming on longevity**. Specifically, a +1°C increase in a country's annual average temperature is associated with about **−0.44 years lower life expectancy** [34] [35], holding other factors constant. Moreover, the interaction of high temperature and altered rainfall (captured via a composite climate index) further amplifies this negative impact: a 10-point increase in the climate index corresponds to ~0.5-year drop in life expectancy [34]. The analysis also noted that **women's life expectancy is even more adversely affected** by climate change than men's, indicating potential vulnerability differentials [35]. This global study drew data from harmonized sources (World Bank for health and socioeconomic data, and World Bank's Climate Knowledge Portal for climate data) and emphasized that the findings portray climate change as a mounting public health crisis [36]. Roy underlined the urgency of mitigation: without curbing greenhouse gas emissions and adapting to climate shifts, life expectancy

gains could be eroded worldwide [37] . (An editorial note accompanied the article advising caution due to concerns about one temperature data source, but the overall conclusions remain qualitatively robust.)

- **Relevance to Thesis:** While centered on **climate variables rather than specific pollutants**, this study is methodologically and conceptually relevant. It illustrates a longitudinal cause-effect linkage between an environmental trend (global warming) and a health outcome across countries, analogous to linking air pollution trends to health. For the thesis, it provides a global-scale validation that **environmental degradation has measurable, econometrically identifiable effects on population health** [34] . The fixed-effects approach over 80 years is notable for controlling for unobserved country traits (e.g. baseline healthcare, genetics) – aligning with the thesis's use of longitudinal models to isolate environmental impacts. Roy's emphasis on data sources and openly shared data (World Bank, etc.) also reinforces reproducibility and transparent research practices. Ethically, the study frames climate action as a health imperative, echoing the thesis theme that **policies to cut GHG emissions (the root of climate change) align with public health ethics**. Incorporating this reference supports any argument that long-term climatic changes (driven by GHGs) and shorter-term air quality changes are both crucial to consider in public health economics analyses.

Harm to human health from air pollution in Europe: burden of disease status, 2024 (EEA Briefing)

- **Authors:** European Environment Agency (Official EU Report)
- **Year:** 2024
- **Region:** Europe (EU-27 and other EEA member countries)
- **Key Findings:** This official briefing provides the latest **epidemiological burden estimates** for air pollution in Europe, using harmonized methods (WHO-recommended concentration–response functions applied to European air quality and population data). It reports that in **2022**, Europeans' exposure to $PM_{2.5}$, NO_2, and O_3 remained well above WHO's recommended limits, resulting in substantial health impacts [38] . **Annual premature deaths attributable to $PM_{2.5}$ were about 239,000 in the EU-27 for 2022**, with an additional 48,000 deaths from NO_2 exposure and 70,000 from O_3 (these impacts cannot be summed due to overlapping exposures) [39] [40] . Importantly, the report highlights progress: between 2005 and 2022, **$PM_{2.5}$-attributable deaths in the EU fell by ~45%**, moving toward the EU's Zero Pollution Action Plan target of a 55% reduction by 2030 [41] . The briefing also quantifies the potential gains from cleaner air – **meeting WHO air quality guidelines would prevent tens of thousands of deaths per year** across Europe [39] . In addition to mortality, the EEA emphasizes morbidity: chronic exposure causes significant disease burden measured in Years of Life Lost (YLL) and Years Lived with Disability (YLD), which translate into hundreds of thousands of DALYs annually. The report carefully explains the **Environmental Burden of Disease methodology**, stressing standardized metrics (deaths, YLL per 100,000, DALYs) to enable comparisons across countries [42] [43] . It also notes why national estimates can differ (e.g. due to different input data or risk assumptions) and cautions that pollution burden estimates for each pollutant are computed separately to avoid double-counting correlated pollutants [44] [45] .
- **Relevance to Thesis:** The EEA (2024) report offers authoritative, up-to-date **contextual evidence** for the thesis. It anchors the analysis in real-world magnitudes, confirming that air pollution remains a leading environmental health threat in Europe – but one that has been significantly reduced through policy. For a thesis focusing on Greece/EU, citing that $PM_{2.5}$ deaths have nearly halved since 2005 [41] provides a hopeful note on the effectiveness of interventions, while the large remaining death toll

underscores the work still to be done. The briefing also exemplifies **best practices in data harmonization**: it uses unified methodologies (WHO's recommendations) and transparent assumptions to ensure reproducibility and comparability of results across countries [44]. Ethical standards are implicit in the approach – e.g. attributing deaths to pollution relies on scientifically established causality and is used to inform policy for saving lives. In summary, this source bolsters the thesis with **policy-relevant statistics** and reinforces the need for robust quantitative models by showing how institutions synthesize data to drive environmental health policies. It validates the thesis's foundational premise that improving air quality (and reducing emissions) translates into measurable public health benefits on a national and regional scale.

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