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Air and noise pollution: A state-of-the-art review of causal health outcomes

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Abstract

Air and noise pollution have in the medical literature been shown to have large negative health effects. However, the findings might exhibit the problem of endogeneity, i.e. that they are not causal. While literature focusing on causal relationships in the area has grown in the last decades, a comprehensive overview has not been performed in recent years.

Aim

This study aims to provide a state-of-the-art review of the causal relationship between air and noise pollution and health outcomes by summarizing the findings from international peer-reviewed articles, as well as informing the reader of the methodological challenges in the field and knowledge gaps in the literature. In addition, we will contribute by comparing the economic literature regarding both air and noise pollution.

Methods

To achieve these aims, we conducted a review of existing international literature. This review identified previous research linking air and noise pollution to health outcomes, focusing on causal estimations using primarily quasi-experimental settings.

Findings

The empirical findings show that air pollution can be linked to several health outcomes, e.g., increased mortality, emergency room visits, and hospitalization, through different risk pathways. The number of studies focused on noise pollution are significantly fewer, with individual studies also finding negative health effects, e.g., sleeping problems, hypertension, and increased medication and healthcare utilization. The evaluation of air and noise pollution differs primarily in temporal aspects and the source of variation used.

Keywords

Air pollution, Noise pollution, Health outcomes, Quasi-experimental design, State-of-the-art review

JEL Codes

C21, C23, C26, I18, Q53

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1. Introduction

Transportation is essential for economic activity and growth but is also associated with several externalities that negatively affect society at large, such as increased greenhouse gas emissions, traffic accidents, barrier effects and habitat fragmentation, and negative health effects. Among health aspects, air and noise pollutions are typically ranked highest among environmental causes of disability-adjusted life years lost (Stansfeld, 2015) – highlighting the importance of evaluating and targeting the sources of these issues. However, causally linking air and noise pollutions to health outcomes is particularly difficult due to endogeneity challenges, such as geographical sorting, harvesting, data availability, to name a few – often requiring creative identification strategies. In the last decades, the economic literature has increasingly utilized quasi-experimental designs. However, to the best of our knowledge, a comprehensive overview has not been performed in the last decade.

Studies examining correlations between pollutants and health effects might exhibit the problem of endogeneity, i.e. biased estimates due to factors such as omitted variables, measurement error, and simultaneity. For example, multiple factors affect both health and the distribution of air pollution, such as weather, socio-economic status, and changes in economic conditions (Beghelli, 2018). Similarly, noise exposure might be correlated with variables such as air quality (Anderson, 2020), individual noise sensitivity (Boes et al., 2013), or an area's population density, share of low-income residents, and proportion of greenspace (Trudeau et al., 2022). For a comprehensive review of environmental justice and pollution, see e.g., Banzhaf et al. (2019) or the recent OECD report (2024).

Other causes of concern are avoidance behavior, residential sorting, and mortality displacement ("harvesting"). The former two refer to the fact that, if knowledge about the harmful effects of pollution is available, exposure can be modified short-term (e.g., staying indoors, avoiding some parts of the town, closing windows, bedroom reallocation, or soundproofing etc.), or by choosing where to live. For example, we might expect self-selection into more noisy areas, where those less affected/annoyed by noise take advantage of lower prices/rents. On the other hand, a lesser socioeconomic status might also lead to residential sorting due to financial reasons. Harvesting in turn refers to the risk of overestimating health effects if, e.g., air pollution primarily affects those already in poor health, who are more likely to become ill or die sooner regardless of the air quality. To tackle this endogeneity problem, more studies have in the last decades been published in the economics literature with the explicit goal of evaluating the causal relationship between air quality, or noise exposure, and health, utilizing quasi-experimental designs, e.g., regression discontinuity, difference-indifference, and instrumental variable methodology. These studies are often based on the results from other fields, such as epidemiology, but typically find larger effects. For example, quasi-experimental estimates for elasticities of air pollution and health are generally larger than conventional (correlational) ones (Alexander & Schwandt, 2022), in line with e.g., avoidance behavior. Regarding harvesting in particular, studies have tried to alleviate, or at least evaluate, the effects by, e.g., lagging the results or experimenting with longer time frames, estimating life-years lost, evaluating long-term effects, or focusing on morbidity.

The first article regarding air pollution and health in a quasi-experimental setting is, to the best knowledge of the author, Ransom and Pope III (1995), who used the temporarily closing of a steel mill in Utah, USA to link steel production to increased hospital admissions for respiratory conditions. Following this, focus often laid on early-life outcomes (e.g., birth weight and infant mortality) due to empirical reasons (Gomez Mahecha, 2024). For a review of the first decades of the literature of causal effects of air pollution on early-life outcomes (health and economic), see

Currie et al. (2014). Similarly, a large body of literature exists regarding the 'Development Origins for Health and Disease' (or fetal origins), explaining long-term impact of adverse nutritional, health, and economic conditions during prenatal and early childhood. For more information on this, see e.g., Currie & Almond (2011) and Almond et al. (2018). Similarly, for a review of causal relationships between air pollution and non-health outcomes (i.e., productivity and labor supply, cognitive performance, and decision making), see Aguilar-Gomez et al. (2022).

Regarding noise pollution, there have been several medical/epidemiological studies estimating the connection between noise and health. The field started in the 1970s with laboratory experiments, followed by field experiments (Beghelli, 2018). These settings have the advantage of allowing researchers great control over noise exposure and monitoring health outcomes, such as hormonal or hearth rate changes, allowing for precise estimates of potential relationships. However, the external validity might be questionable in the sense that the estimates might not be representative for chronic exposure. For example, noise might affect us less over time due to habituation and coping mechanisms (Boes et al., 2013). In this literature, traffic noise has been linked to increased mortality and the incidence of strokes, heath attacks, and cardiovascular illness, in addition to perceived annoyance, sleep disturbance, cognitive impairment, and influencing the endocrine system[1] (Beghelli, 2018). Other observed effects of environmental noise are fatigue, lack of concentration, and reduced enjoyment (Li et al., 2021) as well as substance use and increased aging (Wang et al., 2022). However, few studies have estimated health outcomes using quasi-experimental settings and even less is known about the effects of noise control policies (Lindgren, 2021a).

This study is intended for both economists and non-economists with the aim of providing a state-of-the-art review of the causal relationship between air and noise pollution and health outcomes by summarizing the findings from international peer-reviewed articles, as well as informing the reader of methodological challenges in the field and knowledge gaps in the literature. In addition, we will contribute by comparing the economic literature regarding both air and noise pollution. The structure of the article is as follows. In section 2, the examined literature and the search method are explained and section 3 provides a summary of the results from the examined literature that link air and noise pollution to health outcomes, using causal methodology. Section 5 presents a discussion, followed by conclusions in section 6.

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[1] The pathways could be both auditory and non-auditory, and the most detrimental effect of environmental noise (in contrast to atmospheric and occupational noise) has been attributed to sleep disturbance. However, the effect size is unclear and tends to depend on age and health background (Van Kamp & Davies, 2013). Li et al. (2021) noted that elderly might be more affected by noise exposure since they have a lower residential mobility, spend more time at home, and have a higher sensitivity to environmental influences on sleep disturbance and annoyance. Likewise, different sources of noise have varying acoustic properties (i.e., frequency, sound level, duration, intensity, and psychoacoustic measures) and therefore affect people differently (Beghelli, 2018).

2. Literature examined

A literature review was performed between August 2024 and January 2025 to identify previous research linking air and noise pollution to health outcomes, focusing on causal estimations using primarily quasi-experimental settings. Google Scholar was used to find the relevant articles, both using search strings and finding articles that have cited earlier review articles in the field (e.g., Currie et al., 2014). Together with citation chaining, this resulted in 25 articles and PhD dissertations summarized in this review, of which 20 regard air pollution, four concern noise pollution, and one addresses both. All studies are listed in Table 1 and Table 2 in the appendix.

The articles included regarding air pollution are from 2015 and forward (i.e., after the review article by Currie et al., 2014), where the area of interest has grown from primarily focusing on the effect of air pollution on early-life outcomes to also include adult outcomes, e.g., health status, hospitalization, emergency room visits, adult mortality, and healthcare costs. Most of the articles evaluate short-term shocks and health, while a few attempt to also estimate long-term effects. They have primarily assessed sources from land-based activities (e.g., vehicles or energy production). When it comes to quasi-experimental approaches to noise pollution and health, very few studies were found at all, with the earliest identified publication dating back to 2013[2]. Most made use of long-term air traffic changes due to changes in regulation.

The difference between quasi-experimental studies of air and noise pollution and health regarding the number of available studies, where the former category is significantly larger, might be due to air pollutants being more easily quantified, with many countries having a national network of monitoring stations. In contrast, noise monitoring seems to be sparser, for example located around airports. It might also be that fewer individuals are severely affected by noise pollution, yielding smaller sample sizes and therefore making estimation less precise (and perhaps viewed as having a smaller societal cost), even though a low level of disturbance potentially could affect many. Another reason could be that for noise pollution, disturbance is already considered the most significant health issue, potentially leading to less research focus on other health effects.

[2] Due to the lack of articles published in the last decade, the 2013 study was also included in the review.

3. Empirical review

3.1 Air pollution and health

This section summarizes the research findings related to the causal link between air pollution and health outcomes. It is divided into three subsections: early-life outcomes, mortality, and morbidity and healthcare utilization. Summarized results by pollutant and health outcome can be found in Table 3 in the appendix.

3.1.1 Early-life outcomes

As stated earlier, early-life outcomes of pollution have previously been explored (see, e.g., Almond et al., 2018; Currie & Almond, 2011; Currie et al., 2013). In recent years, several additional studies have found pollution to affect birth weights, infant mortality, and respiratory health.

Regarding birth weight, Lindgren (2021b) found that a stricter sulfur cap in marine fuel in north-western Europe reduced ambient sulfur dioxide (SO_2) and fine particulate matter ($PM_{2.5}$) concentrations, which led to a 5-7 percent decrease in low birthweight incidents in England and Wales. Each microgram per cubic meter (μg/m^3) of annual $PM_{2.5}$ exposure increased the probability of low birthweight by 0.61 percentage points, or 9 percent[3]. Similarly, Alexander & Schwandt (2022) analyzed the Volkswagen "clean diesel" scandal in the US, showing that an extra “cheating” car per 1,000 increased $PM_{2.5}$, particulate matter (PM_{10}), and ozone (O_3) levels by 2.0, 2.2 and 1.3 percent respectively, as well as increased rates of low birthweight by 1.9 percent. It also decreased the average birth weight and gestation length by 6.2 g and 0.016 weeks[4]. Lastly, Fukushima et al. (2024) further supported these findings by evaluating the staggered introduction of "Smoke Control Areas" in England in the 1950s–1970s where smoke emissions (e.g., from coal burning) were prohibited, which resulted in a reduction in black smoke by 19 μg/m^3 once in operation. This increased birthweight by 60 grams for those conceived in regulated areas (in addition to an additional centimeter in adult height), particularly benefiting infant boys. The effects were found to be driven by living in regulated areas, not living downwind from them[5].

For infant mortality, Tanaka (2015), evaluated pollution restrictions for power plants in China for some cities (e.g. mandating the use of coal with less sulfur and restricting expansion of new coal power plants). The author found that infant mortality fell by 3.29 per 1,000 live births (~20%) due to regulatory changes, with the largest effects during the neonatal period and among mothers with low educational attainment. Arceo et al. (2016) in turn made use of thermal inversions to link air pollution and infant mortality in Mexico City, showing that a one μg/m^3 increase in PM_{10} for one day increased weekly infant death rates by 0.23 per 100,000 births. The figure for one part per billion (ppb) increase in an 8-hour maximum carbon monoxide (CO) was 0.0046. Neonatal and infant deaths were observed from respiratory and cardiovascular disease, but not for other, non-

[3] An elasticity for $PM_{2.5}$ and low birthweight of 1.16, compared to earlier estimates of 1-1.1 (Alexander & Schwandt, 2019; Tanaka, 2015). In an economic impact analysis the author used earlier estimates, with healthcare costs ranging between $11,463 and $36,000 for low birthweight births and with lifetime earning losses of around $40,000.

[4] The authors also found that the dose-response effects were linear and not dependent on baseline pollution levels. They further claimed that this quasi-experiment was one of few long-term studies and that the pollution-source was unlikely to be noticed, and therefore acted upon, reducing the risk of compensatory behavior.

[5] The authors further noted that the data on individuals from the UK Biobank was not representative, having participants that generally were healthier and wealthier than the UK average. Additionally, avoidance behavior might have occurred, potentially leading to underestimations of outcomes.

pollution-related issues (e.g. digestive or congenital)[6]. Knittel et al. (2016) consecutively explored vehicle-induced air pollution in California and weekly infant mortality, also using weather variation (thermal inversions, humidity, wind, and rain). They found similar results, that a one μg/m^3 increase in weekly PM_{10} increased infant mortality by roughly 0.19 per 100,000 live births (roughly 10 per year; an elasticity of around 1), while the effect of CO was large but statistically insignificant. The authors also saw higher mortality for low birthweight, premature children, and during cold and humid weeks. In an earlier setting, Clay et al. (2018) studied the impact of coal burning and the Spanish Influenza of 1918, finding that cities with medium or high coal-fired capacity experienced increased infant mortality compared to low capacity cities with 8 and 11 percent respectively. Lastly, Lindgren (2021b), in addition to evaluating low birth weights, also found effects on infant mortality, although with lower statistical precisions. Alexander & Schwandt (2022), likewise, found the increased air pollution from an additional "cheating" car per 1,000 also increased infant mortality by 1.7 percent. The authors concluded that the literature on quasi-experimental studies on pollution and child respiratory conditions across different contexts and measures of issues are remarkably robust.

As a last part of early-life outcomes, Austin et al. (2019) evaluated increased respiratory health (aerobic capacity) due to the retrofitting of diesel school buses in Georgia, USA. Retrofitting the whole fleet of buses was estimated to increase the average aerobic capacity by 4–6 percent (measured as VO2-max), with the largest effect seen for elementary school children (compared to middle and high school). Using earlier estimates for parental willingness-to-pay for improved aerobic capacity in their children yielded benefits nine times higher than the cost of retrofitting.

3.1.2 Mortality

Another very important health outcome is non-infant mortality, where multiple recent studies have shown a relationship with air pollution, either in general, through cardio-respiratory diseases and cancer, or via infectious diseases.

For example, Deryugina et al. (2019) used daily wind direction as an instrument to link increased levels of $PM_{2.5}$ to, among other things, elderly mortality among American Medicare beneficiaries (65–100-year-olds). A one μg/m^3 increase in $PM_{2.5}$ for one day increased mortality by 0.63 additional deaths per million elderly persons over a three-day period[7]. The results were generally robust when simultaneously instrumenting for other air pollutants like CO and O_3. In addition to infant mortality, Clay et al. (2018) also studied the impact of coal burning and the Spanish Influenza of 1918 in general, finding that cities with medium or high coal-fired capacity experienced increased overall mortality by 5 and 10 percent respectively, responsible for 19–26 percent of total pandemic deaths. The authors also found that factors related to poverty, public health, and the timing of onset affected mortality. Deschênes et al. (2017) evaluated the U.S. NO_X Budget Program, a cap-and trade market with the aim of reducing NO_X in summertime for 19 eastern and midwestern states. The program was found to drastically reduce NO_X emissions (40%), and thereby also ambient concentrations of air pollution: NO_2 (6.8–10%), 0_3 (6.0%), and

[6] The estimates were compared to the literature, with relatively larger health detriments for CO but similar for PM10 (even when the compared country, the US, had less pollution).

[7] In addition, using machine learning techniques and detailed information (e.g., age, sex, chronic conditions, medical spending, health care use, and geographic location), the authors estimated that the same amount of pollution yielded 3.0 life-years lost per million individuals.

PM2.5 (7.7%)[8]. In addition, summertime mortality rates were reduced by 0.4 percent, primarily by elderly and for respiratory and cardiovascular deaths. When instrumenting for NO_X emissions, large but not statistically significant effects of reduction in mortality were found. Lastly, Anderson (2020) examined the long-term effects of air pollution exposure on elder mortality in Los Angeles, USA, finding that a one standard deviation increase in the time spent/living downwind of major highways increased mortality for those aged 75 or older by 3–6 percent[9,10]. This translates to a mortality elasticity with regards to near-roadway pollution of NO_2 to be between 0.10–0.18. The author found that property values were not lower downwind, which they argued was evidence that residential sorting, development patterns, and adaptation measures were at least "suboptimal".

A couple of articles evaluated the effect of air pollution on Covid-19 outcomes specifically. Isphording & Pestel (2021) found that a one μg/m³ increase in PM_{10} over three days (after the onset of illness) increased mortality for male patients aged 60–79 in Germany by 0.042 per 100,000 and by 0.16 for those over 80. The estimates for women followed a similar trend but were smaller. Confirmed cases just before and after illness also increased by 0.2–0.45 per 100,000 inhabitants and day. The authors argued that pollution affected patients by worsening existing infections, e.g., by showing that pollution had no effect on pandemic severity if occurring before infection. Gomez Mahecha (2024) in turn found similar results in the US, with a one μg/m³ increase in $PM_{2.5}$ leading to 0.15 additional same-day confirmed cases per 100,000 population (1.8% of the mean case incidence) and a 4–6 percent increase in same-day mortality rates (0.009–0.012 per 100,000). Additional case incidence over a three-day period was 0.35 per 100,000 (1.5%). Finally, the author also found evidence for increased hospitalization, intensive care unit use, and ventilator use.

3.1.3 Morbidity and Healthcare Utilization

The final subsection on air pollution regards healthcare utilization and morbidity, where two common healthcare measures in the literature have been emergency room (ER) visits and planned visits and hospitalization. These are generally categorized into respiratory issues (e.g., asthma, other pulmonary issues, or influenza), nervous and cardiovascular issues, or flu-related issues. In addition, one study regarding long-term exposure and dementia diagnoses was also found.

For ER visits, Schlenker and Walker (2016) used network effects and delays in eastern USA to link airport-related air pollution in California, USA, to ER visits for asthma, respiratory, and heart-related issues. A one standard deviation increase in pollution levels led to a 17 percent increase in ER visits for both asthma and respiratory problems, and a 7 percent increase for heart problems, among residents close to airports[11]. This was reported as largely being driven by CO (in comparison to NO_2 and 0_3) but the authors could not reject that this might come from unobserved pollution correlated with airplane-driven CO emissions[12]. Beghelli (2018) in turn found that a 10 μg/m³ increase in $PM_{2.5}$ led to a 3.9 percent increase in ER visits for nervous conditions over a three-day period, while elective circulatory visits were reduced by 3.3 percent. The former effect

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[8] The results for PM_{10} were found to be inconclusive, probably due to fewer observations.

[9] The pollutants of interest were ultrafine particles ($PM_{0.1}$), NO_2, and CO.

[10] The study identified cardio-respiratory diseases and lung cancer as the main drivers of increased mortality. However, for ages 50–64 and 65–74 no statistically significant effects were found.

[11] These issues led to hospital costs increasing by around $540,000/day for the 6 million living within a 10 km radius (~$3.3 million per 100,000 persons and year), due only to respiratory and heart-related issues.

[12] They also found that infants and elderly were the most vulnerable to pollution and that dose-response effect was non-linear, with decreasing marginal effects – in line with epidemiological results.

was driven by female hospital visits while the second shows some signs of a substitution effect from planned to unplanned visits for circulatory and respiratory conditions. Halliday et al. (2018) uniquely connected volcanic smog (vog) in Hawaii to ER visits, finding that a one μg/m^3 increase in PM_{10} was associated with a 5.7 percent increase in ER admissions for pulmonary issues, and a 7.0 percent increase for $PM_{2.5}$. For additional ER charges the estimates were 8.2 and 6.7 percent. Younger individuals were disproportionately more affected by particulate matter (children under the age of five). The authors argued that avoidance behavior could exist on “voggy” days and that the estimates therefore should be interpreted as lower bounds of the true effects. In addition, no effects were shown for pure SO_2 pollution. Penultimately, Deryugina et al. (2019) found, in addition to increased mortality, that a one μg/m^3 increase in $PM_{2.5}$ for one day increased the three-day emergency visit rate by 2.7 per million American Medicare beneficiaries in addition to $16,000 in inpatient ER spending. Lastly, Alexander & Schwandt (2022) reported a 0.24 percentage point (7%) increase in asthma emergency visits among children aged 0–4 due to increased air pollution from an additional "cheating" diesel car per 1,000.

Regarding planned visits and hospitalizations, Ward (2015) found that a one standard deviation increase in fine particulate matter concentration in Ontario, Canada, led to a 3.6 percent increase in respiratory admissions for children aged 0–19, with acute respiratory admissions primarily affecting children under seven and chronic admissions, specifically asthma, affecting older children[13]. Adults seemed to not be affected at the observed levels. Similarly, O_3 and CO had little effect on any age group. Similarly, Marcus (2017) evaluated cleaner-burning gasoline regulation in California, finding that it decreased pollution for high exposure areas (NO_2 decreased by 2%, CO by 6%, and SO_2 by 11%). As a result, childhood asthma hospitalization decreased by around 4.0–4.5 per 100,000 children (~8%) and hospitalization length of stay was reduced by 3-6 percent. Health benefits were observed to increase over time, indicating long-term accumulation health effects of air pollution. In addition, areas close to highways saw larger reductions, as did areas downwind from the highways and areas with higher traffic volumes. Bauernschauster et al. (2017) in turn made use of short-time strikes (typically one-day ones) in German cities’ public transportation systems to evaluate whether increased usage of increased traffic increased hospital admissions for respiratory diseases and abnormalities of breathing. The authors found that strikes during morning peak hours increased total car hours by 10–13 percent (explained by both increased number of vehicles and travel times), PM_{10} emission by 14 percent and ambient NO_2 concentrations by 4.3 percent. Hospital admissions for respiratory diseases increased by 11 percent for children under the age of 5 while admissions due to breathing problems increased by 13 percent for the whole population and by 34 percent among children. No evidence for changes in respiratory illness in the whole population or amongst the elderly was found[14]. Deschênes et al. (2017), in addition to mortality, also evaluated the U.S. NO_X Budget Program’s effect on pharmaceutical expenditures, which decreased by 1.6 percent, largely led by respiratory and cardiovascular medications. No effect on hospitalization was found; however, the dataset did not include uninsured, Medicate, and Medicaid patients. When instrumenting for NO_X emissions, a 10-percentage point reduction in NO_X lead to 5.7–11% reduction in medical purchases. The authors clarified that NO_X might affect other pollutants like $PM_{2.5}$, and that the results should be interpreted with caution. Halliday et al. (2018), again, linked volcanic smog (vog) in Hawaii to increased hospital admissions, finding that a one μg/m^3 increase in PM_{10} was associated with a

[13] The results were centered on the most recent two days, but with effects up to four days after elevated pollution levels.

[14] In addition, accident-related personal injuries due to increased number of vehicle crashes increased by 20 percent.

5.7 percent increase in pulmonary admissions, and a 7.0 percent increase for $PM_{2.5}$. As stated earlier regarding emergency visits, younger individuals were disproportionately more affected by particulate matter (children under the age of five). Jans et al. (2018) in turn found that thermal inversions in Stockholm on average increased air pollution levels of $PM_{2.5}$ (33%), PM_{10} (25%), NO_2 (16%), NO_X (18%), and SO_2 (25%), in addition to the incidence rate of healthcare visits for respiratory issues, e.g., asthma and bronchitis, among children by 5.5 percent[15,16]. In addition, work absence for the care of sick children rose with 2.9 percent and total benefit compensation by 2.5 percent. Also in Stockholm, Simeonova et al. (2019) showed that a congestion tax implemented in step reduced automobile-related pollution: NO_2 fell by 15–20 percent and PM_{10} by 10–15 percent relative to pre-congestion pricing levels. Simultaneously, acute asthma visits among children under the age of six fell by 16 percent during the trial period and by roughly half after the scheme became permanent. Changes in health were observed to be more gradual than changes in pollution, indicating that the entire health effects might take time to be realized and that short-run estimations of pollution exposure therefore might understate long-run health benefits of pollution reduction programs. Lastly, Graff Zivin et al. (2023) found that a one standard deviation increase in air pollution, measured by monthly air quality index (AQI)[17], increased flu-related inpatient hospitalization by 35.7 percent during the influenza season in the US. The authors found that vaccines mitigate (part of) this relationship[18]. A one standard deviation increase in AQI was estimated to lead to influenza-hospitalization costs of $328,000,000 per influenza season for the whole of the US.

Finally, Bishop et al. (2023) found that long-term exposure to particulate matter increased the probability of a new dementia diagnosis by 2.15 percentage points per one $\mu g/m^3$ increase in decadal $PM_{2.5}$. The effects were more pronounced among women, older individuals, and those with clinical risk factors.

3.2 Noise pollution and health

This section summarizes the research findings related to the causal link between noise pollution and health outcomes. Summarized results by health outcome can be found in Table 4 in the appendix.

Only a few studies utilizing quasi-experimental settings to link noise pollution and health outcomes were found and most made use of air traffic changes due to changed regulations. For example, Boes et al. (2013) linked aircraft noise to subjective health outcomes, utilizing unexpected changes in flight regulations at Zurich airport[19]. The authors found that a one dB(A) increase in daytime noise exposure increased reported sleeping problems by 0.7 percentage

[15] The authors found large differences among income groups, which they investigate and argue are not due to avoidance behavior but rather differences in baseline health.

[16] During inversion days, both PM10 levels and respiratory issues were approximately linear with respect to the strength of inversion.

[17] AQI captures concentrations of $PM_{2.5}$, PM_{10}, SO_2, CO, NO_2, and O_3.

[18] A protection at the mean level (21%) cancelled out the relationship, leading the authors to argue for vaccination as a pollution control and vice versa.

[19] The first regulation change in question was the construction of a new terminal, leading to a runway being closed and aircraft having to depart in another direction. The second involved a German decree aimed to reduce noise disturbance by restricting landings over German territory at certain times – again leading to other runways (and directions) being used.

points and headaches by 1 percentage point[20]. In addition, Beghelli (2018) found that changes in early morning aircraft landings at London Heathrow airport decreased monthly expenditure for medication for central nervous system and respiratory issues by 5.8 and 3.3 percent, respectively. Only weak effects for cardiovascular diseases were observed. The changes occurred during the early morning and the trial was not announced ahead of time, potentially limiting eventual residential sorting or avoidance behavior. Annual savings from reduced prescription medication for respiratory and nervous conditions for those in the area most affected by the trial were estimated to 6.3 million USD. Li et al. (2021) in turn found no significant effects of a noise control policy in the Netherlands on neither noise, depressive symptoms nor other mental health outcomes (life satisfaction, anxiety, sleep, cognition, and loneliness scores). Lastly, Wang et al. (2022) evaluated aircraft noise in New York, finding inconsistent results regarding overall hospital visits and drug prescriptions, with regards to age groups and types of utilization (rate ratios, RR, of 0.86–1.45). However, inpatient and emergency visits for substance use and mental health-related issues increased, especially for minors (RRs of 1.11–1.19 for inpatient visits and 1.45–4.11 for emergency visits). In addition, insomnia increased in all age groups, particularly among minors (odds ratios, OR, of 1.64 compared to 1.17-1.18 for adults), while cardiovascular disease and depression rose for adults (OR of 1.15-1.45 and 1.12-1.20, respectively). Substance use disorder and mood disorder diagnoses increased only in the oldest group, aged 45-64 (OR of 1.24 and 1.10, respectively), and disorders diagnosed young decreased among minors (OR 0.80)[21, 22].

A final study evaluated road traffic noise. Lindgren (2021a) found that a Swedish noise mitigation program reduced cardiovascular diagnoses by 18–19 cases per 1,000 (~10%) after seven years and 22–25 cases per 1000 (~12–14%) after ten years. In contrast, estimates before seven years were close to zero. The results were larger among those exposed to higher base levels of noise, appeared to be non-linear, and primarily driven by a reduction in the risk for hypertension (amounting to around two-thirds of total incident reduction). The author estimated that a 10 dB increase in indoor noise level would increase the seven-year risk of cardiovascular diseases by 12.5 percent – in line with earlier epidemiological estimates.

3.3 Comparing the air and noise pollution literature

The first difference between (causal) quasi-experimental studies of air and noise pollution and health is the temporal aspect of evaluation. Barring a few studies on air pollution, most focused on short-term shocks in order evade potential issues with endogeneity while all noise studies focused on medium- or long-term issues, with indication of short-term effects from laboratory or field experiments. Anderson (2020) explains the problems with evaluating the long-term effects of air pollution exposure as twofold: (i) the difficulty of identifying quasi-random variation in long-term air pollution levels across geographic areas and (ii) migration issues. For Lindgren (2021a), effects of noise mitigation were only observed after seven years, indicating that noise exposure

[20] Nighttime noise had a similar effect on sleeping problems but were only statistically significant at the 10 percent level. Similarly, the authors could not find statistically significant effects regarding weakness/weariness, overall health status, the number of doctor consultations, nor the number of days affected by health problems.
[21] Diagnoses for alcohol use disorder and anxiety was not statistically significantly impacted.
[22] The authors noted some limitations of their study, among them the fact that the sample primarily consisted of New York Chinese-Americans; a population that tends to be unrepresentatively healthy, potentially affecting external validity.

requires longer timeframes than for air pollution to emerge. However, increasing effects over time were also found for air pollution (e.g., Marcus, 2017; Simeonova et al., 2019).

Another difference regards the variation and source of variation in the studies. For air pollution, several sources of variation were observed, e.g., different legislative changes and natural or exogenous sources (often in relation to either road, air, or marine traffic), while for noise only flight paths and one road traffic noise mitigation program were found. This might be due to the environmental sources of noise, such as traffic, varying to a lesser degree. For example, aircraft noise does not significantly vary over longer time periods (Boes et al., 2013) and the location of roads, train tracks, airports, and ports are generally immobile. Changes in traffic flows could potentially be used more, but with noise studies primarily focusing on long-term effects, it might introduce issues with endogeneity. In addition, air pollution can have natural variation with daily meteorological conditions, while noise tends to be more determined by the built environment (e.g., intervening barriers and buildings). The connection between air pollution on health has also had more focus for decades, potentially leading to more observed effects, prompting more regulations and therefore more variation for further studies. Lastly, it might likewise be that interventions regarding air quality have more options and therefore are less costly, for example cleaner fuels or emission standards targeted at source compared to physical noise barriers for the exposed.

Lastly, in a narrative review article (based on non-quasi-experimental settings), Stansfeld (2015) found independent effects of air pollution and environmental noise (i.e., from road traffic, aircraft, and railway) on cardiovascular morbidity, mortality, and cognitive outcomes among children. In comparative burden of disease studies, air pollution generally ranked highest among environmental causes of disability-adjusted life years lost, with noise ranked second in Europe. Stansfeld argued that while the former might affect mortality more, the latter might have the highest effect on quality of life. In addition, while the two pollutants could in some conditions have a high correlation, particularly near road traffic, more moderate correlations were in general observed due to the different dispersion patterns described above. Some sources of noise, such as airplane and electric trains, might also produce less air pollution. Overall, the author argued that the effects of air and noise pollution should be viewed as additive since they tend to have different pathways to cardiovascular issues. Finally, van Kamp & Davies (2013) has argued that a potential interaction effect of air and noise pollution is understudied.

4. Discussion

The aim of this review has been to summarize the latest knowledge regarding health outcomes from air and noise pollution, by collecting results from primarily quasi-experimental settings (to alleviate the problems with endogeneity often seen in other fields of study). Although several articles have been published in the last decade regarding air pollution, the same could not be said about noise pollution. This makes summarizing the health effects of noise pollution, as well as comparing the methodology used for noise and air pollution, difficult. Further, summarizing the field is challenging even regarding air pollution due to the heterogeneous nature of the evidence, with studies examining different health outcomes, pollutants, and measurement approaches. For example, the two articles regarding air pollution and Covid-19 mortality differed both in pollutants (PM_{10} versus $PM_{2.5}$) and measures (three-day exposure split by gender and age versus overall same-day exposure), making it difficult to compare and aggregate the results. It is further unclear how the total effects of air and noise pollution individually are to be aggregated to avoid double-counting. It is possible that some health outcomes measure similar issues and cannot be summed up. However, as stated by Stansfeld (2015), air and noise should at least be viewed as being composable.

As explained by Alexander & Schwandt (2022), quasi-experimental estimates for elasticities of air pollution and health tend to generally be larger than conventional (correlational) ones. This is true for several of the studies in this review, where health effects often are at least a magnitude of order larger (e.g., Alexander & Schwandt, 2022; Deryugina et al., 2019; Deschênes et al., 2017; Graff Zivin et al., 2023; Halliday et al., 2018; Schlenker & Walker, 2016). Similarly, Boes et al. (2013) argued that cross-sectional studies tend to underestimate the health effects of aircraft noise (as seen in their study), possibly due to residential sorting and habituation. However, they stated that while avoidance behavior could downward bias the health effects, it should affect cross-sectional and fixed effects models similarly. Still, even if quasi-experimental settings are used, the effects of pollution could still be understated. Multiple authors argue that the presented estimates are only lower bounds of the total health effects of pollution, with their studies only focusing on particular populations, specific health outcomes, and short-term exposure. Likewise, as stated earlier, several studies indicate increasing health effects over time (Lindgren 2021a; Marcus, 2017; Simeonova et al., 2019). Also, some evaluated issues might need relatively larger pollution to trigger specific health outcomes, e.g., hospitalization, but still affect the public health or be a disturbance. This could potentially be the case with noise pollution.

Another potential issue for estimating the causal relationship is exposure misclassification, sinch researchers often assume air and noise pollution exposure to be based on one's home address – potentially missing other potential sources of exposure, such as occupational ones[23]. For noise pollution, modelled exposure might also be estimated as coarsely as by zip codes and outdoor levels of noise might not reflect indoor levels of exposure.

[23] This is true for cross-sectional data as well as quasi-experimental settings.

5. Conclusions

The empirical findings show that air pollution can be linked to several health outcomes, such as lowered birth weights and increased mortality, emergency room visits, and hospitalization. For the few studies evaluating mortality, cardio-respiratory diseases, cancer, and infectious diseases (i.e., Covid-19) were listed as pathways for increased risk. Increased morbidity, in turn, was primarily studied by evaluating respiratory issues (e.g., asthma, other pulmonary issues, or influenza). Other issues included the nervous and cardiovascular systems and dementia diagnoses. Similarly, noise pollution was less evaluated but individual studies found a varied array of issues, including sleeping problems, headaches, hypertension, increased medication for central nervous system and respiratory issues, as well as healthcare utilization for substance use and mental health-related issues. Generally, for both fields of study, heterogenous effects were observed with respect to e.g., age, gender, and previous health status.

More than the number of available studies, the evaluation of air and noise pollution differs when it comes to temporal aspects and the source of variation used. Air pollution studies tended, with a few exceptions, to primarily focus on short-term shocks while the noise pollution was linked to medium- and long-term issues. The former field also made use of many types of variation (e.g., legislative changes and natural or exogenous sources), often in relation to different types of traffic, while the latter primarily made use of regulation changes for flight paths.

As a last comment, summarizing individual pollutants' specific health effects is challenging due to the heterogeneous nature of the evidence, with studies examining different health outcomes, (combinations of) pollutants, targeted population, and measurement approaches. This makes it difficult to synthesize the results and achieve a more comprehensive meta-understanding.

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All reviewed articles are available on Google Scholar.

Competing interests

The authors declare that they have no competing interests.

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A. Appendix

Table 1. Studies of air pollution and health outcomes

Article	Target group and sample size	Source of variation and methods*	Average pollution (standard deviation)	Health outcomes
Alexander & Schwandt, 2022 USA	Infants and children ~34,800 – 191,000 observation at the county-month level.	DID: Variation in the share of false “clean diesel” cars in the vehicle stock	NA	An extra “cheating” car per 1,000 increased levels of $PM_{2.5}$ (+2.0%), PM_{10} (+2.2%), O_3 (+1.3%). It also increased the rate of low birthweight (+0,12 pp; 1.9%) and infant mortality (+0.009pp; 1.7%), while reduced average birth weight (-6.2g) and gestation length (-0.016 weeks). In addition, asthma emergency visits for children aged 0–4 increased (+0.24 percentage points; 7%).
Anderson, 2020 Los Angeles Basin, USA	Elderly residents 600 meters from a highway ~9,000 observations at the census block level	OLS: Wind direction IV: Orientation to highway	NO_2: 27.4 ppb (implied)	A one standard deviation increase in the proportion of time spent downwind increased mortality (3–6%) and NO_2 levels (7.9–9.2 ppb; 29–33%). This resulted in a NO_2 and mortality elasticity of 0.10–0.18.
Arceo et al., 2016 Mexico City, Mexico	Infants and neonates, residing in municipalities with 15 km of an air monitor ~18,000 observations at the municipality-week level.	IV: Thermal inversions	PM_{10}: 66.94 (23.85) μg/m³ CO: 2707.56 (797.70) ppb	A one μg/m³ increase in PM_{10} for one day increased weekly infant death rates by 0.23 per 100,000 births. A one ppb increase in an 8-hour maximum CO increased weekly infant death rates by 0.0046.
Austin et al., 2019 Georgia, USA	Children in public schools (elementary through high school) ~710 – 1,800 observations at the school district-year level.	First-difference: Timing, location, and magnitude of retrofitting diesel school buses	NA	Retrofitting the whole fleet of school buses would increase aerobic capacity (4–6%).
Bauernschauster et al., 2017 Berlin, Frankfurt, Hamburg, Cologne & Munich, Germany	City residents: general population, under the age of 5 and over the age of 64. ~2,400 – 210,000 observations at city-day or monitor-day level.	DID: Public transportation strikes	PM10 (morning peak): 37.63 μg/m³ NO_2: (morning peak): 76.82 μg/m³	Public transportation strikes in morning peak hours increased total car hours by 10–13%, PM_{10} emissions by 14%, ambient NO_2 concentration by 4.3%. In addition, hospital admissions for respiratory health for children under the age of 5 rose by 11%, breathing problems in general by 13% and breathing problems for children by 34%.

Beghelli, 2018 UK	Residents within local regions containing monitoring stations ~930,000 observations at the Lacal Authority District-age group-gender-day level	IV: Daily variation in local wind direction	$PM_{2.5}$: 15.03 (10) μg/m^3	A 10 μg/m^3 increase in $PM_{2.5}$ increased emergency visits for nervous conditions (+3.9%) and decreased elective visits for circulatory issues* (-3.3%). *Signs of shifting from elective to emergency visits were observed.
Bishop et al., 2023 USA	Medicare beneficiaries (65+), who did not have dementia before regulation change ~1,000,000 – 2,400,000 observations at the individual level	IV: Regulation expansion of the American Clean Air Act	Decadal $PM_{2.5}$: 11.0 (1.69) μg/m^3	A one μg/m^3 increase in $PM_{2.5}$ increased the probability of new dementia diagnosis by 2.15 percentage points.
Clay et al., 2018 USA	Residents in cities with at least 20,000 inhabitants, where coal-fired electricity generation was used ~1,800 observations at the city-year level.	DID: Pandemic event (the Spanish Influence of 1918)	NA	Cities with medium and high capacity coal-fired capacity increased mortality rates, both overall (5–10%) and among infants (8–11%).
Deryugina et al., 2019 USA	Medicare beneficiaries (65–100-year-olds) ~1,900,000 – 2,000,000 observations at county-day level.	IV: (Air monitor cluster-specific) daily wind direction	$PM_{2.5}$: 10.48 (7.13) μg/m^3	A one μg/m^3 increase in $PM_{2.5}$ for one day increased elderly mortality over a three-day period (+0.69 deaths per million elderly), emergency room visits (+2.7 visits), and medical costs (+$16,000). Estimated life years lost was 3.0 life-years.
Deschênes et al., 2017 USA	Residents and individuals in the MarketScan database (medication) ~550-560,000 observations at county-season-year level.	DID/IV: Introduction of a cap-and-trade market for NO_X emissions	CO: 0.44 (0.24) ppm NO_2: 11.45 (5.39) ppb $PM_{2.5}$: 13.33 (4.19) μg/m^3 PM_{10}: 27.28 (6.26) μg/m^3 SO_2 3.26 (2.27) ppb	The U.S. NOX Budget Program reduced NO_X emissions (-40%), and thereby also ambient concentrations of air pollution: NO_2 (-6.8–10%), 0_3 (-6.0%), and $PM_{2.5}$ (-7.7%). In addition, mortality rates were reduced by 0.4 percent, primarily by elderly and for respiratory and cardiovascular deaths. When instrumenting for NO_X emissions, large but not statistically significant effects of reduction in mortality were found. However, a 10-percentage point reduction in NO_X lead to 0.064–0.011 percentage points reduction in medical purchases.

			O_3 (8-hour value): 48.06 (9.28) ppb	
Fukushima et al., 2024 England, UK	Individuals from the UK Biobank, born in County Boroughs ~3,800 – 11,100 (26,200 – 26,300) observations at individual (monitor) levels.	Staggered introduction of Smoke Control Areas	Black smoke: 103.8 (99.9) μg/m^3 SO_2: 132.7 (90.3) μg/m^3	The introduction of "Smoke Control Areas" led to a decrease in black smoke, both at submission (-8 μg/m^3) and once in operation (-19 μg/m^3). Those conceived once the areas were in operation had on average a higher birthweight (+60 g) and adult height (+1 cm).
Gomez Mahecha, 2024 Contiguous USA	Residents within local regions containing monitoring stations ~98,000 observations at county-day level.	IV: (Air monitor cluster-specific) daily wind direction	$PM_{2.5}$: 6.64 (4.23) μg/m^3 Weighted $PM_{2.5}$: 6.17 (4.17) μg/m^3	A one μg/ m^3 increase in $PM_{2.5}$ exposure for one day increased confirmed cases, both for same day exposure (+0.15 per 100,000; 1.8 %) and over a three-day period (+0.35 per 100,000; 1.5%). Same-day mortality increased by 0.009–0.012 deaths (4%–6%). Hospitalization, intensive care unit use, and ventilator use also increased.
Graff Zivin, 2023 21 states, USA	All ~ 4,000 – 20,000 observations at the county-year-month level.	IV: Wind direction and vaccine effectiveness	AQI: 33.27 (10.9)	A one unit increase in Air Quality Index (AQI) increased influenza hospitalization by 2.8% (35.7% for 1 sd, the whole US and influence season). This corresponds to an increase in healthcare costs per influenza season of $328 million for the US.
Halliday et al., 2018 Hawaii, USA	All ~ 6,100 – 6,800 observations at community-day level.	IV: Natural variation in volcanic pollution and wind direction	$PM_{2.5}$: 6.52 (3.30) μg/m^3 PM_{10}:16.04 (6.24) μg/m^3	A one μg/m^3 increase in $PM_{2.5}$ was associated with increased admissions for pulmonary issues (+7.0%) and emergency room charges (+6.7%). A one μg/m^3 increase in PM_{10} saw similar results (+5.7% and 8.2%).
Isphording & Pestel, 2021 Germany	All residents residing in a county within 25 km of air monitor NA	IV: Wind direction	(Three-day averages) PM_{10}: 14.5 (7.2) μg/m^3 $PM_{2.5}$: 8.7 (4.6) μg/m^3 O_3: 62.3 (12.8) μg/m^3	One μg/m^3 increase in a three-day average of PM_{10} increased mortality for men 60–79 (+0.042 deaths per 100,000), men 80+ (+0.16 deaths per 100,000), and females 60–79 (+0.01 deaths per 100,000)*. The number of confirmed cases increased by 0.2–0.45 per 100,000 and day. *For females 80+, only result of a one standard deviation increase is presented: +0.9 deaths per 100,000.

Jans et al., 2018 Stockholm, Sweden	Children (0–18 years old) ~34,000 observations	Thermal inversion	PM_{10} (normal days): 18.07 (13.09) μg/m^3 PM_{10} (inversion days): 28.85 (25.09) μg/m^3	Inversion on average increased air pollutants such as $PM_{2.5}$ (+33%), PM_{10} (+25%), NO_2 (+16%), NO_X (+18%), and SO_2 (+25%). This led to an increase in the incidence rate of health care visits among children for respiratory issues (+5.5%), work absence for care of sick children (+2.9%), and total benefit compensation (+2.5%).
Knittel et al., 2016 California, USA	Infants within 20 miles of a monitor ~73,100,000 observation at the postal code-week level.	IV: Traffic level and weather (thermal inversions, humidity, wind speed, and rainfall)	PM_{10}: 28.94 (14.94) μg/m^3 CO: 1.01 (0.57) ppm	A one μg/m^3 increase in PM_{10} increased weekly infant mortality by 0.19 per 100,000 live births (roughly 10 per year; an elasticity of around 1).
Lindgren, 2021b England and Wales	Newborns ~700 – 2,800 DID-observations at local authority-year level	DID: Stricter regulation regarding sulfur content in marine fuel	$PM_{2.5}$: 13.04 (2.04) SO_2: 2.32 (0.87) μg/m^3	A one μg/m^3 increase in annual $PM_{2.5}$ exposure corresponded to an increase in the probability of low birthweight by 0.61 percentage points (9%).
Marcus, 2017 California, USA	Children (0–10 years old), residing in areas within 20 miles of a monitor stations ~10,400 – 11,600 observations at the zip code-year level (~510,000 – 600,000 at individual-year level)	DID: Stricter regulation regarding cleaner-burning gasoline	NO_2: 41.64 (16.67) ppb CO: 1.52 (0.95) ppb SO_2: 5.05 (3.13) ppb	Regulation decreased NO_2 (-2%), CO (-6%), and SO_2 (-11%) for high exposure areas. Childhood asthma hospitalization decreased by around 4.0–4.5 per 100,000 children (-8%). Individual level estimates suggested a 0.8 percentage point reduction in child hospitalization (-3%) and length of stay by 6%.
Schlenker & Walker, 2016 California, USA	Residents close to airports ~180,000 observations	IV: Eastern US airport runway congestion and wind speed/direction	CO: 576 (368) ppb NO_2: 20.5 (9.7) ppb O_3: 22.8 (10.4) ppb	A one standard deviation in pollution increases emergency room asthma counts (17%), total respiratory problems (17%), and heart problems (7%). This corresponds to hospital costs of roughly $3.3 million per year and 100,000 individuals.
Simeonova et al, 2019 Sweden	Children (0–5 years old) of Swedish mothers, residing in major municipalities that monitor air pollution	DID: Congestion charge implementation	NO_2 (treatment): 33.32 μg/m^3 NO_2 (control): 17.56 μg/m^3	Relative to pre-congestion pricing levels, tax reduced the concentration of NO_2 (-15–20%), PM_{10} (-10–15%).

	~7,400 observations at municipality-month level		PM_{10} (treatment): 33.28 μg/m^3 PM_{10} (control): 13.96 μg/m^3	After the program became permanent, acute asthma visits had reduced by 9.6 visits per 10,000 children, roughly half of pre-program levels.
Tanaka, 2015 China	Infants ~1,280 – 1,340 observations at the site-year level.	DID: Regulation changes in some cities	NA	Due to regulatory change, infant mortality fell by 3.29 per 1,000 live births (-20%)
Ward, 2015 Ontario, Canada	Residents within local regions containing monitoring stations ~110,000 observations at municipality-year-month level	Windborne pollution from the US	$PM_{2.5}$: 8.46 (6.90) μg/m^3	A one standard deviation increase in $PM_{2.5}$ led to an increase in respiratory admissions among children by 3.6%.

Note: *DID = Difference-in-difference, IV = Instrumental Variable, OLS = Ordinary Least Square.

Table 2. Studies of noise pollution and health outcomes

Article	Target group and sample size	Source of variation and methods*	Average noise level, dB(A) (standard deviation)	Health Outcomes
Beghelli, 2018 London, UK	Residents near Heathrow airport ~7,800 observations at the medical practice-month level.	DID: Regulated exclusionary areas for morning traffic	NA	Restricting areas close to the airport every other week reduced monthly medical expenditure by 5.8% for central nervous system issues and 3.3% for respiratory issues.
Boes et al., 2013 Zurich, Switzerland	Residents near Zurich airport, aged 14 and older ~3,800 observations at the person-year level.	Unexpected changes in flight regulation	Leq, day: 40.6 (7.2–9.5) Leq, night: 35.8 (6.9–8.7)	A one dB(A) increase in daytime noise exposure led to a 0.7 percentage points increase in sleeping problems and a 1 percentage point increase in headaches.
Li et al., 2021 Amsterdam, the Netherlands	Residents near Schiphol airport, aged 57 and older ~3,400 observations at the individual-year level.	DID: A policy change to reduce aircraft noise	Lden: 45.7 (3.1)	The policy had no impact of reducing noise levels nor depressive symptoms, life satisfaction, anxiety, sleep, cognition, and loneliness scores.
Lindgren, 2021a Sweden	Residents living near government-owned highways ~114,900 – 151,700 observations at the individual-year level.	DID: A noise mitigation program	Leq: 61.25 (3.53)	Road traffic noise mitigation measures decreased cardiovascular diagnoses by 18–19 cases per 1,000 after seven years (~10%) and 22–25 cases per 1,000 after ten years (~12–14%). Based on earlier measurements of noise reductions, a 10 dB increase in indoor noise level was estimated to increase the seven-year risk of cardiovascular diseases by 12.5%.
Wang et al., 2022 New York City, USA	Medicaid recipients residing near LaGuardia airport or in a socioeconomically similar neighborhood, aged 64 and younger NA	DID: Changed flight paths due to tennis events	NA	The effect of aircraft noise on overall hospital visits and drug prescriptions was inconsistent between age groups and types of utilization: rate ratios (RR) of 0.86–1.45. For substance use and mental health issues, inpatient and emergency visits consistently increased: RRs of 1.11–1.19 for inpatient visits and 1.45–4.11 for emergency visits, especially high for minors. For diagnosis, insomnia increased in all age groups (odds ratios, OR, of 1.17–1.64), cardiovascular disease and depression increased for adults (OR of 1.15–1.45 and 1.12–1.20, respectively), substance use disorder and mood disorder increased for the oldest age group, aged 45-64 (OR of 1.24 and 1.10, respectively), and disorders diagnosed young fell for minors (OR of 0.80).

Note: *DID = Difference-in-difference.

Table 3. Health outcomes from air pollution, sorted by pollutants and health effects

Pollutant	Health effect	Source of pollution	Measure	Health outcomes	Values (standard errors)	Reference	Publication type
Black smoke	Adult height	Energy (e.g., coal burning)	Policy regulation; reduction of black smoke	1 cm increase in adult height.	0.94 (0.18)	Fukushima et al., 2024	Working paper
	Birth weight	Energy (e.g., coal burning)	Policy regulation; reduction of black smoke	60 gram increase in birth weights.	58 (27)	Fukushima et al., 2024	Working paper
CO	Infant mortality	General	One ppb (8-hour maximum)	Increased weekly infant death rates by 0.0046 per 100,000 births.	0.0046 (0.0016)	Arceo et al., 2016	The Economic Journal
NO_2	Mortality	Road traffic	Proportion of time spent downwind (1 sd)	Increased mortality (3–6%) and NO_2 levels (7.9 – 9.2 ppb; 29–33%). This resulted in a NO_2 and mortality elasticity of 0.10–0.18.	3–6% (0.013–0.020); 29–33% (0.008–0.010)	Anderson, 2020	Journal of the European Economic Association
NO_X	Mortality	Energy (e.g., coal burning)	Policy regulation; cap-and-trade market for NO_X	Reduced all-cause, all-age summertime mortality (-0.45%).	0.45% (0.0022)	Deschênes et al., 2017	American Economic Review
	Pharmaceutical expenditure	Energy (e.g., coal burning)	Policy regulation; cap-and-trade market for NO_X / NO_X (10 pp)	Policy decreased pharmaceutical expenditure (-1.6%). / Reduction in medical purchases by 0.064–0.11 percentage points.	1.6% (0.007); 0.064–0.11 pp (0.030–0.071)	Deschênes et al., 2017	American Economic Review
$PM_{2.5}$	Birth weight	Ships	One µg/m³ (yearly)	Increased probability of low birthweight by 0.61 percentage points (9%).	0.61 pp (0.22)	Lindgren, 2021b	Transportation Research Part D: Transport and Environment
	Diagnoses: dementia	General	One µg/m³ (decadal)	Increased probability of new dementia diagnosis by 2.15 percentage points.	2.15 pp (0.846)	Bishop et al., 2023	Review of Economic Studies
	Hospital visits: cardiovascular issues	Air traffic	10 µg/m³ (daily)	Decreased elective visits for circulatory issues (-3.3%).	3.3% (0.019)	Beghelli, 2018	Doctoral dissertation, King's College London
	Hospital visits: nervous issues	Air traffic	10 µg/m³ (daily)	Increased emergency visits for nervous conditions (+3.9%).	3.9% (0.020)	Beghelli, 2018	Doctoral dissertation, King's College London
	Hospital visits: overall	General	One µg/m³ (daily)	Increased emergency room visits (+2.7 visits per million elderly) and medical costs (+$16,000 per million elderly) over a three-day period.	2.7 (0.44); 16,446 (4,266)	Deryugina et al., 2019	American Economic Review

		General	One $\mu g/m^3$ (daily)	Increased hospitalization, intensive care unit use, and ventilator use.	–	Gomez Mahecha, 2024	Doctoral dissertation, Georgia State University
	Hospital visits: respiratory issues	Vulcanic smog (vog)	One $\mu g/m^3$ (daily)	Increased admissions for pulmonary issues (+7.0%) and emergency room charges (+6.7%).	7.0% (0.011); 6.7% (0.015)	Halliday et al., 2018	The Economic Journal
		General	1 sd (daily)	Increase respiratory admissions among children by 3.6%.	3.6% (0.0098)	Ward, 2015	Canadian Journal of Economics/Revue canadienne d'économique
	Mortality	General	One $\mu g/m^3$ (daily)	Increased elderly mortality over a three-day period (+0.69 deaths per million elderly). Estimated life years lost was 3.0 life-years.	0.69 (0.061); 3.0 (0.49)	Deryugina et al., 2019	American Economic Review
		General	One $\mu g/m^3$ (daily)	Increased confirmed cases of Covid-19, both for same day exposure (+0.15 per 100,000; 1.8 %) and over a three-day period (+0.35 per 100,000; 1.5%). Same-day mortality increased by 0.009–0.012 deaths (4%–6%).	0.15 (0.068); 0.35 (0.16); 0.009–0.012 (0.0057–0.0060)	Gomez Mahecha, 2024	Doctoral dissertation, Georgia State University
PM_{10}	Hospital visits: respiratory issues	Vulcanic smog (vog)	One $\mu g/m^3$ (daily)	Increased admissions for pulmonary issues (+5.7%) and emergency room charges (+8.2%).	5.7% (0.010); 8.2% (0.015)	Halliday et al., 2018	The Economic Journal
	Infant mortality	General	One $\mu g/m^3$ (daily)	Increased weekly infant death rates by 0.23 per 100,000 births.	0.23 (0.082)	Arceo et al., 2016	The Economic Journal
		Road traffic	One $\mu g/m^3$ (weekly)	Increased weekly infant mortality by 0.19 per 100,000 live births (roughly 10 per year; an elasticity of around 1).	0.19 (0.09)	Knittel et al., 2016	Review of Economics and Statistics
	Mortality	General	One $\mu g/m^3$ (three days)	Increased Covid-19 mortality for men 60–79 (+0.042 deaths per 100,000), men 80+ (+0.16 deaths per 100,000), and females 60–79 (+0.01 deaths per 100,000). (For females 80+, only result of a one standard deviation increase is presented: +0.9 deaths per 100,000.) The number of confirmed cases increased by 0.2–0.45 per 100,000 and day.	NA	Isphording & Pestel, 2021	Journal of Environmental Economics and Management
Multi	Aerobic capacity	School buses	Policy regulation; retrofitting the whole fleet of school buses	Increased aerobic capacity (4–6%).	4–6% (0.019–0.033)	Austin et al., 2019	Economics of Education Review

	Birth weight	Diesel cars	An extra "cheating" car per 1,000 (O_3, $PM_{2.5}$, PM_{10})	Increased the rate of low birthweight (+0.12 pp; 1.9%), reduced average birth weight (-6.2 g), and gestation length (-0.016 weeks).	0.12 pp (0.022); 6.2 (0.76); 0.016 (0.004)	Alexander & Schwandt, 2022	The Review of Economic Studies
	Infant mortality	Diesel cars	An extra "cheating" car per 1,000 (O_3, $PM_{2.5}$, PM_{10})	Increased rate of infant mortality (+0.009pp; 1.7%).	0.009 pp (0.004)	Alexander & Schwandt, 2022	The Review of Economic Studies
		Energy (e.g., coal burning)	City variation	Cities with medium and high capacity coal-fired capacity increased mortality rates among infants (8–11%).	8–11% (0.034–0.042)	Clay et al., 2018	The Journal of Economic History
		Energy (e.g., coal burning)	Policy regulation; powerplant restrictions	Due to regulatory change, infant mortality fell by 3.29 per 1,000 live births (-20%).	3.29 (2.13)	Tanaka, 2015	Journal of health economics
	Hospital visits: cardiovascular issues	Air traffic	Network effects; increase pollution (1 sd; primarily CO but also NO_2 and 0_3)	Increased emergency room heart problems (7%). This (and respiratory issues) corresponds to hospital costs of roughly $3.3 million per year and 100,000 individuals.	NA	Schlenker & Walker, 2016	The Review of Economic Studies
	Hospital visits: influenza	General	Air Quality Index (AQI) (1 unit)	Increased influenza hospitalization by 2.8% (35.7% for 1 sd, the whole US and influenza season), corresponding healthcare costs per influenza season of $328 million for the US.	2.8% (0.0074); 328 (104)	Graff Zivin et al., 2023	American Economic Journal: Applied Economics
	Hospital visits: respiratory issues	Air traffic	Network effects; increase pollution (1 sd; primarily CO but also NO_2 and 0_3)	Increased emergency room asthma counts (17%) and total respiratory problems (17%). This (and cardiovascular issues) corresponds to hospital costs of roughly $3.3 million per year and 100,000 individuals.	NA	Schlenker & Walker, 2016	The Review of Economic Studies
		Diesel cars	An extra "cheating" car per 1,000 (O_3, $PM_{2.5}$, PM_{10})	Increased asthma emergency visits for children aged 0–4 increased (+0.24 percentage points; 7%).	0.24 (0.12)	Alexander & Schwandt, 2022	The Review of Economic Studies
		General	Thermal inversion (NO_2, NO_X, $PM_{2.5}$, PM_{10}, SO_2)	Increased incidence rate of health care visits among children for respiratory issues (+5.5%), work absence for care of sick children (+2.9%), and total benefit compensation (+2.5%).	5.5% (0.013); 2.9% (0.012); 2.5% (0.014)	Jans et al., 2018	Journal of health economics
		Road traffic	Policy regulation; restriction on gasoline (CO, NO_2, SO_2)	Decreased childhood asthma hospitalization by 4.0–4.5 per 100,000 children (-8%). Individual level estimates suggested a 0.8 percentage point reduction in child hospitalization (-3%) and length of stay by 6%.	4.0–4.5 (0.92–1.2); 0.8 pp (0.25); 6% (0.0074)	Marcus, 2017	Journal of health economics

		Road traffic	Policy regulation; congestion pricing (NO_2, PM_{10})	After the program became permanent, acute asthma visits had reduced by 9.6 visits per 10,000 children, roughly half of pre-program levels.	9.6 (1.9)	Simeonova et al, 2019	Journal of Human Resources
		Road traffic	Public transportation strikes	Strikes increased hospital admissions for respiratory health for children under the age of 5 (+11%), breathing problems in general (+13%), and breathing problems for children (+34%).	11% (0.027); 13% (0.038); 34% (0.082)	Bauernschauster et al., 2017	American Economic Journal: Economic Policy
	Mortality	Energy (e.g., coal burning)	City variation	Cities with medium and high capacity coal-fired capacity increased mortality rates overall (5–10%).	5–10% (0.026–0.035)	Clay et al., 2018	The Journal of Economic History

Table 4. Health outcomes from noise pollution, sorted by health effects

Health effect	Source of pollution	Measure	Health outcomes	Values (standard errors) [confidence intervals]	Reference	Publication type
Hospital visits: nervous issues	Air traffic	Policy regulation; reduced air traffic	Reduced monthly medical expenditure by 3.3% for respiratory issues.	3.3% (0.018)	Beghelli, 2018	Doctoral dissertation, King's College London
Hospital visits: overall and drug prescription	Air traffic	Policy regulation; reduced air traffic	The effect was inconsistent between age groups and types of utilization: rate ratios of 0.86–1.45.	0.86 [0.85–0.87] –1.45 [1.41–1.49]	Wang et al., 2022	BMJ open
Hospital visits: respiratory issues	Air traffic	Policy regulation; reduced air traffic	Reduced monthly medical expenditure by 5.8% for central nervous system issues.	5.8% (0.020)	Beghelli, 2018	Doctoral dissertation, King's College London
Self-reported disturbance	Air traffic	1 dB(A) daytime noise exposure (Leq)	Increased sleeping problems by 0.7 percentage points and headaches by 1 percentage point.	0.7% (0.0036); 1.0% (0.0039)	Boes et al., 2013	Health Economics
Diagnoses: cardiovascular issues	Road traffic	Mitigation measures	Decreased cardiovascular diagnoses by 18–19 cases per 1,000 after seven years (~10%) and 22–25 cases per 1,000 after ten years (~12–14%). A 10 dB increase in indoor noise level was estimated to increase the seven-year risk of cardiovascular diseases by 12.5%.	18–19 (7.9–0.84)	Lindgren, 2021a	Working paper
	Air traffic	Policy regulation; reduced air traffic	Increased cardiovascular disease for adults (odds ratios of 1.15–1.45).	1.15 [1.07–1.25] – 1.45 [1.30–1.62]	Wang et al., 2022	BMJ open
Diagnoses: other	Air traffic	Policy regulation; reduced air traffic	Increased diagnoses for insomnia in all age groups (odds ratios of 1.17–1.64), depression for adults (1.12–1.20), substance use disorder and mood disorder for the oldest age group, aged 45-64 (1.24 and 1.10, respectively). Disorders diagnosed young fell for minors (0.80).	1.17 [1.09–1.26] – 1.64 [1.12–2.39]; 1.12 [1.02–1.24] – 1.20 [1.08–1.33]; 1.24 [1.07–1.44]; 1.10 [1.00–1.20]; 0.80 [0.66–0.97]	Wang et al., 2022	BMJ open
Substance use and mental health issues	Air traffic	Policy regulation; reduced air traffic	Inpatient and emergency visits consistently increased: rate ratios of 1.11–1.19 for inpatient visits and 1.45–4.11 for emergency visits, especially high for minors.	1.11 [1.01–1.22] – 1.19 [1.04–1.36]	Wang et al., 2022	BMJ open

Note: Li et al., 2021 found that a policy to reduce aircraft noise had no impact in reducing noise levels (nor depressive symptoms, life satisfaction, anxiety, sleep, cognition, and loneliness scores). It is therefore not included in the table.