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This site is closed! The effect of decommissioning mining waste facilities on mortality in the long run[☆]

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ABSTRACT

Mining is typically linked to industrial development. However, waste generated by mineral extraction is a major source of environmental deterioration. This poses a trade-off between preserving the environment and fostering growth. We assess the long-run consequences of reduced exposure to mining waste on health by exploiting municipality-level variation in the staggered closure of facilities that treat and store mining waste in Italy over the course of five decades. We find that shutting down waste facilities decreases decadal mortality by 126 deaths per 100,000 inhabitants (i.e., by nearly 15%), while also improving the literacy and employment rates of the resident population. Our results point to positive health effects dominating potentially negative wealth effects.

1. Introduction

The development of the mining industry brings about a trade-off between the need to protect the health of the environment and of local communities and the desire to support economic activities and promote prosperity. This is commonly referred to as the health–wealth trade-off (Von der Goltz and Barnwal, 2019). On the one hand, the presence of the mining sector can potentially foster local industrial development, employment, and income, thus improving well-being via wealth effects (Black et al., 2005; Parker et al., 2016; Feyrer et al., 2017; Allcott and Keniston, 2018; Benschaul-Tolonen, 2019; Ferniough and O'Rourke, 2021). On the other hand, the mining industry produces substantial amounts of waste by-products: the exploitation, extraction, and processing of mineral resources generates solid, liquid, and gaseous waste that can have harmful medium- and long-run environmental and health impacts (Hendryx and Ahern, 2008; Carmo et al., 2020; Hendryx et al., 2020; Black et al., 2021).¹ Contamination, in turn, can have negative repercussions on inequality (Currie, 2011), growth (Hanlon, 2020) and educational attainment (Rau et al., 2015; Billings and Schnepel, 2018).² As a consequence, mining areas often turn into unattractive places to live (Heblich et al., 2021).

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¹ See also Van der Ploeg (2011), Clay et al. (2016), Beach and Hanlon (2018), Hill and Ma (2022). Metcalf and Wang (2019) report greater opioid consumption and mortality resulting from higher rates of injury in underground coal mining.

² There is also evidence that the mining industry is associated with lower levels of human capital accumulation (Esposito and Abramson, 2021; Malpede, 2021) and entrepreneurship (Glaeser et al., 2015), due to specialization in labor-intensive and low-skilled occupations. Mining activities and related clashes over natural resources can also impact conflict and violence levels (Berman et al., 2017; Knutsen et al., 2017; Adhvaryu et al., 2018).

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Accordingly, the decommissioning of mining-related activities is predicted to determine either improvements in environmental quality and well-being of the resident population or a potential deterioration of living standards via disruption to economic performance at the local level. Indeed, recent works find that dismantling the mining industry brings about overall welfare costs due to increased mortality (Boslett and Hill, 2022), loss of job security, and lower wages (Haywood et al., 2021), as well as a substantial drop in the female-to-male ratio of manufacturing workers (Aragón et al., 2018). However, despite the extensive repercussions of the decommissioning of mines in terms of environmental quality and the industrial structure of local economies, less is known about the specific consequences of mining waste decontamination.

This paper investigates the long-run consequences of closing mining waste storage facilities, which treat and handle waste material generated by extraction activities and are a source of pollution and hazards. Mining waste includes materials such as topsoil, which is removed to gain access to mineral resources, waste rock, and tailings.³ Heaps and settling ponds of extractive waste may suffer leakages and drainage of toxic heavy metals, acid, or radioactive tailings, which can penetrate the soil, invade water basins, and eventually enter the food chain (Kossoff et al., 2014). This poses enormous environmental and health risks, not only to workers but also to the people living around waste facilities, and the incidence of certain illnesses such as cancers, digestive and genitourinary diseases, and congenital anomalies is often found at above-average levels in these areas (Cortes-Ramirez et al., 2018; Luberto et al., 2019; Romanello et al., 2021; Black et al., 2021; Bigliardi et al., 2021).

In Europe, mining waste represents one of the largest waste streams, with around 600 million tons generated in 2018 (Eurostat, 2020). In the United States, total domestic mining and waste removal for non-fuel mineral materials production (i.e., excluding products such as coal, oil, and gas) amounted to 4.38 billion tons in 2015 (U.S. Geological Survey, 2015). Yet, mining waste management is very costly, and firms often have an incentive to avoid proper remediation, leaving this burden to taxpayers (Garbarino et al., 2020; Aghakazemjournabbaf and Insley, 2021). It is estimated that there are nearly 3,500 closed and abandoned waste facilities in the European Union, as from official inventories of 18 Member States for which data are available (European Commission, 2017). The United States records approximately 38,991 abandoned mine sites, while in Canada Aghakazemjournabbaf and Insley (2021) report that over 10,000 mines are classified as abandoned without being cleaned up.⁴ Yang and Davis (2018) mention that 19.4% of farmland in mainland China is contaminated, especially due to heavy metals generated by mining which have not been reclaimed. Thus, understanding the long-run impacts of removing this source of contamination on local communities is imperative.

We exploit the local shock induced by the closure of a mining waste facility at the lowest geographical administrative level in Italy (i.e., the municipality) to investigate effects on local-level outcomes over five decades (1971–2011). According to law, a waste facility is declared permanently closed only after the authorities in charge have inspected the site and certified that the necessary reclamation measures have been undertaken.⁵ We focus on the mortality rate of the resident population, as this is directly affected by the quality of the surrounding environment and by the presence of contamination sources (Adamowicz et al., 2011; Clay et al., 2016; Cortes-Ramirez et al., 2018; Jha and Muller, 2018; Cheung et al., 2020). Then, we assess additional effects on socio-economic outcomes related to literacy and labor market performance.

We combine two unique administrative sources on mining activities and deaths. The first database provides rich information on all mining sites in Italy, such that we can reconstruct the history of every site operating since the late 1800s, its location, the type of materials extracted, treated, or stored, and its risk classification. The second database details all deaths occurring yearly in any given municipality by gender, age, and cause of death. In addition, we gather socio-economic indicators from five decennial census waves (1971–2011).

It is difficult to empirically assess the causal effect of eradicating mining waste from other concomitant factors such as the endogenous sorting of people into a territory, location-specific amenities, and the lack of appropriate data on pollution at the local level. We follow an indirect approach by exploiting the temporal variation provided by the closure of a waste facility, resulting in a quasi-experimental setting. We adopt a difference-in-differences design with staggered treatment using municipality-level data over the period 1971–2011.

Our empirical strategy leverages the fact that not all sites where minerals are extracted also host a waste facility, as some extraction processes produce little or no hazardous waste. In other instances, waste may be transported to a treatment facility in another location. Hence, we define three groups of Italian municipalities: (i) those hosting mining activities *and* a mining waste facility, (ii) those hosting mining activities *but no* mining waste facility, and (iii) adjacent municipalities, to control for potential spillovers. In our main specification, we consider the first group of municipalities as treated and compare them to the latter two categories, which make up the control group. To account for the presence of heterogeneous treatment effects, we use the estimator recently proposed by De Chaisemartin and D'Haultfoeulle (2022).

We find that the closure of mining waste facilities is associated with an average decadal drop in mortality of 126 deaths per 100,000 inhabitants in treated municipalities compared to the counterfactual trend of untreated units. This corresponds to a nearly 15% decrease in overall mortality at the local level. Using an event-study analysis, we show that the negative effect becomes increasingly larger over the post-treatment period: mortality drops by 84 deaths in the first decade, increasing to nearly 170 deaths four decades after the shock. The absence of pre-treatment differentials across units experiencing the closure of mining waste facilities and those belonging to the control group rules out potential anticipation effects. Our main estimate translates into around

³ See details at https://ec.europa.eu/environment/topics/waste-and-recycling/mining-waste_en, last accessed on 18 November 2022.

⁴ See <https://www.fs.usda.gov/managing-land/natural-resources/geology/abandoned-mine-lands>, last accessed on 18 November 2022.

⁵ See the European Extractive Waste Directive (2006/21/EC) and the Italian Decree 152/2006, and subsequent amendments. We assume that the cleanup is executed in the same decade as the closure, as recorded in official inventories. Even in case remediation was incomplete or delayed in some locations, we would be identifying a lower-bound estimate.

7,886 lives saved, averaging to overall total monetary benefits associated with the decommissioning of mining waste facilities of EUR 26.82 bln (or USD 28.69 bln) over the period 1971–2011.⁶

Our results are supported by several robustness checks, different sample selections, and falsification exercises, including a test of the validity of the stable unit treatment value assumption (SUTVA). In addition, we demonstrate that the drop in mortality does not depend on changes in the target population. To further support the causal interpretation of our findings, we show that a large set of covariates is cross-sectionally balanced across groups. Importantly, our model accounts for the closure of mining extraction sites even when a waste facility does not exist.

Mortality especially decreases when underground facilities are decommissioned, suggesting that the complete reclamation of open-air sites may be a more challenging process (Li et al., 2021). Moreover, when we consider facilities by type of waste, we find that the effect is particularly meaningful for those treating and storing asbestos. Similarly, drops in mortality are associated with locations where extraction involves ultrafemic minerals (including asbestos), and, to a lesser extent, metallic minerals. Indeed, we show evidence that current asbestos levels are lower in municipalities undergoing mining waste facility closures.

The decline in mortality is mainly driven by a drop in deaths by neoplasms and diseases of the circulatory, genitourinary, and digestive systems, in line with medical research on mortality associated with mining activities (see, e.g., Rockette, 1977; Hendryx and Ahern, 2008; Fernández-Navarro et al., 2012; Cortes-Ramírez et al., 2018; Hendryx et al., 2020). The negative effect on mortality holds both across genders and age groups. The impact is greater for females, suggesting that improvements in health reach the general population and not only (typically, male) workers in the mining sector. Additionally, the response increases in magnitude by age class. Although imprecisely estimated, we register a large impact on mortality for young people (aged 0–19), suggesting the existence of intergenerational health effects (Aizer and Currie, 2014).

While the estimated drop in mortality can be interpreted as a net effect with respect to income changes, we also investigate the impact of waste facility closures on other socio-economic indicators. We detect positive responses in terms of education, with a 13% decrease in the illiteracy rate, and in terms of the employment of males, which rises by around 2%. The coefficient for female employment is also positive, although not statistically significant. Overall, these results point to positive health effects associated with the closure of waste facilities dominating potentially negative wealth effects. As for locations where extraction sites were shut down but waste facilities were never present, the health–wealth trade-off does not yield clear-cut results. In other words, in the absence of mining waste storage facilities, the gains from eradicating mining-related activities do not seem to overcome the losses attributable to the foregone economic development.

This is the first paper to causally estimate the long-run impact of decommissioning facilities treating and storing waste from mining on mortality and other socio-economic outcomes at the local level. The existing economic literature focuses predominantly on extraction activities, rather than on the presence of mining waste, and usually relies on shorter time intervals. To the best of our knowledge, only Jha and Muller (2018) analyze a similar context, assessing the effects of particulate matter emitted by coal storage plants on mortality using an IV strategy. Our findings are consistent with their results, as we also estimate a direct link between the storage of mineral products and mortality. Yet, our setting differs from theirs along many dimensions: instead of relying on an IV strategy, we exploit the staggered occurrence of closures across locations, and we distinguish detailed mortality outcomes by age, gender, and cause of death at a very fine-grained geographical level (Italian municipalities have a median area of about 20 km² and a median population of 2,000 inhabitants), allowing us to circumvent the absence of appropriate environmental quality data from the past, thus extending the observational window to half a century.⁷ In addition, our analysis relates to a more comprehensive set of polluting agents, as we do not focus only on coal and can exploit information on different types of minerals.

Other literature on the relationship between environmental quality and health outcomes typically focuses on specific causes of air (Beach and Hanlon, 2018; Cheung et al., 2020; Bigliardi et al., 2021; Hollingsworth et al., 2021, among the most recent) or water pollution (Hill and Ma, 2022; Adamowicz et al., 2011), or the presence of hazardous materials in the primary residence (Billings and Schnepel, 2017, 2018).⁸ We consider a more pervasive source of contamination that encompasses all realms of environmental deterioration (i.e., mining waste, which can leak and drain into the soil and groundwater or be dispersed in the air). We do so by using nationwide administrative data at the lowest geographical area level, covering half a century, and by exploiting recent econometric advances that allow the proper identification of the effect of interest (De Chaisemartin and D'Haultfoeuille, 2022). We also contribute to the small list of studies documenting the economic repercussions of the ongoing decarbonization process in Western countries (Aragón et al., 2018; Haywood et al., 2021; Boslett and Hill, 2022; Rud et al., 2022).

The remainder of the paper proceeds as follows. Section 2 describes the data and the empirical strategy. Section 3 presents the main results, the heterogeneous effects of waste facility closures, and a discussion of the health–wealth trade-off. Section 4 offers some concluding remarks.

⁶ These figures are expressed at current values. They are computed based on the total population of treated municipalities (1.25 mln) and a value of statistical life (VSL) estimated by Tonin et al. (2012) at EUR 2.6 mln (at 2007 prices), which we adjust to EUR 3.40 mln to account for past inflation and changes in real income over the period 1971–2011, taking income elasticity at 0.8. The estimate by Tonin et al. (2012) is especially appropriate here because willingness to pay is specifically computed in the context of public programs that would provide for remediation at abandoned industrial contaminated sites in Italy. As robustness, we use the baseline VSL adopted by the European Commission of EUR 1.4 mln (at 2000 values), which we convert to EUR 3.9 mln at current values (accounting for inflation and changes in real income over 1971–2011). We obtain similar results: EUR 31.05 bln or USD 33.23 bln.

⁷ Data on environmental quality, contamination, and pollution at this level of granularity are only available from the late 1990s, and coverage is often not systematic.

⁸ See also Troesken 2008, Auffhammer and Kellogg 2011, Björ et al. 2013, Clay et al. 2016.

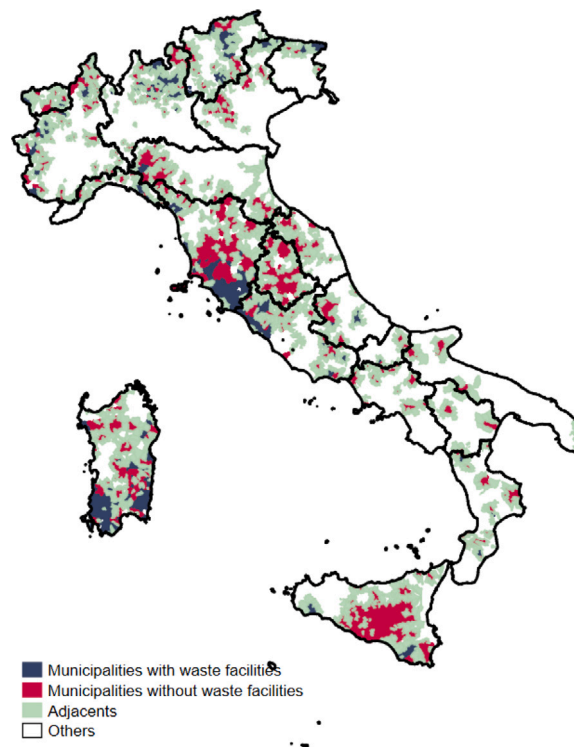


Fig. 1. Geographical distribution of mining extraction sites and waste facilities.

Note: Geographical distribution of municipalities by group: municipalities that hosted an extraction site *and* a mining waste facility (225, in blue), those that hosted an extraction site *but no* waste facility (504, in red), and adjacent municipalities (1,974, in green). Municipalities in white (4,777) are excluded from the main sample as they do not fall into any of the previous categories (they never hosted mining-related activities and are not adjacent to municipalities that did). Black lines indicate regional borders (20 NUTS-2 areas). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

2. Data and empirical strategy

In this section, we present the data used in the analysis. Then, we outline the identification strategy based on a difference-in-differences design and provide descriptive statistics.

2.1. Data sources

Mining extraction sites and waste facilities

Mining activities consist of a set of complex operations. After a mineral deposit is discovered, the material is then extracted. This involves the removal of the topsoil to gain access to the mineral resources and their actual extraction, which can occur either via surface mining or underground mining. Minerals are then separated from rocks, ore, and other unprofitable materials (i.e., gangue) and treated. This stage typically generates a large amount of hazardous and polluting waste, as it involves multiple mechanical, physical, and chemical processes (Eurostat, 2020; Garbarino et al., 2020).⁹ The waste resulting from these processes (e.g., heavy metals, other non-combustible material, and cleaning chemicals) is often highly toxic to the environment and needs to be transferred to a waste facility where it undergoes treatment and is stored in surface impoundments or injected underground (Kossoff et al., 2014; Carmo et al., 2020). In some instances, the waste treatment facility is adjacent to the extraction site. If this is not the case, waste from mineral extraction is transported to a treatment facility in another location, where it is eventually treated and stored.

We gather detailed data on mining extraction sites and mining waste facilities from the corresponding national inventories managed by the Italian Higher Institute for Environmental Protection and Research (ISPRA). The inventory of mining extraction sites refers to all solid mineral extraction sites that have ever operated since 1870, i.e., soon after the country's unification under the Kingdom of Italy in 1861.¹⁰ Of the 3,015 sites recorded in the database, which have an average size of 211 hectares, almost all are no longer in operation.

⁹ Additionally, mining activities modify the landscape by exposing previously undisturbed earthen materials (Feng et al., 2019).

¹⁰ These are defined as first-category mines. Second-category mines (quarries and peat bogs) and the extraction of liquid and gas fuels (such as oil and methane), mineral and thermal waters, and geothermal fluids are excluded.

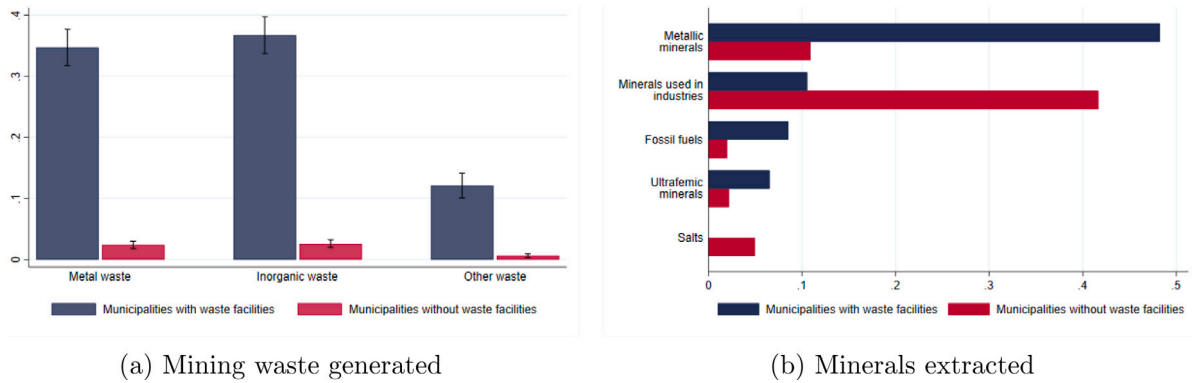


Fig. 2. Mining waste and minerals extracted by type.

Note: Blue bars refer to municipalities hosting both an extraction and a waste treatment facility. Red bars represent locations that only host an extraction site (and no waste facility). Panel (a) shows the proportion of municipalities generating a given type of mineral waste. Panel (b) reports the share of municipalities where a given type of mineral is extracted. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

The inventory of mining waste facilities includes all sites where mineral waste deriving from extraction has been treated and stored since 1870. These facilities are classified based on of their riskiness: “standard” or “type A” (high-risk) facilities. The latter are associated with certain dangerous substances and may represent a serious threat to human health or the environment in the short or medium run.¹¹ The two databases contain information on the exact location of each site or facility, the type of minerals extracted, the potential waste generated, and the year of closure.

In our analysis, we consider municipality-level data and classify each location based on the presence of extraction and waste storage activities. Fig. 1 shows the geographical distribution of the 7,480 Italian municipalities in our initial sample. We define three groups: (i) municipalities that have ever hosted a mining extraction site *and* a waste facility (in blue, 225); (ii) municipalities that have ever hosted a mining extraction site *but not* a waste facility (in red, 504); and (iii) municipalities adjacent to those belonging to either of the previous groups (in green, 1,974). Mining activities are distributed across the national territory. Municipalities hosting waste facilities are located in the north (19.68% in Lombardy, 11.00% in Piedmont, and 8.68% in Trentino Alto Adige), in the center (14.76% in Tuscany), and in the south (22.18% in Sardinia). Similarly, municipalities where an extraction site but no waste facility exists are spread around the country, mainly in Tuscany (12.55%), Piedmont (11.87%), Sicily (11.35%), Sardinia (10.56%), and Lombardy (9.36%). Fig. 2 describes the characteristics of the municipalities in terms of the waste produced and the types of minerals extracted. Municipalities hosting a waste facility and those without mineral waste facilities display substantial differences in terms of the presence of mineral waste (panel a) and the types of minerals extracted (panel b).

Panel (a) of Fig. 2 shows that sites hosting a waste facility (in blue) are characterized by the presence of metal (35%) or inorganic waste (36%), while in around 12% of cases other forms of waste are produced (mostly asbestos). Conversely, municipalities where only mining extraction sites exist (i.e., without waste facilities; in red) produce little or no waste.¹² Panel (b) describes the prevalence of the types of minerals extracted by group. The minerals extracted in locations with waste facilities (in blue) are predominantly metals (such as iron, copper, etc.), fossil fuels (e.g., oil shale), or ultrafemic minerals (e.g., asbestos and olivine). In municipalities with no waste treatment facilities (in red), extraction usually involves minerals used in industry and construction (e.g., clay and feldspars) and salts. Overall, Fig. 2 shows that the two groups of municipalities differ substantially from each other in terms of their predominant mining activities.

Yet, despite these differences municipalities hosting a waste facility and those that do not are very similar in terms of observable socio-economic outcomes measured in 1951 and 1961 (prior to the period considered in our analysis), as well as in 1971. This test is reported in Fig. 3, where each coefficient indicates the estimated difference across the two groups of municipalities in terms of a given indicator. In particular, we consider population, density, education (measured through the incidence of illiterates), and employment by gender and by sector. We observe little difference between municipalities with and without waste facilities in terms of observables, which supports the suitability of the comparison of these two groups, even cross-sectionally.

¹¹ Riskiness is defined according to the criteria listed in Decree 117/2008. A waste facility is classified as “type A” if: (i) any failure or malfunction, such as the collapse of a mound or dam, could cause a major incident, based on factors such as size, location, and the environmental impact of the facility; or (ii) it contains extraction waste or other substances classified as dangerous by European Directives 67/548/CEE and 1999/45/CE or by the Italian Decree 152/2006 and subsequent amendments (namely, waste or other substances that are explosive, oxidizing, flammable, irritating, toxic, carcinogenic, corrosive, infectious, mutagenic, sensitizing, or eco-toxic) beyond certain limits.

¹² The plot excludes a residual category where information on the type of waste treated in waste facilities is missing (18% of entries). Among the municipalities without waste facilities, 2% produces metal waste, 3% produces inorganic waste and less than 1% produces other waste.

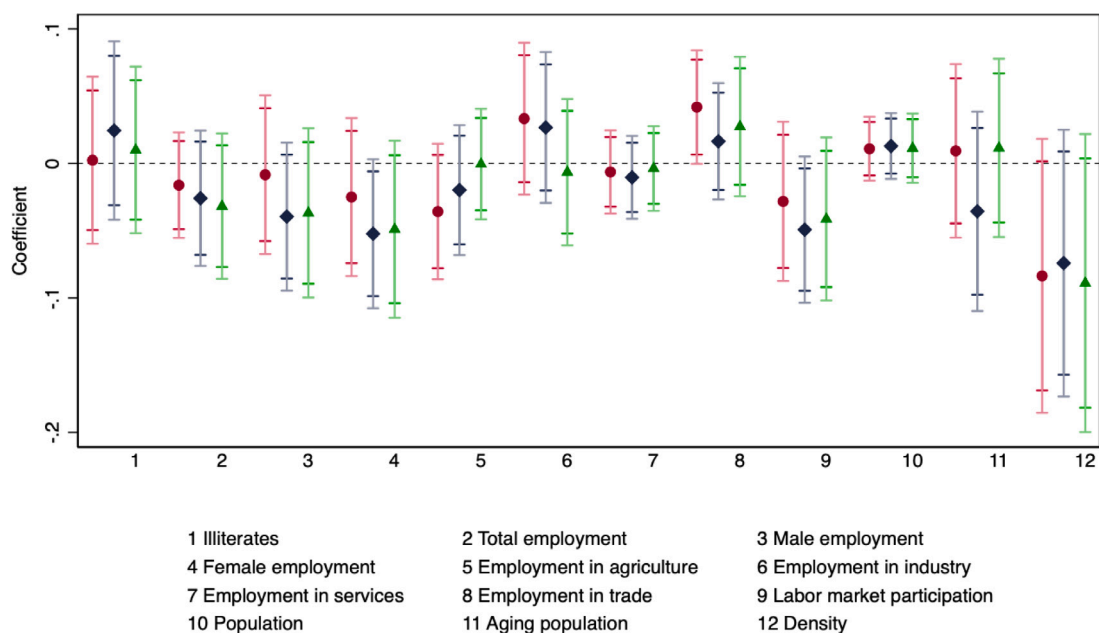


Fig. 3. Municipalities with and without waste facilities, balancing test.

Note: Each coefficient and the corresponding confidence intervals, indicated at the 95 and 99 percent level, are associated with a regression where the dependent variable is a dummy that takes a value of one for municipalities that have ever hosted a waste treatment facility and an extraction site and zero for municipalities that have ever hosted an extraction site but not a waste treatment facility. The dependent variables are drawn from the 1951 (red circles), 1961 (blue diamonds), and 1971 (green triangles) decennial censuses. All variables are standardized. Regressions include region fixed effects. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Mortality

We draw municipality-level data on mortality from cause of death statistics provided by the Italian National Institute of Statistics (ISTAT), which is the main comprehensive source of epidemiological information in Italy and that on which the government, parliament, and local authorities rely on. The dataset has full coverage of all deaths occurring within the national territory in each calendar year. We construct the average mortality rate over five decades (1971–2011).¹³

Events are classified on the basis of the initial cause of death according to the ICD-9 (International Statistical Classification of Diseases, Injuries, and Causes of Death) provided by the World Health Organization (WHO). Fig. 4 shows cause of death trends over time. Over the decades considered, disorders of the immune system and neoplasm incidence have surged substantially (Bosetti et al., 2020), while the proportion of deaths caused by diseases of the circulatory and respiratory systems has decreased (Monasta et al., 2019). Furthermore, the data contains death counts by gender and age groups, which we use in the heterogeneity analysis.

Census data

Finally, to investigate potential channels and wealth effects we employ information from the five decennial censuses from 1971 to 2011, provided by ISTAT. The data comprise a set of municipality-level socio-economic and demographic characteristics taken from the general population and housing censuses. We select indicators for population size, the share of illiterates, and gender-specific labor market participation (LMP) and employment.

2.2. Identification strategy

Our aim is to estimate the impact of removing a source of environmental contamination, i.e., mining waste. We exploit variation in the timing of mining waste facility closures to understand whether their closure triggers health and economic consequences at the local level.

In the absence of systematic data on environmental quality for the second half of the 1900s, we focus on the impact in terms of health (namely, mortality), an outcome directly affected by shocks to the quality of the local environment (Cortes-Ramirez et al., 2018; Jha and Muller, 2018; Cheung et al., 2020). In this context, the shutting down of a waste treatment facility can be thought of as a (positive) shock to environmental quality in a given location, because closures are typically accompanied by decontamination

¹³ The death rate is computed as the average yearly mortality in the years observable prior to the start of the decade. That is, for the 1971 decade we consider deaths occurring in 1969–1970; for the 1981 decade, we consider deaths occurring in 1971–1980; and so on.

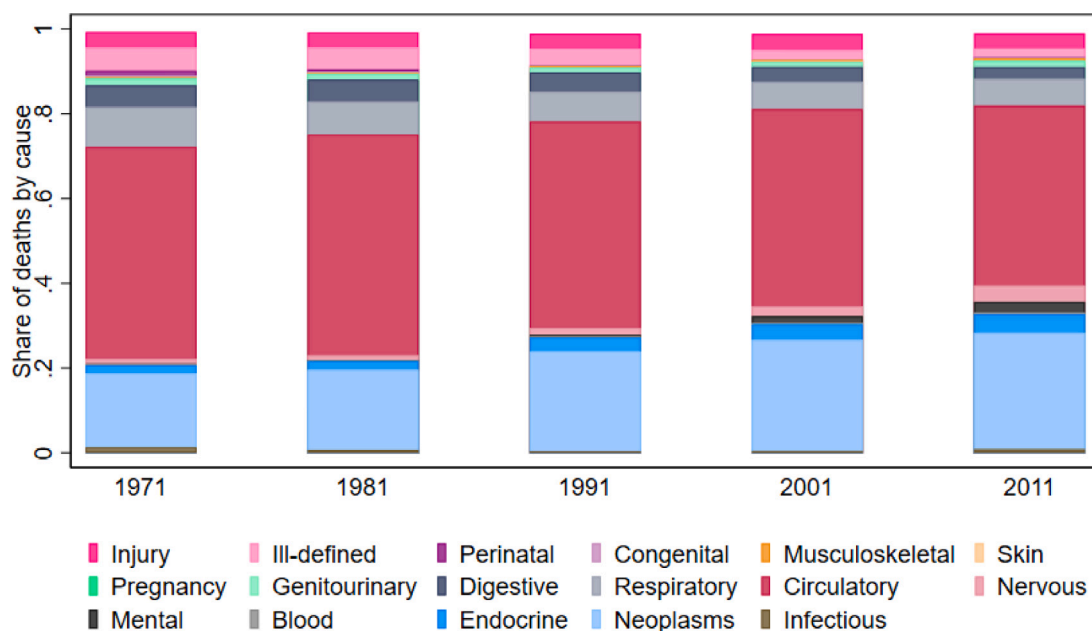


Fig. 4. Deaths by cause and year.

Note: Shares of deaths by cause and by census year. The categories are based on the International Classification of Diseases, 9th revision (ICD-9): (I) infectious and parasitic diseases; (II) neoplasms; (III) endocrine, nutritional and metabolic diseases, and immunity disorders; (IV) diseases of the blood and blood-forming organs; (V) mental disorders; (VI) diseases of the nervous system and sense organs; (VII) diseases of the circulatory system; (VIII) diseases of the respiratory system; (IX) diseases of the digestive system; (X) diseases of the genitourinary system; (XI) complications of pregnancy, childbirth, and the puerperium; (XII) diseases of the skin and subcutaneous tissue; (XIII) diseases of the musculoskeletal system and connective tissue; (XIV) congenital anomalies; (XV) certain conditions originating in the perinatal period; (XVI) symptoms, signs, and ill-defined conditions; and (XVII) injury and poisoning.

measures taken to reclaim the corresponding area, as prescribed by law.¹⁴ Importantly, and as shown in Fig. A.1, the closing of a waste facility corresponds to the cessation of all mining activities in the municipality, as in most of the locations that host a waste facility this was dismantled in the same year as the extraction site. As second-order outcomes, we consider socio-economic indicators related to labor market performance and education, in order to shed light on the health–wealth trade-off at the local level.

We distinguish the municipalities in our sample based on the presence of mining activities within the boundaries of each precinct: (i) municipalities hosting a mining extraction site *and* a waste facility, (ii) those hosting a mining extraction site *but no* waste facility, and (iii) adjacent municipalities where no mining site exists. The treated units are those in the first group, i.e., municipalities that undergo the closure of a waste facility. The control group is composed of the second and third categories, namely, municipalities that host a mining extraction site (but no waste facility) and adjacent municipalities. Both categories are reasonably comparable to the treated units. The former are specialized in mining activities, like the treated group, with the only difference being that they do not host a facility where mining waste is treated and stored (see Fig. 3). The latter are not specialized in mining activities but are comparable to the treated units in terms of geographic proximity.

Our identification strategy combines the cross-sectional variation between treated and control units with the temporal variation given by the closure of the waste facilities. Fig. 5 describes the number of site closures by decade and type. While the inventories of mining sites start from 1870, the very first closure occurred in 1907. We distinguish between closures that occurred before (out-of-sample, in lighter colors) and after 1971 (in-sample, in darker colors). We use 1971 as a threshold because it corresponds to the first available decade in the mortality data. Blue bars refer to the number of waste facilities shut down in a given decade, while red bars indicate the closures of sites hosting an extraction site only.¹⁵ The black dotted line represents the overall death rate per 100,000 inhabitants. This has steadily declined over the period considered, from 961 deaths per 100,000 inhabitants in 1971 to 762 in 2011.

Our identification strategy is based on a staggered difference-in-differences approach:

$$Y_{mt} = \beta \text{Closure}_{mt} + \eta M_{mt} + \mu_m + \tau_t + \gamma_{pt} + \varepsilon_{mt}, \quad (1)$$

¹⁴ We assume that remediation and securing are carried out upon closure of the waste facility. It should be noted that even in cases where a waste facility was abandoned without immediate and complete decontamination and securing, its closure would still imply a cessation of waste streams into that location. In this context, our estimates would be biased downward.

¹⁵ National accounts estimate that the number of workers employed nationwide in the mining industry in 1969 was around 119,000 (i.e., 0.6% of the total labor force). This workforce then decreased to 38,500 in 1996 and to 14,850 in 2015. ISTAT provides these estimates in the Italian Statistical Yearbook (*Annuario Statistico Italiano*). See details at <https://www.istat.it/it/archivio/48261>, last accessed on 18 November 2022.

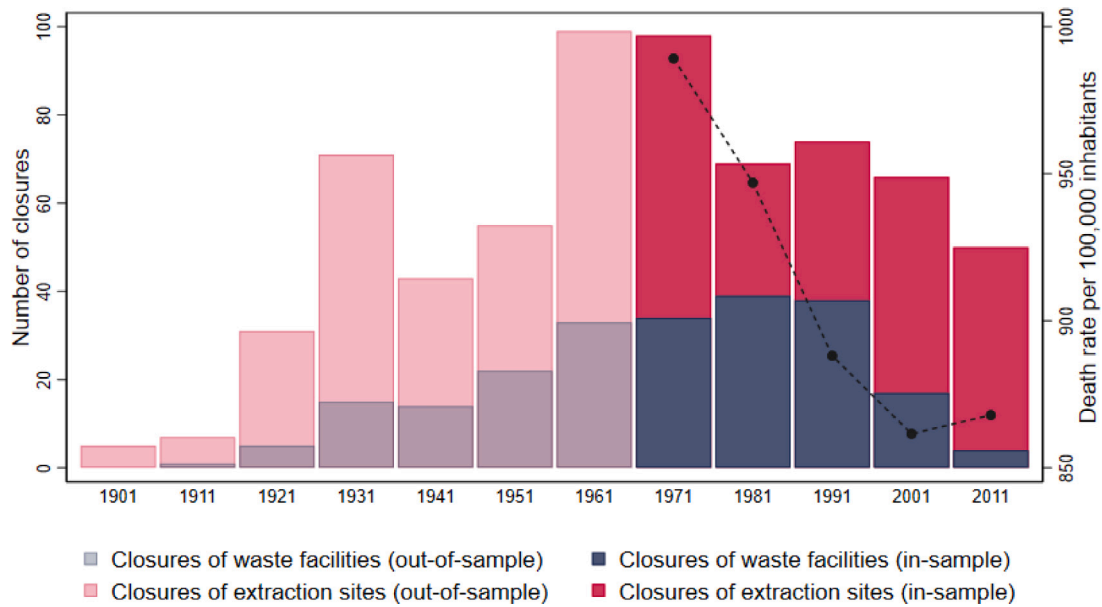


Fig. 5. Site closures and death rate by decade.

Note: Bars represent the number of closures of extraction sites *with* waste facilities (in blue) and of extraction sites *without* waste facilities (in red) by decade. Lighter bars refer to closures that occurred before the period of observation (out-of-sample), while darker bars refer to closures occurring in the decades considered in the main analysis (1971–2011). The black line is the average number of deaths per 100,000 inhabitants. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

where Y_{mt} defines the outcome, that is, the overall death rate and other socio-economic variables in municipality m in decade t . First, we investigate the effect of the closures on the total mortality rate per 100,000 inhabitants. Then, we dig into the different causes of death and analyze mortality by gender and age profile. Finally, we consider socio-economic outcomes drawn from the census (population, labor market outcomes, and literacy) to analyze possible economic spillovers and discuss health–wealth trade-offs at the local level.

The main coefficient of interest, β , relates to the dummy variable *Closure*, which equals one when a waste facility is closed in municipality m and decade t . Our preferred specification includes municipality (μ_m) and decade fixed effects (τ_t), to account for temporal and spatial heterogeneity and exploit within-municipality variation. Given that our sample is restricted to municipalities with a history of mining activities and their neighboring municipalities, we control for whether a mining extraction site is shut down in municipalities *without* waste facilities through the dummy M_{mt} . This is to avoid potential confounding effects generated by the closure of a mine within the same area.

We also include a set of region-by-decade fixed effects (γ_{pt}) to take into account heterogeneity related to changes in health services, which are managed at the regional level in Italy. Moreover, restricting the variability to the regional dimension increases the comparability across locations in terms of potential exposure to a given mineral waste, since the types of raw materials extracted are geographically clustered. Finally, ε_{mt} represents the error term and standard errors are clustered at the municipality level.

As we are using a staggered treatment, a standard difference-in-differences estimated with OLS may yield biased results in the presence of heterogeneous treatment effects.¹⁶ Thus, we adopt the procedure recently proposed by De Chaisemartin and D'Haultfoeuille (2022) and compute event-study analyses with their estimator, which is robust to heterogeneous or dynamic treatment effects.¹⁷ Indeed, estimates generated by this procedure do not rely on the constant treatment effect assumption and allow testing the parallel trends assumption by generating placebo estimators and dynamic effects.

As discussed by De Chaisemartin and D'Haultfoeuille (2022), their procedure uses as controls units whose treatment does not change between consecutive periods. Under the parallel trends assumption, the outcome evolution among non-switcher units can be used as the counterfactual evolution of the switchers. A difference-in-differences estimator that compares the outcomes of both groups before and after the intervention can estimate average treatment effects among the switchers (De Chaisemartin and D'Haultfoeuille, 2022). At time t , it compares the evolution of the mean outcome between $t - 1$ and t in two groups: the municipalities that closed waste facilities at period t and those that remained untreated. Under the assumption that the mean

¹⁶ The recent literature has highlighted issues with dynamic difference-in-differences designs, and especially the possibility that some units might receive negative weights when their outcomes are aggregated to form treatment effects, which may bias the resulting estimates (De Chaisemartin and D'Haultfoeuille, 2020; Callaway and Sant'Anna, 2021; Goodman-Bacon, 2021).

¹⁷ Except for the robustness checks estimated with Poisson Pseudo Maximum Likelihood (PPML), all regressions in this paper are computed using the Stata command `did_multilegt` (De Chaisemartin et al., 2019).

Table 1
Effect of waste facility closures on mortality.

Dep. Variable:	Death rate per 100,000 inhabitants			
	(1)	(2)	(3)	(4)
Closure	−128.402*** (42.867)	−125.189*** (40.649)	−126.340*** (40.45)	−107.178* (55.307)
Placebo	0.692	0.886	0.885	0.924
Dynamic effects				
$t - 3$	56.124 (98.35)	−11.741 (103.574)	−11.016 (103.466)	−20.654 (102.464)
$t - 2$	67.022 (95.624)	43.312 (94.431)	43.822 (94.363)	35.051 (103.062)
t	−86.711*** (33.126)	−83.971*** (29.286)	−84.482*** (29.172)	−73.546* (37.998)
$t + 1$	−123.639*** (47.379)	−119.489*** (44.038)	−120.548*** (43.877)	−99.886* (58.282)
$t + 2$	−165.319*** (52.817)	−164.893*** (53.714)	−166.455*** (53.491)	−143.394* (74.778)
$t + 3$	−172.95** (87.237)	−165.314* (86.397)	−167.506* (86.224)	−138.813 (101.075)
No. of Obs	24,758	24,758	24,758	19,759
Switchers	310	310	310	310
Mean outcome	863.22	863.22	863.22	843.522
Municipality FE	✓	✓	✓	✓
Decade FE	✓	✓	✓	✓
Region X Decade	✓	✓	✓	✓
Controls			✓	✓
Sample	Main	Main	Main	Adj

Note: Regressions estimated using the procedure proposed by De Chaisemartin and D'Haultfoeuille (2022). The outcome variable is the overall mortality rate per 100,000 inhabitants. *Closure* is a dummy equal to one when a mining waste facility is closed in a given municipality. *Placebo* reports the *p*-value for the placebo tests based on the pre-treatment periods. *Switchers* is the number of municipalities that have switched into the treatment. *Controls* include a dummy flagging the closure of an extraction site. The *Main* sample includes municipalities with waste facilities, those with mineral extraction but no waste facilities, and their neighbors. The *Adj* sample excludes municipalities with mining extraction but no waste facilities. Standard errors are estimated using 50 bootstrap replications clustered at the municipality level.

p* < .10 ** *p* < .05 * *p* < .01.

outcome of municipalities in the switching group with respect to the untreated ones would evolve in parallel in the absence of the closure of a waste facility, we can estimate the average treatment effect for the switchers at period t . Thus, $\beta_{Closure_{mt}}$ is an unbiased estimator for the average treatment effect among switchers in the period they switch.

3. Results

In this section, we outline the results regarding the long-run effect of closing a mining waste facility on mortality rates. We also briefly present some robustness checks. Then, we describe the heterogeneity based on the characteristics of the waste facility and based on age, gender, and cause of death. Finally, we discuss the implications in terms of the health–wealth trade-off.

3.1. Waste facility closures and mortality

Table 1 shows the effect of waste facility closures on the overall mortality rate at municipality level over the five decades considered (1971 to 2011). The top panel reports statistics related to the treatment variable of interest (*Closure*) and the *p*-value associated with the placebo estimate. When the *p*-value is above 0.1, this implies that the estimated leads are not statistically relevant at any conventional level, suggesting the absence of differential pre-treatment trends. The panel reporting the dynamic effects presents the coefficients associated with each lead and lag in an event-study analysis fashion.

In column 1, we present the estimates using the main sample (i.e., municipalities with and without waste facilities and their neighboring municipalities) with the inclusion of municipality and time fixed effects. Here, we find a differential improvement in terms of mortality rate between treated and control units. The effect is negative and statistically significant, amounting to around 128 deaths per 100,000 inhabitants, on average, compared to the counterfactual. This corresponds to a decrease of about 14% with respect to the sample mean.¹⁸

We find a similar result in column 2, where we control for potential heterogeneity at the macro-area level by including region-by-decade fixed effects. This takes into account changes in waste management regulations and public services provided by the regional health authorities (Di Novi et al., 2019), as well as differences in the type of minerals extracted across areas. In column 3, we

¹⁸ In comparison to the average mortality in 1971 (961 deaths per 100,000 inhabitants), the drop is about 13%.

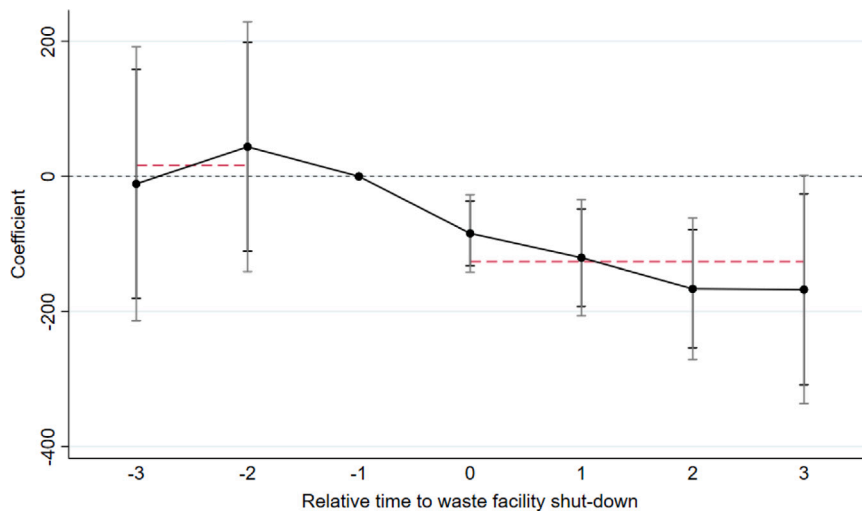


Fig. 6. Effect of waste facility closures on mortality.

Note: Effect on the overall death rate per 100,000 inhabitants. The treatment is *Closure*, which is a dummy equal to one when a mining waste facility is closed in a given municipality. The regression includes municipality, decade, and region-decade fixed effects and controls for the closure of a mining extraction site. Standard errors are estimated using 50 bootstrap replications clustered at the municipality level. Confidence intervals are shown at the 95 and 99 percent level.

account for possible shocks induced by the closure of an extraction site in municipalities that do not host a waste facility. In this specification, which is our preferred one, the point estimate is indistinguishable from the previous results.

In the last column, we exclude locations with an extraction site (but no waste treatment) from the sample. Here, the comparison relies on municipalities *with* a waste facility against adjacent municipalities. This is to ensure that the drop in mortality is not driven by the inclusion of municipalities where minerals are extracted in the control group. Although the sample size is reduced by more than 20%, we find a decline of 107 deaths per 100,000 inhabitants in the mortality rate, or 12%, which is in line with the main estimate. As the reported p-values indicate, all placebo tests based on the pre-treatment periods yield zero effects.

Fig. 6 shows the event-study analysis based on our preferred specification, i.e., column 3 of Table 1. It highlights the existence of a sharp and persistent negative impact of waste facility closures on overall mortality at the local level. In the first decade following the closure of a waste facility, mortality decreases by 84 deaths. The effect increases in magnitude over time and stabilizes at 166 deaths per 100,000 inhabitants by the third decade. This pattern is consistent with the fact that decontamination is expected to produce measurable effects on the health of local communities gradually: it suggests modest improvements in the first decades after the closure of a facility (i.e., shortly after exposure to pollutants is interrupted), and larger effects as time goes by (i.e., when fewer “surviving” inhabitants have been exposed to the waste facility in operation). To the left of zero, coefficients are null in terms of both magnitude and statistical significance, supporting the credibility of the parallel trends assumption. This points to the absence of systematic differences in mortality trends across treated and control municipalities before the closure of a waste facility, as well as the absence of potential anticipation effects.

Overall, this result documents a substantial and persistent improvement in the health conditions of the overall population in municipalities where mining waste facilities are shut down.

Robustness checks

We provide support for the causal interpretation of our results in different ways. These additional checks are reported in the Online Appendix.

First, we test for the stability and validity of the design using different samples. Figure OA.1 shows the event-study analysis based on column 4 of Table 1, i.e., where the treated group of municipalities with a waste facility are compared to the subsample of adjacent municipalities only. Figure OA.2 refers to a restricted sample where we compare municipalities hosting mining extraction activities with and without waste facilities only, meaning that we exclude the subgroup of adjacent municipalities. In Figure OA.3, we also include all other Italian municipalities (i.e., those in white in Fig. 1).

In Figure OA.4, we consider our main sample (as in column 3 of Table 1) but aggregate data using 5-year intervals instead of decades. We also acknowledge that in some treated municipalities, waste facilities and extraction sites are not closed at the same time (see Fig. A.1). To avoid potential confounding effects that might be generated by these non-contemporaneous closures, we restrict the subsample of treated units to municipalities where waste and extraction facilities are closed in the same decade and compare this to the control group used in our main specification (i.e., municipalities that do not host a waste facility and adjacent municipalities). The results are reported in Figure OA.5. In all cases, we obtain decreasing patterns that are in line with our preferred specification displayed in Fig. 6.

Second, we check for the absence of geographical spillovers across municipalities. This is relevant from an econometric point of view because if there are geographical spillovers, the stable unit treatment value assumption (SUTVA) does not hold, and estimated

Table 2
Effect of waste facility closures on mortality, by type.

Dep. Var:	Death rate per 100,000 inhabitants						
	Hazardousness		Type of facility		Type of waste		
	High-risk (1)	Standard-risk (2)	Open-air (3)	Underground (4)	Metals (5)	Inorganic (6)	Asbestos (7)
Closure	−128.262*** (36.613)	−82.199 (124.145)	−41.655 (60.322)	−230.965** (91.633)	−95.947 (82.554)	−65.788 (76.401)	−195.520*** (67.969)
Placebo	0.755	0.170	0.573	0.190	0.888	0.729	0.416
No. of Obs	24,999	26,306	26,072	25,233	25,150	25,629	26,367
Switchers	236	74	204	106	172	163	65
Mean outcome	863.22	863.22	863.22	863.22	863.22	863.22	863.22
Municipality FE	✓	✓	✓	✓	✓	✓	✓
Decade FE	✓	✓	✓	✓	✓	✓	✓
Region X Decade	✓	✓	✓	✓	✓	✓	✓
Controls	✓	✓	✓	✓	✓	✓	✓
Sample	Main	Main	Main	Main	Main	Main	Main

Note: Regressions estimated using the procedure proposed by De Chaisemartin and D'Haultfoeulle (2022). The outcome variable is the overall mortality rate per 100,000 inhabitants. *Closure* is a dummy equal to one when a mining waste facility is closed in a given municipality. Treatment subgroups are defined based on the hazardousness of the waste facility (high-risk or standard), its location (open-air or underground), and the type of waste treated and stocked (metals, inorganic, and asbestos). *Placebo* reports the p-values of the placebo tests based on the pre-treatment periods. *Switchers* is the number of municipalities that have switched into the treatment. *Controls* include a dummy flagging the closure of an extraction site. The *Main* sample includes municipalities with waste facilities, those with mineral extraction but no waste facilities, and their neighbors. Standard errors are estimated using 50 bootstrap replications clustered at the municipality level.

* $p < .10$ ** $p < .05$ *** $p < .01$.

effects are likely downward-biased. To address this issue, we assign each closure to the municipality adjacent to that where the closure occurred. Figure OA.6 provides empirical support for the SUTVA. We then consider potential migration effects induced by the closure of a waste facility (Heblich et al., 2021; Chen et al., 2022). Figure OA.7 shows that these closures do not yield differences in population trends. Hence, the sudden and substantial drop in the mortality rate discussed above is unlikely to be ascribable to population changes or migration effects.

Third, we run a placebo exercise to alleviate concerns about spurious correlations. We randomly allocate the time of the treatment to the sample of locations that never experienced mining activities (i.e., municipalities in white in Fig. 1). The randomized distribution shown in Figure OA.8 is centered on a value close to zero, and this seems to exclude that our main results are driven by spurious relationships.

3.2. Heterogeneous effects

We further investigate heterogeneity in the effect by type of waste facility (i.e., heterogeneity of the treatment) and by cause of death and subpopulation (i.e., heterogeneity of the outcome) to assess which subgroups, if any, react more to changes in environmental local conditions.

Heterogeneity by type of waste facility

We assess whether our main results can be ascribed to the closure of specific types of waste treatment facilities. We differentiate with respect to their risk classification (high or standard), their position (open-air or underground), and the type of waste treated (metals, inorganic, or other waste). Results are reported in Table 2, where three interesting pieces of evidence emerge.

First, when we split the treatment according to the level of riskiness of the facility undergoing closure (columns 1 and 2), we observe that it is the shutting down of high-risk facilities that determines a decrease in mortality. In contrast, shutting down less hazardous facilities yields only a mild decrease in mortality at the local level. The event-study analysis associated with the two subgroups confirms the validity of this result (Fig. A.2). In particular, in both cases, there is no systematic pattern before the treatment occurs and a stable decline in mortality rates is observed in the decades following the closure of high-risk facilities only. This suggests that environmental benefits are more evident when the abatement of dangerous pollutants occurs in more highly contaminated locations.

Second, the main result seems to be driven by the shutting down of underground facilities, while the closure of open-air facilities does not appear to affect mortality rates (columns 3 and 4, respectively). This might be explained by the fact that eradicating hazardous chemical substances can be more challenging in open-air facilities, as their dispersion is facilitated by atmospheric processes such as wind (Li et al., 2021). The corresponding event-study analysis is shown in Fig. A.3.

Third, in the case of sites treating and stocking metal and inorganic waste, the effect on mortality is negative but not statistically significant, with the drop in overall mortality being largely due to the closure of facilities that treat asbestos (columns 5–7). Indeed, panels (a), (b), and (c) of Fig. A.4 indicate that mortality tends to decrease following the shut-down of waste facilities and that the

Table 3

Effect of waste facility closures on mortality by gender and age.

Dep. Variable:	Death rate per 100,000 inhabitants				
	Female (1)	Male (2)	00–19 (3)	20–64 (4)	65+ (5)
Closure	–75.928*** (21.793)	–50.216** (21.829)	–8.650 (6.879)	–38.331*** (12.449)	–79.163*** (28.208)
Placebo	0.997	0.598	0.577	0.422	0.786
No. of Obs	24,758	24,758	24,758	24,758	24,758
Switchers	310	310	310	310	310
Mean outcome	440.377	469.156	16.642	163.399	729.492
Municipality FE	✓	✓	✓	✓	✓
Decade FE	✓	✓	✓	✓	✓
Region X Decade	✓	✓	✓	✓	✓
Controls	✓	✓	✓	✓	✓
Sample	Main	Main	Main	Main	Main

Note: Regressions estimated using the procedure proposed by [De Chaisemartin and D'Haultfoeuille \(2022\)](#). The outcome variable is the mortality rate per 100,000 inhabitants by gender and age group (0–19; 20–64; over 65). *Closure* is a dummy equal to one when a mining waste facility is closed in a given municipality. *Placebo* reports the p-values of the placebo tests based on the pre-treatment periods. *Switchers* is the number of municipalities that have switched into the treatment. *Controls* include a dummy flagging the closure of an extraction site. The *Main* sample includes municipalities with waste facilities, those with mineral extraction but no waste facilities, and their neighbors. Standard errors are estimated using 50 bootstrap replications clustered at the municipality level.

* $p < .10$ ** $p < .05$ *** $p < .01$.

Table 4

Effect of waste facility and extraction site closures on mortality and other outcomes.

Panel (a): Closure of waste facilities	(1)	(2)	(3)	(4)	(5)	(6)
	Health outcome	Socio-Economic outcomes				
	Death rate	Illiterates	Male LMP	Female LMP	Male Emp	Female Emp
Closure	–234.993** (103.435)	–0.408** (0.207)	0.742 (0.549)	0.346 (0.579)	1.101* (0.575)	0.308 (0.555)
Placebo	0.735	0.324	0.368	0.316	0.381	0.585
No. of Obs	5,433	5,433	5,433	5,433	5,433	5,433
Switchers	310	310	310	310	310	310
Mean outcome	932.63	3.048	63.502	31.606	57.685	26.637
Panel (b): Closure of extraction sites	(1)	(2)	(3)	(4)	(5)	(6)
	Health outcome	Socio-Economic outcomes				
	Death rate	Illiterates	Male LMP	Female LMP	Male Emp	Female Emp
Closure	98.817 (64.329)	0.356 (0.245)	0.008 (0.357)	0.809 (0.566)	0.215 (0.415)	0.697 (0.545)
Placebo	0.555	0.210	0.837	0.634	0.864	0.701
No. of Obs	3,627	3,627	3,627	3,627	3,627	3,627
Switchers	373	373	373	373	373	373
Mean outcome	932.63	3.048	63.502	31.606	57.685	26.637
Municipality FE	✓	✓	✓	✓	✓	✓
Decade FE	✓	✓	✓	✓	✓	✓
Region X Decade	✓	✓	✓	✓	✓	✓
Controls	✓	✓	✓	✓	✓	✓

Note: Regressions are estimated using the procedure proposed by [De Chaisemartin and D'Haultfoeuille \(2022\)](#). The outcome variables are the mortality rate per 100,000 inhabitants; the proportion of illiterates; the share of the population participating in the labor market and the employment rate, both by gender. In panel (a), *Closure* is a dummy equal to one when a mining waste facility is closed in a given municipality. In panel (b), *Closure* is a dummy equal to one when an extraction site is closed in a given municipality. *Placebo* reports the p-values of the placebo tests based on the pre-treatment periods. *Switchers* is the number of municipalities that have switched into the treatment. *Controls* include a dummy flagging the closure of an extraction site (panel a) or the closure of a waste facility (panel b). The sample includes municipalities with waste facilities and those with an extraction site but no waste facility. Standard errors are estimated using 50 bootstrap replications clustered at the municipality level.

* $p < .10$ ** $p < .05$ *** $p < .01$.

impact is especially relevant for sites handling asbestos. Similarly, in [Fig. A.5](#) we evaluate effects by the type of mineral extracted.¹⁹ In line with the evidence on the type of waste treated, these latter results suggest that the drop in mortality is associated with the closure of waste facilities where extraction involves ultrafemic minerals (including asbestos), and, to a lesser extent, metallic minerals. These results are especially relevant given that Italy has been the second largest producer of asbestos in Europe for most of the 20th century. As highlighted extensively in the medical literature ([Bourdès et al., 2000](#)), environmental exposure to asbestos

¹⁹ The group choice reflects the one presented in [Fig. 2](#). However, due to computational issues related to cell size, we could only run separate regression for metallic minerals, ultrafemic minerals, and a residual group that contains minerals used in industries, salts, and fossil fuels.

Table A.1

Effect of waste facility closures on mortality by cause of death.

Dep. Variable:	Death rate per 100,000 inhabitants								
Panel A	All (1)	I (2)	II (3)	III (4)	IV (5)	V (6)	VI (7)	VII (8)	VIII (9)
Closure	-126.340*** (40.45)	-0.298 (2.111)	-28.627** (11.626)	-2.544 (2.301)	-0.454 (0.538)	-1.459 (0.996)	-1.474 (1.710)	-35.319* (19.443)	-14.191* (7.754)
Placebo	0.885	0.238	0.743	0.782	0.297	0.653	0.326	0.438	0.167
No. of Obs	24,758	24,758	24,758	24,758	24,758	24,758	24,758	24,758	24,758
Switchers	310	310	310	310	310	310	310	310	310
Mean outcome	863.22	7.140	190.315	25.232	2.235	7.230	16.259	413.447	65.095
Dep. Variable:	Death rate per 100,000 inhabitants								
Panel B	IX (1)	X (2)	XI (3)	XI (4)	XIII (5)	XIV (6)	XV (7)	XVI (8)	XVII (9)
Closure	-14.920*** (5.298)	-3.997** (1.591)	-0.026 (0.225)	-0.105 (0.242)	0.162 (0.403)	-1.500 (1.058)	-4.286 (2.998)	-5.395 (8.176)	-12.212* (6.349)
Placebo	0.769	0.502	0.402	0.005	0.778	0.186	0.056	0.017	0.065
No. of Obs	24,758	24,758	24,758	24,758	24,758	24,758	24,758	24,758	24,758
Switchers	310	310	310	310	310	310	310	310	310
Mean outcome	37.739	11.735	0.193	0.784	2.394	2.418	3.77	34.74	33.479
Municipality FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
Decade FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
Region X Decade	✓	✓	✓	✓	✓	✓	✓	✓	✓
Controls	✓	✓	✓	✓	✓	✓	✓	✓	✓
Sample	Main	Main	Main	Main	Main	Main	Main	Main	Main

Note: Regressions estimated using the procedure proposed by [De Chaisemartin and D'Haultfoeuille \(2022\)](#). The outcome variable is the mortality rate per 100,000 inhabitants by cause of death: I—infectious and parasitic diseases; II—neoplasms; III—endocrine, nutritional, and metabolic diseases and immunity disorders; IV—diseases of the blood and blood-forming organs; V—mental disorders; VI—diseases of the nervous system and sense organs; VII—diseases of the circulatory system; VIII—diseases of the respiratory system; IX—diseases of the digestive system; X—diseases of the genitourinary system; XI—complications of pregnancy, childbirth, and the puerperium; XII—diseases of the skin and subcutaneous tissue; XIII—diseases of the musculoskeletal system and connective tissue; XIV—congenital anomalies; XV—certain conditions originating in the perinatal period; XVI—symptoms, signs, and ill-defined conditions; XVII—injury and poisoning. *Closure* is a dummy equal to one when a mining waste facility is closed in a given municipality. *Placebo* reports the p-values of the placebo tests based on the pre-treatment periods. *Switchers* is the number of municipalities that have switched into the treatment. *Controls* include a dummy flagging the closure of an extraction site. The *Main* sample includes municipalities with waste facilities, those with mineral extraction but no waste facilities, and their neighbors. Standard errors are estimated using 50 bootstrap replications clustered at the municipality level.

* $p < .10$ ** $p < .05$ *** $p < .01$.

substantially increases the risk of asbestos-related diseases, especially neoplasms such as mesothelioma ([Fazzo et al., 2012](#); [Wang et al., 2013](#); [Ferrante et al., 2020](#)).

Using novel data on asbestos across Italian municipalities in 2010, we observe that locations hosting a waste facility register lower levels of asbestos exposure compared to places hosting mining extraction sites without a waste facility.²⁰ Asbestos exposure is measured using three indicators: the weight of asbestos present in the municipality (in kg), the number of sites contaminated with particles of hazardous material, and the total area exposed to asbestos (in m²). [Fig. A.6](#) shows coefficients associated with these three asbestos-related outcomes and different model specifications (without any control variable and with socio-economic control variables measured in each census wave). In all cases, coefficients are stable, negative, and statistically different from zero. While this evidence is only suggestive, it is consistent with the hypothesis that the closure and decontamination of waste facilities may have effectively lowered asbestos levels in treated areas, thus reducing the exposure of local communities and overall mortality rates in these locations.

Heterogeneity by cause of death and population subgroup

Next, we focus on the impact on mortality rates by cause of death. [Table A.1](#) shows the effect of waste facility closures on mortality rates separately for each of the 17 categories of cause of death. The overall negative effect on mortality is largely driven by a decrease in deaths by neoplasms (II) and diseases of the circulatory (VII), respiratory (IX), and genitourinary systems (X), as well as by injuries and poisoning (XVII). The event studies reported in [Fig. A.7](#), however, suggest that the most substantial drops pertain to neoplasms and diseases of the circulatory, genitourinary, and digestive systems.²¹ These are all conditions associated with excess mortality in communities exposed to mining-related activities (see, for example, [Rockette, 1977](#); [Hendryx and Ahern, 2008](#); [Fernández-Navarro et al., 2012](#); [Cortes-Ramírez et al., 2018](#)). As discussed in the previous paragraph, a decrease in mortality from these causes of death would also be consistent with a decreased exposure to asbestos, a substance that is linked to lung cancer, and possibly to gastrointestinal cancer ([Bourdès et al., 2000](#); [Fazzo et al., 2012](#); [Wang et al., 2013](#); [Luberto et al., 2019](#)).

²⁰ Data are gathered by the Italian Ministry of Ecological Transition (MITE) under the *National Asbestos Plan*, which obliges regional authorities to provide full mapping of asbestos presence across the national territory.

²¹ The drop in deaths by injury would also be consistent with a reduction in the workforce employed in the mining sector. Event studies for the remaining causes of death, for which we do not record any systematic pattern in mortality, are reported in [Figures OA.10 and OA.11](#).

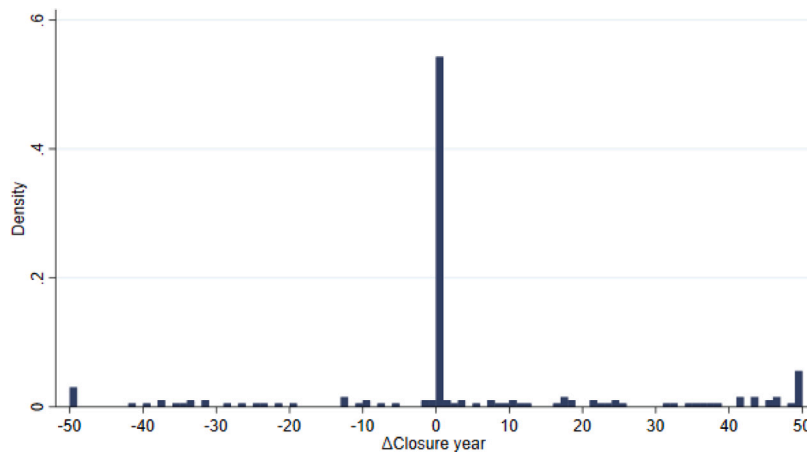
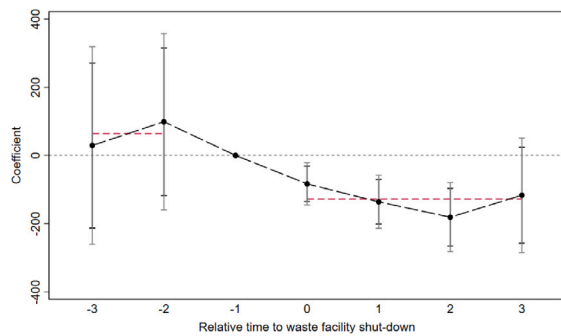
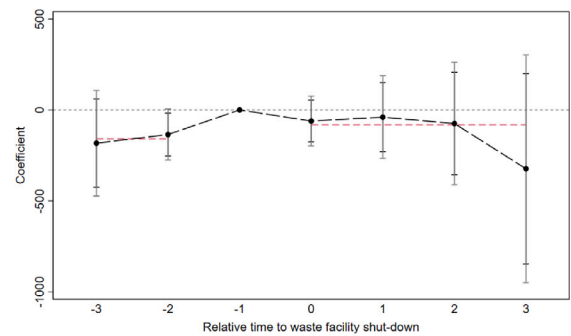


Fig. A.1. Difference in year of closure between waste and extraction facilities.

Note: Proportion of municipalities where both a waste facility and an extraction facility are present, by difference in the year of closure between the waste facility and the extraction site.



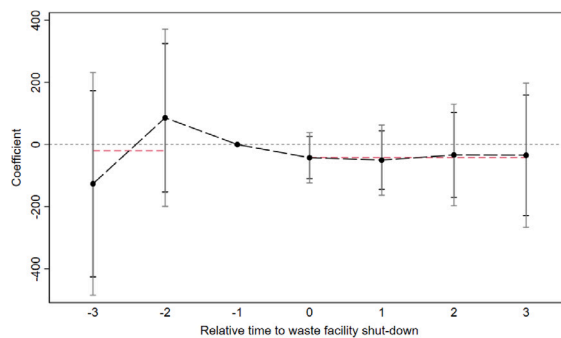
(a) High risk



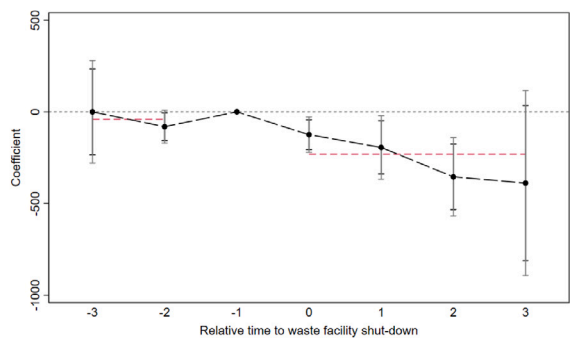
(b) Standard risk

Fig. A.2. Effect of waste facility closures on mortality by hazardousness.

Note: Effect on the overall death rate per 100,000 inhabitants. Treatment subgroups are defined based on the hazard risk (high and standard). Regressions include municipality, decade, and region-decade fixed effects and control for the closure of an extraction site. The sample includes municipalities with waste facilities, those with mineral extraction but no waste facilities, and their neighbors. Standard errors are estimated using 50 bootstrap replications clustered at the municipality level. Confidence intervals are shown at 95 and 99 percent level.



(a) Open-air



(b) Underground

Fig. A.3. Effect of waste facility closures on mortality by type of facility.

Note: Effect on the overall death rate per 100,000 inhabitants. Treatment subgroups are defined based on the location of the facility (open-air or underground). Regressions include municipality, decade, and region-decade fixed effects and control for the closure of an extraction site. The sample includes municipalities with waste facilities, those with mineral extraction but no waste facilities, and their neighbors. Standard errors are estimated using 50 bootstrap replications clustered at the municipality level. Confidence intervals are shown at 95 and 99 percent level.

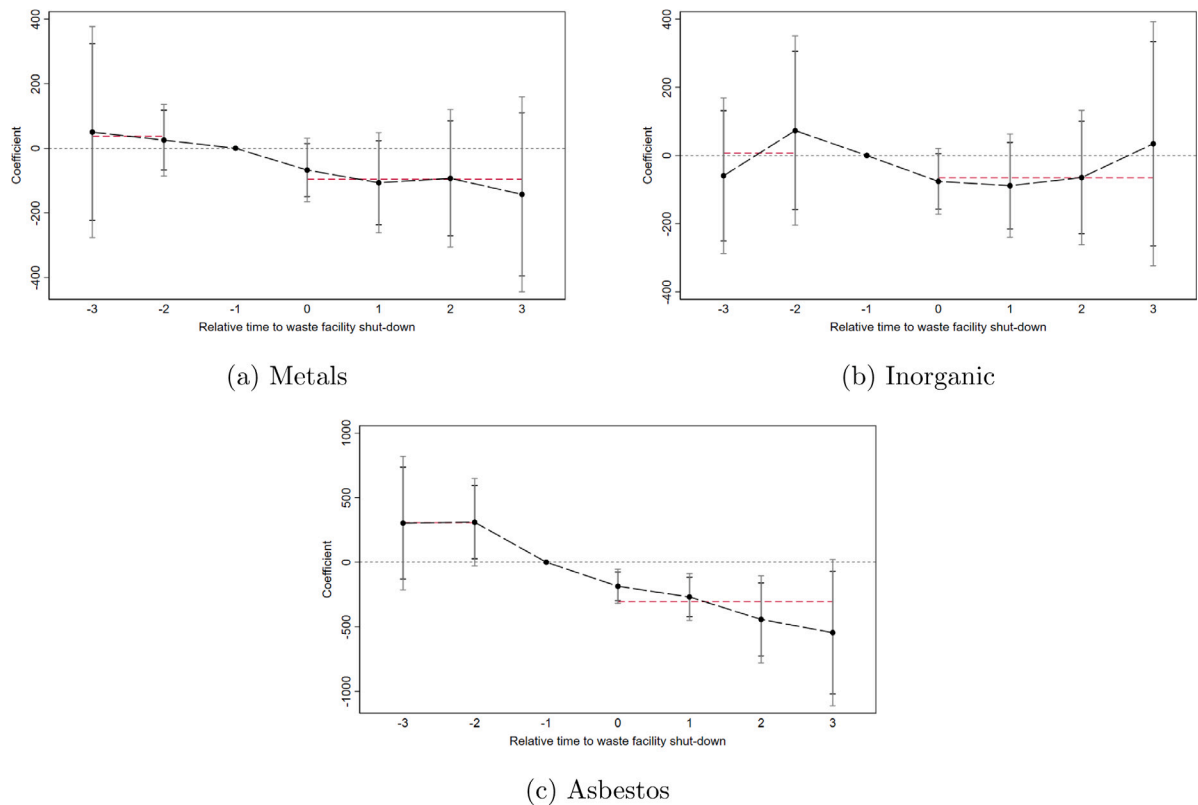


Fig. A.4. Effect of waste facility closures on mortality, by type of waste.

Note: Effect on the overall death rate per 100,000 inhabitants. Treatment subgroups are defined based on the type of waste treated and stored (metals, inorganic, or asbestos). Regressions include municipality, decade, and region-decade fixed effects and control for the closure of an extraction site. The sample includes municipalities with waste facilities, those with mineral extraction but no waste facilities, and their neighbors. Standard errors are estimated using 50 bootstrap replications clustered at the municipality level. Confidence intervals are shown at 95 and 99 percent level.

We also question whether the drop in overall mortality due to the closure of waste facilities can be attributed to specific subgroups of the population. In Table 3, we consider mortality separately by gender and age. The reported coefficients in columns 1 and 2 reveal that mortality decreases significantly for both males (by 10%) and females (by 17%). The effect on the female subpopulation is larger in magnitude compared with that of males, who are disproportionally employed in the mining industry. This points to a general improvement in environmental quality following the closure of a waste facility, and thus in the overall health conditions of the population, rather than a mere reduction in exposure to contaminating substances in the workplace. Fig. A.8 confirms the validity of these estimates. In both cases, the event-study analysis suggests the absence of pre-existing trends, given that the coefficients associated with the pre-treatment period are very small in magnitude and never statistically different from zero. At the same time, the post-treatment coefficients denote an increasingly negative effect on mortality for both female and male residents.

Last, in columns 3 to 5 we analyze heterogeneous effects based on three age groups: individuals aged up to 19 years of age, those aged between 20–64, which proxy the working population, and the elderly (aged 65 or above). Results imply an overall improvement in the health conditions of adults in particular. The working-age (20–64) and retirement-age (above 65) subpopulations both display a significant decrease in the number of deaths per 100,000 inhabitants, corresponding to a drop of around 23% and 11% with respect to the corresponding mean. The magnitude is consistent with the latter group of individuals being exposed to mining waste contamination for a longer period during their lifetime, compared to the former group. For the youngest age group, a waste facility closure implies a 50% decrease in mortality, although this is imprecisely estimated. This suggests the possible existence of intergenerational health effects (Aizer and Currie, 2014), as these individuals were born after the decommissioning of the waste facility and the reclaiming of the surrounding environment.²² As in the previous distinction by gender, the event-study analysis referring to mortality by age supports the common trends assumption (i.e., the coefficients referring to the pre-treatment decades are not different from zero) and the effect in the post-treatment period is persistent over time (Fig. A.9). Overall, the robustness

²² This is also consistent with the large, negative, but imprecisely estimated coefficients reported in columns 6 and 7 of panel (b), Table A.1, which imply a reduction in deaths from congenital anomalies and from certain conditions originating in the perinatal period.

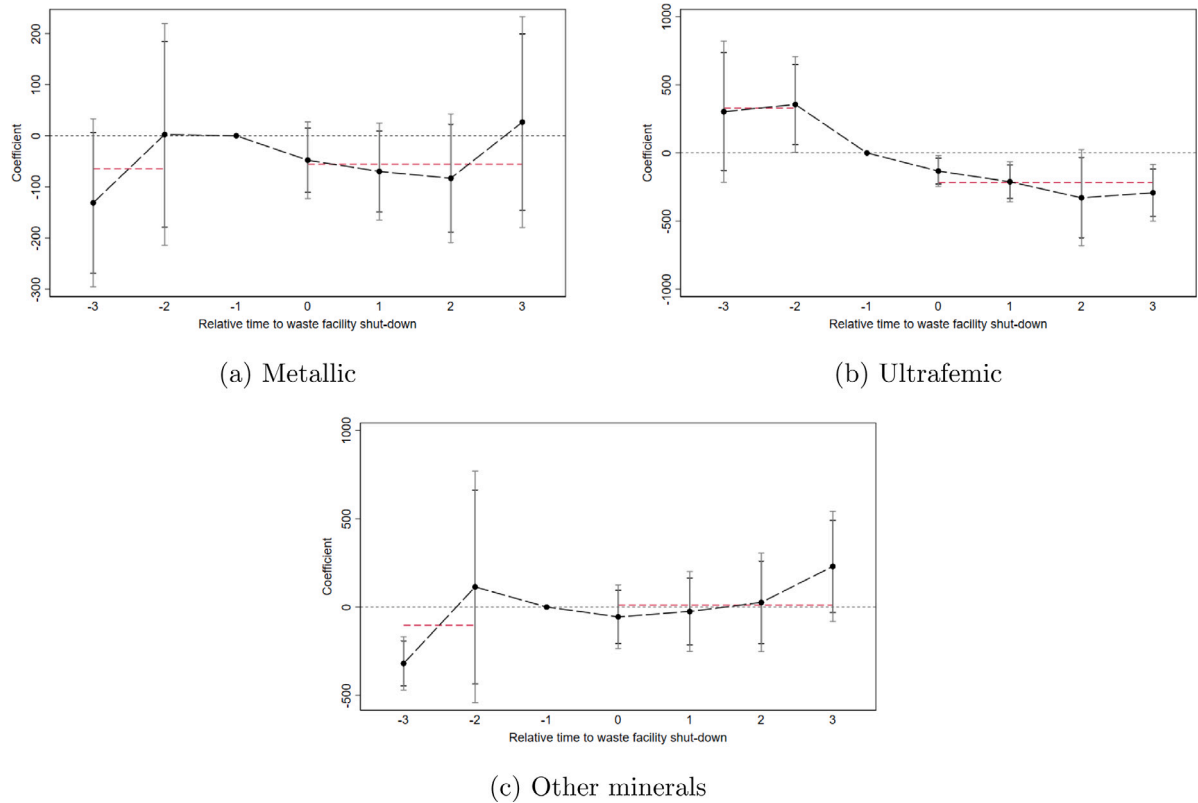


Fig. A.5. Effect of waste facility closures on mortality, by type of mineral.

Note: Effect on the overall death rate per 100,000 inhabitants. Treatment subgroups are defined based on the type of mineral extracted (metallic, ultrafemic, and other minerals used in industries, salts and fossil fuels). Regressions include municipality, decade, and region-decade fixed effects and control for the closure of an extraction site. The sample includes municipalities with waste facilities, those with mineral extraction but no waste facilities, and their neighbors. Standard errors are estimated using 50 bootstrap replications clustered at the municipality level. Confidence intervals are shown at 95 and 99 percent level.

of the estimated effect and the absence of pre-existing trends within each sub-group supports the causal interpretation of our main results.²³

3.3. The health–wealth trade-off

The health–wealth trade-off implies that the presence of mining activities can have two conflicting effects. On the one hand, these may foster industrial development and employment, thus improving well-being via wealth effects. On the other hand, the extraction and processing of minerals produce large amounts of mineral waste and pollutants, which can jeopardize the quality of the environment and the health of the resident population, leading to deteriorated living standards.

However, the closure of waste facilities and mining extraction sites may benefit local communities via positive health effects, thanks to the interruption of activities and the reclamation of the areas where they took place. At the same time, the cessation of such activities is likely to yield negative wealth effects due to local shocks to the industrial structure and the labor market. Whether positive health effects or negative wealth effects dominate is the empirical question that we address in this paper. The results presented so far point to the preeminence of health effects, as the drop in mortality following the closure of a waste facility can be viewed as net of changes in income. In this section, we assess the consistency of this result with regard to additional socio-economic outcomes. The richness of our data also allows us to distinguish this relationship separately for the closure of waste facilities and the shutting down of extraction sites.

In Table 4, we compare the effects of closing down waste facilities and extraction sites on mortality and socio-economic indicators (i.e., education and labor market outcomes). To maximize comparability across units, we only consider municipalities that are

²³ Figure OA.9 shows an additional heterogeneity analysis based on local healthcare accessibility. We compute the minimum distance from the closest health clinic, either public or private, for any given municipality in 2014. Then, we split the sample into two groups of municipalities: above and below the median of the overall distribution (20 km). We find that the drop in mortality is concentrated in locations that are closer to health clinics. This evidence may indicate that the benefits from decontamination are possibly enhanced by proximity to health care services, thanks to, e.g., easier access to screenings and early treatments.

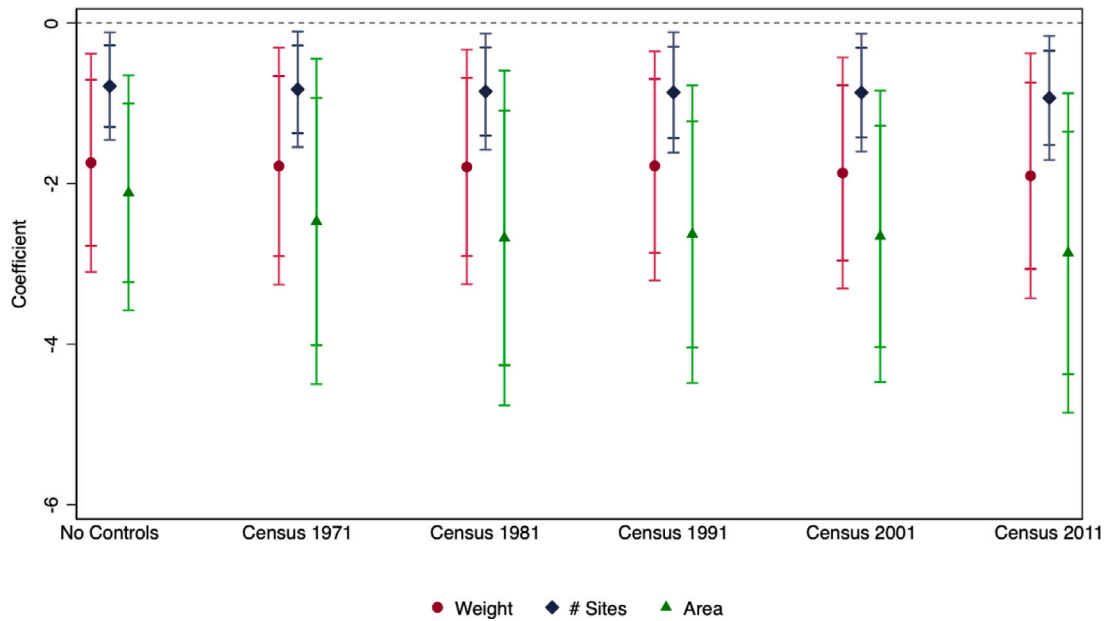


Fig. A.6. Current exposure to asbestos.

Note: Coefficients and corresponding 95 and 99 percent confidence intervals associated with PPML regressions where the dependent variables are weight in kg (red circles), the number of sites (blue diamonds), and the total area contaminated with asbestos in m^2 (green triangles). The independent variable is a dummy equal to one for municipalities that have ever hosted a waste treatment facility and zero for municipalities that have ever hosted an extraction site *but not* a waste treatment facility. Regressions are estimated without control variables and with control variables (total population, population density, share of elderly, labor market participation rate, and employment rate) drawn from different census waves, respectively. Standard errors are clustered at municipality level. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

specialized in mining activities. Hence, we compare the performance of municipalities hosting a mining extraction site *and* a waste facility *vis-à-vis* similar municipalities where an extraction site but no waste facility is located.²⁴

In panel (a), we analyze the impact of closing a waste facility on overall mortality and on education and labor market outcomes. As column 1 shows, the coefficient associated with mortality is negative and significant.²⁵ Column 2 indicates a reduction in the share of illiterates, while columns 3–6 report the effect on labor market participation and employment. The impact on employment is asymmetric across genders: municipalities undergoing the closure of a waste facility witness an increase of 1 percentage point in the employment rate of males (around 2%) in comparison to counterfactual municipalities, while the coefficient for the female employment rate is positive but not significant.²⁶ Overall, the drop in mortality and the improvements in the educational investment and labor market performance of males point to positive health effects dominating negative wealth effects following the closure of a waste facility.

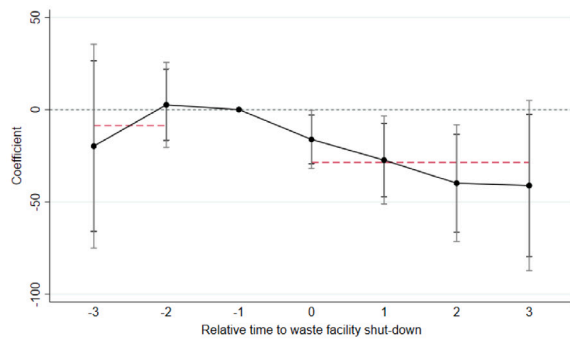
In panel (b), we consider the impact of closing extraction sites where waste facilities are not present. Here, the amount of hazardous mining waste stored is relatively negligible, as reported in Fig. 2. Thus, we would expect the potential gains from restored environmental quality to be substantially less important in comparison to cases where a waste facility is shut down and reclaimed. Indeed, we do not find evidence of improvements in terms of the overall mortality rate. If anything, the coefficient implies a mild increase, consistent with a weak dominance of negative wealth effects, as estimated by Boslett and Hill (2022) using US data. Similarly, the share of illiterates and labor market performance are hardly affected, as coefficients are positive but not statistically different from zero.

Overall, the evidence suggests the existence of sizable gains in living standards for local communities that experience the closure of mining waste facilities, as mortality and other socio-economic outcomes improve. However, the closure of extraction sites alone does not appear to yield similar benefits for resident populations. This may be due to limited health effects and, possibly, the counteracting impacts of relatively stronger negative wealth effects.

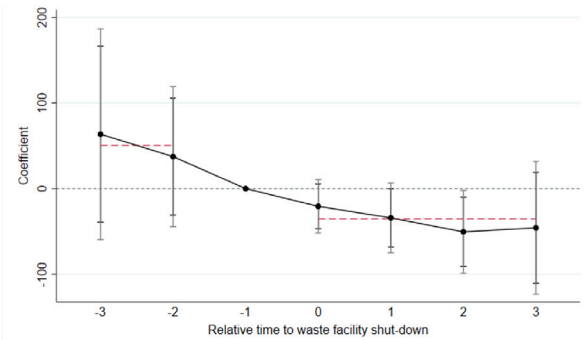
²⁴ In doing so, we drop the subsample of adjacent municipalities, which may have very different economic and industrial structures given that they do not host a mining site. Yet, if we include this subsample in the analysis the results are very similar.

²⁵ This coefficient corresponds to the event-study analysis in Figure OA.2.

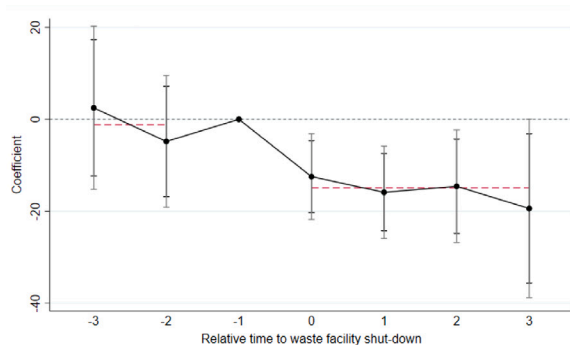
²⁶ Note that the rise in male employment is unlikely to be attributable to the surge in demand for remediation, as the effect is persistent and sizable.



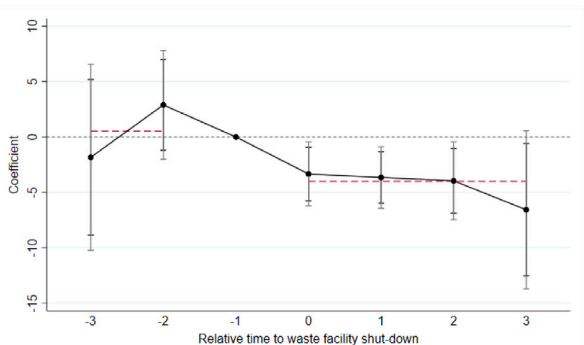
(a) Neoplasms



(b) Diseases of the circulatory system



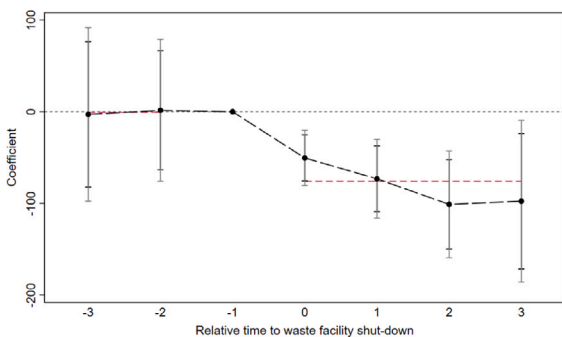
(c) Diseases of the digestive system



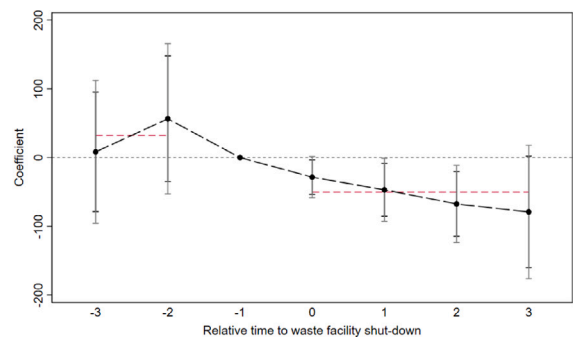
(d) Diseases of the genitourinary system

Fig. A.7. Effect of waste facility closures on mortality by cause of death.

Note: Effect on the death rate per 100,000 inhabitants by cause of death. Regressions include municipality, decade, and region-decade fixed effects and control for the closure of an extraction site. The sample includes municipalities with waste facilities, those with mineral extraction but no waste facilities, and their neighbors. Standard errors are estimated using 50 bootstrap replications clustered at the municipality level. Confidence intervals are shown at the 95 and 99 percent level.



(a) Female



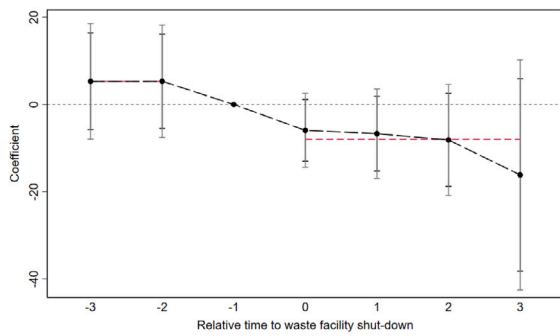
(b) Male

Fig. A.8. Effect of waste facility closures on mortality by gender.

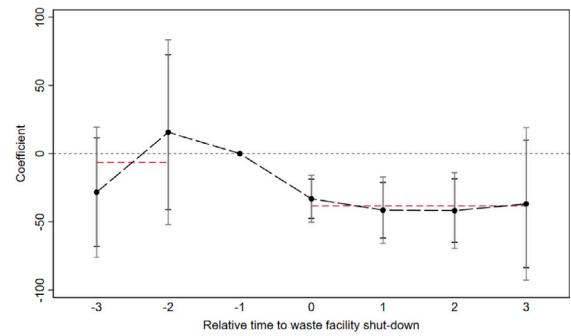
Note: Effect on the death rate per 100,000 inhabitants by gender. Regressions include municipality, decade, and region-decade fixed effects and control for the closure of an extraction site. The sample includes municipalities with waste facilities, those with mineral extraction but no waste facilities, and their neighbors. Standard errors are estimated using 50 bootstrap replications clustered at the municipality level. Confidence intervals are shown at the 95 and 99 percent level.

4. Conclusions

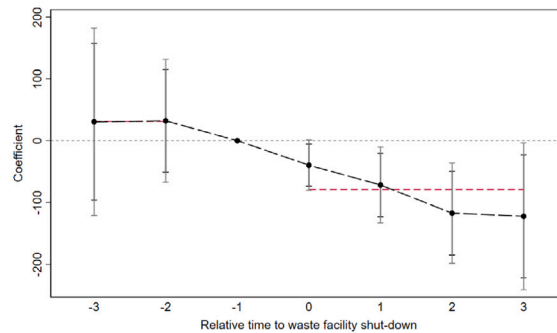
The European Green Deal foresees a gradual phasing out of the exploitation and extraction of natural resources. However, this process is currently at risk of being delayed due to economical and politically strategic reasons. This raises concerns about local communities being further exposed to mining extraction and mining waste treatment activities, not only in Europe but also



(a) Age 0-19



(b) Age 20-64



(c) Age 65+

Fig. A.9. Effect of waste facility closures on mortality by age.

Note: Effect on the death rate per 100,000 inhabitants by age group. Regressions include municipality, decade, and region-decade fixed effects and control for the closure of an extraction site. The sample includes municipalities with waste facilities, those with mineral extraction but no waste facilities, and their neighbors. Standard errors are estimated using 50 bootstrap replications clustered at the municipality level. Confidence intervals are shown at 95 and 99 percent level.

in emerging countries, where the mining sector is constantly expanding following the rise in the global demand for metals and minerals (De Haas and Poelhekke, 2019). Indeed, the mining industry produces billions of tons of waste annually (Carmo et al., 2020; Eurostat, 2020). Mining waste consists of minerals and chemically hazardous substances that can have disastrous and long-lasting consequences on the environment surrounding the facilities that process and store these materials and on the living standards of the population residing in the vicinity.

While the overall impact of mining activities on local communities has been analyzed in previous literature, there is scant evidence regarding the specific role of the presence of mining waste, partly due to a lack of suitable data. This research fills this gap by providing well-identified evidence on the long-term impact of shutting down mining waste facilities on mortality and on other socio-economic outcomes at the local level. Given that information on soil and water contamination referring to pre-2000 years is largely unavailable, we consider the mortality of the resident population as a proxy for environmental quality. Thanks to a rich dataset, we can assess long-term effects spanning over five decades and discuss these in terms of the health-wealth trade-off.

We estimate that the closure of waste facilities determines a substantial drop in mortality for the resident population by 126 deaths per 100,000 inhabitants per decade (i.e., almost 15%), particularly due to a reduction in deaths caused by neoplasms and diseases of the circulatory, genitourinary, and digestive systems. The impact is homogeneous across genders and age groups of the residing population. We also find that the effect varies depending on the hazard risk associated with the characteristics of these facilities and the materials hosted therein. In particular, the decrease in mortality is more pronounced after the shutting down of waste facilities classified as high-risk and those located underground. Moreover, the decrease in mortality is particularly appreciable in the case of sites handling and stocking asbestos. These results suggest that the closure and reclamation of waste facilities yields an improvement in the environmental quality of surrounding areas, thus benefiting the health of the resident population, and that the impact is particularly noticeable when severely hazardous sites are shut down.

At the same time, the closure of a waste facility does not seem to worsen socio-economic outcomes such as labor market performance and literacy at the local level. We detect a positive response in terms of literacy and male employment in municipalities experiencing a closure in comparison to untreated locations. We argue that this might be due to the reallocation of male workers from the mining industry to other sectors, in combination with a potentially increased employability ascribable to the improved health conditions of the population. Importantly, we do not observe changes in the resident population, which suggests the absence of migration effects.

Our results are especially relevant as they demonstrate the existence of substantial gains from eradicating severely polluting activities linked to the treatment and storage of mining waste. The sizable reduction in mortality and the (albeit weak) improvement in employment outcomes suggest that positive health effects dominate negative wealth effects. In this context, decommissioning mining waste facilities may contribute to reducing social and health inequalities, as adverse effects from environmental contamination are likely to disproportionately hit vulnerable groups. The results are less clear-cut when we consider shutting down extraction sites only, i.e., not in combination with the closure of mining waste treatment and storage facilities.

Appendix A. Tables and figures

See Table A.1.

See Figs. A.1–A.9.

Appendix B. Supplementary data

Supplementary material related to this article can be found online at <https://doi.org/10.1016/j.jeem.2023.102797>.

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