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The Mafia–Cancer Nexus: Evidence from the Land of Fires

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Abstract

This paper studies the relationship between mafia-driven illegal waste disposal and cancer mortality in the Land of Fires (Campania, Italy). We assemble a new municipality-level dataset combining standardized cancer mortality rates with georeferenced contaminated sites. To address the non-random spatial distribution of waste disposal, we use variation in criminal infiltration -captured by a Mafia Presence Index - as an instrument for environmental exposure. Municipalities with stronger mafia presence exhibit a higher concentration of contaminated sites, and the resulting two-stage least squares estimates point to a substantial association between waste-related contamination and cancer mortality. Effects are particularly pronounced for environmentally mediated cancers (lung, larynx, stomach, bladder, kidney), consistent with epidemiological evidence for the region. A series of robustness analyses, including placebo outcomes, sensitivity analysis and alternative exposure measures, reinforce the interpretation of these results.

JEL classification: P35, I18, Q53

Keywords: Environmental crime, Cancer mortality, Illegal waste disposal, Organized crime

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1 Introduction

Over the past three decades, the Land of Fires in Southern Italy has become emblematic of the intersection between organized crime, environmental degradation, and public health (Bianchi et al., 2004; Nature Editorial, 2014; Senior & Mazza, 2004). Numerous reports by parliamentary commissions and environmental agencies have documented the illegal disposal of hazardous industrial waste by mafia-type organizations, particularly Camorra clans, in the provinces of Naples and Caserta (Italian Parliament, 1998, 2013, 2018; Italian Senate, 2017). Yet, despite mounting evidence of excess mortality and widespread contamination, the causal link between organized crime and adverse health outcomes has remained elusive. Official institutions long attributed excess cancer mortality to lifestyle factors rather than to environmental exposure (e.g. Greco, 2016; Sannino, 2014), a position that was facilitated by the fact that the scientific literature remained predominantly epidemiological and correlational in nature (e.g. Alberti, 2022; Triassi et al., 2015).

This paper provides the first systematic econometric evidence of a causal relationship between mafia infiltration and cancer mortality, operating through illegal waste disposal. We develop an identification strategy that explicitly accounts for the endogenous nature of environmental contamination in the Land of Fires. Our empirical approach combines epidemiological data on cancer mortality with georeferenced information on potentially contaminated sites across 550 municipalities in Campania. To address endogeneity concerns, we exploit exogenous variation in mafia presence as an instrument for illegal waste exposure. The underlying idea agrees with the evidence that mafia-type organizations have historically specialized in the management of illegal waste flows, thereby generating spatial variation in contamination that is plausibly unrelated to other socio-economic determinants of health.

The instrumental variable employed in this study — the Mafia Presence Index (MPI) — aggregates multiple signals of organized crime activity. Specifically, it incorporates the number of confiscated assets and firms, together with the dissolution of municipal councils under Italian law due to documented mafia infiltration (detailed information is provided in the Supplementary Information, SI from now on). By leveraging this index within a two-stage least squares (2SLS) framework, we estimate the causal impact of mafia-driven environmental exposure on cancer mortality. A key concern in a cross-sectional setting is whether the Mafia Presence Index (MPI) captures long-standing patterns of criminal infiltration rather than short-run variation that may correlate with unobserved determinants of health. Although the MPI is measured contemporaneously with the registry of contaminated sites, its underlying components—such as confiscated assets, repeated law-enforcement interventions, and documented episodes of municipal council dissolution—reflect persistent and historically rooted forms of criminal control rather than transitory shocks. In particular, confiscated assets represent the culmination of lengthy judicial processes and typically reveal criminal penetration that predates their official registration by many years. As such, the MPI proxies deep, long-run mafia settlement patterns rather than contemporaneous socio-economic conditions that could directly affect cancer mortality. This interpretation is especially plausible in the institutional context of Campania, where mafia presence exhibits strong temporal inertia and where criminal organizations established territorial control well before the expansion of illegal waste trafficking during the 1980s and 1990s. Accordingly, cross-municipal variation in the MPI captures pre-existing criminal settlement patterns that facilitated the emergence and concentration of illegal waste disposal sites, rather than reflecting short-term socio-economic differences across municipalities. Combined with extensive municipal-level controls and province fixed effects, this feature of the MPI strengthens the credibility of our identification strategy in a cross-sectional setting.

Our results reveal a strong and robust effect: municipalities with higher exposure to illegal waste driven by organized crime experience significantly higher relative risks of cancer mortality. Because the distribution of contaminated sites is extremely skewed - most municipalities host zero or very few sites, while a smaller set forms true "clusters" with several dozen or even hundreds of sites - the health impact is best understood in terms of these large, spatially concentrated jumps in exposure rather than marginal changes. The IV estimates indicate that moving from a municipality with negligible environmental exposure to one characterized by the average cluster intensity -approximately 62 contaminated sites within a 5 km radius -increases the relative risk of cancer mortality by about 6.3 percentage points, corresponding to roughly a 7% increase relative to the regional mean. Overall, our estimates suggest that cancer mortality risk is between 7 and 12% higher in highly contaminated municipalities. These estimates are comparable in magnitude to established socio-economic determinants of health, underscoring that environmental crime constitutes a major source of population health inequality. Moreover, they indicate that the health burden is driven by the presence of concentrated clusters of illegal waste sites rather than by small, incremental increases in exposure: once a municipality falls within a cluster area, the associated increase in cancer mortality becomes both economically and epidemiologically meaningful.

We are aware that the validity of our identification strategy rests on the assumption that mafia infiltration affects cancer mortality only through illegal waste disposal. While this exclusion restriction cannot be tested directly in a cross-sectional setting, we address this concern through a combination of rich controls and an extensive battery of robustness and falsification exercises. First, we include a comprehensive set of socio-economic and demographic covariates, together with province fixed effects, to account for observable sources of heterogeneity across municipalities. In addition, our results are robust to the inclusion of a Deprivation Index - commonly regarded as a reliable proxy for the overall health status of a population (Alberti, 2022) - as well as to variables explicitly capturing lifestyle-related confounders at the municipal level, such as smoking, alcohol consumption, and obesity. This control, important but largely neglected in the literature so far (e.g. Triassi et al., 2015), is captured by myocardial infarction mortality. The rationale is that the behavioural determinants of cardiovascular diseases largely overlap with those responsible for lifestyle-related cancers (e.g. Jaiswal et al., 2023; Meijers & de Boer, 2019). Hence, by controlling for municipal-level variation in myocardial infarction mortality, we indirectly account for behavioural factors — such as diet, smoking, and alcohol abuse — that are typically associated with individual responsibility in cancer mortality. Beyond covariate adjustment, we subject our findings to a wide range of robustness and falsification tests. These include placebo outcome tests using mortality causes unrelated to environmental contamination; alternative spatial definitions of environmental exposure; sample restrictions to the historical core of the Land of Fires (the provinces of Naples and Caserta); falsification exercises focusing on municipalities with no documented contaminated sites; and specifications that explicitly control for the institutional components of the Mafia Presence Index, such as municipal council dissolution and confiscated assets. Finally, we assess the sensitivity of our IV estimates to plausible violations of the exclusion restriction using the framework proposed by Conley, Hansen, and Rossi (2012). Across all these checks, the results remain stable, lending strong support to a causal interpretation of the relationship between mafia-driven illegal waste disposal and excess cancer mortality.

The paper contributes to three strands of literature. First, it connects research on health and the economics of crime by identifying a new channel through which organized crime affects welfare, namely environmental contamination. Second, it complements the epidemiological evidence on the Land of Fires with a rigorous causal analysis based on econometric identification. Third, it informs the growing literature on institutional quality and public health, showing that weak governance and criminal capture can translate into measurable mortality costs. The remainder of the paper is organized as follows. Section 2 reviews the institutional background and related literature. Section 3 describes the data and variable construction. Section 4 outlines the empirical strategy. Section 5 presents the main results, while Section 6 discusses robustness checks. Section 7 concludes with implications for environmental policy, health governance, and anti-mafia interventions.

2 Institutional background and related literature

2.1 Institutional background

The Land of Fires (Terra dei Fuochi) refers to a densely populated area between the provinces of Naples and Caserta in the Campania region of Southern Italy. Since the 1980s, this territory has been at the center of illegal waste trafficking managed by Camorra clans, mafia-type organizations deeply embedded in local economies and politics. Through collusion with firms operating in Northern Italy seeking to avoid the high costs of legal disposal, these groups orchestrated the burial and open-air burning of millions of tons of hazardous industrial waste in agricultural and peri-urban areas. Official parliamentary inquiries, beginning in 1995, documented the extensive role of organized crime in the waste sector and its long-term environmental consequences. Despite this, Italian health authorities for years denied any causal link between waste exposure and excess mortality, attributing regional health disparities primarily to behavioral risk factors. In 2025, the European Court of Human Rights (ECHR) ruled in Cannavacciuolo and Others v. Italy that the Italian government had failed to protect residents from the health risks of uncontrolled waste disposal and burning. This judgment marked a turning point in institutional recognition of the problem, confirming what decades of investigative reporting and local activism had long argued: environmental degradation in the Land of Fires is not an accidental by-product of poor regulation, but a direct outcome of organized criminal governance and state neglect. Defining the boundaries of the Land of Fires, however, remains controversial. Different agencies — including the Ministry of Health, the National Institute of Health (ISS), and the regional environmental protection agency (ARPAC) — have identified varying sets of municipalities affected by illegal waste disposal. The absence of a clear criterion for delineation has hindered consistent epidemiological monitoring and policy targeting. This ambiguity motivates our approach: rather than relying on arbitrary geographical definitions, we use the spatial distribution of mafia infiltration as an evidence-based criterion to define exposure.

2.2 Related literature

Although journalistic investigations (Capacchione, 2008; Iovene, 2008; Saviano, 2008) and law enforcement inquiries (European Court of Human Rights, 2025) have long documented the role of organized crime in driving environmental degradation in the Campania region, the scientific literature has remained predominantly epidemiological in nature (Alberti, 2022; Bianchi et al., 2004; Fazzo et al., 2023; Martuzzi et al., 2009; Senior & Mazza, 2004; Triassi et al., 2015). In general, existing studies have mainly attempted to establish correlations between environmental contamination and cancer mortality, without investigating the social mechanisms underlying this association. The national SENTIERI project, for instance, identified significant excesses in several diseases consistent with environmental contamination, but deliberately refrained from inferring causality, citing potential confounding factors and emphasizing that its design was not intended for causal inference (Musmeci et al., 2015). Likewise, many biomonitoring studies have struggled to provide convincing causal evidence, both because of the limited number of subjects examined and the insufficient control for confounding variables (Barba et al., 2011; De Felice et al., 2012; Forte et al., 2020; Rivezzi et al., 2013; Triassi et al., 2015). In so doing the causal pathway linking the presence of mafia type organizations to cancer mortality through illegal waste disposal has remained unexplored (Nature Editorial, 2014). Addressing this gap is crucial for two main reasons. First, it would provide a clear and consistent criterion for identifying the so-called Land of Fires, that is, the area to be monitored for the health consequences arising from environmental damage caused by the activities of criminal organizations. In the absence of such a criterion, competing boundaries — involving different sets of municipalities — have been proposed. In 2014, the Ministry of Health designated 39 municipalities, later extended to 41. A joint study by the Italian National Institute of Health and the Prosecutor's Office of Naples North focused on 38 municipalities in the provinces of Naples and Caserta, indicating that the Land of

Fires was partially included within this area (Fazzo et al., 2023). The SENTIERI project considered 55 (later 77) municipalities, while other works adopted alternative delimitations (Triassi et al., 2015). The problem is that the Land of Fires is not a naturally given entity but a contested and politically constructed category. In the absence of a clear criterion, the delimitation of the analysis becomes inherently ambiguous. Second, the mere presence of waste disposal sites does not necessarily cause excess cancer mortality. What matters is the existence of illegal sites, often used to dump hazardous industrial waste that bypasses costly legal disposal procedures (European Court of Human Rights, 2025), thereby posing a serious threat to public health.

Existing epidemiological studies typically treat environmental contamination as exogenous, whereas in reality it is endogenously shaped by organized crime. Our identification strategy explicitly builds on this observation. In particular, we use the intensity of mafia presence as an instrument for the number of illegal waste sites. The underlying rationale is that mafia-type organizations have long facilitated the illegal disposal of urban and industrial waste (Italian Parliament, 2013), thereby generating exogenous variation in environmental exposure across municipalities. This strategy provides an evidence-based criterion for delineating the Land of Fires: not through ad hoc definitions, but through the territorial footprint of mafia clans, which have historically driven environmental contamination. In so doing, we add to the large body of research on the health effects of environmental pollution. Classic studies have examined how exposure to hazardous waste, air pollutants, or industrial emissions affects morbidity and mortality. However, most of this literature treats pollution as exogenous, often overlooking the social and institutional mechanisms that generate environmental risk. In the context of Southern Italy, epidemiological projects such as SENTIERI have documented excess mortality from cancer and congenital anomalies in contaminated areas, but explicitly refrained from causal inference due to data and design limitations.

We also contribute to the economics of crime and governance. A growing literature shows that organized crime distorts resource allocation, reduces investment, and undermines institutional quality. Empirical work has documented the effects of mafia infiltration on entrepreneurship, public procurement and fiscal capacity (e.g. Mirenda et al., 2022). Yet, little is known about the health costs of organized crime. By focusing on environmental contamination as a transmission channel, we extend the analysis of criminal externalities from economic to public health outcomes.

Finally, our work relates to research on institutional quality and public health. Recent evidence from both developed and developing countries suggests that weak governance and corruption are linked to poorer health outcomes through underinvestment in prevention and regulatory enforcement (Achim et al., 2020; Holmberg & Rothstein, 2011). We show that when criminal organizations capture environmental governance, the consequences are measurable in population mortality. In this sense, our paper bridges the economics of health and the political economy of crime, highlighting how institutional failures can manifest as an environmental and epidemiological crisis.

Taken together, this institutional and theoretical background motivates our empirical analysis. We interpret mafia-driven illegal waste disposal as a quasi-natural experiment in environmental governance failure, generating spatially heterogeneous exposure to contamination across municipalities. In the next section, we describe the data sources and the construction of the key variables used to test this hypothesis.

3 Data and variables

3.1 Data sources

The empirical analysis combines multiple administrative and institutional data sources at the municipal level for the 550 municipalities of the Campania region. The dependent variable is the Relative Risk (RR) of mortality from malignant tumors, constructed from the *Atlante della Mortalità della Regione Campania*. The *Atlante* provides Standardized Mortality Ratios (SMRs) by municipality, gender, and cause of death over the period 2006–2014. These ratios are produced through indirect age standardization: for each municipality, observed deaths from malignant tumors are divided by expected deaths computed using regional age-specific mortality rates, and the resulting value is multiplied by 100. The RR therefore measures excess mortality net of demographic composition, with values above 100 indicating mortality higher than expected given the regional baseline. For the main analysis, we use the pooled RR, obtained by averaging male and female SMRs, while gender specific RRs and cancer-site specific RRs are employed for robustness checks and heterogeneous effects.

Environmental exposure is captured using the official registry of potentially contaminated sites maintained by the regional environmental protection agency (ARPAC). This registry contains georeferenced information on a broad set of areas identified as environmentally critical, including illegal waste dumping sites, informal landfills, open-air burning zones, industrial residues, polluted soils and brownfields, as well as sites under investigation for possible contamination. For each site, ARPAC provides precise GPS coordinates and descriptive attributes on the source and type of contamination. We spatially link the coordinates to municipal centroids and count the number of sites within circular buffers of 5 km around each centroid, an approach that approximates short-range exposure to illegal waste activities and aligns with the average spatial scale of municipalities in Campania. To assess the robustness of our results to alternative definitions of spatial proximity, we also reconstruct exposure using 10 km and 20 km radii. The distribution of contaminated sites is extremely skewed: while the median municipality hosts only two sites within 5 km, the mean is 62 and the maximum exceeds 700, highlighting the presence of a limited number of municipalities that form dense clusters of environmental risk.

Given the endogenous nature of environmental exposure, we instrument the number of contaminated sites with an index capturing the territorial presence of organized crime. This indicator, the Mafia Presence Index (MPI), follows the methodology proposed by Dugato et al. (2020) and aggregates two administrative signals. The first is whether a municipality has experienced dissolution of its local council under Law 164/1991 due to organized-crime infiltration. Council dissolution represents an extreme institutional remedy imposed by the Ministry of the Interior and signals direct interference of criminal groups in local administrative processes, including procurement, waste management and public service provision. The second component is the number of real estate assets, firms, and land parcels confiscated from organized crime following final judicial convictions, drawn from the registry of the National Agency for Confiscated Assets (ANBSC) and normalized by population size. These confiscations capture long-term and structural forms of criminal influence that remain even when institutional control does not reach the threshold required for council dissolution. Both components are normalized to a 0–100 scale, standardized, and then averaged to obtain a composite index that varies widely across municipalities (mean 27, standard deviation 26). The full construction of the MPI, including normalization steps, population weights and descriptive distributions, is documented in the SI.

To reduce confounding, the regressions include a rich set of demographic, socio-economic and behavioural controls. These include average age and its square, population density, the share of households with more than three members, firm density, per-capita GDP, and the share of residents without primary education, which proxies long-term deprivation. An important behavioural control is the municipal mortality rate from myocardial infarction, which serves as a proxy for lifestyle-related risk factors - such as smoking, diet and alcohol consumption - that influence both cardiovascular disease and cancer. Variable definitions and data sources are provided in the Appendix (Table A.1).

Together, these sources yield a comprehensive dataset that links standardized health outcomes, geospatial measures of environmental exposure, institutional and economic indicators of organized crime infiltration, and an extensive set of socio-demographic controls.

3.2 Descriptive statistics

Table A.2 in the Appendix highlights the substantial heterogeneity that characterizes municipalities across Campania. The relative risk (RR) of mortality from malignant tumors, our core outcome variable, averages 89.2, with a range extending from roughly 71 to more than 130. This dispersion remains even after indirect standardization, reflecting persistent spatial inequalities in cancer mortality across the region. Disaggregated values show that men experience slightly higher risk (mean RR of 90.5) than women (88.0), consistent with broader epidemiological patterns. Importantly, these descriptive patterns already indicate that excess cancer mortality is not uniformly distributed but instead exhibits strong territorial concentration.

The variables capturing environmental exposure reveal even more striking spatial asymmetries. Although the median municipality hosts only two potentially contaminated sites within a 5 km radius, the mean rises to 62, and in extreme cases municipalities exhibit over 700 sites. This highly right-skewed distribution suggests that only a subset of municipalities faces an environmental burden of exceptional magnitude, while large portions of the region have relatively limited exposure. Expanding the radius to 10 or 20 km naturally increases the number of sites, but the same pattern persists: a small number of localities lie at the centre of large clusters of potentially contaminated sites, matching well-known descriptions of the ”Land of Fires” as an area characterized by environmental hotspots rather than diffuse, uniformly distributed contamination.

These spatial patterns become visually apparent in Figure 1, which maps both the location of potentially contaminated sites and the spatial distribution of excess cancer mortality. The map shows that municipalities with the highest concentration of contaminated sites form dense clusters primarily in northern Naples and southern Caserta, the historical core of illegal waste disposal activities. These same municipalities are those in which cancer mortality exceeds regional expectations most substantially. Conversely, inland and southern municipalities, particularly those in mountainous or less densely populated areas, display far fewer contaminated sites and correspondingly lower cancer mortality. The alignment between environmental exposure and adverse health outcomes is evident even before formal econometric analysis: the most heavily contaminated territories are also those facing the most severe epidemiological burden.

Turning to the institutional dimension, the Mafia Presence Index (MPI) exhibits substantial variation, with a mean of 27 and a standard deviation of 26 on a 0–100 scale, indicating that mafia infiltration is far from uniform across the region. Some municipalities show no detectable signals of criminal activity, while others reach the upper bound of the index, reflecting a deep and persistent presence of organized crime within local administrative and economic structures.

Figure 2 illustrates the spatial distribution of the MPI and reveals a pattern that closely mirrors the geography of environmental exposure seen in Figure 1. Areas with the highest mafia presence - particularly the corridor linking northern Naples to southern Caserta - are also those most densely covered by contaminated sites. This spatial overlap is central to the empirical motivation for our identification strategy: if organized crime historically controlled illegal waste disposal, then municipalities where mafia networks are more entrenched should exhibit markedly higher exposure to contaminated sites. Figures 1 and 2 visually support this premise. In municipalities farther from these criminal strongholds - such as much of the Avellino, Benevento, and Salerno provinces - both environmental and institutional risks appear substantially lower.

Additional socio-economic and demographic indicators reported in Table A.2 further underscore the heterogeneity across municipalities. Population density varies from fewer than 1,000 to more than 9,000 inhabitants per km^2, with the highest values concentrated in areas that show intense contamination. Education levels, household composition, and firm density also display wide variability, reflecting uneven development patterns across the region. Notably, myocardial infarction mortality - our proxy for lifestyle-related cancer risk - shows substantial variation across municipalities, although without the extreme clustering observed for environmental exposure. This suggests that behavioural heterogeneity alone is unlikely to explain the concentrated spatial pattern of cancer mortality.

Cancer mortality, environmental contamination, and mafia presence are all highly heterogeneous across the Campania region and share a common spatial structure characterized by pronounced clustering in a limited number of municipalities. These stylized facts provide the empirical motivation for the instrumental variable approach developed in the next section. The strong spatial correlation between contamination and mafia infiltration, documented in Figures 1 and 2, is not interpreted as causal but rather as a key feature of the data that informs the identification strategy: mafia presence provides a source of exogenous variation that plausibly drives illegal waste exposure, which in turn affects health outcomes.

4 Empirical Strategy

This section describes the empirical strategy used to identify the relationship between exposure to potentially contaminated sites and the relative risk (RR) of cancer mortality at the municipal level. We proceed in two steps. First, we specify a set of cross-sectional Ordinary Least Squares (OLS) models that quantify the association between environmental exposure and mortality risk. Second, we address the identification challenges that affect OLS estimates and introduce an instrumental variables (IV) strategy that exploits exogenous variation in criminal-organization infiltration to recover the causal effect of mafia-driven illegal waste disposal on health outcomes.

4.1 OLS Framework

We start from a reduced-form specification in which the relative risk of mortality from malignant tumours in municipality i is modelled as a function of environmental exposure and municipal characteristics:

$$RR_i = \alpha + \theta S_i + X_i'\delta + \mu_p + \varepsilon_i, \tag{1}$$

where RR_i denotes the relative risk of cancer mortality; S_i is a measure of exposure to potentially contaminated sites; X_i is a vector of demographic, socio-economic, and behavioural controls; and μ_p are province fixed effects that capture structural differences across provinces (e.g. health system organisation, regulatory capacity, or background environmental quality).

The key explanatory variable S_i is constructed from the georeferenced registry of potentially contaminated sites. Our baseline measure is the number of sites within a 5 km radius of the municipal centroid, which captures short-range exposure consistent with the average territorial scale of Campania's municipalities. Given the highly right-skewed distribution of contaminated sites, and the presence of dense clusters in a limited number of municipalities, we complement this continuous measure with a threshold indicator equal to one if the number of sites within 5 km exceeds the sample median (two sites). This dual specification allows us to distinguish between the intensive margin of exposure (incremental changes in the number of sites) and the extensive margin (crossing a minimal concentration threshold that may already signal substantial environmental risk.

All OLS specifications progressively introduce controls in X_i for demographic composition, socio-economic conditions, and behavioural proxies such as myocardial infarction mortality, as well as province fixed effects μ_p. Standard errors are clustered at the province level to allow for spatial correlation in unobserved shocks. These models are intended to describe the association between environmental exposure and cancer mortality, not to provide causal estimates. The detailed OLS results, including coefficient magnitudes and their interpretation, are presented in Section 5.1 below.

4.2 Identification Challenges and Motivation for IV

The OLS specification in equation (1) cannot be given a causal interpretation because the placement and intensity of illegal waste disposal are plausibly endogenous. Municipalities with weaker institutions, lower enforcement capacity, or deeper criminal infiltration may be more likely to host illegal dumping sites and may also exhibit worse health outcomes for reasons unrelated to environmental contamination. In this case, S_i would be correlated with omitted determinants of RR_i, and the OLS coefficient θ would capture both the effect of contamination and the influence of unobserved confounders.

Additional concerns arise from the difficulty of fully observing and controlling for informal governance structures, civic capacity, and historical patterns of political capture, all of which may shape both environmental risk and population health. Reverse causality may also contribute to bias if long-term socio-economic decline or demographic changes make certain municipalities more attractive for illegal activities, generating a correlation between exposure and mortality that does not reflect a direct causal pathway. Finally, both contaminated sites and cancer mortality are spatially clustered; if residual spatial dependence remains after controlling for province fixed effects and observable covariates, standard OLS inference may overstate statistical significance.

These considerations motivate an instrumental variables strategy that isolates the variation in environmental exposure driven by mafia infiltration, thereby addressing the endogeneity of S_i.

4.3 Instrumental Variables Strategy

To address the identification problems outlined above, we use a two-stage least squares (2SLS) approach in which exposure to contaminated sites is instrumented with the Mafia Presence Index (MPI), a composite measure of criminal organization infiltration at the municipal level. The empirical framework is:

$$S_i = \alpha + \pi\, MPI_i + X_i'\gamma + \mu_p + u_i, \tag{2}$$

$$RR_i = \beta\, \widehat{S}_i + X_i'\delta + \mu_p + \varepsilon_i, \tag{3}$$

where MPI_i denotes the Mafia Presence Index and $\widehat{S}_i$ is the predicted exposure from the first stage. The first-stage equation (2) exploits the fact that mafia-type organizations - according to robust evidence from numerous official reports - historically acted as key intermediaries in the illegal waste market, thereby shaping the spatial distribution of contaminated sites. The second stage uses only the component of exposure explained by MPI_i to estimate the effect of mafia-driven contamination on cancer mortality.

The MPI aggregates administrative signals of organized crime activity, including the dissolution of municipal councils under Law 164/1991 for mafia infiltration and the number of real estate assets and firms confiscated from organized crime, normalized by population and rescaled to a 0–100 index. These components are constructed from administrative records that are collected independently of health outcomes and reflect the political and economic footprint of criminal organizations rather than epidemiological conditions. See the SI for details.

Because our design is cross-sectional, omitted variables are a valid concern if the historical drivers of Mafia presence correlate with unobserved local characteristics that also shape mortality risks. Several features of the institutional setting mitigate this problem. First, the instrument exploits exogenous settlement patterns of organized crime, long before the expansion of illegal waste trafficking in the 1980s–1990s. These origins preceded modern political institutions, industrial development, and healthcare infrastructure, which are the main proximate determinants of current mortality. Second, we absorb province fixed effects so that identification comes exclusively from short-range spatial variation between municipalities exposed to the same provincial governance, health systems, and environmental regulation. Third, we control flexibly for a wide set of contemporary municipal characteristics (income, education, age structure, urbanization) to remove remaining confounding correlates. Fourth, our instrument exhibits no predictive power for placebo mortality causes unrelated to environmental contamination, which would not be the case under a spurious correlation story. Together, these arguments support the validity of our instrument in a cross-sectional setting.

For the IV strategy to be valid, two conditions must hold. First, *relevance*: mafia presence must be strongly correlated with environmental exposure, i.e. $\pi \neq 0$ in equation (2). This is an empirical requirement and is evaluated through first-stage estimates and F-statistics reported in the Results section. Second, the *exclusion restriction*: conditional on the controls X_i and province fixed effects μ_p, mafia presence should affect cancer mortality only through its impact on illegal waste exposure, not through other unobserved channels. While this assumption cannot be tested directly, we mitigate concerns by including rich socio-economic and behavioural covariates, by exploiting within-province variation, and by performing placebo tests using health outcomes that are unlikely to be affected by environmental contamination (e.g. viral hepatitis mortality).

We estimate both continuous and threshold IV specifications, mirroring the OLS framework. In addition to the 5 km radius used in the baseline, we consider alternative neighbourhood definitions based on 10 km and 20 km buffers, to assess the robustness of the results to the spatial scale of exposure. We further augment the set of controls with a municipal Deprivation Index and measures of social capital to capture contextual disadvantage and civic engagement.

Standard errors in all IV regressions are clustered at the province level. Under this set-up, the coefficient β in equation (3) identifies the Local Average Treatment Effect (LATE), namely the causal effect of mafia-driven illegal waste exposure on cancer mortality for the subset of municipalities whose contamination levels respond to changes in mafia penetration. The next section presents the empirical results and interprets the magnitude of both the OLS and IV estimates.

5 Results

5.1 Descriptive Patterns and Baseline OLS Estimates

We begin by examining how cancer mortality varies with environmental exposure in the OLS framework described in equation (1). The dependent variable is the relative risk (RR) of mortality from malignant tumours at the municipal level, and the key explanatory variable is the number of potentially contaminated sites located within a 5 km radius from each municipal centroid. This measure captures the intensity of environmental exposure to illegal waste. As documented in the descriptive statistics, the distribution of contaminated sites is highly right-skewed, with some municipalities hosting hundreds of sites while many others only a few. For this reason, we also consider an alternative specification in which the key explanatory variable is a binary indicator equal to one if the number of sites exceeds the sample median of two. The rationale for this measure is that, given the strong clustering of illegal waste activities, the very presence of more than a minimal number of sites may already signal substantial environmental exposure, even without accounting for the intensive margin.

Table 1 reports the baseline OLS estimates of the relationship between the presence of contaminated sites and the relative risk of cancer mortality, pooling men and women. Results are presented for both exposure measures described above (continuous *N* Sites in columns 1–4, and the above-median dummy, *D Sites*, in columns 5–8). This dual approach allows us to test both the intensive margin of exposure - the incremental effect of additional sites—and the extensive margin - the discrete effect of living in an area where contaminated sites are non-negligibly concentrated.

Table 1 near here

In the first specification, the coefficients on the number of contaminated sites are positive, highly significant, and remarkably large in magnitude. The bivariate model in column (1) indicates that each additional site increases the RR of cancer mortality by 0.0677 points. Given an average RR of about 90, this corresponds to roughly 0.075 percent of the mean. Cumulatively, adding 100 contaminated sites, well within the observed range, would imply an increase of almost 6.8 points in the RR, or about 7.5 percent of the average. When demographic, socio-economic, and provincial controls are progressively included, the estimated coefficient declines but remains substantial. In the fully specified model (column 4), the coefficient is 0.0112, suggesting that 100 additional sites raise the RR by 1.12 points, or about 1.2 percent of the mean. This attenuation indicates that part of the raw correlation reflects confounding provincial and demographic factors; nevertheless, the persistence of a statistically significant effect underscores that the accumulation of contaminated sites independently contributes to excess cancer mortality.

The alternative specification, based on the dummy for above-median exposure D Sites, reveals an even more striking pattern. In the bivariate regression (column 5), municipalities with more than two contaminated sites exhibit an RR that is 15.99 points higher than those below the threshold—an increase of nearly 18 percent relative to the sample mean. Even after including controls for lifestyle proxies, socio-economic conditions, and provincial fixed effects, the estimated impact remains large and robust: in the fully controlled model (column 8), the coefficient is 4.8, corresponding to an increase of about 5.3 percent relative to the mean. This discontinuity suggests that the health burden is not linear in the number of sites but accelerates once a threshold concentration of contamination is reached. In other words, merely residing in an area with a non-negligible concentration of contaminated sites entails a substantial increase in mortality risk, even before accounting for the intensity of exposure.

Control variables behave largely as expected. Preventive behaviour, proxied by myocardial infarction mortality, does not display a stable relationship with cancer mortality, suggesting that lifestyle differences, while relevant for overall health, do not confound the specific link between contamination and cancer. By contrast, socio-economic and demographic factors matter: higher population density, larger household size, and lower education levels are positively associated with cancer mortality, while firm density exerts a protective effect. Provincial fixed effects absorb a large portion of the heterogeneity, with the fit of the models (R^2) rising from around 0.41 in the simplest specification to above 0.80 in the fully controlled ones. These patterns reveal that cancer mortality is heavily clustered in certain territories - especially Caserta and parts of Naples - where organized crime infiltration and illegal waste disposal are historically most entrenched.

From an economic perspective, the coefficients in Table 1 quantify the health cost of illegal waste exposure in a way that is both statistically rigorous and substantively alarming. An increase of 100 contaminated sites, a change that corresponds to moving from relatively spared municipalities to those in the heart of the *Land of Fires*, translates into a 1 to 7 percent rise in cancer mortality risk, depending on the specification. Even more starkly, merely crossing the threshold of two sites raises mortality risk by over 5 percent in the fully controlled model. These magnitudes imply that the presence and concentration of contaminated sites constitute a public health shock of the same order as structural socio-economic determinants.

Tables S2 and S3 in the SI refine the pooled analysis of Table 1 by reporting separate estimates for men and women and comparing the continuous and threshold measures of exposure. This disaggregation is important because environmental contaminants affect male and female cancer risks differently, owing to variations in baseline mortality, occupational exposure, and biological susceptibility. Table S2 estimates the effect of the number of contaminated sites within 5 km on cancer mortality. Among men, the baseline coefficient is 0.070 (about 7 points per 100 sites, 8% of the mean), declining to 0.011 after full controls (1.1 points). Among women, coefficients are 0.065 and 0.012, respectively, implying a similar marginal health cost of contamination once demographic and territorial heterogeneity is accounted for. Table S3 uses the above-median dummy to capture potential discontinuities in risk. For men, being above the threshold raises the RR by 17.2 points in the bivariate model and by 5.1 after controls (about 6% of the mean); for women, the corresponding effects are 14.8 and 4.5 points (about 5%). Overall, the results show that both the intensity of exposure and the presence of non-trivial contamination are strongly associated with higher cancer mortality, with consistent magnitudes across genders.

5.2 Instrumental Variables Estimates

The OLS results reveal a strong association between environmental exposure and cancer mortality, but they remain vulnerable to the endogeneity concerns outlined in the Empirical Strategy section. We now turn to the 2SLS framework in equations (2) and (3), where exposure is instrumented with the Mafia Presence Index.

Table 2 reports the IV estimates, showing that instrumented exposure to contaminated sites has a strong and statistically significant impact on cancer mortality risk, both when using the number of potentially contaminated sites and the above-median dummy specification. The first-stage regressions confirm the strength of the instrument: the MPI strongly predicts both the continuous exposure measure and the probability of being above the median number of sites, with F-statistics well above conventional thresholds, indicating no concern about weak instruments.

Table 2 near here

Table S4 in the online SI disaggregates the IV estimates by gender, focusing on the intensity of exposure measured as the number of contaminated sites within a 5 km radius of the municipal centre. The first-stage regressions again show that the MPI is a strong predictor of exposure for both men and women. In the second stage, the estimated effects of exposure on cancer mortality are positive, statistically significant, and of comparable magnitude across genders. Specifically, a 100-site increase translates into an excess risk of about 10 points for men and a slightly smaller but statistically indistinguishable increase for women. These results indicate that the health costs of exposure to illegal waste are broadly shared, reinforcing the interpretation of environmental contamination as a general rather than gender-specific health hazard.

Table S5 in the online SI presents IV results using the dummy specification. The first stage confirms the validity of the instrument, with the MPI strongly predicting whether a municipality falls above or below the exposure threshold. The second-stage results reveal a sharp and discontinuous increase in cancer mortality risk once the threshold is crossed. For both men and women, living in municipalities with more than two contaminated sites entails a substantial and statistically significant rise in relative risk, on the order of 4–6 percentage points compared with the mean. This discontinuity reinforces the evidence from OLS and IV specifications alike: even minimal clustering of contaminated sites produces significant public health penalties, and these penalties apply equally to men and women.

Figures 3 and 4 present the instrumental-variable estimates for the pooled population, disaggregated by cancer type. Specifically, Figure 3 refers to the continuous exposure measure (number of contaminated sites within 5 km), whereas Figure 4 reports the results using the threshold specification (above-median exposure). The results show that exposure to contaminated sites significantly increases the relative risk of mortality for several major cancer types - particularly lung, larynx, stomach, bladder, and kidney tumours - which are widely recognized in the epidemiological literature as being environmentally sensitive. Our results disaggregated by cancer type are in general fully consistent with the epidemiological literature on cancer risks in the Land of Fires (e.g. Alberti, 2022). A distinct pattern, however, emerges for liver cancer. In this case, the estimated coefficient is not statistically significant, mainly due to the large variability of the estimate and the correspondingly wide standard error. This instability is plausibly explained by the high incidence of viral hepatitis in certain areas of Campania, a well-documented phenomenon in epidemiological research (Fusco et al., 2008). When the model is re-estimated including controls for the incidence of viral hepatitis, the coefficient for liver cancer becomes statistically significant, confirming that the initial imprecision likely reflects omitted-variable bias rather than the absence of an underlying association (results are available upon request).

Figures 3–4 near here

Importantly, the threshold specification in Figure 4 confirms the presence of non-linear effects: once municipalities cross the minimum contamination threshold, the excess cancer risk rises sharply, even without further increments in site counts. Figures S3–S5 in the online SI replicate both models separately by gender. The estimated coefficients are positive and statistically significant for most environmentally related cancers, with remarkably similar magnitudes across genders. Men display relatively higher excess risks for tumours such as those of the colon, while women exhibit stronger associations with cancers of the pancreas, breast, and soft tissues. Overall, the evidence points to a broad-based increase in cancer mortality risk affecting both men and women once exposure to illegal waste is present.

Taken together, Figures 3–4 and S3–S5 provide compelling evidence that the health costs of mafia-driven environmental contamination are not confined to a single demographic group or cancer type. Instead, they are systematic, consistent with known pathways of toxic exposure, and discontinuous in nature, supporting the view that even relatively limited concentrations of illegal waste sites translate into severe and widespread public health consequences.

6 Robustness Checks

Our identification strategy rests on two key assumptions. The first is instrument relevance: mafia infiltration must be positively correlated with illegal waste exposure. This condition is well supported by extensive empirical evidence and investigative reports documenting the central role of organized crime in managing illegal waste disposal in Campania (Italian Parliament, 1998, 2013; Italian Senate, 2017). Consistent with this, our first-stage estimates confirm a strong and statistically significant association between the Mafia presence index and the number of contaminated sites. These results provide direct empirical support for the relevance of the instrument within our sample, in line with the broader evidence from judicial and investigative sources.

The second assumption is the exclusion restriction, which requires that mafia infiltration affects cancer mortality only through its impact on environmental contamination, and not through other unobserved channels. While organized crime may also influence outcomes such as local governance or economic performance, we address this concern by controlling for a rich set of socio-economic covariates and by conducting a battery of robustness and sensitivity analyses. In addition, we perform placebo tests using health outcomes that are unlikely to be affected by environmental degradation.

Before assessing our findings through a series of robustness checks, it is important to note that our analysis relies on mortality data. In principle, cancer incidence or hospitalization records could serve as alternative outcomes. Yet incidence data are not available (Fazzo et al., 2023) as a comprehensive cancer registry has never been fully established, while hospitalization data (SDO) do not provide the necessary municipal-level detail.

Placebo Test

As a falsification exercise, we replace cancer mortality with mortality from viral hepatitis, a disease that has no plausible causal link with environmental contamination from waste disposal (World Health Organization, 2017). The logic of this test is that if our estimates were merely capturing unobserved socio-economic differences, data artefacts, or spurious correlations induced by the Mafia Presence Index, we would expect to detect a statistically significant association also for this unrelated health outcome. Tables S6–S7 in the online SI show that no such association emerges: both the continuous and the dummy measures of contaminated sites yield coefficients close to zero and statistically insignificant for men and women alike. This absence of spurious effects indicates that our results do not generalize to conditions unrelated to environmental exposure, thereby reinforcing their causal interpretation.

Controlling for civic engagement

A further concern is that our estimates may be confounded by omitted variables capturing differences in civic engagement and collective action. To address this, we augment the baseline specification with a measure of social capital, proxied by the number of non-profit associations per 100,000 residents (Putnam et al., 1994). Municipalities with stronger civic engagement might display both greater collective capacity to resist mafia infiltration and better public health outcomes (Buonanno et al., 2009; Ciccone et al., 2014; Italian Parliament, 2018; Ministry of the Interior, 2014; Nannicini et al., 2013). The results, reported in Tables S8 and S9 in the online SI, are unchanged: the coefficients on contaminated sites remain positive, significant, and stable in magnitude, while the social capital variable itself is statistically irrelevant. This indicates that our findings are not driven by systematic differences in social capital across municipalities.

Geographic Restriction

We further assess the robustness of our findings by restricting the analysis to the provinces of Naples and Caserta, which constitute the historical core of the Land of Fires and the epicentre of mafia-controlled waste trafficking. Table S10 in the Supplementary Information reports the results of this robustness check. First-stage estimates confirm a strong and statistically significant association between the Mafia Presence Index (MPI) and the number of potentially contaminated sites (column 1), as well as with the binary indicator identifying municipalities above the median number of sites (column 3). In both cases, the corresponding F-statistics are well above conventional thresholds, indicating strong instrument relevance. Second-stage results (columns 2 and 4) show that, even within this restricted sample, both the continuous and the dummy specifications yield positive and highly significant effects of contaminated sites on cancer mortality. These findings indicate that the estimated relationship is not driven by peripheral municipalities, but instead reflects a causal mechanism operating precisely in the areas most heavily affected by illegal waste disposal in Campania.

Alternative Definitions of Neighbourhood

Finally, we examine the sensitivity of our findings to alternative definitions of neighbourhood exposure. In our baseline, contaminated sites are counted within a 5 km radius of the municipal centroid. We replicate the analysis using broader radii of 10 km and 20 km (Tables S11 and S12 in the online SI). In all cases, the estimated coefficients remain positive and statistically significant, though the magnitude declines with distance, consistent with the intuition that closer sites exert stronger local health impacts. The consistency of results across different spatial definitions demonstrates that our findings are not mechanically dependent on the chosen neighbourhood size.

Separating Mafia Presence from Structural Characteristics

We re-estimate our models adding the bare components of the MPI (council dissolution and confiscated assets) as direct controls. If the MPI were capturing structural disadvantages rather than mafia infiltration, adding these components should absorb its explanatory power. The results show that this is not the case (see Tables S13 - S15 in SI). The coefficient on instrumented exposure remains stable in magnitude and statistical significance, while the coefficients on the MPI components are small and statistically insignificant. This indicates that the identifying variation does not operate through persistent institutional or socio-economic characteristics correlated with mafia presence, but rather through the channel of mafia-driven illegal waste disposal. Overall, this evidence supports the interpretation of the MPI as a source of exogenous variation in environmental exposure rather than as a proxy for underlying structural disadvantages.

Evidence from Non-Exposed Municipalities

To further assess the plausibility of the causal chain linking mafia presence to environmental contamination and cancer mortality, we re-estimate the baseline OLS specifications on samples restricted to municipalities with no documented contaminated sites, using increasingly stringent definitions of non-exposure. Specifically, we exclude, first, municipalities hosting contaminated sites within their administrative boundaries and, more stringently, municipalities with any contaminated site located within a 5 km radius of the municipal centre. The results of these falsification exercises are reported in the Supplementary Information. The estimated MPI-cancer mortality association weakens substantially once we focus on municipalities that are plausibly unexposed to contaminated sites. In particular, considering the most stringent restriction, the MPI coefficient is no longer statistically different from zero. This is consistent with our main interpretation: the association between Mafia and mortality is stronger in municipalities where environmental exposure is more likely to be relevant, and it weakens in municipalities without documented contaminated sites.

Sensitivity Analysis of the IV Estimates

IV estimation relies on the assumptions of relevance and validity. While relevance can be empirically assessed, validity crucially depends on the exclusion restriction. This restriction requires the instrument to affect the outcome only through the endogenous regressor, implying zero correlation between the instrument and the structural error term. However, this assumption is difficult to defend. In fact, instruments are often plausibly exogenous rather than strictly exogenous and they might have a small but non-zero direct effect on the outcome. To this end, we propose the plausibly exogenous framework developed by Conley et al. (2012) as a robustness check for our IV estimates. The idea is to check how sensitive the IV results are to small and plausible violations of the exclusion restriction. Specifically, instead of assuming that the instrument is perfectly valid, the approach examines how our IV results change when deviations from strict exogeneity are allowed.

Formally, the approach allows the instrument to enter the structural equation directly,

$$Y = X\beta + Z\gamma + \varepsilon, \tag{4}$$

where X denotes the endogenous regressor, Z the instrument, and γ captures the magnitude of the potential violation of the exclusion restriction. The standard IV model is obtained as a special case when $\gamma = 0$. Rather than imposing this restriction, the plausibly exogenous framework treats γ as unknown but bounded or probabilistic, and conducts inference on β under weaker and more transparent assumptions.

A first approach is the Union of Confidence Intervals (UCI) method. This procedure specifies a plausible range for the direct effect of the instrument on the outcome, $\gamma \in [\underline{\gamma}, \overline{\gamma}]$. For each value of

γ within this range, the outcome variable is adjusted as $Y_i - Z_i\gamma$, and the model is re-estimated using two-stage least squares. The confidence interval for the parameter of interest, β, is then constructed as the union of the confidence intervals obtained for each admissible value of γ. This approach delivers conservative inference under minimal assumptions, allowing for bounded violations of the exclusion restriction.

The second approach is the Local-to-Zero (LTZ) approximation. In this case, the violation parameter is assumed to follow a distribution centered close to zero, typically $\gamma \sim \mathcal{N}(\mu_\gamma, \Omega_\gamma)$. This assumption reflects the idea that any violation of the exclusion restriction is likely to be small, but not necessarily equal to zero. As a result, uncertainty about the exclusion restriction is explicitly incorporated into inference on the parameter of interest.

Specifically, the asymptotic distribution of the estimator is given by

$$\hat{\beta} \sim \mathcal{N}\big(\beta + A\mu_\gamma,\ V_{\text{2SLS}} + A\Omega_\gamma A'\big)\,, \tag{5}$$

where $A = (X'Z(Z'Z)^{-1}Z'X)^{-1}X'Z$. Compared with standard two-stage least squares, the mean of the distribution is shifted by $A\mu_\gamma$ to account for a non-zero average violation of the exclusion restriction. The variance increases by $A\Omega_\gamma A'$ to reflect uncertainty about the magnitude of that violation. Here, V_{2SLS} denotes the conventional two-stage least squares variance.

In our empirical setting, we first implement the UCI approach and then apply the LTZ approximation as complementary robustness checks (Clarke & Matta, 2018; Van Kippersluis & Rietveld, 2018).

Starting from our main IV specifications, we allow the exclusion restriction to be violated within a set of predefined and plausible bounds. Specifically, we consider values of the violation parameter γ around zero that imply small (± 0.05), moderate (± 0.10), and relatively large (± 0.20) direct effects of the instrument on the outcome. For each value of γ within these ranges, the outcome variable is adjusted accordingly and the model is re-estimated using two-stage least squares. The confidence interval for the parameter of interest is constructed as the union of the γ-specific confidence intervals. Then, robustness is assessed by checking whether these intervals continue to exclude zero across different levels of allowed violations.

According to the LTZ approximation, potential violations of the exclusion restriction are assumed to be small and centered around zero. Specifically, we set the mean of the violation parameter to zero and fix its variance at a low value, reflecting small but non-zero departures from strict exogeneity. Moreover, we assume $\mu_\gamma = 0$ and $\Omega_\gamma = 0.01$, and apply the LTZ approach to the same baseline IV specifications. Then, robustness is assessed by comparing the resulting estimates with the IV coefficients, focusing on whether the magnitude and sign of the estimated effects remain stable once local violations of the exclusion restriction are allowed.

The results of this sensitivity analysis are reported in the Supplementary Information (Table S 16). The UCI-based results show robustness to small and moderate violations of the exclusion restriction, with identification weakening only under very extreme assumptions. Consistent evidence emerges from the LTZ approximation, as allowing for small violations centered around zero does not affect the sign or the magnitude of our IV estimates. Overall, the sensitivity analysis indicates that our main findings are not driven by departures from the exclusion restriction within plausible ranges.

Interpretation and Magnitude

Taken together, the robustness checks corroborate the validity of our identification strategy. The placebo tests indicate that the results are not spurious; the inclusion of additional controls does not affect the estimates; restricting the sample to the most affected provinces confirms their stability; alternative neighbourhood definitions yield consistent patterns; and adding the bare components of the MPI as direct controls leaves the results unchanged. This convergence of evidence provides strong support for our interpretation that mafia-driven illegal waste disposal has generated severe environmental contamination with measurable consequences for excess cancer mortality in the Land of Fires. Overall, these findings indicate that the IV estimates are reliable and support a robust causal link between mafia-driven illegal waste disposal and cancer mortality. The implied magnitudes are economically and epidemiologically large: moving from a relatively unexposed to a highly contaminated municipality corresponds to a 7–12% increase in cancer mortality risk. These estimates are comparable in scale to established socio-economic determinants of health, underscoring that environmental crime constitutes a major source of population health inequality. The next section discusses the broader implications of these findings for environmental governance, institutional accountability, and public health policy.

7 Discussion and Policy Implications

Our empirical findings highlight the existence of a causal link between mafia-driven illegal waste disposal and excess cancer mortality in the Campania region. The strength and robustness of this relationship - across specifications, gender, and cancer types - suggest that the mechanism operates through environmental contamination rather than through socio-economic confounding. In the context of the Land of Fires, organized crime has acted not only as an economic intermediary but also as a substitute regulator of the waste market, converting governance failures into environmental externalities with measurable population-level health costs.

The IV strategy isolates the effect of illegal waste exposure induced by mafia penetration, providing an internally valid estimate of the Local Average Treatment Effect (LATE). Given the territorial persistence of mafia organizations, this effect can be interpreted as the health cost of criminal control over local environmental governance. Our placebo and robustness checks further support the exclusion restriction, indicating that mafia infiltration does not affect mortality through other unobserved channels such as lifestyle or civic engagement. These results have important implications for the economics of crime, public health, and environmental policy. First, they extend the literature on the economic costs of organized crime by uncovering a new transmission channel: beyond its effects on investment, productivity, and institutional trust, mafia activity directly worsens population health outcomes. This mechanism operates through the illegal management of externalities.

Second, the findings underscore the interaction between weak institutions and health inequality. Where state capacity is low and law enforcement is co-opted, the social costs of crime are magnified through environmental degradation. In such settings, health disparities cannot be understood solely as a function of individual behaviour or economic deprivation; they also reflect a special form of governance failure.

Third, the magnitude of the estimated effects suggests that environmental remediation and anti-mafia interventions should be treated as complementary public health policies. Targeting contaminated sites without dismantling the criminal networks that generate them risks reproducing the same health hazards over time. Conversely, strengthening institutional accountability and enforcement capacity in waste management may yield substantial health returns, particularly in regions with entrenched organized crime.

From a policy perspective, our results highlight three main issue. Environmental remediation programs should explicitly incorporate anti-mafia enforcement mechanisms, as the root causes of contamination are institutional and criminal rather than purely technical. The absence of consistent and granular data on waste sites and emissions hampers both epidemiological surveillance and policy evaluation. Building integrated datasets linking environmental, health, and judicial information would enhance accountability and early detection of illegal disposal practices. Promoting civic engagement and institutional integrity at the municipal level can reduce the vulnerability of local administrations to criminal capture and improve the enforcement of environmental regulations.

These recommendations align with recent European initiatives on environmental justice and the World Health Organization's emphasis on addressing structural determinants of health (Organization et al., 2008; Savona & Vettori, 2009). They also provide a quantitative benchmark for evaluating the social costs of organized crime, suggesting that the health burden of mafia-driven pollution may rival that of major socio-economic determinants.

The evidence from the Land of Fires carries broader implications beyond the Italian context. In many regions worldwide - from Latin America to Eastern Europe - criminal organizations operate in pollution-intensive sectors such as waste management, mining, and logging. Our results suggest that the health consequences of these activities can be both large and persistent, especially where institutional capture allows illegal environmental practices to flourish. Future research could extend this framework to examine dynamic effects, intergenerational health outcomes, and the fiscal burden of pollution-related morbidity.

Overall, our analysis reframes environmental crime as a public health issue. By quantifying the health costs of mafia-driven contamination, we show that improving governance and enforcing environmental law are not only matters of justice but also effective instruments for reducing premature mortality and improving population welfare.

8 Conclusion

This paper provides the first causal evidence linking organized crime to population health through the channel of environmental contamination. Using municipal-level data from the Campania region of Southern Italy - the so-called *Land of Fires* - we show that mafia infiltration has played a decisive role in shaping patterns of illegal waste disposal and, consequently, excess cancer mortality.

Our identification strategy, based on a two-stage least squares framework with a Mafia Presence Index as an instrument, isolates exogenous variation in exposure to contaminated sites driven by criminal activity. Results reveal large and robust effects: municipalities with greater mafia-driven exposure face cancer mortality rates 7–12% higher than comparable areas, even after controlling for socio-economic, demographic, and behavioural differences. These findings demonstrate that environmental crime constitutes a significant and quantifiable source of health inequality.

From a policy standpoint, the results highlight the need for integrated interventions that combine environmental remediation, institutional strengthening, and anti-mafia enforcement. Reducing the health burden of contamination requires not only cleaning up polluted sites but also dismantling the criminal networks and governance structures that sustain illegal waste markets.

More broadly, our findings underscore that effective public health policy depends not only on medical and behavioural determinants but also on the quality of institutions that govern environmental and social life.

References

Achim, M. V., Văidean, V. L., & Borlea, S. N. (2020). Corruption and health outcomes within an economic and cultural framework. *The European Journal of Health Economics*, 195–207.

Alberti, P. (2022). The ‘land of fires’: Epidemiological research and public health policy during the waste crisis in Campania, Italy. *Heliyon*, *8*(112), 1–9.

Barba, M., Mazza, A., Guerriero, C., Di Maio, M., Romeo, F., Maranta, P., Marino, I., Paggi, M., & Giordano, A. (2011). Wasting lives: The effects of toxic waste exposure on health. the case of Campania, Southern Italy. *Cancer Biology & Therapy*, *12*(2), 106–11.

Bianchi, F., Comba, P., Martuzzi, M., Palombino, R., & Pizzuti, R. (2004). Italian “triangle of death”. *The Lancet Oncology*, *5*, 710.

Buonanno, P., Montolio, D., & Vanin, P. (2009). Does social capital reduce crime? *The Journal of Law & Economics*, *52*(1), 145–170.

Capacchione, R. (2008). *L’oro della camorra*. BUR Biblioteca Universale Rizzoli.

Ciccone, D. K., Vian, T., Maurer, L., & Bradley, E. H. (2014). Linking governance mechanisms to health outcomes: A review of the literature in low- and middle-income countries. *Social Science & Medicine*, *117*, 86–95. https://doi.org/https://doi.org/10.1016/j.socscimed.2014.07.010

Clarke, D., & Matta, B. (2018). Practical considerations for questionable ivs. *The Stata Journal*, *18*(3), 663–691.

Conley, T. G., Hansen, C. B., & Rossi, P. E. (2012). Plausibly exogenous. *Review of Economics and Statistics*, *94*(1), 260–272.

De Felice, B., Nappi, C., Zizolfi, B., Guida, M., di Spiezio Sardo, A., Bifulco, G., & Guida, M. (2012). Telomere shortening in women resident close to waste landfill sites. *Gene*, *500*(1), 101–106.

European Court of Human Rights. (2025). Case of cannavacciuolo and others v. italy [Applications nos. 51567/14, 52194/14, 55123/14 and 7472/15, Judgment of 30 January 2025].

Fazzo, L., Manno, V., Iavarone, I., Minelli, G., De Santis, M., Beccaloni, E., Scaini, F., Miotto, E., Airoma, D., & Comba, P. (2023). The health impact of hazardous waste landfills and illegal dumps contaminated sites: An epidemiological study at ecological level in italian region. *Frontiers in Public Health*, *11*, 01–18.

Forte, I., Indovina, P., Costa, A., Iannuzzi, C., Costanzo, L., Marfella, A., & et al. (2020). Blood screening for heavy metals and organic pollutants in cancer patients exposed to toxic waste in southern Italy: A pilot study. *Journal of Cellular Physiology*, *235*, 5213–22.

Fusco, M., Girardi, E., Piselli, P., Palombino, R., Polesel, J., Maione, C., & Scognamiglio, P. (2008). Epidemiology of viral hepatitis infections in an area of southern Italy with high incidence rates of liver cancer. *European Journal of Cancer*, *44*, 847–853.

Greco, C. (2016). Blaming the southern victim. *Anthropology Today*, *32*(3), 16–19.

Holmberg, S., & Rothstein, B. (2011). Dying of corruption. *Health Economics, Policy and Law*, *6*(4), 529–547.

Iovene, B. (2008). *Campania infelix*. Biblioteca Universale Rizzoli.

Italian Parliament. (1998, July). Report on campania region.

Italian Parliament. (2013). Commissione parlamentare di inchiesta sulle attività illecite connesse al ciclo dei rifiuti (parliamentary committee of inquiry into illegal activities connected with the waste cycle) [Doc. XXIII, No. 19]. *Rome, Senate Printing Office*.

Italian Parliament. (2018). Commissione parlamentare di inchiesta sul fenomeno delle mafie e sulle altre associazioni criminali, anche straniere - relazione conclusiva (parliamentary committee of inquiry into the phenomenon of mafias and other criminal organizations, including foreign ones – final report).

Italian Senate. (2017, November). Sugli effetti dell'inquinamento ambientale sull'incidenza dei tumori, delle malformazioni feto-neonatali ed epigenetica (the effects of environmental pollution on the incidence of tumours, feto-neonatal malformations and epigenetics) [Doc. XVII, n. 12].

Jaiswal, V., Ang, S. P., Agrawal, V., Hameed, M., Saleeb, M. R. A., Jaiswal, A., Shah, M., Lao, N. M., Chia, J. E., Paudel, K., Gimelli, A., & Zacks, J. (2023). Association between heart failure and the incidence of cancer: A systematic review and meta-analysis. *European Heart Journal Open, European Society of Cardiology*, *3*(5), 1–11.

Martuzzi, M., Mitis, F., Bianchi, F., Minichilli, F., Comba, P., & Fazzo, L. (2009). Cancer mortality and congenital anomalies in a region of Italy with intense environmental pressure due to waste. *Occupational and Environmental Medicine*, *66*(11), 725–732.

Meijers, W., & de Boer, R. (2019). Common risk factors for heart failure and cancer. *Cardiovascular Research*, *115*, 844–853.

Ministry of the Interior. (2014). Attività delle commissioni straordinarie degli enti sciolti per infiltrazioni e condizionamento di tipo mafioso (activities of the extraordinary commissions of the bodies dissolved for mafia-type infiltration and conditioning).

Mirenda, L., Mocetti, S., & Rizzica, L. (2022). The economic effects of mafia: Firm level evidence. *American Economic Review*, *112*(8), 2748–73. https://doi.org/10.1257/aer.20201015

Musmeci, L., Comba, P., Fazzo, L., Iavarone, I., Salmaso, S., Conti, S., Manno, V., & Minelli, G. (2015). Mortalità, ospedalizzazione e incidenza tumorale nei comuni della terra dei fuochi in Campania (relazione ai sensi della legge 6/2014).

Nannicini, T., Stella, A., Tabellini, G., & Troiano, U. (2013). Social capital and political accountability. *American Economic Journal: Economic Policy*, *5*(2), 222–50. https://doi.org/10.1257/pol.5.2.222

Nature Editorial. (2014). A toxic legacy. *Nature*, *508*, 431.

Organization, W. H., et al. (2008). Closing the gap in a generation: Health equity through action on the social determinants of health.

Putnam, R., Leonardi, R., & Nanetti, R. (Eds.). (1994). *Making democracy work: Civic traditions in modern Italy*. Princeton University Press. https://books.google.it/books?id=gKZP8%5C_Tp27UC

Rivezzi, G., Piscitelli, P., Scortichini, G., Giovannini, A., Diletti, G., Migliorati, G., Ceci, R., Cirasino, L., & Carideo, P. (2013). A general model of dioxin contamination in breast milk: Results from a study on 94 women from the Caserta and Naples areas in Italy. *International Journal of Environmental Research and Public Health*, *11*, 5953–5970.

Sannino, C. (2014). Terra dei fuochi, su twitter botta e risposta Lorenzin-Saviano.

Saviano, R. (2008). *Gomorrah: Italy's other mafia*. Macmillan.

Savona, E. U., & Vettori, B. (2009). Evaluating the cost of organised crime from a comparative perspective. *European journal on criminal policy and research*, *15*(4), 379–393.

Senior, K., & Mazza, A. (2004). Italian "triangle of death" linked to waste crisis. *The Lancet Oncology*, *5*, 525–527.

Triassi, M., Alfano, R., Illario, M., Nardone, A., Caporale, O., & Montuori, P. (2015). Environmental pollution from illegal waste disposal and health effects: A review on the "triangle of death". *International Journal of Environmental Research and Public Health*, *12*, 1216–1236.

Van Kippersluis, H., & Rietveld, C. A. (2018). Beyond plausibly exogenous. *The Econometrics Journal*, *21*(3), 316–331.

World Health Organization. (2017). Global hepatitis report. Geneva: World Health Organization.

Table 1: Environmental exposure and relative risk of cancer mortality: OLS estimates

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				Dependent variable: RR				
N Sites (5Km)	0.0677***	0.0673***	0.0443***	0.0112***				
	(0.00458)	(0.00460)	(0.00378)	(0.00346)				
D Sites (5Km)					15.99***	15.90***	10.60***	4.801***
					(0.750)	(0.758)	(0.593)	(0.607)
Effort		2.460*	0.667	0.812		1.442	0.201	0.540
		(1.322)	(0.891)	(0.787)		(1.038)	(0.757)	(0.695)
AV			-11.71***	-8.416***			-9.345***	-7.339***
			(0.950)	(0.753)			(0.825)	(0.689)
BN			-10.18***	-6.711***			-10.42***	-6.847***
			(1.019)	(0.806)			(1.063)	(0.810)
NA			-1.231	-6.302***			2.141*	-5.370***
			(1.409)	(1.070)			(1.272)	(1.016)
SA			-15.07***	-10.76***			-12.97***	-10.17***
			(0.824)	(0.709)			(0.812)	(0.667)
Age				-6.034***				-5.387***
				(1.532)				(1.429)
Age^2				0.0549***				0.0496***
				(0.0163)				(0.0152)
Family>3 (%)				12.75***				9.084**
				(4.305)				(3.757)
PopDensity				0.00174***				0.00189***
				(0.000299)				(0.000266)
GDP p.c.				1.388***				1.130***
				(0.236)				(0.241)
Firms density				-0.0890***				-0.0716***
				(0.0176)				(0.0171)
% No primary school				0.407***				0.395***
				(0.0885)				(0.0848)
R^2	0.410	0.415	0.635	0.797	0.461	0.463	0.672	0.814
Obs.	550	550	550	550	550	550	550	550

Notes: This table presents OLS estimates of the association between environmental exposure and the relative risk of malignant cancer mortality, pooling men and women. Columns (1)–(4) use the number of contaminated sites within a 5 km radius of the municipal centre as the main regressor; whereas columns (5)–(8) use a dummy variable equal to 1 if the number of sites exceeds the sample median of two. Controls are added progressively: (1) and (5) include only the exposure variable; (2) and (6) add myocardial infarction mortality to proxy preventive behavior (Effort); (3) and (7) introduce provincial fixed effects; (4) and (8) add demographic and socioeconomic controls (average age and its square, share of families with more than three members, population density, per-capita income, firm density, and share without education) . Robust standard errors in parentheses. Significance: $p < 0.10$, $p < 0.05$, $p < 0.01$.

Table 2: Environmental exposure and relative risk of cancer mortality: IV estimates

	(1)	(2)	(3)	(4)
	1st Stage	2nd Stage	1st Stage	2nd Stage
Dependent variable	N Sites (5Km)	RR	D Sites (5Km)	RR
MPI	1.5145***		0.0104***	
	(0.276)		(0.001)	
N Sites (5Km)		0.1017***		
		(0.020)		
D Sites (5Km)				14.8150***
				(1.781)
Controls	✓	✓	✓	✓
FE: Province	✓	✓	✓	✓
Obs.	550	550	550	550
F-stat First Stage	45.114		102.151	

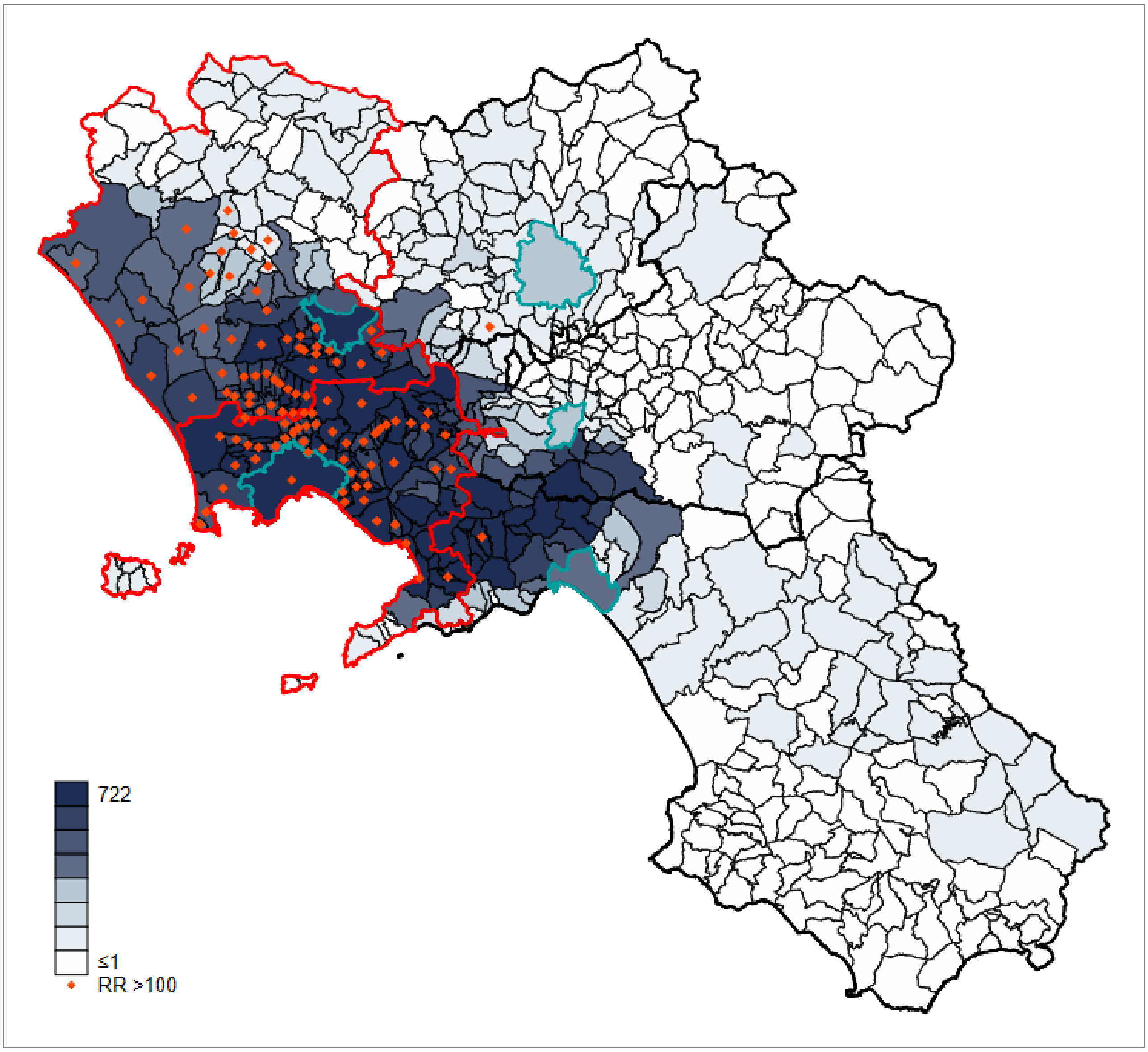
Notes: Table 2 presents two-stage least squares estimates of the impact of environmental exposure, instrumented by the Mafia Presence Index, *MPI*, on the relative risk of malignant cancer mortality. Columns (1) and (2) use *MPI* as an instrument for the number of contaminated sites within a 5 km radius as the main regressor (*N Sites (5Km)*); whereas columns (3) and (4) apply the same strategy to *D Sites (5Km)* (a dummy variable equal to 1 if the number of sites exceeds the sample median of two). The first-stage F-statistic is reported to assess instrument strength. Robust standard errors in parentheses. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The number of obervations (Obs.) is shown below each column.

Table 3: Environmental exposure and relative risk of cancer mortality: IV estimates

	(1)	(2)	(3)	(4)
	1st Stage	2nd Stage	1st Stage	2nd Stage
Dependent variable	N Sites (5Km)	RR	D Sites (5Km)	RR
MPI	1.8569***		0.0110***	
	(0.333)		(0.001)	
NSites5km		0.1080***		
		(0.019)		
D Sites (5Km)				18.1736***
				(1.845)
DPI	39.5678**	0.0610	-0.2440***	8.7679***
	(17.725)	(2.254)	(0.086)	(1.667)
Controls	✓	✓	✓	✓
FE: Province	✓	✓	✓	✓
Obs.	550	550	550	550
F-stat First Stage	72.296		123.038	

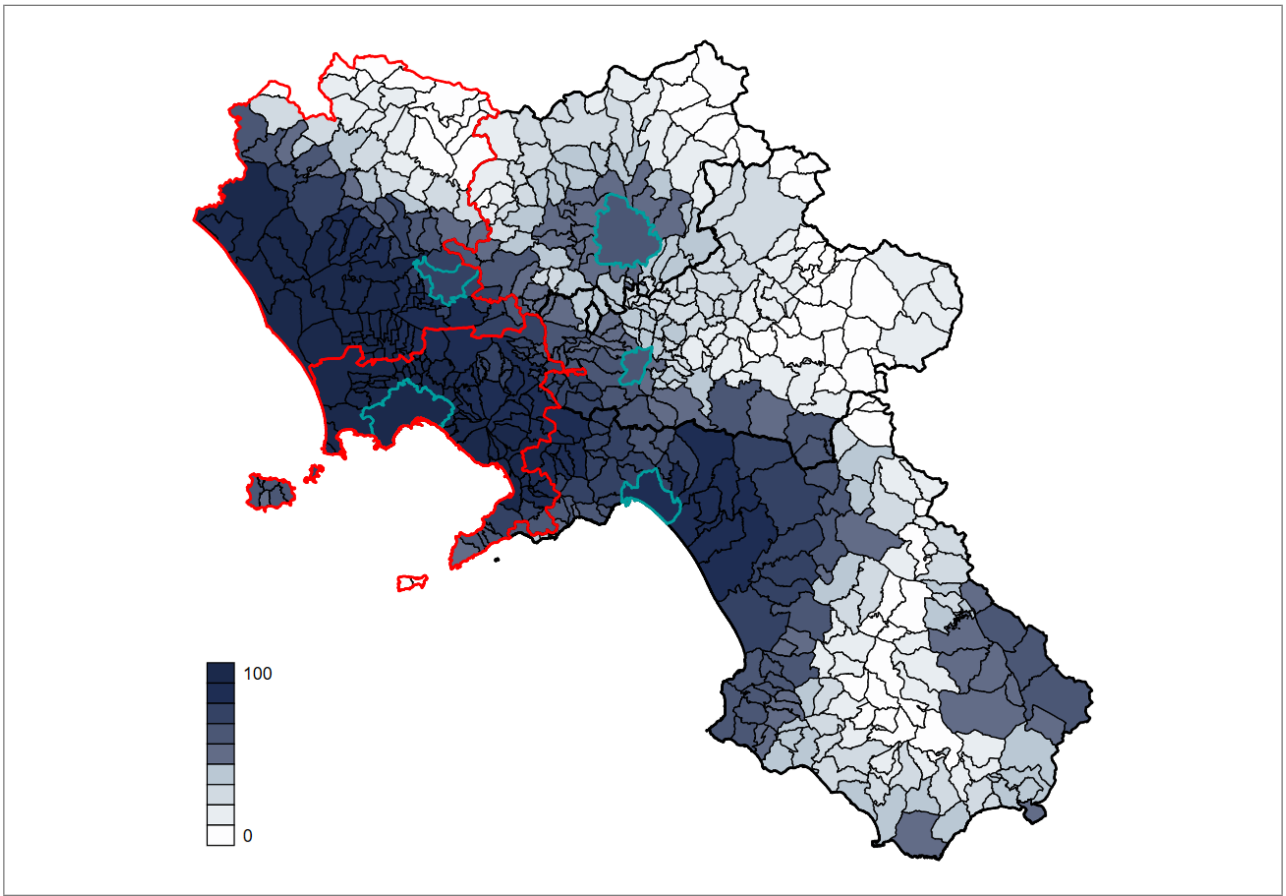
Notes: Table 3 presents two-stage least squares estimates of the impact of environmental exposure cntrolling for the deprivation index, instrumented by the Mafia Presence Index, *MPI*, on the relative risk of malignant cancer mortality. Columns (1) and (2) use *MPI* as an instrument for the number of contaminated sites within a 5 km radius as the main regressor (*N Sites (5Km)*); whereas columns (3) and (4) apply the same strategy to *D Sites (5Km)* (a dummy variable equal to 1 if the number of sites exceeds the sample median of two). The first-stage F-statistic is reported to assess instrument strength. Robust standard errors in parentheses. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The number of obervations (Obs.) is shown below each column.

Figure 1: Contaminated sites within a 5 km radius and cancer mortality



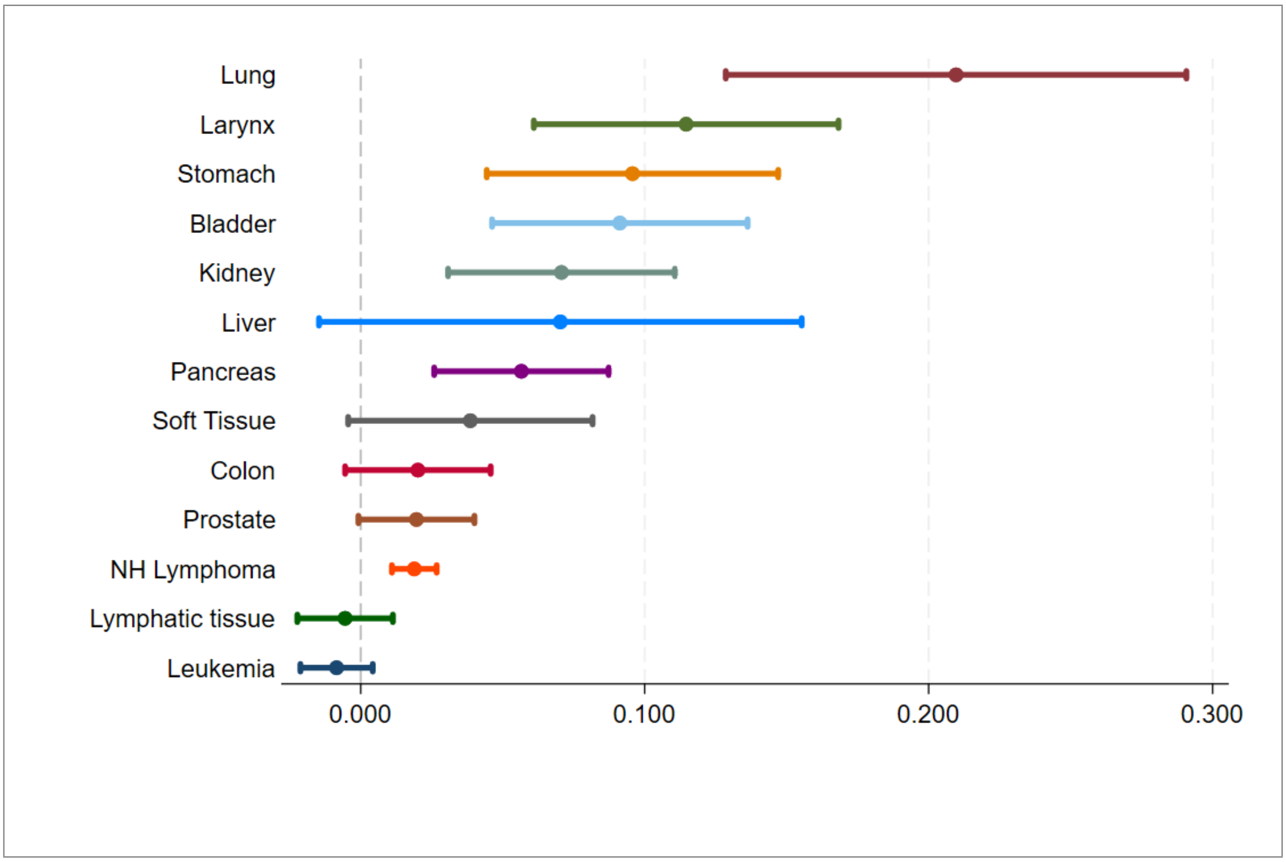
Notes: The map displays the spatial distribution of potentially contaminated sites within a 5 km radius of each municipal centre, with darker colours indicating a higher number of sites (up to the maximum observed value of 722). Red dots mark municipalities with a relative risk of death from malignant tumours greater than 100, that is, above the regional average. Darker outlines delineate the boundaries between the provincial capitals (Avellino, Benevento, Caserta, Napoli, and Salerno) and their respective municipalities. Light blue lines indicate the boundaries of the provincial capitals; red lines highlight the boundaries of the provinces of Naples and Caserta; and black lines denote the boundaries of the remaining three provinces (Avellino, Benevento, and Salerno).

Figure 2: Mafia Presence Index at the municipal level



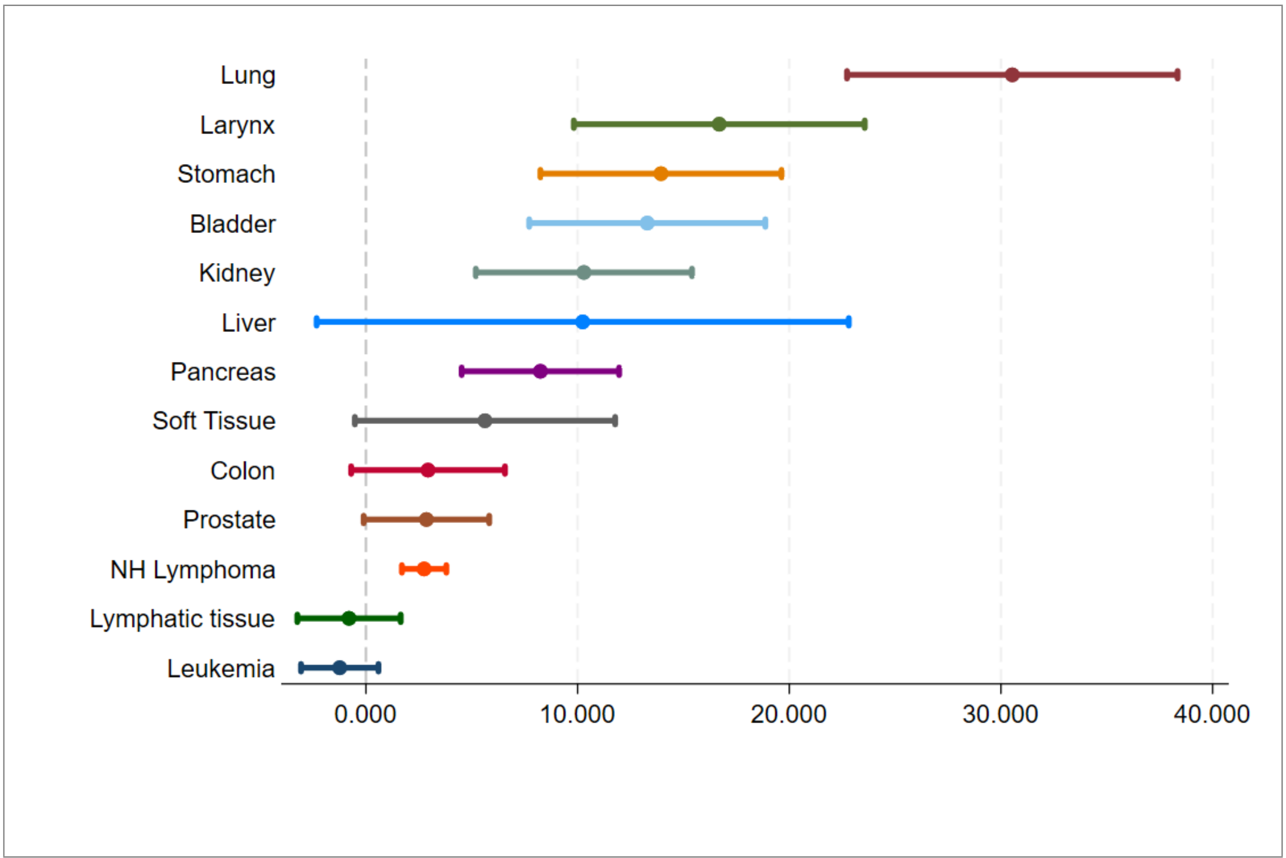
Notes: The map displays the spatial distribution of the smoothed Mafia Presence Index (MPI) across Campania's municipalities. Darker shades denote higher index values, revealing pronounced concentrations around the greater Naples metropolitan area, the Caserta plain, and the Salerno coast. In contrast, inland and mountainous zones - particularly Avellino and Benevento - exhibit lighter tones, indicating comparatively low Mafia presence. Light blue lines indicate the boundaries of the provincial capitals; red lines highlight the boundaries of the provinces of Naples and Caserta.

Figure 3: Environmental exposure and relative risk of cancer mortality: IV estimates (Model I)



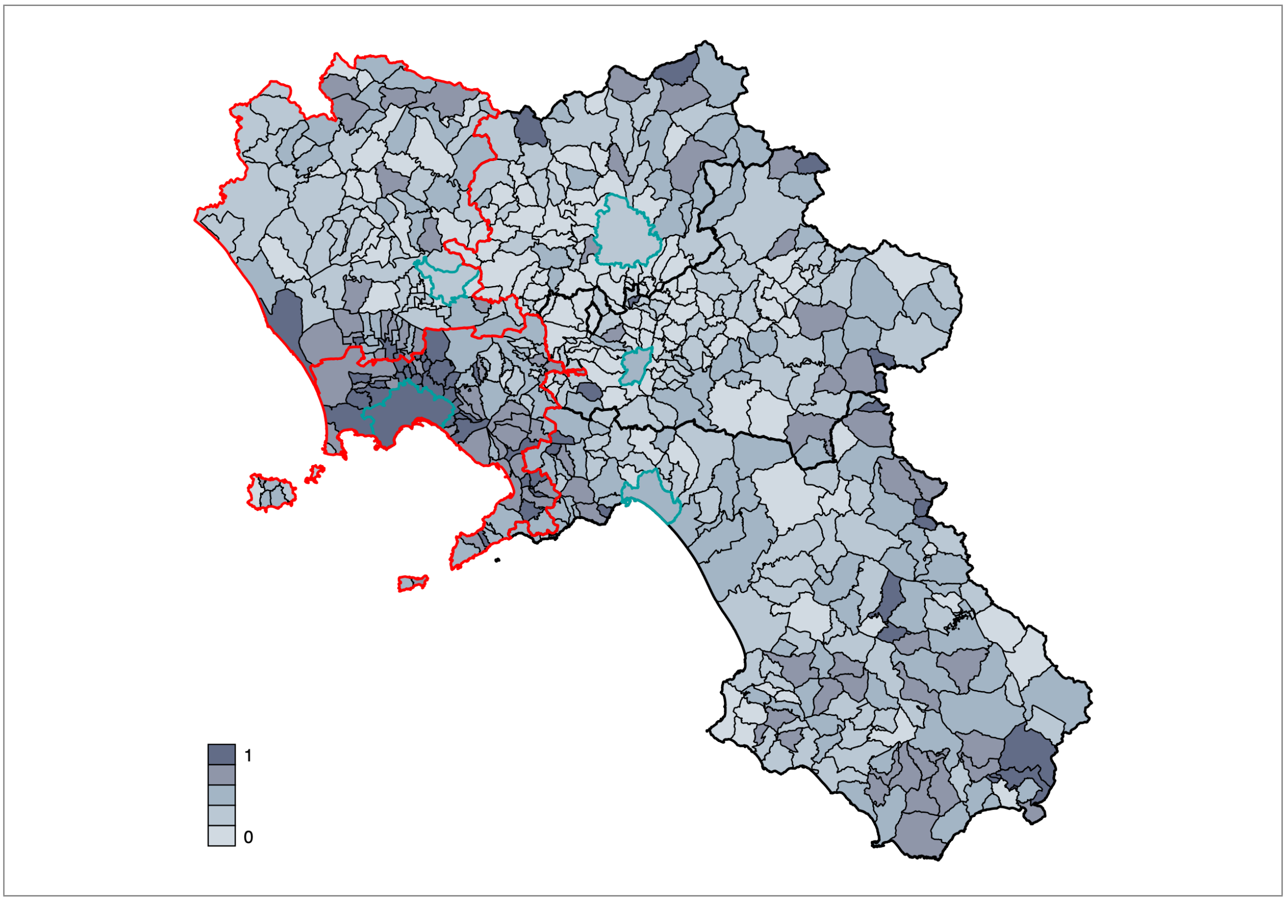
Notes: Estimated coefficients and 95% confidence intervals for the effect of proximity to contaminated sites on cancer mortality, by cancer type. Each coefficient is obtained from a fully specified IV regression, instrumenting the number of potentially contaminated sites within a 5km radius of the municipal centre with the MPI.

Figure 4: Environmental exposure and relative risk of cancer mortality: IV estimates (Model II)



Notes: Estimated coefficients and 95 % confidence intervals for the effect of proximity to contaminated sites on cancer mortality, by cancer type. Each coefficient is obtained from a fully specified IV regression, instrumenting *D Sites* (5km) - a dummy variable equal to 1 when the number of potentially contaminated sites within a 5km radius of the municipal centre exceeds the sample median - with the MPI.

Figure 5: Deprivation Index at the municipal level



Notes: Figure 5 displays the spatial distribution of the Deprivation Index across Campania's municipalities. Darker shades denote higher index values, highlighting pronounced concentrations in the inland and mountainous areas, as well as in the southern part of the region.

Appendix

Table A.1: Variable Description

Variable	Description	Source
RR Male	Relative risk of male cancer mortality municipality vs. regional average, 2006–2014	Mortality Atlas of the Campania Region, 2020
RR Female	Relative risk of female cancer mortality, municipality vs. regional average, 2006–2014	Mortality Atlas of the Campania Region, 2020
RR	Aggregate relative risk of cancer mortality, municipality vs. regional average, 2006–2014	Mortality Atlas of the Campania Region, 2020
N Sites	Number of potentially contaminated sites identified in 2005, 2010, 2013 and 2018	Regional Agency for Environmental Protection of Campania (ARPAC), 2019
N Sites (5Km)	Number of potentially contaminated sites whitin a 5 km radius of the munipal centre	Authors' elaboration of ARPAC data
N Sites (10Km)	Number of potentially contaminated sites whitin a 10 km radius of the munipal centre	Authors' elaboration of ARPAC data
N Sites (20Km)	Number of potentially contaminated sites whitin a 20 km radius of the munipal centre	Authors' elaboration of ARPAC data
D Sites (5Km)	Dummy variable equal to 1 for municipalities with a number of PCS above or equal to the median, within a 5km radius	Authors' elaboration of ARPAC data
D Sites (10Km)	Dummy variable equal to 1 for municipalities with a number of PCS above or equal to the median, within a 10km radius	Authors' elaboration of ARPAC data
D Sites (20Km)	Dummy variable equal to 1 for municipalities with a number of PCS above or equal to the median, within a 20km radius	Authors' elaboration of ARPAC data
MPI	Mafia Presence Index, range 0–100, interpolated via Thin Plate Spline on municipal coordinates	Authors' elaboration on Ministry of Home Affairs data, 1990-2024
PopDensity	Municipal population density (inhabitants/km²), municipal average, 2014-2022	Italian National Institute of Statistics, ISTAT
Age	Average age of the municipal population, municipal average, 2014-2022	Italian National Institute of Statistics, ISTAT
Effort Male	Relative Risk of Male mortality due to myocardial infraction, municipal average, 2006-2014	Mortality Atlas of the Campania Region, 2020
Effort Female	Relative Risk of Female mortality due to myocardial infraction, 2006-2014	Mortality Atlas of the Campania Region, 2020
Family> 3	Percentage of family with more than three members, municipal average, 2014-2022	Italian National Institute of Statistics, ISTAT
% No primary school	Percentage of people with no primary education, municipal average in 2011	Italian National Institute of Statistics (ISTAT), 2011 Population and Housing Census.
Firms density	Number of active firms per 1,000 residents, municipal average, 2014–2022	Italian National Institute of Statistics, ISTAT
GDP p.c	Income per capita, municipal average, 2014-2022	Italian National Institute of Statistics, ISTAT
Social Capital	Number of non-profit institutions per 100,000 residents, by municipality, in 2019	Italian National Institute of Statistics, ISTAT
DPI	Deprivation Index, range 0-1, in 2011	Italian National Institute of Statistics (ISTAT), 2011 Population and Housing Census.

Table A.2: Descriptive statistics

Variables	mean	sd	min	p25	median	p75	max	n
RR Male	90.489	13.356	67	81	88	99	138	550
RR Female	87.996	11.038	69	79	86	94	123	550
RR	89.243	11.780	71	79.5	87	96.5	130.5	550
N Sites	5	25	0	0	0	1	471	550
N Sites (5Km)	62	111	0	1	2	87	722	550
N Sites (10Km)	168	251	0	2	8	306	1122	550
N Sites (20Km)	489	613	0	10	159	886	2166	550
MPI	27	26	0	6	14	44	100	550
DPI	0.457	0.224	0	0.305	0.429	0.599	1	550
PopDensity	5.458	1.532	0.984	4.327	5.073	6.588	9.411	550
Age	44.226	3.605	34.338	41.734	44.238	46.516	56.183	550
Effort Male	0.974	0.282	0.490	0.800	0.920	1.070	3.960	550
Effort Female	0.912	0.428	0.310	0.670	0.815	1.040	5.050	550
RR Viral Hepatises Male	73.231	37.996	22	47	62	86	291	550
RR Viral Hepatises Female	77.541	47.204	10	48	63.5	93	440	550
Family> 3(%)	0.536	0.097	0.280	0.470	0.530	0.610	0.790	550
% No primary school	12.496	4.43d	3.78	9.37	11.57	14.77	32.49	550
Firms density	55.314	15.695	13.242	44.595	53.572	62.402	148.057	550
GDP p.c.	8.391	1.460	5.110	7.504	8.315	9.127	16.594	550
Social Capital	366.089	168.506	0	0	340.570	454.287	1489.362	550

Supplementary Information

The Crime-Cancer Nexus: Evidence from the *Land of Fires*

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Contents

Supplementary Tables

Supplementary Figures

1 Relative Risk (RR) of Malignant Cancer Mortality

To measure spatial differences in cancer mortality across Campania, we rely on the municipal-level Relative Risk (RR) indicators provided by the *Atlante della Mortalità della Regione Campania*. These indicators summarise the extent to which observed deaths exceed (or fall below) those expected under a benchmark mortality profile, after accounting for population size and demographic composition at the municipal level.

For each municipality $i = 1, \ldots, 550$, the Atlante reports:

$$RR_i = \theta_i = \frac{O_i}{E_i},$$

where O_i denotes the observed number of deaths from malignant cancers and E_i denotes the expected number of deaths, computed by applying age-specific and sex-specific regional mortality rates to the municipal demographic structure. This standardisation ensures that differences in RR_i are not mechanically driven by age or sex composition.

Importantly, the RR values published in the Atlante are not raw ratios but are obtained through a spatial smoothing procedure based on the Besag–York–Mollié (BYM) Bayesian hierarchical model. The Atlante applies this methodology to stabilise mortality estimates in small municipalities and to recover meaningful geographical patterns in cancer mortality.

In the BYM framework, observed deaths are modelled as:

$$O_i \mid \theta_i \sim \text{Poisson}(E_i \theta_i),$$

and the log-relative risk is decomposed as:

$$\log \theta_i = \alpha + u_i + v_i,$$

where u_i captures unstructured heterogeneity and v_i follows a conditional autoregressive (CAR) prior that induces spatial dependence among neighbouring municipalities. The combination of these components produces smoothed posterior estimates of θ_i that reduce random noise and enhance the detection of spatial clustering.

The RR values used in our empirical analysis correspond to the posterior means of θ_i released by the Atlante and represent a standard, epidemiologically validated measure of local cancer mortality risk. These RR estimates serve as the dependent variable in all OLS and IV specifications reported in Tables S1–S12 of the Supplementary Material.

2 Mafia Presence Index (MPI)

In order to assess the presence of mafia organizations in each Campania municipality, we drew on the methodology developed by Dugato et al., 2020, which combines multiple indicators to estimate mafia penetration at the local level. Unlike Dugato et al., 2020, who also include variables such as mafia-related homicides and the number of active clans, our approach focuses on the political and economic consequences of mafia infiltration as more meaningful signals of criminal consolidation. The underlying idea is that mafia power does not necessarily expand through visible violence or organizational proliferation. Rather, it strengthens when violence subsides and illicit networks achieve a stable equilibrium with the legal economy and local institutions. In this phase of criminal governance, overt conflict gives way to forms of collusion, control over public contracts, and the capture of local political and economic resources, all of which better capture the structural dimension of mafia power.

The Mafia Presence Index (MPI) employed in this paper is constructed from a set of municipal-level indicators capturing the political and economic footprint of organized crime. Specifically, it includes:

- the number of real estate assets confiscated and held under judicial administration (R_A);
- the number of real estate assets confiscated and reallocated (R_C)
- the number of firms confiscated and held under judicial administration (F_A);
- the number of firms confiscated and subsequently reallocated for legal use (F_C);
- a dummy variable indicating whether the municipal council has ever been dissolved due to Mafia infiltration (D).

We log-transform each quantitative variable, adding 0.001 to accommodate zeros, in order to mitigate skewness. Each transformed measure is then rescaled to the $[0, 100]$ range. We denote the resulting normalized scores as

$$Z_i^{R(A)},\ Z_i^{R(C)},\ Z_i^{F(A)},\ Z_i^{F(C)},\ Z_i^{D},$$

Then, we compute the raw MPI for municipality i as

$$\text{MPI}_i \ = \ \frac{1}{5}\Big(Z_i^{R(A)} + Z_i^{R(C)} + Z_i^{F(A)} + Z_i^{F(C)} + Z_i^{D}\Big). \tag{1}$$

A further methodological concern in constructing a mafia presence index relates to spillover effects (Di Cataldo & Mastrorocco, 2022). The literature typically refers to this term as the contagious influence that organized crime exerts on neighbouring municipalities. The underlying rationale is that proximity to a so-called mafia municipality may expose adjacent areas to indirect effects of criminal activity, such as corruption, intimidation, or illicit economic exchanges.

To account for this spatial interdependence, we apply a thin-plate spline (TPS) interpolation to the raw MPI values computed at municipal centroids, following the approach of Dugato et al. Dugato et al., 2020. This procedure generates a smooth continuous surface representing the spatial intensity of mafia presence across Campania. After masking the interpolated surface to the true municipal boundaries, we denote by $\widehat{\text{MPI}}(x, y)$ the TPS-predicted value at planar coordinates (x, y). [1]

Let $\mathcal{A}_i$ be the polygon corresponding to municipality i. We then define

$$\text{MPI}_i^{\text{smoothed}} = \max_{(x,y)\in\mathcal{A}_i} \widehat{\text{MPI}}(x, y). \tag{2}$$

on the rationale that mafia activity is typically concentrated in a few localized hot spots. The maximum value within each municipal boundary therefore captures the highest potential level of criminal exposure, whereas mean or median measures would tend to dilute that spatial signal.

Next, we rescale these peak values to the $[0, 100]$:

$$\text{MPI}_i^{\text{smoothed}*} = 100 \times \frac{\text{MPI}_i^{\text{smoothed}} - \min_j \text{MPI}_j^{\text{smoothed}}}{\max_j \text{MPI}_j^{\text{smoothed}} - \min_j \text{MPI}_j^{\text{smoothed}}}. \tag{3}$$

The resulting smoothed MPI provides a single, percentage-scaled metric that (i) preserves the cross-municipality ranking of mafia presence intensity, (ii) incorporates spatial spillovers through geographic interpolation, and (iii) remains directly interpretable for both descriptive mapping and the identification strategies employed in this study.

[1] Coordinates are expressed in the WGS 84 / UTM Zone 33N projected system (EPSG:32633).

3 Municipal Deprivation Index

To account for contextual socioeconomic differences across municipalities, we constructed a deprivation index according to a linear programming methodology: Data Envelopment Analysis (DEA). This is a comprehensive and widely applicable method for evaluating relative efficiency with strong theoretical and practical foundations in economics, mathematics, and management science (Boussofiane et al., 1991; Cooper et al., 2011).

Using this approach we obtain a multidimensional indicator which provides a consistent basis for linking contextual deprivation to health outcomes and territorial disparities in mortality rates across the Campania region.

Over the years, several efforts have been made to estimate deprivation in Italy, like the *OsservaSalute* report. However, these studies assume equal weights across variables, which is a restrictive and unrealistic hypothesis, since different socioeconomic dimensions may not contribute equally to deprivation.

Unlike these attempts to measure deprivation, our approach is actually data-driven. In particular, we propose a weighted system that not only reflects the empirical relationships among dimensions of deprivation, but also ensures comparability across municipalities of different sizes; therefore preserving the multidimensional nature of the phenomenon, without imposing linear aggregation constraints

From a practical standpoint, the DEA model compares each municipality with the best-performing ones in terms of socioeconomic structure. Specifically, it builds an efficiency frontier representing the minimum attainable level of deprivation given the observed combination of local characteristics. Municipalities located on this frontier are considered reference units, as they achieve the lowest deprivation among comparable peers. Those lying below the frontier are relatively less efficient.

Primarily, the model yields efficiency scores, where higher values denote better socioeconomic performance (lower deprivation). To express deprivation directly, these efficiency scores were transformed by taking their reciprocal, so that higher values correspond to greater levels of deprivation. The resulting DEA-based Deprivation Index thus measures how far each municipality lies from the benchmark of minimum deprivation.

Subsequently, to ease interpretation and comparability across municipalities, the index was normalized between 0 and 1, where 0 indicates the least deprived and 1 the most deprived municipalities in the region.

From an analytical standpoint, each municipality is treated as a *Decision-Making Unit (DMU)* that transforms a set of favorable socioeconomic characteristics (*inputs*) into a set of undesirable outcomes (*outputs*) representing different dimensions of deprivation. The Data Envelopment Analysis (DEA) model applies a linear programming procedure to estimate an *efficiency frontier* formed by municipalities achieving the lowest attainable level of deprivation given their structural conditions. Each municipality is then evaluated relative to this frontier, and the resulting efficiency score indicates its distance from the benchmark of minimum deprivation.

Formally, for each municipality $j = 1, \ldots, n$, the output-oriented DEA problem under *variable returns to scale (VRS)* is defined as:

$$
\begin{aligned}
\max_{\phi,\lambda} \quad & \phi \\
\text{s.t.} \quad & \sum_{j=1}^{n} \lambda_j x_{ij} \le x_{i0}, \qquad & i = 1, \ldots, m, \\
& \sum_{j=1}^{n} \lambda_j y_{rj} \ge \phi\, y_{r0}, \qquad & r = 1, \ldots, s, \\
& \sum_{j=1}^{n} \lambda_j = 1, \\
& \lambda_j \ge 0, \qquad & j = 1, \ldots, n.
\end{aligned}
\tag{4}
$$

where x_{ij} and y_{rj} denote, respectively, the i-th input and r-th output for municipality j; λ_j are intensity variables defining the convex combination of efficient municipalities; and $\phi \ge 1$ represents the proportional expansion factor of deprivation dimensions needed for each unit to reach the efficiency frontier.

Municipalities on the frontier ($\phi = 1$) are considered *efficient*, exhibiting the lowest observed deprivation, while those with $\phi > 1$ are progressively more deprived. To express deprivation directly, efficiency scores were transformed by taking their reciprocal, $D_j = 1/E_j$, and subsequently normalized between 0 and 1, where higher values indicate greater deprivation.

We employed a *VRS specification* to account for potential scale heterogeneity among municipalities, and an *output orientation* because the outputs represent undesirable conditions. Specifically, this orientation allows the model to evaluate how far each municipality lies from the frontier of minimum deprivation.

To measure deprivation, we used five domains indicated in the *OsservaSalute* report (Rosano et al., 2020), derived from the 2011 Population and Housing Census. Specifically, we considered:

- The share of 15-60 population that has received an education at or below the elementary school level. This indicator was calculated as the ratio between the number of individuals who completed only primary school (or have no qualification) and the total population in the same age group. This restriction excludes children and older cohorts, whose low education reflects historical effects, rather than current deprivation.

- The percentage of working-age population, 15 years and over, that is unemployed or seeking first-time employment. This quantity was computed as the ratio between non-employed individuals and the total labour force.

- The percentage of rented dwellings, measured as the ratio between the number of rented dwellings and the total number of occupied dwellings. Therefore, a proxy for limited household wealth and asset ownership is obtained.

- The share of inhabitants per 100 m^2. This ratio was calculated as the total resident population divided by the total area of occupied dwellings. This indicator captures potential overcrowding and poor housing conditions.
- The proportion of single-parent households, computed as the number of families composed of one parent living with children under the age of 18 divided by the total number of families.

Together, these dimensions capture the main structural aspects of socioeconomic disadvantage at the municipal level. Their combined interpretation allows for a comprehensive assessment of the contextual deprivation affecting communities across the Campania region.

Table S1: Environmental exposure and relative risk of cancer mortality, by gender: OLS estimates (Model I)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	RR Male				RR Female			
N Sites (5Km)	0.0702***	0.0702***	0.0466***	0.0107**	0.0652***	0.0648***	0.0422***	0.0116***
	(0.006)	(0.006)	(0.005)	(0.005)	(0.004)	(0.004)	(0.003)	(0.003)
Effort		3.1336*	1.3200	2.2586*		1.2738	0.1312	-0.0031
		(1.620)	(1.253)	(1.241)		(0.878)	(0.609)	(0.486)
AV			-14.0613***	-10.2755***			-9.3907***	-6.5675***
			(1.250)	(1.094)			(0.823)	(0.635)
BN			-9.8617***	-6.0345***			-10.5260***	-7.4265***
			(1.349)	(1.165)			(0.867)	(0.673)
NA			-2.7470	-7.9918***			0.2450	-4.7592***
			(1.745)	(1.417)			(1.313)	(1.033)
SA			-17.1739***	-12.2439***			-13.0133***	-9.3066***
			(1.089)	(1.024)			(0.765)	(0.655)
Age				-6.0694***				-6.0890***
				(1.905)				(1.487)
Age^2				0.0543***				0.0563***
				(0.020)				(0.016)
Family>3 (%)				12.5366**				12.8519***
				(6.023)				(3.547)
PopDensity				0.0018***				0.0017***
				(0.000)				(0.000)
GDP p.c.				1.1964***				1.5961***
				(0.328)				(0.229)
Firms density				-0.1061***				-0.0718***
				(0.023)				(0.016)
% No primary school				0.4795***				0.3391***
				(0.118)				(0.076)
R^2	0.3435	0.3479	0.5659	0.7167	0.4331	0.4356	0.6378	0.7978
Obs	550	550	550	550	550	550	550	550

Notes: This table presents OLS estimates of the association between environmental exposure and the relative risk of malignant cancer mortality, separately for men (columns 1–4) and women (columns 5–8). Environmental exposure is measured by the number of contaminated sites whitin a 5 km radius of the munipal centre. Columns (1) and (5) report the bivariate association; columns (2) and (6) add myocardial infarction mortality to proxy preventive behavior; columns (3) and (7) include provincial fixed effects; columns (4) and (8) add demographic and socioeconomic controls. Robust standard errors in parentheses. Significance: $p < 0.10$, $p < 0.05$, $p < 0.01$.

Table S2: Environmental exposure and relative risk of cancer mortality, by gender: OLS estimates (Model II)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	RR Male				RR Female			
D Sites (5Km)	17.1739***	17.1235***	11.3063***	5.0852***	14.8123***	14.7359***	9.9044***	4.4927***
	(0.885)	(0.891)	(0.779)	(0.804)	(0.710)	(0.716)	(0.560)	(0.577)
Effort		1.6224	0.5157	1.8890*		0.8016	-0.0519	-0.1509
		(1.319)	(1.084)	(1.122)		(0.757)	(0.546)	(0.452)
AV			-11.4779***	-9.1130***			-7.2240***	-5.5796***
			(1.124)	(1.044)			(0.752)	(0.592)
BN			-10.0338***	-6.1446***			-10.8156***	-7.5880***
			(1.339)	(1.156)			(0.969)	(0.694)
NA			0.7952	-7.0151***			3.4754***	-3.8624***
			(1.574)	(1.353)			(1.202)	(1.000)
SA			-14.8945***	-11.6037***			-11.0728***	-8.7511***
			(1.073)	(0.998)			(0.787)	(0.623)
Age				-5.2688***				-5.5945***
				(1.814)				(1.390)
Age^2				0.0476**				0.0526***
				(0.019)				(0.015)
Family>3 (%)				8.5142				9.5984***
				(5.507)				(3.143)
PopDensity				0.0020***				0.0019***
				(0.000)				(0.000)
GDP p.c.				0.9162***				1.3612***
				(0.337)				(0.233)
Firms density				-0.0875***				-0.0558***
				(0.022)				(0.017)
% No primary school				0.4645***				0.3295***
				(0.116)				(0.071)
R^2	0.4137	0.4149	0.6015	0.7320	0.4506	0.4516	0.6700	0.8132
Obs	550	550	550	550	550	550	550	550

Notes: This table presents OLS estimates of the association between environmental exposure and the relative risk of malignant cancer mortality, separately for men (columns 1–4) and women (columns 5–8). Environmental exposure is measured by a dummy variable equal to 1 if the municipality has more than two contaminated sites (the sample median) within 5 km radius of the municipal centre. Columns (1)–(4) refer to men and (5)–(8) to women. Controls are added progressively as in Table 3: (1) and (5) bivariate; (2) and (6) with preventive behavior; (3) and (7) with provincial fixed effects; (4) and (8) fully specified. Robust standard errors in parentheses. Significance: $p < 0.10$, $p < 0.05$, $p < 0.01$.

Table S3: Environmental exposure and relative risk of cancer mortality, by gender: IV estimates (Model I)

	(1)	(2)	(3)	(4)
	1st Stage (Male)	2nd Stage (Male)	1st Stage (Female)	2nd Stage (Female)
Dependent variable	N Sites (5Km)	RR	D Sites (5Km)	RR
MPI	1.5156^{***}		1.5149^{***}	
	(0.276)		(0.276)	
N Sites (5km)		0.1025^{***}		0.1006^{***}
		(0.023)		(0.020)
Controls	✓	✓	✓	✓
FE: Province	✓	✓	✓	✓
Obs.	550	550	550	550
F-stat First Stage	28.882		45.157	

Notes: This table presents two-stage least squares estimates of the impact of environmental exposure, i.e., the number of potentially contaminated sites within a 5 km radius of the municipal center (*N Sites (5Km)*), instrumented by the Mafia Presence Index, on the relative risk of malignant cancer mortality. Columns (1) and (3) report first-stage results for men and women, respectively, demonstrating the strength of the instrument. Columns (2) and (4) show the corresponding second-stage estimates. All specifications include province fixed effects. Second-stage models additionally control for myocardial-infarction relative risk, average age, share of families with more than three members, population density, per-capita income, firms density, and education. Robust standard errors are used. The first-stage F-statistic is reported to assess instrument strength. Robust standard errors in parentheses. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The number of obervations (Obs.) is shown below each column.

Table S4: Environmental exposure and relative risk of cancer mortality, by gender: IV estimates (Model II)

	(1)	(2)	(3)	(4)
	1st Stage (Male)	2nd Stage (Male)	1st Stage (Female)	2nd Stage (Female)
Dependent variable	N Sites (5Km)	RR	D Sites (5Km)	RR
MPI	0.0104***		0.0104***	
	(0.001)		(0.001)	
D Sites (5Km)		14.9457***		14.6378***
		(2.186)		(1.856)
Controls	✓	✓	✓	✓
FE: Province	✓	✓	✓	✓
Obs.	550	550	550	550
F-stat First Stage	102.076		102.351	

Notes: This table presents two-stage least squares estimates of the impact of environmental exposure, i.e. a dummy variable equal to 1 when the number of potentially contaminated sites within a 5 km radius of the municipal center exceeds the sample median (D Sites (5Km)), instrumented by the Mafia Presence Index, on the relative risk of malignant cancer mortality. Columns (1) and (3) report first-stage results for men and women, respectively, demonstrating the strength of the instrument. Columns (2) and (4) show the corresponding second-stage estimates. All specifications include province fixed effects. Second-stage models additionally control for myocardial-infarction relative risk, average age, share of families with more than three members, population density, per-capita income, firms density, and education. The first-stage F-statistic is reported to assess instrument strength. Robust standard errors in parentheses. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The number of obervations (Obs.) is shown below each column.

Table S5: Placebo Test – Environmental Exposure and the Relative Risk of Viral Hepatitis Mortality (Model I)

	(1)	(2)	(3)	(4)
	1st Stage (Male)	2nd Stage (Male)	1st Stage (Female)	2nd Stage (Female)
Dependent variable	N Sites (5Km)	RR	D Sites (5Km)	RR
MPI	1.5156***		1.5149***	
	(0.276)		(0.276)	
N Sites (5km)		0.0701		0.0439
		(0.056)		(0.085)
Controls	✓	✓	✓	✓
FE: Province	✓	✓	✓	✓
Obs.	550	550	550	550
F-stat First Stage	45.159		45.157	

Notes: This table S7 presents two-stage least squares estimates of the impact of environmental exposure, instrumented by the Mafia Presence Index, *MPI*, on the relative risk of viral hepatitis mortality. The instrumented variable, *N Sites (5KM)*, is the number of contaminated sites within a 5 km radius of the municipal centre. Robust standard errors in parentheses. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The number of obervations (Obs.) is shown below each column.

Table S6: Placebo Test – Environmental Exposure and the Relative Risk of Viral Hepatitis Mortality (Model II)

	(1)	(2)	(3)	(4)
	1st Stage (Male)	2nd Stage (Male)	1st Stage (Female)	2nd Stage (Female)
Dependent variable	N Sites (5Km)	RR	D Sites (5Km)	RR
MPI	0.0104***		0.0104***	
	(0.001)		(0.001)	
D Sites (5Km)		10.2196		6.3829
		(8.162)		(12.401)
Controls	✓	✓	✓	✓
FE: Province	✓	✓	✓	✓
Obs.	550	550	550	550
F-stat First Stage	102.076		102.351	

Notes: This table presents two-stage least squares estimates of the impact of environmental exposure, instrumented by the Mafia Presence Index, *MPI*, on the relative risk of viral hepatitis mortality. The instrumented variable, *D Sites (5KM)*, is a dummy variable equal to 1 if the number of sites exceeds the sample median of two. Robust standard errors in parentheses. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The number of obervations (Obs.) is shown below each column.

Table S7: Environmental exposure and relative risk of cancer mortality - IV estimates controlling for social capital (Model I)

	(1)	(2)	(3)	(4)
	1st Stage (Male)	2nd Stage (Male)	1st Stage (Female)	2nd Stage (Female)
Dependent variable	N Sites (5Km)	RR	D Sites (5Km)	RR
MPI	1.5132***		1.5128***	
	(0.277)		(0.277)	
N Sites (5km)		0.1017***		0.0997***
		(0.023)		(0.019)
SocialCapital	0.0028	0.0015	0.0025	0.0016
	(0.011)	(0.002)	(0.011)	(0.002)
Controls	✓	✓	✓	✓
FE: Province	✓	✓	✓	✓
Obs.	550	550	550	550
F-stat First Stage	44.634		44.656	

Notes: This table presents two-stage least squares estimates of the impact of environmental exposure, i.e., the number of potentially contaminated sites within a 5 km radius of the municipal center (N Sites (5Km)), instrumented by the Mafia Presence Index, on the relative risk of malignant cancer mortality. The main control variable is *SocialCapital*, that is, the number of non-profit institutions per 100,000 residents in each municipality in 2019. Robust standard errors in parentheses. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The number of obervations (Obs.) is shown below each column.

Table S8: Environmental exposure and relative risk of cancer mortality - IV estimates controlling for social capital (Model II)

	(1)	(2)	(3)	(4)
	1st Stage (Male)	2nd Stage (Male)	1st Stage (Female)	2nd Stage (Female)
Dependent variable	N Sites (5Km)	RR	D Sites (5Km)	RR
MPI	0.0102***		0.0103***	
	(0.001)		(0.001)	
D Sites (5Km)		15.0382***		14.7081***
		(2.227)		(1.888)
Social capital	0.0002*	-0.0011	0.0002*	-0.0009
	(0.000)	(0.002)	(0.000)	(0.002)
Controls	✓	✓	✓	✓
FE: Province	✓	✓	✓	✓
Obs.	550	550	550	550
F-stat First Stage	98.749		99.108	

Notes: This table presents two-stage least squares estimates of the impact of environmental exposure, i.e., a dummy variable equal to 1 when the number of potentially contaminated sites within a 5 km radius of the municipal center exceeds the sample median (D Sites (5Km), instrumented by the Mafia Presence Index, on the relative risk of malignant cancer mortality. The main control variable is *SocialCapital*, that is, the number of non-profit institutions per 100,000 residents in each municipality in 2019. Robust standard errors in parentheses. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The number of obervations (Obs.) is shown below each column.

Table S9: Environmental Exposure and the Relative Risk of Cancer Mortality – IV Estimates with Geographic Restrictions (Naples and Caserta Provinces)

	(1)	(2)	(3)	(4)
	1st Stage (Male)	2nd Stage (Male)	1st Stage (Female)	2nd Stage (Female)
Dependent variable	N Sites (5Km)	RR	D Sites (5Km)	RR
MPI	1.4707^{***}		0.0076^{***}	
	(0.354)		(0.001)	
N Sites (5Km)		0.1133^{***}		
		(0.031)		
D Sites (5Km)				21.8080^{***}
				(3.665)
Controls	✓	✓	✓	✓
FE: Province	✓	✓	✓	✓
Obs.	196	196	196	196
F-stat First Stage	14.482		48.755	

Notes: This table reports instrumental variable (IV) estimates of the effect of environmental exposure, instrumented by the Mafia Presence Index (MPI), on the relative risk (RR) of cancer mortality at the municipal level. The analysis focuses exclusively on municipalities located in the provinces of Naples and Caserta. Robust standard errors are reported in parentheses. Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The number of observations (Obs.) is reported below each column.

Table S10: Summary table of alternative neighbourhood definitions — Environmental exposure and relative risk of cancer mortality (Male)

	(1)	(2)	(3)	(4)	(5)	(6)
Model I						
N Sites (5km)	0.1025***					
	(0.023)					
N Sites (10km)		0.0473***				
		(0.009)				
N Sites (20km)			0.0198***			
			(0.004)			
Model II						
D Sites (5Km)				14.9457***		
				(2.186)		
D Sites (10Km)					18.2845***	
					(2.864)	
D Sites (20Km)						27.9092***
						(5.885)
Obs.	550	550	550	550	550	550
F-stat First Stage	45.159	70.059	77.205	73.590	73.590	38.878

Notes: The table reports second-stage estimates of the impact of environmental exposure , instrumented by the Mafia Presence Index, *MPI*, on the relative risk of malignant cancer mortality among males. In *Model I*, the instrumented variable is, in turn, the number of contaminated sites within a 5-, 10-, or 20-km radius of the municipal centre. In *Model II*, the instrumented variable is a dummy variable equal to 1 if the number of sites exceeds the sample median within a 5-, 10-, or 20-km radius of the municipal centre (i.e., 2, 8, and 159 sites, respectively). The first-stage F-statistic is reported to assess instrument strength. Robust standard errors in parentheses. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The number of obervations (Obs.) is shown below each column.

Table S11: Summary table of alternative neighbourhood definitions — Environmental exposure and relative risk of cancer mortality (Female)

	(1)	(2)	(3)	(4)	(5)	(6)
Model I						
N Sites (5Km)	0.101 ***					
	(5.13)					
N Sites (10Km)		0.0464***				
		(5.98)				
N Sites (20Km)			0.0194 ***			
			(6.16)			
Model II						
D Sites (5Km)				14.64***		
				(7.89)		
D Sites (10Km)					17.87***	
					(6.75)	
D Sites (20Km)						27.36***
						(5.20)
Obs.	550	550	550	550	550	550
F-stat First Stage	45.157	70.137	77.462	102.351	74.364	38.964

Notes: The table reports second-stage estimates of the impact of environmental exposure , instrumented by the Mafia Presence Index, *MPI*, on the relative risk of malignant cancer mortality among females. In *Model I*, the instrumented variable is, in turn, the number of contaminated sites within a 5-, 10-, or 20-km radius of the municipal centre. In *Model II*, the instrumented variable is a dummy variable equal to 1 if the number of sites exceeds the sample median within a 5-, 10-, or 20-km radius of the municipal centre (i.e., 2, 8, and 159 sites, respectively). The first-stage F-statistic is reported to assess instrument strength. Robust standard errors in parentheses.
Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The number of obervations (Obs.) is shown below each column.

Table S12: Summary table of alternative neighbourhood definitions — Environmental exposure and relative risk of cancer mortality, excluding all provincial capital municipalities

	(1)	(2)	(3)	(4)	(5)	(6)
Model I						
N Sites (5Km)	0.113***					
	(0.02)					
N Sites (10Km)		0.050***				
		(0.01)				
N Sites (20Km)			0.020***			
			(0.00)			
Model II						
D Sites (5Km)				15.206***		
				(1.84)		
D Sites (10Km)					18.389***	
					(2.52)	
D Sites (20Km)						27.991***
						(5.37)
Obs.	545	545	545	545	545	545
F-stat First Stage	39.690	63.861	71.840	98.048	72.058	38.995

Notes: The table reports second-stage estimates of the impact of environmental exposure , instrumented by the Mafia Presence Index, *MPI*, on the relative risk of malignant cancer mortality among population. In *Model I*, the instrumented variable is, in turn, the number of contaminated sites within a 5-, 10-, or 20-km radius of the municipal centre. In *Model II*, the instrumented variable is a dummy variable equal to 1 if the number of sites exceeds the sample median within a 5-, 10-, or 20-km radius of the municipal centre (i.e., 2, 8, and 159 sites, respectively). The first-stage F-statistic is reported to assess instrument strength. Robust standard errors in parentheses.
Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The number of obervations (Obs.) is shown below each column.

Table S13: Environmental exposure and relative risk of cancer mortality controlling for municipal council dissolution

	(1)	(2)	(3)	(4)	(5)	(6)
Model I						
N Sites (5km)	0.105***					
	(0.0234)					
N Sites (10Km)		0.0475***				
		(0.00888)				
N Sites (20Km)			0.0193***			
			(0.00329)			
Model II						
D Sites (5Km)				14.15***		
				(1.771)		
D Sites (10Km)					16.69***	
					(2.261)	
D Sites (20Km)						25.56***
						(4.703)
Dissolved	-0.909	-0.306	0.342	1.18	2.02***	2.01
	(2.52)	(1.68)	(1.42)	(0.998)	(1.04)	(1.50)
Controls	✓	✓	✓	✓	✓	✓
FE: Province	✓	✓	✓	✓	✓	✓
Obs.	550	550	550	550	550	550
F-stat First Stage	38.083	61.765	71.633	101.470	79.183	41.363

Notes: The table reports second-stage estimates of the impact of environmental exposure , instrumented by the Mafia Presence Index, *MPI*, on the relative risk of malignant cancer mortality among population. In *Model I*, the instrumented variable is, in turn, the number of contaminated sites within a 5-, 10-, or 20-km radius of the municipal centre. In *Model II*, the instrumented variable is a dummy variable equal to 1 if the number of sites exceeds the sample median within a 5-, 10-, or 20-km radius of the municipal centre (i.e., 2, 8, and 159 sites, respectively). The first-stage F-statistic is reported to assess instrument strength. Robust standard errors in parentheses. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The number of obervations (Obs.) is shown below each column.

Table S14: Environmental exposure and relative risk of cancer mortality controlling for confiscated assets

	(1)	(2)	(3)	(4)	(5)	(6)
Model I						
N Sites (5km)	0.121***					
	(0.0307)					
N Sites (10Km)		0.0497***				
		(0.00956)				
N Sites (20Km)			0.0184***			
			(0.00307)			
Model II						
D Sites (5Km)				13.48***		
				(1.725)		
D Sites (10Km)					16.14***	
					(2.275)	
D Sites (5Km)						25.33***
						(4.915)
Confiscated Assets	-0.039	-0.012	0.012	0.019*	0.023*	0.018
	(0.04)	(0.018)	(0.016)	(0.011)	(0.011)	(0.013)
Controls	✓	✓	✓	✓	✓	✓
FE: Province	✓	✓	✓	✓	✓	✓
Obs.	550	550	550	550	550	550
F-stat First Stage	27.732	52.956	72.802	103.637	78.215	38.811

Notes: The table reports second-stage estimates of the impact of environmental exposure, instrumented by the Mafia Presence Index, *MPI*, on the relative risk of malignant cancer mortality among population. In *Model I*, the instrumented variable is, in turn, the number of contaminated sites within a 5-, 10-, or 20-km radius of the municipal centre. In *Model II*, the instrumented variable is a dummy variable equal to 1 if the number of sites exceeds the sample median within a 5-, 10-, or 20-km radius of the municipal centre (i.e., 2, 8, and 159 sites, respectively). The first-stage F-statistic is reported to assess instrument strength. Robust standard errors in parentheses. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The number of obervations (Obs.) is shown below each column.

Table S15: Environmental exposure and relative risk of cancer mortality controlling for muncipal council dissolution and confiscated assets

	(1)	(2)	(3)	(4)	(5)	(6)
Model I						
N Sites (5km)	0.124***					
	(0.0317)					
N Sites (10Km)		0.0501***				
		(0.0102)				
N Sites (20Km)			0.0183***			
			(0.00319)			
Model II						
D Sites (5Km)				13.01***		
				(1.717)		
D Sites (10Km)					15.15***	
					(2.122)	
D Sites (20Km)						23.70***
						(4.460)
Dissolved	-0.725	-0.218	0.219	0.928	1.651	1.73
	(2.81)	(1.73)	(1.39)	(1.00)	(1.03)	(1.43)
Confiscated Assets	-0.041	-0.012	0.012	0.019*	0.021**	0.017
	(0.041)	(0.018)	(0.016)	(0.01)	(0.01)	(0.01)
Controls	✓	✓	✓	✓	✓	✓
FE: Province	✓	✓	✓	✓	✓	✓
Obs.	550	550	550	550	550	550
F-stat First Stage	24.330	48.199	68.464	103.188	82.794	41.193

Notes: The table reports second-stage estimates of the impact of environmental exposure, instrumented by the Mafia Presence Index, *MPI*, on the relative risk of malignant cancer mortality among population. In *Model I*, the instrumented variable is, in turn, the number of contaminated sites within a 5-, 10-, or 20-km radius of the municipal centre. In *Model II*, the instrumented variable is a dummy variable equal to 1 if the number of sites exceeds the sample median within a 5-, 10-, or 20-km radius of the municipal centre (i.e., 2, 8, and 159 sites, respectively). The first-stage F-statistic is reported to assess instrument strength. Robust standard errors in parentheses. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The number of obervations (Obs.) is shown below each column.

Table S16: Conley UCI and LTZ Sensitivity Analysis

	IV coeff	UCI ±0.05 LB	UCI ±0.05 UB	UCI ±0.10 LB	UCI ±0.10 UB	UCI ±0.20 LB	UCI ±0.20 UB	LTZ coeff
Model I								
N Sites (5km)	0.102	0.042	0.177	0.014	0.219	-0.052	0.303	0.102
N Sites (10km)	0.047	0.022	0.077	0.008	0.095	-0.024	0.132	0.047
N Sites (20km)	0.020	0.009	0.032	0.003	0.039	-0.010	0.054	0.020
Model II								
D Sites (5km)	14.815	6.908	23.867	2.38	29.406	-7.533	40.630	14.815
D Sites (10km)	18.076	8.364	29.571	2.942	36.542	-9.333	50.657	18.076
D Sites (20km)	27.682	11.881	47.959	4.305	59.484	-14.692	82.742	27.682
Controls	✓	✓	✓	✓	✓	✓	✓	✓
FE: Province	✓	✓	✓	✓	✓	✓	✓	✓
Obs.	550	550	550	550	550	550	550	550

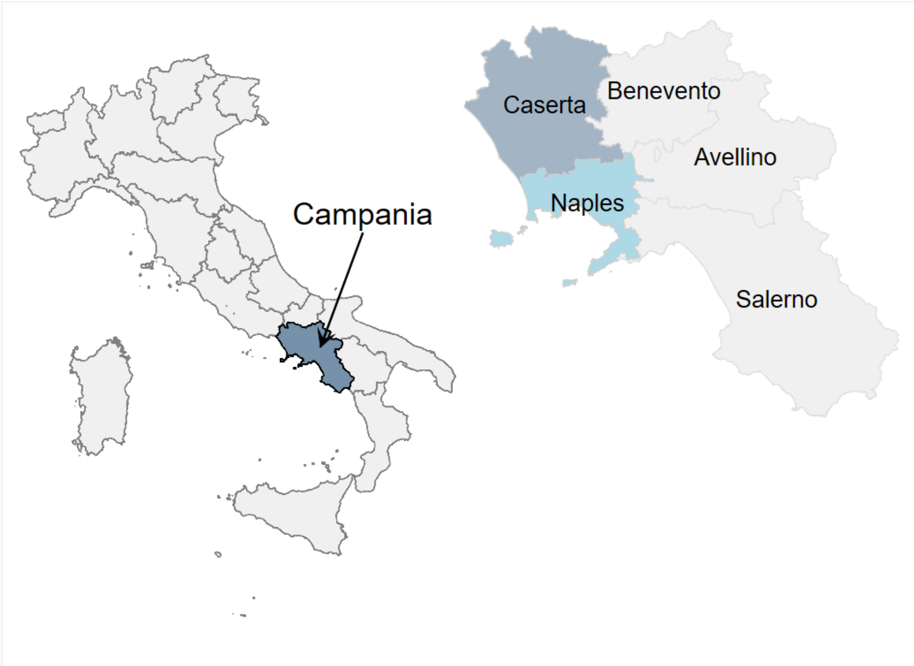
Notes: The table reports sensitivity analyses allowing for violations of the exclusion restriction. UCI columns report lower and upper bounds under increasing degrees of admissible violation (±0.05, ±0.10, ±0.20). LTZ estimates assume small violations centred at zero. *Model I* uses continuous measures of environmental exposure, while *Model II* relies on binary indicators based on the sample median. All specifications include the full set of controls and province fixed effects. The number of obervations (Obs.) is shown below each column.

Table S17: Mafia Presence and Cancer Mortality: OLS Estimates in Restricted Samples without Contaminated Sites

	Dependent variable: RR							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
MPI	0.333***	0.330***	0.346***	0.193***	0.170	0.180	0.256**	0.133
	(0.0228)	(0.0231)	(0.0223)	(0.0251)	(0.134)	(0.134)	(0.122)	(0.128)
RR Effort		1.784*	0.0898	0.433		0.967	0.0509	-0.429
		(1.000)	(0.788)	(0.773)		(0.679)	(0.606)	(0.472)
AV			-5.477***	-6.586***			-7.520***	-7.000***
			(0.868)	(0.810)			(1.780)	(1.845)
BN			-4.135***	-4.669***			-5.728***	-3.646*
			(0.978)	(0.884)			(2.021)	(2.133)
NA			-5.486***	-11.11***				
			(1.699)	(1.669)				
SA			-11.47***	-10.90***			-11.58***	-10.30***
			(0.832)	(0.840)			(1.449)	(1.670)
Age				-3.882**				-2.552
				(1.608)				(2.761)
Age^2				0.0348**				0.0212
				(0.0170)				(0.0291)
Family>3 (%)				4.428				-5.539
				(4.903)				(5.942)
PopDensity				0.00261***				0.00520
				(0.000561)				(0.00425)
GDP p.c.				1.142***				0.725
				(0.269)				(0.458)
Firms density				-0.0733***				-0.0657**
				(0.0184)				(0.0301)
% No primary school				0.174**				0.0355
				(0.0833)				(0.132)
R-squared	0.481	0.486	0.660	0.760	0.0235	0.0316	0.428	0.519
Obs	378	378	378	378	105	105	105	105

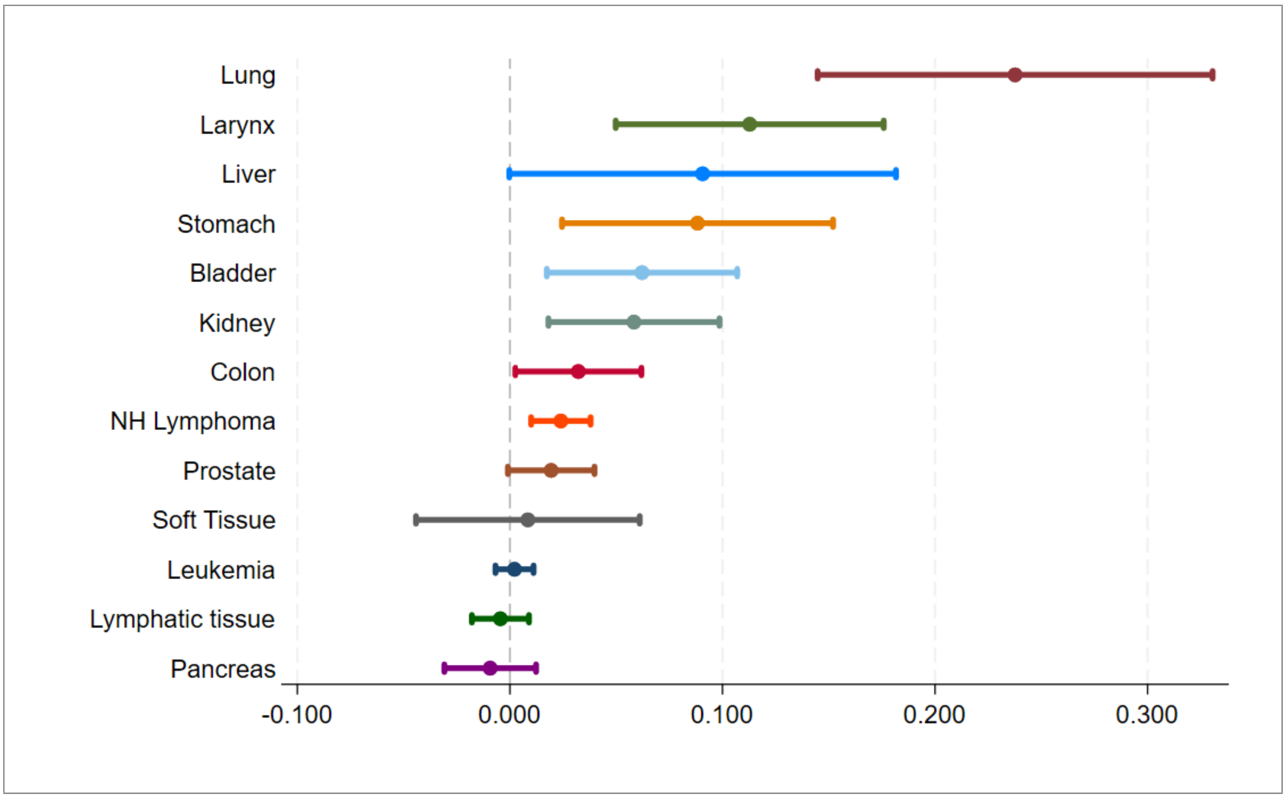
Notes: The table reports OLS estimates of the relationship between mafia presence and the relative risk of malignant cancer mortality, pooling men and women. Columns (1)–(4) restrict the sample to municipalities with no contaminated sites within the municipal territory, while columns (5)–(8) restrict the sample to municipalities with no contaminated sites within a 5 km radius of the municipal centre. The main explanatory variable is the Mafia Presence Index (MPI). Controls are added progressively across specifications: columns (1) and (5) include only MPI; columns (2) and (6) additionally control for myocardial infarction mortality to proxy preventive behaviour (Effort); columns (3) and (7) include provincial fixed effects; columns (4) and (8) further add demographic and socioeconomic controls, namely average age and its square, the share of families with more than three members, population density, per-capita income, firm density, and the share of individuals without primary education. Robust standard errors are reported in parentheses. Significance levels: $p < 0.10$, $p < 0.05$, $p < 0.01$.

Figure S1: Geographical Location of the Campania Region and the Land of Fires Area



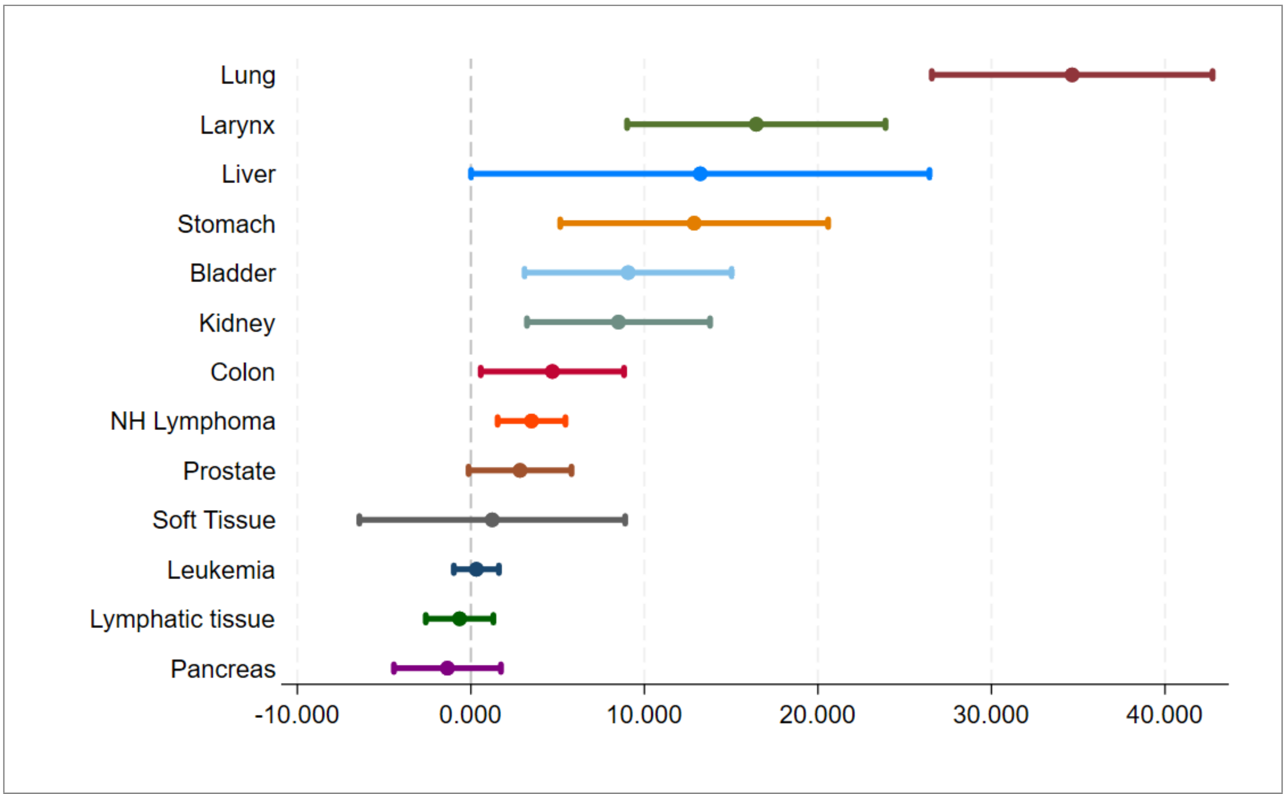
Notes: The map shows the location of the Campania region in southern Italy. The inset highlights the provinces of Caserta and Naples, which comprise the area known as the Land of Fires. Naples has approximately 2.9 million inhabitants and Caserta about 0.9 million, together accounting for roughly 69% of the region's total population.

Figure S2: Environmental exposure and relative risk of cancer mortality: IV estimates (Model I - Male)



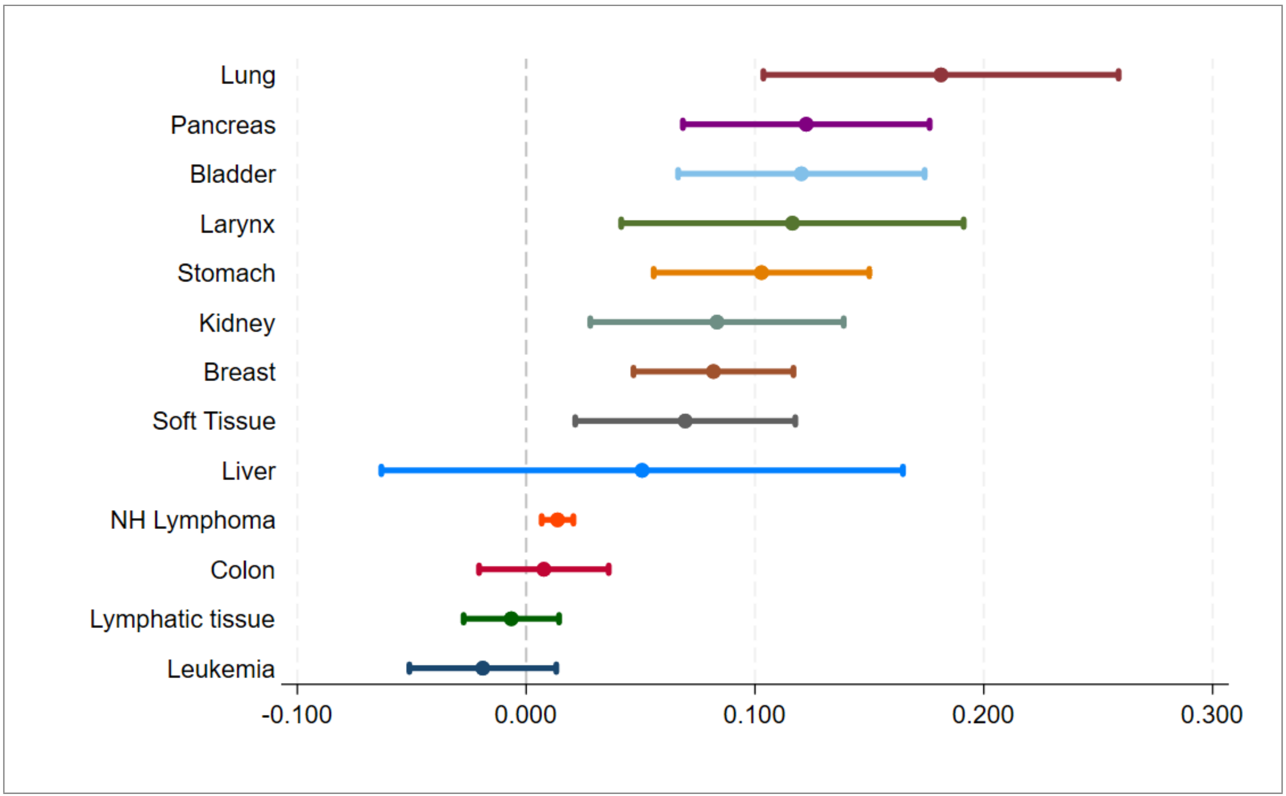
Notes: Estimated coefficients and 95% confidence intervals for the effect of proximity to contaminated sites on male mortality, by cancer type. Each coefficient is obtained from a fully specified IV regression, instrumenting the number of potentially contaminated sites within a 5km radius of the municipal centre with the MPI.

Figure S3: Environmental exposure and relative risk of cancer mortality: IV estimates (Model II - Male)



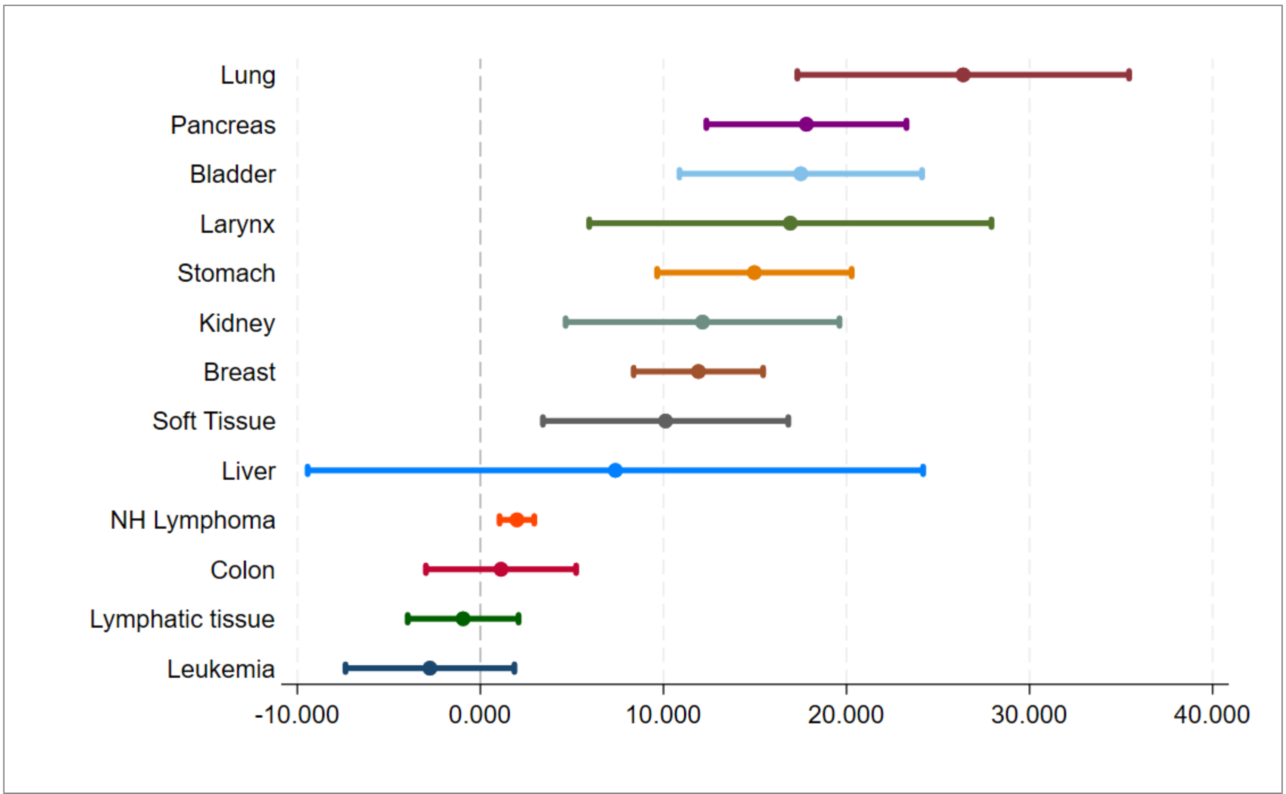
Notes: Estimated coefficients and 95 % confidence intervals for the effect of proximity to contaminated sites on male mortality, by cancer type. Each coefficient is obtained from a fully specified IV regression, instrumenting *D Sites (5km)*, a dummy variable equal to 1 when the number of potentially contaminated sites within a 5km radius of the municipal centre exceeds the sample median, with the MPI.

Figure S4: Environmental exposure and relative risk of cancer mortality: IV estimates (Model I - Female)



Notes: Estimated coefficients and 95% confidence intervals for the effect of proximity to contaminated sites on female mortality, by cancer type. Each coefficient is obtained from a fully specified IV regression, instrumenting the number of potentially contaminated sites within a 5km radius from the municipal centre with the MPI.

Figure S5: Environmental exposure and relative risk of cancer mortality: IV estimates (Model II - Female)



Notes: Estimated coefficients and 95 % confidence intervals for the effect of proximity to contaminated sites on female mortality, by cancer type. Each coefficient is obtained from a fully specified IV regression, instrumenting *D Sites (5km)*, a dummy variable equal to 1 when the number of potentially contaminated sites within a 5km radius of the municipal centre exceeds the sample median, with the MPI.

References

Boussofiane, A., Dyson, R. G., & Thanassoulis, E. (1991). Applied data envelopment analysis. *European journal of operational research*, *52*(1), 1–15.

Cooper, W. W., Seiford, L. M., & Zhu, J. (2011). Data envelopment analysis: History, models, and interpretations. In *Handbook on data envelopment analysis* (pp. 1–39). Springer.

Di Cataldo, M., & Mastrorocco, N. (2022). Organized crime, captured politicians, and the allocation of public resources. *The Journal of Law, Economics, and Organization*, *38*(3), 774–839.

Dugato, M., Calderoni, F., & Campedelli, G. (2020). Measuring organised crime presence at the municipal level. *Social Indicators Research*, *147*(1), 237–261.

Rosano, A., Pacelli, B., Zengarini, N., Costa, G., Cislaghi, C., & Caranci, N. (2020). Aggiornamento e revisione dell'indice di deprivazione italiano 2011 a livello di sezione di censimento. *Epidemiol Prev*, *44*(2-3), 162–70.