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Hazardous sites exposure on poverty effects: "coming to the nuisance" phenomenon?

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Abstract

Beyond monetary disadvantage, according to extensive literature, poverty is associated with an increased risk of exposure to various environmental nuisances. In this study, we assess the relative effect of exposure on poverty and its intensity in metropolitan France, seeking to identify the causal mechanism behind it. To achieve this, we utilize socio-economic data from 2,287,871 200-meter square geographic units published by Insee and the location of 3895 E-PRTR sites. We employ Antle (1983)'s statistical moments approach to analyze the effect of exposure on poverty and its intensity. We also evaluate the relative effect of exposure on the number of poor households and the growth in the number of poor households. Our results indicate that exposed urban and peri-urban areas are associated with increased and intensified poverty. In contrast, exposed rural areas exhibit lower poverty and experience less intensification of poverty. Moreover, on a national scale, past exposure is associated with a higher number of poor households and an increased trend, highlighting a "coming to the nuisance" mechanism for poor households.

Keywords: Environmental justice, poverty, polluting sites, moment-based approach.

JEL classification: O15, O13, Q53, Q56.

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1 Introduction

In 2020, 9 million individuals were categorized as poor in metropolitan France, representing 14.4% of the population (Gerardin, 2023). This relative measure of monetary poverty, commonly employed by the *"Institut national de la statistique et des études économiques"* (hereafter Insee), is derived from the population's overarching distribution of living standards. It entails establishing a threshold below which an individual is considered poor. This threshold is standardized at 60% of the median standard of living and corresponds, in 2020, to 1,120 euros per consumption unit (Gerardin, 2023). Despite integrating poverty alleviation and prevention measures into governmental reforms, as evidenced by the National Strategy for the Prevention and Combat against Poverty launched in 2018, the poverty rate and its intensity[1] have exhibited marginal change in France since the late 1990s (Insee, 2021).

Beyond monetary deprivation and the associated social risks, a substantial body of literature highlights a disproportionate burden of environmental hazards supported by the most economically modest households (e.g., Collins et al., 2016; Glatter-Götz et al., 2019; Zwickl, 2019). For instance, Fosse et al. (2022) and Salesse (2022) demonstrate that the least affluent households in France are the most affected by pollution. This overexposure of economically modest households may exacerbate the social risks these households already face. On the one hand, overexposure of economically modest households can, as explained by Banzhaf et al. (2019b), contribute to perpetuating the phenomenon of poverty traps. On the other hand, this overexposure may, according to Hajat et al. (2015), accentuate the risk of poor health, even as existing health disparities exist (see, for instance, McLean et al., 2014 and Schäfer et al., 2012).

The analysis of disparities in exposure to environmental hazards falls within the concept of environmental justice, a subject that has garnered extensive scholarly attention[2]. The concept of environmental justice originated in the United States in the 1980s, emanating from civil protests against installing a landfill in Warren County, which, among other factors, housed a significant proportion of low-income households. According to Banzhaf et al. (2019b), the pioneering work of the US General Accounting Office (1983), Bullard (1983), and United Church of Christ (1987) placed exposure disparities as a stylized fact in social sciences.

Most studies approach the issue of environmental justice from the perspective of distributive justice (Collins et al., 2016; Glatter-Götz et al., 2019; Zwickl, 2019), corresponding to one of the four components of Kuehn (2000)'s taxonomy of environmental justice. Distributive justice refers to the notion that environmental burdens and amenities should be equitably distributed, with no segment of the population disproportionately exposed. In cases of disparities in exposure to environmental hazards, this concept advocates for reducing environmental burdens rather than reallocating among different populations. Timmons Roberts et al. (2018) summarize the concept of distributive justice: *"Distributive justice refers to inequalities in the distribution of neighborhood environmental quality, both bad and good, such as the presence (or absence) of contaminated sites and air and water pollution in neighborhoods and the absence (or presence) of trees, parks, open space in them."*

As suggested by Banzhaf et al. (2019b), understanding the causal mechanism leading to these environmental inequalities would serve the dual purpose of identifying the origin of these disparities and enhancing public policies to mitigate them. The literature highlights the mechanism of "voting with their feet" for environmental quality as one of the two phenomena that can explain the overrepresentation of poor households around environmental hazards (see Banzhaf et al.,

[1] Insee defines the intensity of poverty as the difference between the median standard of living of poor households and the poverty threshold.

[2] See Cain et al. (2023) and Di Fonzo et al. (2022) for a literature review.

2019a,b; Mohai and Saha, 2015a). For instance, Banzhaf and Walsh (2008) highlight a decrease in population density and average income in California areas experiencing environmental quality degradation. However, this study does not identify whether it is a "coming to the nuisance" phenomenon by low-income households, a "fleeing from the nuisance" phenomenon by affluent households, or both simultaneously. Levasseur et al. (2021) identify an intention to "fleeing from the nuisance" for the highest income quintile in the Southwest of Europe. To our knowledge, no study distinctly evaluates low-income households' presence or absence of a "coming to the nuisance" phenomenon.

The aim of this study is twofold. Firstly, we analyze the effect of exposure to hazardous sites, compared to non-exposure, on poverty and its intensity. The objectives involve providing additional proof regarding exposure disparities and addressing the question of the intensity of poverty around hazardous sites, which, to our knowledge, has yet to be studied. Secondly, we examine past exposure's effect on the number of poor households and its growth compared to non-exposure. The objective aims to evaluate low-income households' presence or absence of a "coming to the nuisance" mechanism.

To address this dual objective, we utilize the proportion of poor households in metropolitan France in 2019, taken from the gridded data with a 200-meter resolution published by Insee. These data represent the finest available geographical scale in France. As the exposure variable, we employ the location of sites listed in the European Pollutant Release and Transfer Register (E-PRTR) in metropolitan France in 2010. We apply Antle (1983)'s statistical moments approach to measure exposure's effect on poverty and its intensity compared to non-exposure. As a robustness check, we conduct the same analysis using the average standard of living per geographical unit. To address an endogeneity issue induced by simultaneity bias, we implement a temporal lag between the proportion of poor households and the exposure. Additionally, applying a temporal lag allows for examining the "coming to the nuisance" mechanism for poor households. Thus, compared to non-exposure, we assess the average effect of exposure in 2010 on the number of poor households in 2019 and the evolution of the number of poor households between 2015 and 2019. To account for the heterogeneity introduced by population density in the relationship between poverty and exposure (as Neier, 2021 or Salesse, 2022), we interact the exposure variable with the associated municipality density. We conduct a comprehensive robustness check to ensure the independence of our results from the methodology used.

The remainder of this paper is structured as follows. The next section presents a literature review of the main findings and challenges related to environmental justice. Section 3 presents the methodology, data, and descriptive statistics. Section 4 presents the main results. Section 5 presents the sensitivity analysis results, and section 6 comments and concludes on the results obtained.

2 Literature review

The concept of environmental justice emerged in the United States in the 1980s from a social protest against installing a landfill contaminated with polychlorinated biphenyls in Warren County, where a significant proportion of low-income groups and some ethnic groups were concentrated. The seminal work of the US General Accounting Office (1983) and Bullard (1983) showed, for some counties, an over-representation of some ethnic groups and people with low incomes around landfills and waste incinerators. The first nationwide study, by the United Church of Christ (1987), confirms the previous findings. According to Banzhaf et al. (2019b), these three studies place inequalities in exposure to environmental nuisances as a stylized fact in social science. Since then, although the methodologies used to apprehend exposure to environ-

mental nuisances have varied, the studies identified a relationship between economic disadvantage and exposure to environmental hazards. Indeed, while some studies highlight an overexposure of the most economically modest households to certain types of pollutants (e.g., Jbaily et al., 2022; Rosofsky et al., 2018; Salesse, 2022), others reveal an overrepresentation of poor households around environmental hazards (e.g., Neier, 2021; Schaeffer and Tivadar, 2019; Zwickl, 2019).

While highlighting the overexposure of modest households to air pollution is of public utility, mainly due to the unequal health impacts it can generate (see Lavaine, 2015 or Ouidir et al., 2017), visible environmental nuisances rather than the presence of pollutants in the air influence more the residential choice. This influence is attributed, in part, to the imperfect information available to households (Hausman and Stolper, 2021). Recognizing disparities in exposure to visible nuisances can deepen our understanding of the underlying mechanisms. The literature highlights an overrepresentation of modest households in proximity to various environmental hazards, such as waste treatment sites (e.g., Mohai and Saha, 2015b), fracking activities (e.g., Zwickl, 2019), industrial sites (e.g., Neier, 2021), and landfills (e.g., Baden and Coursey, 2002). Moreover, some studies also explore the unequal distribution of environmental amenities. For instance, in the Grenoble-Alpes metropolitan area in France, Schaeffer and Tivadar (2019) demonstrate that the poorest households are farther away (respectively closer) to green spaces (respectively hazardous sites) than the wealthiest households. The investigation into the overrepresentation of poor households near environmental hazards is well-documented in the United States and Europe. However, studies addressing this issue in France are more sporadic and often concentrated on specific geographic areas. For instance, Hautdidier et al. (2021), focusing on the Aix-Marseille-Provence metropolitan area, and Viel et al. (2011), examining the Franche-Comté region, emphasize the overrepresentation of disadvantaged households around polluting sites. To our knowledge, the sole nationwide study exploring the relation between economic disadvantage and overrepresentation around hazardous sites is Laurian and Pottratz (2008)'s research.

As previously mentioned, the discernible presence of environmental nuisances significantly influences household residential decisions (Hausman and Stolper, 2021). Consequently, most environmental justice studies rely on residential proximity to potential pollution sources as a proxy for exposure to environmental hazards (e.g., Neier, 2021; Schaeffer and Tivadar, 2019; Zwickl, 2019). Shao et al. (2021) describe the three primary methodologies employed in the literature to investigate the correlation between economic disadvantage and exposure to environmental hazards. The first method, better suited for aggregated data, such as a municipality in France or a county in the United States, corresponds with the spatial coincidence method. In this approach, if a geographical area hosts at least one environmental hazard, it is considered an exposed unit. Although suitable for aggregated data, this methodology raises, among other issues, an "edge effect problem" (Chakraborty et al., 2011). A geographic area whose neighboring area hosts a site near its border will be considered an unexposed unit. The second methodology, considered an alternative to the limitations of the first (Chakraborty et al., 2011; Mohai and Saha, 2006, 2007, 2015a,b), distinguish three approaches to apprehending this methodology. By first defining a buffer zone, in the "50% areal containment" approach, consider a geographical unit exposed if at least half of its area belongs to the buffer zone. For the "areal apportionment" approach, deem a geographical unit exposed when it intersects the buffer zone (with socioeconomic characteristics weighted by the area of intersection). Consider a geographical unit exposed if it intersects the buffer zone in the' boundary intersection' approach. Some studies, such as Neier (2021) or Rüttenauer and Best (2021), use the exact distance between the centroid of the geographical unit under study and the nearest source of nuisance. These approaches require having data at a relatively fine geographical scale. The third methodology involves accounting for pollutant emissions by weighting them according to their risks to human health. The assignment of the exposure status of a geographical unit can be accomplished by employing either of the two methodologies

mentioned above or by employing pollution plume modeling.

Although methodologies for approximating residential proximity to environmental nuisances are various, the conclusions drawn from the literature highlight an overrepresentation of disadvantaged households around environmental nuisances (e.g., Laurian and Pottratz, 2008; Mohai and Saha, 2015b; Neier, 2021). As noted in the introduction, understanding the causal mechanisms behind these exposure disparities would, according to Banzhaf et al. (2019b), help identify their origins, thereby improving public policies to reduce them. The literature primarily identifies two causal mechanisms (Banzhaf et al., 2019a,b; Mohai and Saha, 2015a,b) without, however, establishing the superiority of one mechanism over the other, hence drawing an analogy to the "Chicken and the Egg" debate as noted by Mohai et al. (2009) in addressing this type of issue. The first mechanism, "disproportionate siting," describes the phenomenon wherein polluting sites predominantly install themselves in areas that concentrate low-income groups. Arguments presented in the literature (e.g., Banzhaf et al., 2019a; Glatter-Götz et al., 2019; Mohai and Saha, 2015a; Rüttenauer, 2018; Zwickl, 2019) assert that areas harboring a substantial concentration of disadvantaged households exhibit characteristics such as relatively lower land prices, an available labor force, diminished political influence, minimal opposition, and an abundant transportation network. These factors partly explain why hazardous sites focus on establishing themselves in these areas (see Wolverton, 2009). The second mechanism, called a "post-siting demographic change," describes the phenomenon wherein pollutant sites' establishment or past presence induces demographic changes in exposed areas. Environmental nuisances potentially trigger a mechanism of "fleeing from the nuisance" for wealthier households, simultaneously leading to a mechanism of "coming to the nuisance" for more modest households. Both of these mechanisms originate from the extension of Tiebout (1956)'s "vote by feet" mechanism, as developed by Banzhaf et al. (2019b). According to this theory, households make a trade-off between neighborhood amenities, encompassing environmental quality and consumption, encompassing housing expenses. Environmental nuisances can generate negative externalities, such as noise, visual disruptions, or smelly emissions, which may diminish the area's attractiveness and contribute to a decline in land value. Indeed, as Currie et al. (2015) and Hanna (2007) highlight, hazardous sites can exert downward pressure on land prices. Although households, regardless of income, generally derive higher utility from a clean environment, not all are equally willing to pay for access to high environmental quality. Wealthier households are typically willing to pay relatively more than less affluent households to have a clean environment. Areas subjected to environmental nuisances may thus prompt wealthier households to move away from these zones while drawing less affluent households to reside in them, complicating the determination of the predominance of one mechanism over the other. Some studies highlight a "vote by feet" mechanism, as demonstrated by Banzhaf and Walsh (2008) in California or Rüttenauer (2018) in West Germany, without, however, specifying whether it involves "fleeing from the nuisance" and, or "coming to the nuisance." Conversely, as Levasseur et al. (2021) observed in a study focusing on a sample of households in Southwest Europe, exposure is associated with a "fleeing from nuisance" mechanism among wealthier households. The "disproportionate siting" and "post-siting demographic change" mechanisms seem not independent. In a longitudinal study, Mohai and Saha (2015b) demonstrate that establishing waste treatment sites in the United States led to higher economic disparities, indicating a "post-siting demographic change." However, they also note that this demographic shift had begun before establishing these sites, revealing a "disproportionate siting."

Empirically testing the presence of disparities in exposure to environmental nuisances amounts to testing one of the two mechanisms mentioned above. Specifically, are less affluent households more exposed than the rest of the population because they have settled closer to the nuisance or because the nuisance has installed itself close to them? An endogeneity issue arises, induced by

a simultaneity bias. Most empirical studies identify the disparities in exposure to environmental nuisances by assessing whether the level of economic disadvantage in a geographical area is a relevant determinant of exposure (e.g., Laurian and Pottratz, 2008; Levasseur et al., 2021; Neier, 2021; Zwickl, 2019). The primary strategies presented in the literature to address the reverse causality between income and exposure involve instrumenting or considering a past income. For instance, Levasseur et al. (2021), in assessing the likelihood of living in a polluted area, use individual size and parents' education level to instrument income. Conversely, Zwickl (2019), in evaluating the effect of income on residential distance with fracking activities, considers a past income level, explaining that disparities in exposure to environmental nuisances can be interpreted, in this case, as a phenomenon of "disproportionate siting" rather than a phenomenon of "post-siting demographic change." In fact, beyond correcting simultaneity bias, applying a temporal lag can also help understand the causal mechanism behind disparities in exposure to environmental nuisances. As highlighted by Banzhaf and Walsh (2008), who seek to identify a "vote by feet" mechanism, considering past exposure cannot be the consequence of a specific present income level but is the cause.

Given the existing literature, the contribution of this study is twofold. Firstly, by utilizing fine geographical data, we investigate the issue of the relative effect of exposure on poverty and a measure of its intensity, which previous studies have yet to address. Secondly, we assess whether a "coming to the nuisance" mechanism exists for poor households in France, an aspect that the literature has not already distinctly tested.

3 Methodology and data

3.1 Empirical strategy

To assess the effect of exposure on the poverty distribution across the territory, we adopted a statistical moment-based approach inspired by Antle (1983). We consider the proportion of poor households as a function, which has an exposure index, a component linked to socioeconomic and demographic characteristics, and a component related to what we will define as the intensity of poverty. It can be represented as follows:

$$\%Poverty_i = g(Exposed_i, X_i, \epsilon_i), \tag{1}$$

where the index i corresponds to the geographical unit considered. The variable $\%Poverty$ corresponds to the proportion of poor households in the geographical unit considered. The variable $Exposed$ indicates the units considered exposed to a potential source of environmental hazards. X is a vector representing a unit's socioeconomic and demographic characteristics. ϵ is a vector of unobservable and, or omitted variables that can influence the proportion of poor households.

We employ a statistical moment-based approach to assess the probability distribution of the stochastic poverty function $g(Exposed_i, X_i, \epsilon_i)$. To do that, we proceed to estimate an Ordinary Least Squares (OLS) model, whose econometric specification takes the following form:

$$g(Exposed_i, X_i, \epsilon_i) = f_1(Exposed_i, X_i, \beta_1) + u_i, \tag{2}$$

where β_1 represents the various vectors of model parameters indexed by 1 to characterize the moment of order 1, the error term u is a random variable of zero mean and constant variance in

the case of our specification. Thus, $f_1(Exposed_i, X_i, \beta_1)$ corresponds to the expectation of the poverty function, that is, the first statistical moment, where β_1 are estimated parameter vectors representing the effects of the exposure index, socioeconomic and demographic characteristics on the average proportion of poor households per unit.

Higher-order statistical moments of Eq. (2) are expressed as follows :

$$E[(g(Exposed_i, X_i, \epsilon_i) - f_1(Exposed_i, X_i, \beta_1))^k | X] = f_k(Exposed_i, X_i, \beta_k). \tag{3}$$

When $k = 2$, $f_2(Exposed_i, X_i, \beta_2)$ refers to the moment of order 2, where β_2 describes the effect of the exposure index and socioeconomic and demographic characteristics on the variance of the proportion of poor households. When $k = 3$, $f_3(Exposed_i, X_i, \beta_3)$ refers to the moment of order 3, where β_3 describes the effect of exposure and socioeconomic and demographic characteristics on the skewness of the proportion of poor households.

This statistical moment-based approach enables us to distinguish the effect of exposure, relative to non-exposure, on the average, the variance, and the skewness of the proportion of poor households. To estimate the average effect, we use the following econometric specification based on Eq. (2) :

$$\%Poverty_i = \beta_0 + \beta_1 Exposed_i + \beta_2 X_i + u_i. \tag{4}$$

We deduce the estimated residuals from the estimated coefficients, corresponding to the difference between observed value and estimated value. Thus, to estimate the effect of exposure, relative to non-exposure, on the variance of the proportion of poor households, we take the variance of the residuals obtained from Eq. (4) as the dependent variable. This estimate is derived from Eq. (3) when $k = 2$ and takes the following form:

$$(\hat{u}_i)^2 = \sigma_0 + \sigma_1 Exposed_i + \sigma_2 X_i + \theta_i, \tag{5}$$

where θ_i refers to error term. The variance of the proportion of poor households quantifies the dispersion of its distribution around the mean. A positive (respectively, negative) dispersion coefficient indicates that exposed units are associated with a larger (respectively, smaller) dispersion of the proportion of poor households than non-exposed units. A relatively larger dispersion of the proportion of poor households in exposed units can indicate a more pronounced poverty intensity in these areas. Analyzing the third-order moment coefficient will help identify the origin of a relatively higher (respectively, smaller) dispersion on the one hand and assess the question of poverty intensity on the other.

To estimate the effect of exposure, relative to non-exposure, on the skewness of the proportion of poor households, we use Eq. (3) when $k = 3$, which takes the following form:

$$(\hat{u}_i)^3 = \lambda_0 + \lambda_1 Exposed_i + \lambda_2 X_i + \rho_i, \tag{6}$$

where ρ_i refers to error term. To understand the sign of the skewness coefficient, a statistical analysis of the skewness of the distribution of the proportion of poor households will help identify the type of skewness describing the sample. A distribution skewed to the right or left corresponds to positive or negative skewness, assessed through the difference between the mean and the median. Geographical units that are exposed, relative to those that are not, described by a positive (respectively, negative) estimated skewness coefficient, will have the skewed of their distribution accentuated (respectively, reduced). A more pronounced intensity of poverty in exposed units will be associated with a more pronounced variance in the proportion of poor households than in non-exposed units, resulting from an accentuation of the skewed to the right of the distribution. In other words, this indicates that exposed units, relative to non-exposed

units, will have relatively more extreme values on the right tail of the distribution than non-exposed units.

The econometric specification employed suggests the presence of heteroscedasticity in the error terms. Indeed, using the second (Eq. (5)) and third moments (Eq. (6)) implies that the variance of the error terms is not constant. While the estimators remain unbiased, they are no longer of minimum variance, potentially affecting the precision of the tests. To address the heteroscedasticity issue, we consider a bootstraped standard erros.

3.2 Data

3.2.1 Socioeconomic data

Derived from the *"Fichier Localisé Social et Fiscal (FiLoSoFi)"* and produced by Insee, the gridded data with 200-meter sides from 2019 are employed to estimate the models presented in Eq. (4) to (6). These gridded data correspond to the finest available analysis scale in France. The sample comprises 2,313,783 geographical units, including 2,287,884 units in the metropolitan area. The gridded data determines the proportion of poor households per geographical unit. This variable represents a relative measure of poverty, with the threshold set at 60% of the median standard of living. To account for socioeconomic factors that may influence the level of poverty in a geographical unit, we use the proportion of single-parent families and the proportion of homeowner households as control variables. Indeed, family structure can be a relevant predictor of poverty (e.g., Gerardin, 2023; Di Fonzo et al., 2022). Moreover, poor households have the lowest homeownership rate among different income categories (André et al., 2021).

To account for certain economic specificities at the municipal level, we include the proportion of households whose reference person holds a position as a farmer or an artisan, merchant, or business owner in 2019. These two variables are derived from the Population Census, specifically Insee's "Couple - Families - Households" survey. Both correspond to a self-employed status, considered an economic disadvantage (Sicsic, 2018). Finally, to account for differences in attractiveness among different municipalities, we introduce a categorical variable representing the municipal density in 2019. This variable will partially approximate housing prices. Combes et al. (2019), and Le Hir and Bono (2023) note a positive relationship between population density and real estate prices. The more attractive an area is, particularly in terms of services offered to the population or employment opportunities, the more it will concentrate a significant number of individuals, exerting pressure on housing prices. Therefore, considering real estate prices would challenge the assumption of independence of explanatory variables. Derived from the 7-level municipal grid published by Insee, the density variable considers the total number of inhabitants and their concentration within the territory. The density variable takes the value of 2 if the municipality is an urban area (including large urban centers and intermediate urban centers), 1 if the municipality is a peri-urban area (including urban fringes and small towns), and 0 if the municipality is a rural area (including rural towns, rural municipalities with dispersed housing, and rural municipalities with very dispersed housing). To assign these municipal data to geographical units, we compute the intersection area between the geographical units and the municipalities. We assign municipal data to geographical units with the highest intersection area with a municipality.

3.2.2 Exposure index

For the exposure variable, we consider the location of the 3895 sites listed in the European Pollutant Release and Transfer Register (E-PRTR) in metropolitan France in 2010. The location of these sites is taken from the Pollutant Release and Transfer Register (PRTR), published by the French Ministry for Ecological Transition and Territorial Cohesion. This register of pollutant emissions is a national inventory of chemical substances released into the air, water, and soil. Also, it includes sites producing and processing hazardous and non-hazardous waste. This inventory meets the obligation of European Union member states (Regulation n°166/2006 of 18/01/06) to transfer data on pollutant emissions from sites carrying out at least one of the nine activities[3] listed in Annex I of the previous Regulation to the European Commission. Although the geographical coordinates of these polluting sites are provided,

[3]The energy sector, production and processing of metals, mineral industry, chemical industry, waste and wastewater management, manufacture and processing of paper and wood, products of animal or vegetable origin from the food and beverage industry, and others (Annex 1, of Regulation n°166/2006 of 18/01/06).

for the sake of homogeneity, we have redefined them using the geocoding service of the official national website Adresse.data.gouv.fr, as the reference geographical coordinate system had different projections in the initial database.

To construct the exposure index[4], we determine a buffer zone of 3 km around each E-PRTR site. Studies in environmental justice generally consider a buffer zone with a radius between 1 km and 3 km (Glatter-Götz et al., 2019; Viel et al., 2011; Mohai and Saha, 2015b). To distinguish units exposed from units not exposed to sites registered to the E-PRTR, we use the "50% areal containment" method of Mohai and Saha (2006). This methodology involves calculating the intersection area between cell grids and the associated buffer zone, considering as exposed units those cell grids whose intersection represents at least 50% of their area.

To account for potential endogeneity bias identified in the literature, we apply a time lag between the dependent and exposure variable, as Zwickl et al. (2014) or Zwickl (2019). We consider a time lag of nine years[5]. Regarding robustness, we consider various years of pollutant site localization, ensuring a minimum time lag of two years between the dependent variable and the exposure variable to consider the simultaneity bias issue (see Appendix A.2 to Appendix A.5). Banzhaf and Walsh (2008) noted that considering past exposure allows us to correct the endogeneity problem induced by simultaneity bias since past exposure cannot be the consequence of future socioeconomic disadvantage but is the cause. Thus, implementing a temporal lag between the dependent variable and the exposure variable also allows for addressing the issue of a "vote by feet" mechanism, mainly focusing on the phenomenon of "coming to the nuisance" among poor households.

3.2.3 Descriptive statistics

Table 1 distinguishes between exposed and non-exposed geographical units as it presents the descriptive statistics of the sample variables. The sample comprises 2,287,871[6] geographical units, with 1,771,768 identified as non-exposed and 516,104 as exposed. Descriptive statistics reveal that, on average, non-exposed geographical units exhibit a poverty rate of 12%, compared to 11% for exposed units. Simultaneously, non-exposed units, on average, feature a lower number of poor households than exposed units. These findings imply a relatively higher population density in exposed units, explaining the lower average proportion of poor households and the concurrently higher average number of poor households compared to non-exposed units. Analyzing the density variable, it becomes evident that while most non-exposed units are situated in rural areas, the trend reverses for exposed units primarily in peri-urban or urban areas. Consequently, these descriptive statistics underscore the significance of accounting for density in understanding the relationship between poverty and exposure.

Figure 1 illustrates the distribution of the proportion of poor households for both exposed and non-exposed units, distinguishing the three different densities. In instances where exposed rural units exhibit a lower average and median proportion of poor households compared to their non-exposed rural counterparts, the opposite trend is observed for urban units, with a lesser extent of distinction in peri-urban

[4]We do not consider emissions induced by the sites nor the toxicity of the emissions when constructing our exposure index. Indeed, as shown by Currie et al. (2015), the impact of the opening of a polluting site on the housing price is independent of the site's toxicity. They justify this phenomenon by the imperfect information available to households. Moreover, as Hausman and Stolper (2021) point out, the fact that some pollutants are invisible and odorless implies that households, in their choice of location, unwittingly do not take into account the types of pollutants in the air and their toxicity to health, but rather consider what is visible, such as distance from a source of environmental nuisance.

[5]This strategy can remain relevant even if a polluting site has closed during this period. For example, Currie et al. (2015) have shown that closing polluting sites does not increase housing prices, which remain attractive to the most disadvantaged. They justify this effect by visual disamenities, concern about contamination in the site's surrounding areas, and anticipation of a site reopening. Messer et al. (2006) have shown that the closure of a polluting site accompanied by a clean-up could increase the perception of risk and lead to a decline in the area's attractiveness. Although a clean-up may be done, Rüttenauer and Best (2021) have shown that it does not necessarily imply a visible signal of improved environmental quality.

[6]The initial sample comprises 2,287,884 units. However, within the data from the "Couple - Families - Households" survey conducted by Insee, 12 municipalities exhibit a complete absence of households. Consequently, the 13 corresponding geographical units were excluded from the sample, constituting less than 0.01% of the overall sample.

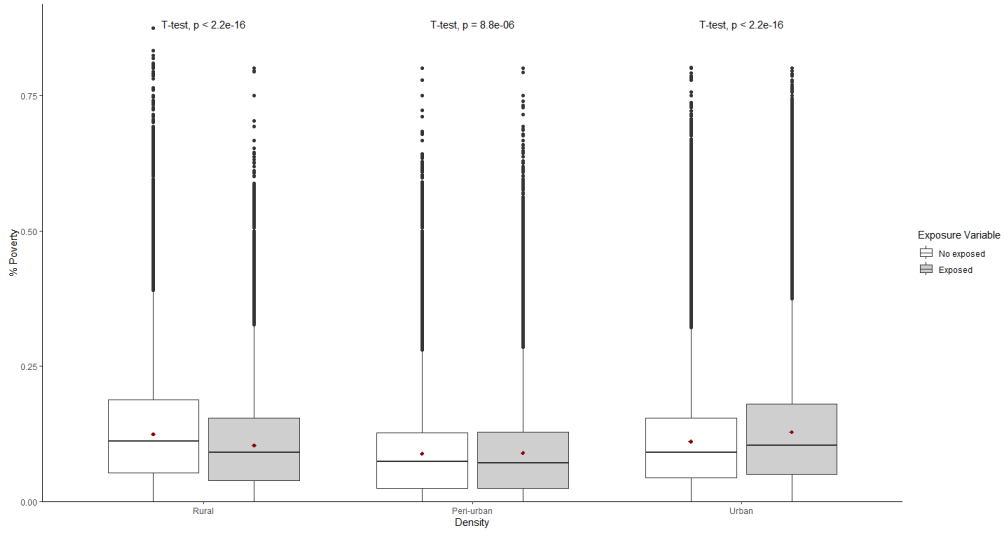
Table 1: Descriptive statistics

Variable	Non-exposed		Exposed		Overall	
	Mean	SD	Mean	SD	Mean	SD
% poverty	0.12	0.10	0.11	0.10	0.12	0.10
# Poor households	0.94	4.54	4.42	14.89	1.73	8.25
% single parents	0.08	0.07	0.09	0.07	0.08	0.07
% owners	0.81	0.15	0.75	0.22	0.80	0.07
% farmers	0.03	0.05	0.01	0.03	0.03	0.05
% artisans and others	0.06	0.04	0.05	0.02	0.06	0.04
Density : Obs. number (%)						
Rural	1,500,479 (85%)		245,756 (48%)		1,746,234 (76%)	
Peri-urban	177,200 (10%)		111,403 (21%)		288,603 (13%)	
Urban	94,089 (5%)		158,945 (31%)		253,034 (11%)	

Notes: The variable "Exposed" characterizes the units for which at least 50% of their area belongs to a 3 km buffer zone around at least one polluting site in 2010. SD corresponds to the standard deviation. % farmers corresponds to the percentage of farmers at the municipality level. % artisans and others corresponds to the percentage of artisans, merchants, and business owners at the municipality level.

units.[7] The mean difference test confirms the presence of a statistically significant difference between the average proportion of poor households and exposure status for urban, peri-urban, and rural units. Consequently, we propose that density implies heterogeneity in the relationship between poverty and exposure, characterized by exposure disparities to polluting sites in urban and peri-urban units and the absence of disparities disadvantaging the poorest in rural units.

Figure 1: % Poverty distribution by density and exposure index



Notes: % Poverty corresponds to the percentage of poverty by geographical unit. The variable "exposed" characterizes the units for which at least 50% of their area belongs to a 3km buffer zone around at least one polluting site in 2010. The t-test corresponds to a test of mean difference. The rhombus in the boxplots represent the mean of the proportion of poor households. See Figure 2 in Annexe A.1 for a 2km buffer zone.

[7] Refer to Figure 2 in Appendix A.1 for a 2km buffer zone, where the distribution of the proportion of poor households between exposed and non-exposed units is more pronounced for each density type.

Regardless of exposure and density, the distribution of the proportion of poor households is characterized by a left-skewed skewness, indicating a significant concentration of a low proportion of poor households. This observation aligns with the national poverty rate reported by Gerardin (2023), reaching 14.4% in 2020. However, we observe that the skewed to the right of the distribution of the proportion of poor households varies based on density and exposure. Exposure in rural units is marked by a lower value of the first and third quartile compared to non-exposure, accompanied by a lesser presence of extreme values in the tail of the distribution. Conversely, exposed urban units, and to a lesser extent, exposed peri-urban units, are characterized by a higher value of first and third quartile compared to non-exposure, along with a more substantial presence of extreme values in the tail of the distribution. By the definition we provide for the intensity of poverty (see subsection 3), we suggest that density also induces heterogeneity in the relationship between the intensity of poverty and exposure. This heterogeneity is characterized by a higher presence of a higher proportion of poor households in exposed urban and peri-urban units than their non-exposed counterparts. Conversely, the opposite trend is observed for exposed rural units.

4 Results

4.1 The impact of exposure on poverty and poverty intensity

To identify the effect of exposure to polluting sites on the proportion of poor households and the intensity thereof, we employ the statistical moments approach proposed by Antle (1983). Table 2 presents the estimation results for Eq. (4), (5), and (6), with columns 1 to 3 reporting the results of the first-order moment (Eq. (4)).

The results in column 1 indicate a significantly negative effect of exposure, relative to non-exposure, on the poverty rate. In other words, compared to those not exposed, exposed units are associated, on average, with a lower proportion of poor households (column 1). On the one hand, this result appears counterintuitive since the negative externalities associated with exposure to polluting sites should have the opposite effect. On the other hand, this finding is not aligned with the literature, especially in French. Indeed, studies by Salesse (2022) and Fosse et al. (2022) highlight a negative relationship between economic disadvantage and exposure to environmental nuisances. However, as suggested by these authors, density implies heterogeneity in the relationship between poverty and exposure to environmental nuisances. Furthermore, as Figure 1 illustrates, the distribution of the proportion of poor households and the distribution of the population's exposure to polluting sites are highly heterogeneous across rural, peri-urban, and urban areas.

The results, incorporating the role of density in shaping the relationship between poverty and exposure to polluting sites, appear in columns 2 and 3 of Table 2. As expected, we observe that the relationship between the proportion of poor households and exposure to polluting sites varies depending on the density of the municipalities where the units under study reside. Indeed, households' relative exposure is associated with a lower proportion of poor households in rural areas, while it is associated with a higher proportion of poor households in urban and peri-urban areas. These findings align with the work of Salesse (2022) for France and Neier (2021) for Austria. We can comprehend the heterogeneity in the relationship between exposure and poverty that we identify through the prism of housing prices.

The literature establishes an increasing relationship between population density and housing prices (e.g., Combes et al., 2019; Le Hir and Bono, 2023). Indeed, the presence of amenities (such as public services, public transportation, shops, and employment opportunities) enhances the attractiveness of a geographical area, leading to increased pressure on housing prices. Conversely, a physical environmental nuisance can generate negative externalities (such as noise and visual disturbances, unpleasant smelly emissions, and environmental pollution), making the area exposed to this nuisance less desirable. The reduced desirability of the exposed area can result in lower attractiveness and a decline in housing prices. For instance, Currie et al. (2015) and Hanna (2007) show that polluting sites decrease surrounding real estate prices. These exposed areas become relatively more attractive to lower-income households, especially poor households. Hence, urban exposed areas, and to a lesser extent, peri-urban areas, on average, experience a higher proportion of poor households than non-exposed areas. However, the mechanisms at play in understanding the relationship between exposure and the proportion of poor households in rural areas are different, but we suggest that the lens of housing prices partially drives them. Relatively fewer amenities and a more dispersed population characterize rural areas. We propose that the

Table 2: Moments-based approach estimates for the proportion of poverty

	Dependent variable:				
	% Poverty			Variance	Skewness
	(1)	(2)	(3)	(4)	(5)
Exposed	−0.012***	−0.021***	−0.015***	−0.002***	−0.0002***
	(0.0002)	(0.0002)	(0.0002)	(0.00004)	(0.00001)
Exposed*peri-urban		0.022***	0.014***	0.001***	0.0003***
		(0.0004)	(0.0003)	(0.0001)	(0.00003)
Exposed*urban		0.038***	0.019***	0.002***	0.0004***
		(0.0005)	(0.0004)	(0.0001)	(0.00003)
Peri-urban		−0.036***	−0.029***	−0.003***	−0.0003***
		(0.0002)	(0.0002)	(0.00004)	(0.00001)
Urban		−0.014***	−0.021***	−0.002***	−0.0002***
		(0.0003)	(0.0003)	(0.0001)	(0.00002)
% Single parents			0.127***	−0.0001	−0.0003***
			(0.001)	(0.0002)	(0.0001)
% Owners			−0.184***	−0.012***	−0.001***
			(0.0005)	(0.0001)	(0.00002)
% Farmers			0.392***	0.032***	0.0001*
			(0.002)	(0.0002)	(0.0001)
% Artisans and others			0.139***	0.011***	0.001***
			(0.002)	(0.0003)	(0.0001)
Constant	0.120***	0.125***	0.241***	0.017***	0.001***
	(0.0001)	(0.0001)	(0.0004)	(0.0001)	(0.00002)
Observations	2,287,871	2,287,871	2,287,871	2,287,871	2,287,871
R^2	0.003	0.017	0.163	0.030	0.001
Adjusted R^2	0.003	0.017	0.163	0.030	0.001
Residual Std. Error	0.098	0.098	0.090	0.015	0.006
F Statistic	5,973.376***	8,000.391***	49,452.460***	7,933.328***	191.055***

*Notes: Rural areas correspond to the reference density. The variable "Exposed" characterizes the units for which at least 50% of their area belongs to a 3km buffer zone around at least one polluting site in 2010. % farmers correspond to the percentage of farmers at the municipality level. % artisans and others correspond to the percentage of artisans, merchants, and business owners at the municipality level. Bootstrap standard errors in parenthesis. ***, **, *, . indicate 0.1%, 1%, 5% and 10% significance level, respectively.*

presence of polluting activities induces the existence of surrounding activities (public services, shops), which makes exposed areas relatively more attractive than non-exposed ones. Consequently, and due to these areas' employment opportunities, the relatively higher attractiveness can exert pressure on housing prices. Therefore, Exposed rural areas become less attractive for lower-income households, explaining why, on average, the proportion of poor households in exposed areas is relatively lower than that of poor households in non-exposed rural areas. Moreover, in a note, Gerardin (2023) observes that most poor households in rural areas are households considered distant from the labor market (retirees and those with very low income).

Regarding socio-demographic factors, column 3 of Table 2 highlights that the proportion of single-parent families is positively associated with the poverty rate, consistent with the existing literature (Gerardin, 2023; Di Fonzo et al., 2022). The percentage of self-employed individuals also positively correlates with the poverty rate, confirming that this occupational status indicates economic disadvantage (Sicsic, 2021). Finally, the proportion of homeowners among occupied housing units negatively correlates with the poverty rate. While some poor households own their homes, poor households belong to the income category with the lowest homeownership rate (André et al., 2021).

To address the question of poverty intensity, we focus on the second and third moments of Antle (1983)'s statistical moments approach. Insee defines poverty intensity as a relative gap between poor households' median standard of living and the poverty threshold. In this study, we examine the poverty intensity by comparing the dispersion (column 4) and skewness (column 5) of the distribution of the proportion of poor households in exposed units to that of non-exposed units.

Exposed urban and peri-urban units are associated with higher dispersion in the distribution of the proportion of poor households compared to non-exposed units. These exposed units exhibit more significant disparities in the proportion of poor households than non-exposed units. Column 5 indicates that the increased dispersion in the proportion of poor households is linked to a more pronounced skewed to the right in the distribution of the proportion of poor households in exposed units compared to non-exposed units. In other words, exposed urban and peri-urban units have more units experiencing high poverty levels than non-exposed units. Thus, a higher intensity of poverty characterizes urban and peri-urban exposed units than non-exposed units. The higher intensity of poverty in exposed units may suggest a potentially exacerbated economic segregation phenomenon in the exposed areas. Indeed, while the study by Beaubrun-Diant and Maury (2022) does not explicitly address exposure to environmental nuisances, it highlights France's increasing socioeconomic segregation between 1999 and 2015. This phenomenon implies a rising concentration of populations with similar economic characteristics within analysis units such as departments, municipalities, and cadastral sections. Conversely, exposed rural units are associated with a lower dispersion in the distribution of the proportion of poor households compared to non-exposed rural areas. This relatively lower dispersion is linked to a less pronounced skewed to the right in the distribution of the proportion of poor households. Consequently, exposed rural units are characterized by a relatively lower intensity of poverty than non-exposed units. These results align with the analysis of the first-order moment and emphasize potentially more marked economic segregation in non-exposed areas.

4.2 Is there a « Coming to nuisance » phenomenon?

The extension made by Banzhaf et al. (2019b) of Tiebout (1956)'s "vote with your feet" mechanism can explain the potential household flows induced by past exposure. This mechanism asserts that households make a trade-off between the amenities of a geographical area (including environmental quality) and their consumption (including housing). Regardless of wealth level, according to this mechanism, each household benefits from higher utility in a geographical location characterized by good environmental quality. However, each type of household has a different willingness to pay to live in a clean environment. Lower-income households will prioritize essential consumption, implying that their willingness to pay for a less degraded environment is relatively lower than that of wealthier households.

To suggest a potential "vote with your feet" mechanism by low-income households, we re-estimate Eq. (4), using the number of poor households per geographical unit as the dependent variable. Table 3 shows the results of this new estimation. A temporal lag between the dependent and exposure variables characterizes the chosen econometric specification[8]. This temporal lag involves analyzing the differentiated effects of a past exposure relative to a past non-exposure on the current characteristics of the geographical units under study. Thus, this new specification allows us to suggest the presence or absence of a "coming to the nuisance"[9] phenomenon for poor households.

Independent of density, Table 3 (column 1) highlights a similar trend in the effect of past exposure relative to non-exposure on the number of poor households. Indeed, compared to those that have not, units exposed are associated with a currently higher number of poor households in urban, peri-urban, or rural areas. These results suggest a "coming to the nuisance" phenomenon for poor households. They

[8]Beyond correcting the bias induced by a reversal of causation, the application of a temporal lag between the dependent variable and the exposure variable allows for an understanding of the effect of a past exposure on current demographic and economic characteristics (see Banzhaf and Walsh, 2008 and Banzhaf et al., 2019a).

[9]The literature on this topic primarily distinguishes between two phenomena (see Banzhaf et al., 2019a,b). The first corresponds to the "coming to the nuisance" phenomenon, describing the coming of poor households following the installation of a nuisance or past exposure. The second corresponds to the "fleeing from nuisance" phenomenon, describing the out of wealthier households following the installation of a nuisance or past exposure. However, given the variables at our disposal, we cannot identify wealthier households.

Table 3: Effects of relative exposure on the number of poor households and the growth of the number of poor households

	Dependent variable:	
	NbPoor	ΔNbPoor
	(1)	(2)
Exposed	0.095***	0.009***
	(0.005)	(0.001)
Exposed*peri-urban	0.219***	0.016***
	(0.018)	(0.003)
Exposed*urban	4.671***	0.035***
	(0.073)	(0.006)
Peri-urban	0.202***	0.05***
	(0.01)	(0.002)
Urban	2.915***	0.111***
	(0.047)	(0.005)
% Single parents	3.739***	−0.113***
	(0.06)	(0.009)
% Owners	−16.505***	−0.024***
	(0.08)	(0.004)
% Farmers	−2.613***	−0.225***
	(0.03)	(0.005)
% Artisans and others	−3.809***	−0.074***
	(0.054)	(0.007)
Constant	14.144***	0.07***
	(0.067)	(0.003)
Observations	2,287,871	2,164,342
R^2	0.238	0.007
Adjusted R^2	0.238	0.007
Residual Std. Error	7.200	0.636
F Statistic	79,542.250***	1,584.089***

*Notes: Rural areas correspond to the reference density. The variable "Exposed" characterizes the squares for which at least 50% of their area belongs to a 3km buffer zone around at least one polluting site in 2010. % farmers correspond to the percentage of farmers at the municipality level. % artisans and others correspond to the percentage of artisans, merchants, and business owners at the municipality level. The dependent variable in Column 1 corresponds to the number of poor households in 2019. The dependent variable in Column 2 corresponds to the growth rate of poor households between 2015 and 2019. Bootstrap standard errors in parenthesis. ***, **, *, . indicate 0.1%, 1%, 5% and 10% significance level, respectively.*

corroborate findings from Banzhaf and Walsh (2008), which suggest a similar phenomenon for lower-income households.

A higher number of poor and a lower proportion of poor households characterize the rural units exposed in the past, suggesting a "coming to the nuisance" phenomenon. Moreover, these findings presuppose a higher coming of non-poor households than poor households, explaining the lower proportion of poor households in exposed rural areas. These elements support previous arguments stating that although there are polluting economic activities in rural areas, these activities may make these areas more attractive relative to those without such activities and exert upward pressure on housing prices.

To test the hypothesis that there is indeed a "coming to the nuisance" phenomenon, we analyze the effect of exposure in 2010 on the evolution of the number of poor households between 2015 and 2019. For this purpose, we estimate the following specification:

$$\%\Delta NbPoor_i = \kappa_0 + \kappa_1 Exposed_i + \kappa_2 X_i + \zeta_i, \tag{7}$$

such as $\%\Delta NbPoor_i$ corresponds to the growth rate of the number of poor households between 2015 and 2019 for geographic unit i; $Exposed_i$ represents the geographic units i where at least 50% of the area belongs to the 3 km buffer zone drawn around each 2010 hazardous sites; X_i corresponds to the other characteristics of the geographic units i; and ζ_i corresponds to the error term. Like Banzhaf and Walsh (2008), the control variables we add correspond to the initial characteristics of the geographical units under study.

Table 3 (column 2) presents the estimates of Eq. (7), which identifies past relative exposure's effect on poor households' growth rate. As suggested earlier, we indeed observe a "coming to the nuisance" phenomenon. Independent of the unit under study density, previously exposed units are associated with a relatively higher growth rate in poor households than those not exposed. Past exposure's effect on poor households' growth rate between 2015 and 2019 is higher in urban areas than in peri-urban and rural areas. This phenomenon is partly structural. Indeed, poor households are more numerous in urban areas, which can explain a relatively more substantial movement of poor households than in other density types.

5 Sensitivity analysis

In this section, we analyze the relative effect of past exposure (in 2010) on the logarithm of the standard of living in 2019. This variable is taken from the FiLoSoFi database for 2019. Initially disseminated as a sum of winsorized[10] living standards per geographical unit, we have divided it by the number of households present in the geographical unit to deduce an average standard of living[11] per household and geographical unit. We employ Antle (1983)'s statistical moments approach to assess the relative effect of past exposure on the standard of living and disparities in the current standard of living.

Table 4 presents the results of the relative effect of past exposure on the standard of living and current disparities in standard of living. The first column reveals that the relative exposure of rural units is, on average, associated with a higher standard of living. Conversely, exposed urban and peri-urban units, relative to those that are not exposed, are associated with a standard of living that is, on average, lower. These results align with the literature (Salesse, 2022; Neier, 2021). Exposed rural units experience relatively lower disparities in terms of standard of living than non-exposed units (column 2). Conversely, exposed urban and peri-urban units experience relatively higher disparities in standard of living than non-exposed units. These results reinforce the previous conclusions regarding the relationship between poverty and relative exposure to polluting sites. However, the relative effect of exposure on living standard skewness differs between urban and peri-urban units (see table A.6.1 in Appendix A.6 for descriptive statistics on living standards). Compared with non-exposure, exposure accentuates the skewed to the left (column 3) in urban units, explaining the presence of higher economic disparities. However, the relative exposure in peri-urban areas reduces the skewed to the left of the standard of living, while at the same time, the disparities are higher in these units. This result suggests that exposed peri-urban units have fewer low-income and potentially more high-income households than non-exposed units. These results can be related to those of Le Hir and Bono (2023), especially concerning the size of dwellings. Le Hir and Bono (2023) highlight a positive relationship between population density and housing prices. They emphasize that urban areas are characterized by high housing prices, partially offset by smaller-sized dwellings, mainly located in multi-unit buildings. In contrast, peripheral areas (peri-urban zones) are distinguished by relatively lower housing prices, the presence of individual dwellings, and larger-sized dwellings. In exchange for higher transportation costs, some affluent households might be willing to move away from urban areas to access larger dwellings and, or homeownership. As the

[10] Winsorization means dealing with the extreme values of a variable, in this case, the standard of living. The thresholds were established based on departmental standards of living. If the standard of living associated with a geographical unit is higher than the 95th percentile of the associated departmental standard of living, then this standard of living is adjusted to this threshold; if it is lower than the 5th percentile, it is adjusted to this threshold.

[11] For clarity, we will refer to this variable as "standard of living," even though it is an average winsorized standard of living.

Table 4: Moments-based approach estimates for standard of living

	Dependent variable:		
	AverStandLiv	Variance	Skewness
	(1)	(2)	(3)
Exposed	0.021***	−0.006***	0.0005***
	(0.0005)	(0.0002)	(0.0001)
Exposed*peri-urban	−0.053***	0.003***	−0.001***
	(0.001)	(0.0004)	(0.0002)
Exposed*urban	−0.052***	0.006***	0.001***
	(0.001)	(0.0004)	(0.0003)
Peri-urban	0.154***	0.007***	0.002***
	(0.001)	(0.0002)	(0.0001)
Urban	0.176***	0.013***	0.004***
	(0.001)	(0.0003)	(0.0002)
% Single parents	−0.134***	−0.044***	0.007***
	(0.002)	(0.001)	(0.001)
% Owners	0.591***	−0.028***	0.001***
	(0.001)	(0.0003)	(0.0002)
% Farmers	−0.913***	0.028***	0.004***
	(0.003)	(0.001)	(0.001)
% Artisans and others	0.148***	0.077***	−0.002**
	(0.004)	(0.001)	(0.001)
Constant	10.436***	0.070***	−0.002***
	(0.001)	(0.0003)	(0.0002)
Observations	2,287,871	2,287,871	2,287,871
R^2	0.220	0.010	0.001
Adjusted R^2	0.220	0.010	0.001
Residual Std. Error	0.225	0.080	0.056
F Statistic	71,716.610***	2,470.203***	215.403***

*Notes: AverStandLiv corresponds to the average standard of living in logarithm. Rural areas correspond to the reference density. The variable "exposed" characterizes the squares for which at least 50% of their area belongs to a 3km buffer zone around at least one polluting site in 2010. % farmers correspond to the percentage of farmers at the municipality level. % artisans and others correspond to the percentage of artisans, merchants, and business owners at the municipality level. Bootstrap standard errors in parenthesis. ***, **, *, . indicate 0.1%, 1%, 5% and 10% significance level, respectively.*

presence of pollutant sites can exert downward pressure on housing prices (Currie et al., 2015; Hanna, 2007), dwellings in peri-urban zones can become relatively more attractive. Additionally, Levasseur et al. (2021) highlight a positive relationship between dwelling size and the probability of living in a polluted area. Thus, these factors may explain the higher presence of affluent households in exposed peri-urban zones compared to those that are not exposed.

6 Discussion and concluding remarks

Our study represents France's first comprehensive national investigation to determine whether residential proximity to environmental nuisances is a relevant indicator of poverty. To gauge the relative effect of exposure on poverty and its intensity, we employ the statistical moment's approach proposed by Antle (1983). In addressing an endogeneity issue induced by simultaneity bias, as to Zwickl (2019) or Zwickl et al. (2014), we implement a temporal lag between the exposure index and the dependent variable. Furthermore, our study is the pioneer in identifying a "coming to the nuisance" mechanism among poor French households. To achieve this, we assess the relative effect of past exposure on the growth rate of poor households between two periods. Our findings align with existing literature.

Similar to Salesse (2022) and Neier (2021), our findings indicate that exposure in urban and peri-urban areas is associated with a higher proportion of poor households. Urban and peri-urban areas have high population density and a substantial service supply, which pressures housing prices (Combes et al., 2019; Le Hir and Bono, 2023). However, the presence of polluting sites generating negative externalities can lead to a decline in housing prices, as demonstrated by Currie et al. (2015) and Hanna (2007). Consequently, exposed areas become more attractive to lower-income households. Furthermore, we demonstrate that the relative effect of exposure in these areas is associated with a higher intensity of poverty. We suggest that the relative effect of exposure exacerbates economic segregation in France, a phenomenon on the rise, as noted by Beaubrun-Diant and Maury (2022). We highlight an absence of exposure disparities, disadvantaging poor households, to polluting sites in rural areas (as observed by Salesse, 2022 and Neier, 2021). We demonstrate that exposed rural areas are associated with a relatively lower proportion of poor households and a lower poverty intensity than non-exposed areas. Characterized as predominantly distant from the labor market (Gerardin, 2023), poor households in rural areas appear to reside outside zones with relatively higher economic activity. However, in rural there are other environmental nuisances to which the poor households may be exposed. In contrast to our findings, Fosse et al. (2022) identify exposure disparities, to the detriment of the less affluent, in rural areas, particularly related to agricultural pollution, which is, in part, not considered in this study.

We also highlight a relatively higher number of poor households in previously exposed units than non-exposed units, suggesting a "coming to the nuisance" phenomenon. Consequently, we assess the effect of past exposure, relative to non-exposure, on the growth of the number of poor households between 2015 and 2019. Our findings indicate that poor French households "come to the nuisance," as partly suggested by Banzhaf and Walsh (2008) in California. However, based on the available data, we cannot determine whether there is also a phenomenon of "fleeing from the nuisance" by more affluent households. Nevertheless, a study by Levasseur et al. (2021) reveals a positive relationship between the intention to leave a polluted area and the highest income quintile, highlighting a "fleeing from the nuisance" by wealthier households. These two phenomena may co-occur, as highlighted by Mohai and Saha (2015b).

We conducted several robustness checks to ensure the robustness of our results and verify that they are not contingent on methodological choices, such as the selection of the temporal lag or the buffer zone. To analyze the relative effect of exposure on the proportion of poor households, we estimated the specifications of Eq. (4), (5), and (6), incorporating methodological adjustments. Firstly, we applied different exposure years (2011, 2012, and 2013). Secondly, we replicated the estimations using gridded data from the FiLoSoFi database of 2017 and 2015, applying the same exposure years as for the 2019 gridded data. Thirdly, we reproduced all previous estimations considering a buffer zone of 2 km. To analyze the relative effect of exposure on the number of poor households, we estimated Eq. (4), considering different exposure years (2011, 2012, and 2013). These exposure years were also applied to the gridded data for 2015 and 2017, considering buffer zones of 3 km and 2 km. Finally, to analyze the relative effect of exposure on the growth rate of the number of poor households, we estimated the specification of Eq. (7), considering different exposure years (2011, 2012, and 2013) and replicating the analysis for a 2 km buffer zone. Our results remain robust (see Appendix A.2 to Appendix A.5).

The fact that poor French households are more exposed to environmental nuisances, partially due to their "coming to the nuisances," raises concerns regarding health and equality of opportunities. As highlighted in the introduction, Hajat et al. (2015) shed light on Triple Jeopardy for low-income households. Their overexposure increases the risk of poor health, even though they already face a heightened risk compared to the rest of the population. Additionally, Banzhaf et al. (2019b) emphasize the risk of perpetuating the poverty trap for future generations. Finally, an Gerardin (2023) report noted that many poor French households live in social housing (17.2%). Given that the construction of social housing is a responsibility delegated to municipalities, questions arise regarding the location of social housing, which, since the late 1990s, tends to accommodate more low-income households (Beaubrun-Diant and Maury, 2022). These elements underscore the necessity of incorporating environmental factors into public health, poverty alleviation, and urbanization policies to ensure equal opportunities among individuals.

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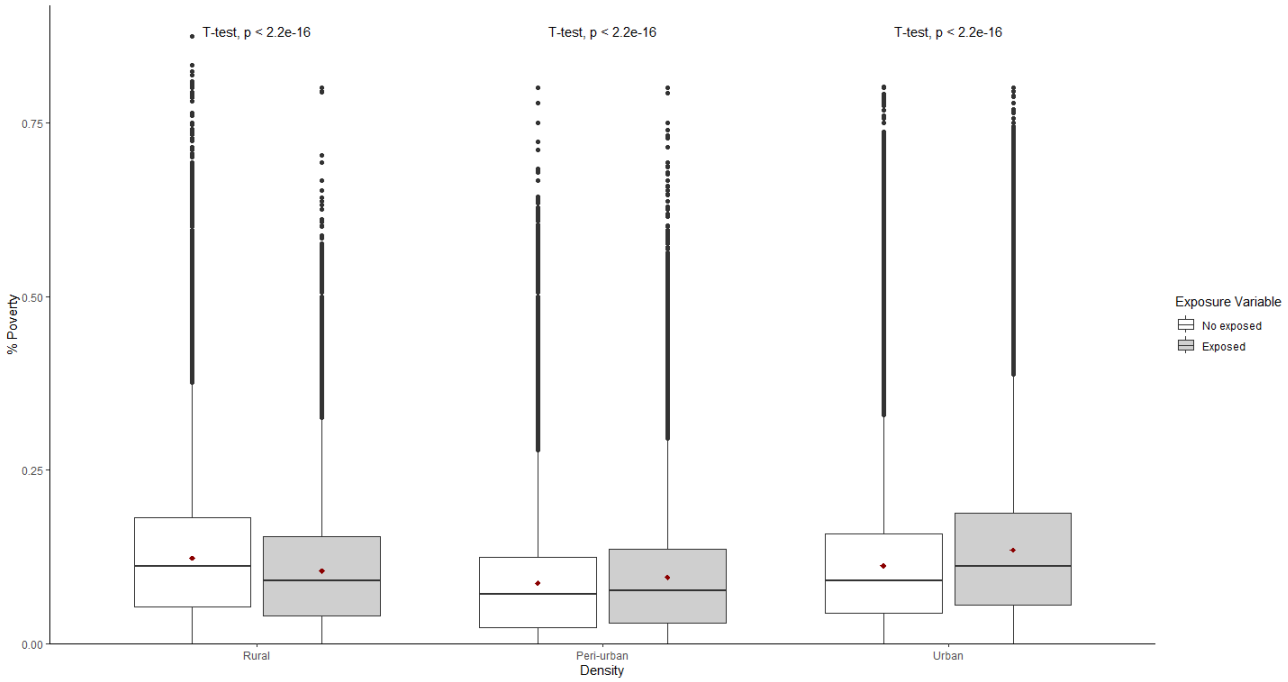
A Appendix

A.1 Boxplot for 2km buffer zone

Figure 2: % Poverty distribution by density and exposure index



Notes: % Poverty corresponds to the percentage of poverty by geographical unit. The variable "exposed" characterizes the squares for which at least 50% of their area belongs to a 2km buffer zone around at least one polluting site in 2010. The t-test corresponds to a test of mean difference. The rhombus in the boxplots represent the mean of the proportion of poor households.

A.2 Robustness of mean effect

A.2.1 FiLoSoFi database and year of exposure

Table A.2.1: Effects of past exposure on % poverty in 2019

	Dependent variable:		
	% Poverty		
	(1)	(2)	(3)
Exposed	−0.015***	−0.015***	−0.016***
	(0.0002)	(0.0002)	(0.0002)
Exposed*peri-urban	0.014***	0.013***	0.013***
	(0.0004)	(0.0004)	(0.0004)
Exposed*urban	0.019***	0.018***	0.019***
	(0.0004)	(0.0004)	(0.0004)
Peri-urban	−0.029***	−0.029***	−0.029***
	(0.0002)	(0.0002)	(0.0002)
Urban	−0.021***	−0.021***	−0.021***
	(0.0003)	(0.0003)	(0.0003)
% Single parents	0.126***	0.126***	0.126***
	(0.001)	(0.001)	(0.001)
% Owners	−0.184***	−0.184***	−0.184***
	(0.0005)	(0.0004)	(0.0004)
% Farmers	0.391***	0.392***	0.391***
	(0.0019)	(0.001)	(0.001)
% Artisans and others	0.139***	0.138***	0.138***
	(0.0018)	(0.002)	(0.002)
Constant	0.241***	0.241***	0.242***
	(0.0004)	(0.0004)	(0.0004)
Observations	2,287,871	2,287,871	2,287,871
R^2	0.163	0.163	0.163
Adjusted R^2	0.163	0.163	0.163
Residual Std. Error	0.090	0.090	0.090
F Statistic	49,485.370***	49,464.530***	49,567.880***

*Notes: Rural areas correspond to the reference density. The variable "Exposed" characterizes the squares for which at least 50% of their area belongs to a 3km buffer zone around at least one polluting site in 2011 (column 1), 2012 (column 2), and 2013 (column 3). % farmers correspond to the percentage of farmers at the municipality level. % artisans and others correspond to the percentage of artisans, merchants, and business owners at the municipality level. Bootstrap standard errors in parenthesis. ***, **, *, . indicate 0.1%, 1%, 5% and 10% significance level, respectively.*

Table A.2.2: Effects of past exposure on % poverty in 2017

	Dependent variable:			
	% Poverty			
	(1)	(2)	(3)	(4)
	−0.016***	−0.017***	−0.016***	−0.017***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Exposed*peri-urban	0.013***	0.014***	0.013***	0.013***
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Exposed*urban	0.019***	0.019***	0.018***	0.019***
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Peri-urban	−0.031***	−0.031***	−0.031***	−0.031***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Urban	−0.025***	−0.025***	−0.025***	−0.025***
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
% signle parents	0.142***	0.142***	0.142***	0.142***
	(0.001)	(0.001)	(0.001)	(0.001)
% Owners	−0.176***	−0.176***	−0.176***	−0.176***
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
% farmers	0.411***	0.410***	0.411***	0.409***
	(0.001)	(0.001)	(0.001)	(0.001)
% Artisans and others	0.123***	0.123***	0.123***	0.122***
	(0.002)	(0.002)	(0.002)	(0.002)
Constant	0.241***	0.241***	0.241***	0.241***
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Observations	2,294,716	2,294,716	2,294,716	2,294,716
R^2	0.161	0.162	0.161	0.162
Adjusted R^2	0.161	0.162	0.161	0.162
Residual Std. Error	0.092	0.092	0.092	0.092
F Statistic	49,053.510***	49,119.810***	49,078.070***	49,202.480***

*Notes: Rural areas correspond to the reference density. The variable "Exposed" characterizes the squares for which at least 50% of their area belongs to a 3km buffer zone around at least one polluting site in 2010 (column 1), 2011 (column 2), 2012 (column 3), and 2013 (column 4). % farmers correspond to the percentage of farmers at the municipality level. % artisans and others correspond to the percentage of artisans, merchants, and business owners at the municipality level. Bootstrap standard errors in parenthesis. ***, **, *, . indicate 0.1%, 1%, 5% and 10% significance level, respectively.*

Table A.2.3: Effects of past exposure on % poverty in 2015

	Dependent variable:			
	% Poverty			
	(1)	(2)	(3)	(4)
Exposed	−0.016***	−0.017***	−0.017***	−0.018***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Exposed*peri-urban	0.013***	0.014***	0.014***	0.014***
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Exposed*urban	0.018***	0.018***	0.017***	0.018***
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Peri-urban	−0.031***	−0.031***	−0.031***	−0.031***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Urban	−0.025***	−0.025***	−0.025***	−0.025***
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
% Single parents	0.163***	0.163***	0.163***	0.163***
	(0.001)	(0.001)	(0.001)	(0.001)
% Owners	−0.172***	−0.172***	−0.172***	−0.172***
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
% Farmers	0.405***	0.405***	0.405***	0.404***
	(0.001)	(0.001)	(0.001)	(0.001)
% Artisans and others	0.094***	0.093***	0.093***	0.093***
	(0.002)	(0.002)	(0.002)	(0.002)
Constant	0.237***	0.237***	0.237***	0.237***
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Observations	2,289,012	2,289,012	2,289,012	2,289,012
R^2	0.159	0.159	0.159	0.159
Adjusted R^2	0.159	0.159	0.159	0.159
Residual Std. Error	0.092	0.092	0.092	0.092
F Statistic	47,931.790***	48,010.070***	47,995.050***	48,114.400***

*Notes: Rural areas correspond to the reference density. The variable "Exposed" characterizes the squares for which at least 50% of their area belongs to a 3km buffer zone around at least one polluting site in 2010 (column 1), 2011 (column 2), 2012 (column 3), and 2013 (column 4). % farmers correspond to the percentage of farmers at the municipality level. % artisans and others correspond to the percentage of artisans, merchants, and business owners at the municipality level. Bootstrap standard errors in parenthesis. ***, **, *, . indicate 0.1%, 1%, 5% and 10% significance level, respectively.*

A.2.2 Buffer zone

Table A.2.4: Effects of past exposure on % poverty in 2019

	Dependent variable:			
	% Poverty			
	(1)	(2)	(3)	(4)
Exposed	−0.014***	−0.014***	−0.014***	−0.015***
	(0.0004)	(0.0003)	(0.0003)	(0.0003)
Exposed*peri-urban	0.017***	0.017***	0.016***	0.016***
	(0.0004)	(0.0005)	(0.0005)	(0.0005)
Exposed*urban	0.022***	0.023***	0.022***	0.023***
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Peri-urban	−0.029***	−0.029***	−0.029***	−0.028***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Urban	−0.021***	−0.021***	−0.021***	−0.021***
	(0.0002)	(0.0003)	(0.0003)	(0.0003)
% Single parents	0.127***	0.126***	0.126***	0.126***
	(0.001)	(0.001)	(0.001)	(0.001)
% Owners	−0.183***	−0.183***	−0.183***	−0.183***
	(0.0005)	(0.0004)	(0.0004)	(0.0004)
% Farmers	0.396***	0.396***	0.396***	0.395***
	(0.0019)	(0.001)	(0.001)	(0.001)
% Artisans and others	0.143***	0.143***	0.143***	0.143***
	(0.0018)	(0.002)	(0.002)	(0.002)
Constant	0.240***	0.240***	0.240***	0.240***
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Observations	2,287,871	2,287,871	2,287,871	2,287,871
R^2	0.162	0.162	0.162	0.162
Adjusted R^2	0.162	0.162	0.162	0.162
Residual Std. Error	0.090	0.090	0.090	0.090
F Statistic	49,140.490***	49,160.500***	49,141.060***	49,193.070***

*Notes: Rural areas correspond to the reference density. The variable "Exposed" characterizes the squares for which at least 50% of their area belongs to a 3km buffer zone around at least one polluting site in 2010 (column 1), 2011 (column 2), 2012 (column 3) and 2013 (column 4)). % farmers correspond to the percentage of farmers at the municipality level. % artisans and others correspond to the percentage of artisans, merchants, and business owners at the municipality level. Bootstrap standard errors in parenthesis. ***, **, *, . indicate 0.1%, 1%, 5% and 10% significance level, respectively.*

Table A.2.5: Effects of past exposure on % poverty in 2017

	Dependent variable:			
	% Poverty			
	(1)	(2)	(3)	(4)
Exposed	−0.016***	−0.017***	−0.016***	−0.017***
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Exposed*peri-urban	0.017***	0.018***	0.017***	0.016***
	(0.0005)	(0.0005)	(0.0005)	(0.0005)
Exposed*urban	0.023***	0.023***	0.022***	0.023***
	(0.0005)	(0.0005)	(0.0005)	(0.0005)
Peri-urban	−0.031***	−0.031***	−0.031***	−0.031***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Urban	−0.025***	−0.025***	−0.025***	−0.025***
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
% Single parents	0.142***	0.142***	0.142***	0.142***
	(0.001)	(0.001)	(0.001)	(0.001)
% Owners	−0.176***	−0.176***	−0.176***	−0.176***
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
% Farmers	0.415***	0.415***	0.415***	0.414***
	(0.001)	(0.001)	(0.001)	(0.001)
% Artisans and others	0.128***	0.127***	0.127***	0.127***
	(0.002)	(0.002)	(0.002)	(0.002)
Constant	0.239***	0.239***	0.239***	0.239***
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Observations	2,294,716	2,294,716	2,294,716	2,294,716
R^2	0.160	0.161	0.160	0.161
Adjusted R^2	0.160	0.160	0.160	0.161
Residual Std. Error	0.092	0.092	0.092	0.092
F Statistic	48,703.290***	48,746.420***	48,720.110***	48,767.890***

*Notes: Rural areas correspond to the reference density. The variable "Exposed" characterizes the squares for which at least 50% of their area belongs to a 2km buffer zone around at least one polluting site in 2010 (column 1), 2011 (column 2), 2012 (column 3), and 2013 (column 4). % farmers correspond to the percentage of farmers at the municipality level. % artisans and others correspond to the percentage of artisans, merchants, and business owners at the municipality level. Bootstrap standard errors in parenthesis. ***, **, *, . indicate 0.1%, 1%, 5% and 10% significance level, respectively.*

Table A.2.6: Effects of past exposure on % poverty in 2015

	Dependent variable:			
	% Poverty			
	(1)	(2)	(3)	(4)
Exposed	−0.016***	−0.017***	−0.017***	−0.017***
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Exposed*peri-urban	0.017***	0.017***	0.017***	0.016***
	(0.0005)	(0.0005)	(0.0005)	(0.0005)
Exposed*urban	0.022***	0.023***	0.022***	0.023***
	(0.0005)	(0.0005)	(0.0005)	(0.0005)
Peri-urban	−0.031***	−0.031***	−0.031***	−0.031***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Urban	−0.025***	−0.025***	−0.025***	−0.025***
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
% Single parents	0.163***	0.163***	0.163***	0.163***
	(0.001)	(0.001)	(0.001)	(0.001)
% Owners	−0.172***	−0.172***	−0.172***	−0.172***
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
% Farmers	0.409***	0.409***	0.409***	0.408***
	(0.001)	(0.001)	(0.001)	(0.001)
% Artisans and others	0.098***	0.098***	0.098***	0.098***
	(0.002)	(0.002)	(0.002)	(0.002)
Constant	0.235***	0.235***	0.235***	0.236***
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Observations	2,289,012	2,289,012	2,289,012	2,289,012
R^2	0.158	0.158	0.158	0.158
Adjusted R^2	0.158	0.158	0.158	0.158
Residual Std. Error	0.092	0.092	0.092	0.092
F Statistic	47,570.780***	47,624.620***	47,615.640***	47,652.020***

*Notes: Rural areas correspond to the reference density. The variable "Exposed" characterizes the squares for which at least 50% of their area belongs to a 2km buffer zone around at least one polluting site in 2010 (column 1), 2011 (column 2), 2012 (column 3), and 2013 (column 4). % farmers correspond to the percentage of farmers at the municipality level. % artisans and others correspond to the percentage of artisans, merchants, and business owners at the municipality level. Bootstrap standard errors in parenthesis. ***, **, *, . indicate 0.1%, 1%, 5% and 10% significance level, respectively.*

A.3 Robustness variance and skewmess

A.3.1 FiLoSoFi database and year of exposure

Table A.3.1: Variance and Skewness for 2019 FiLoSoFi database

	% Poverty					
	2011		2012		2013	
	Variance	Skewness	Variance	Skewness	Variance	Skewness
	(1)	(2)	(3)	(4)	(5)	(6)
Exposed	−0.002***	−0.0002***	−0.002***	−0.0002***	−0.002***	−0.0002***
	(0.00003)	(0.00001)	(0.00003)	(0.00001)	(0.00003)	(0.00001)
Esposed*peri-urban	0.001***	0.0003***	0.001***	0.0002***	0.001***	0.0002***
	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0001)	(0.00002)
Exposed*urban	0.002***	0.0004***	0.002***	0.0004***	0.002***	0.0004***
	(0.0001)	(0.00003)	(0.0001)	(0.00003)	(0.0001)	(0.00003)
Peri-urban	−0.003***	−0.0003***	−0.003***	−0.0003***	−0.003***	−0.0003***
	(0.00004)	(0.00001)	(0.00004)	(0.00001)	(0.00004)	(0.00001)
Urban	−0.002***	−0.0001***	−0.003***	−0.0002***	−0.002***	−0.0001***
	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0001)	(0.00002)
% Single parents	−0.0001	−0.0003***	−0.0001	−0.0003***	−0.0001	−0.0003***
	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0001)
% Owners	−0.012***	−0.001***	−0.012***	−0.001***	−0.012***	−0.001***
	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0001)	(0.00002)
% Farmers	0.032***	0.0001	0.032***	0.0001	0.032***	0.0001
	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0001)
% Artisans and others	0.011***	0.001***	0.011***	0.001***	0.011***	0.001***
	(0.0003)	(0.0001)	(0.0003)	(0.0001)	(0.0003)	(0.0001)
Constant	0.017***	0.001***	0.017***	0.001***	0.017***	0.001***
	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0001)	(0.00002)
Observations	2,287,871	2,287,871	2,287,871	2,287,871	2,287,871	2,287,871
R^2	0.030	0.001	0.030	0.001	0.030	0.001
Adjusted R^2	0.030	0.001	0.030	0.001	0.030	0.001
Residual Std. Error	0.015	0.006	0.015	0.006	0.015	0.006
F Statistic	7,947.970***	194.747***	7,947.978***	194.339***	7,967.043***	196.120***

*Notes: Rural areas correspond to the reference density. The variable "Exposed" characterizes the squares for which at least 50% of their area belongs to a 3km buffer zone around at least one polluting site in 2011 (column 1 and 2), 2012 (column 3 and 4), and 2013 (column 5 and 6). % farmers correspond to the percentage of farmers at the municipality level. % artisans and others correspond to the percentage of artisans, merchants, and business owners at the municipality level. Bootstrap standard errors in parenthesis. ***, **, *, . indicate 0.1%, 1%, 5% and 10% significance level, respectively.*

Table A.3.2: Variance and Skewness for 2017 FiLoSoFi database

	% Poverty							
	2010		2011		2012		2013	
	Variance	Skewness	Variance	Skewness	Variance	Skewness	Variance	Skewness
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exposed	−0.002***	−0.0002***	−0.002***	−0.0003***	−0.002***	−0.0002***	−0.002***	−0.0002***
	(0.00003)	(0.00001)	(0.00003)	(0.00001)	(0.00003)	(0.00001)	(0.00003)	(0.00001)
Exposed*peri-urban	0.001***	0.0002***	0.001***	0.0002***	0.001***	0.0002***	0.001***	0.0002***
	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0001)	(0.00002)
Exposed*urban	0.002***	0.0004***	0.002***	0.0004***	0.002***	0.0004***	0.002***	0.0004***
	(0.0001)	(0.00003)	(0.0001)	(0.00003)	(0.0001)	(0.00003)	(0.0001)	(0.00003)
Peri-urban	−0.003***	−0.0003***	−0.003***	−0.0003***	−0.003***	−0.0003***	−0.003***	−0.0003***
	(0.00004)	(0.00001)	(0.00004)	(0.00001)	(0.00004)	(0.00001)	(0.00004)	(0.00001)
Urban	−0.003***	−0.0001***	−0.003***	−0.0001***	−0.003***	−0.0001***	−0.003***	−0.0001***
	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0001)	(0.00002)
% Single parents	−0.00005	−0.0002***	−0.0001	−0.0002***	−0.0001	−0.0002***	−0.00004	−0.0002***
	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0001)
% Owners	−0.011***	−0.001***	−0.011***	−0.001***	−0.011***	−0.001***	−0.012***	−0.001***
	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0001)	(0.00002)
% Farmers	0.032***	−0.0001	0.032***	−0.0001	0.032***	−0.0001	0.032***	−0.0001
	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0001)
% Artisans and others	0.010***	0.001***	0.010***	0.001***	0.010***	0.001***	0.010***	0.001***
	(0.0003)	(0.0001)	(0.0003)	(0.0001)	(0.0003)	(0.0001)	(0.0003)	(0.0001)
Constant	0.017***	0.001***	0.017***	0.001***	0.017***	0.001***	0.017***	0.001***
	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0001)	(0.00002)
Observations	2,294,716	2,294,716	2,294,716	2,294,716	2,294,716	2,294,716	2,294,716	2,294,716
R^2	0.030	0.001	0.030	0.001	0.030	0.001	0.030	0.001
Adjusted R^2	0.030	0.001	0.030	0.001	0.030	0.001	0.030	0.001
Residual Std. Error	0.016	0.006	0.016	0.006	0.016	0.006	0.016	0.006
F Statistic	7,756.911***	182.641***	7,771.948***	184.570***	7,758.456***	182.131***	7,785.199***	184.641***

*Notes: Rural areas correspond to the reference density. The variable "Exposed" characterizes the squares for which at least 50% of their area belongs to a 3km buffer zone around at least one polluting site in 2010 (column 1 and 2), 2011 (column 3 and 4), 2012 (column 5 and 6), and 2013 (column 7 and 8). % farmers correspond to the percentage of farmers at the municipality level. % artisans and others correspond to the percentage of artisans, merchants, and business owners at the municipality level. Bootstrap standard errors in parenthesis. ***, **, *, . indicate 0.1%, 1%, 5% and 10% significance level, respectively.*

Table A.3.3: Variance and Skewness for 2015 FiLoSoFi database

	% Poverty							
	2010		2011		2012		2013	
	Variance	Skewness	Variance	Skewness	Variance	Skewness	Variance	Skewness
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exposed	−0.002***	−0.0003***	−0.002***	−0.0003***	−0.002***	−0.0003***	−0.002***	−0.0003***
	(0.00003)	(0.00001)	(0.00003)	(0.00001)	(0.00003)	(0.00001)	(0.00003)	(0.00001)
Exposed*peri-urban	0.001***	0.0003***	0.001***	0.0003***	0.001***	0.0002***	0.001***	0.0002***
	(0.0001)	(0.00003)	(0.0001)	(0.00003)	(0.0001)	(0.00003)	(0.0001)	(0.00003)
Exposed*urban	0.002***	0.0004***	0.002***	0.0004***	0.002***	0.0004***	0.002***	0.0004***
	(0.0001)	(0.00003)	(0.0001)	(0.00003)	(0.0001)	(0.00003)	(0.0001)	(0.00003)
Peri-urban	−0.003***	−0.0003***	−0.003***	−0.0003***	−0.003***	−0.0003***	−0.003***	−0.0003***
	(0.00004)	(0.00001)	(0.00004)	(0.00001)	(0.00004)	(0.00002)	(0.00004)	(0.00002)
Urban	−0.002***	−0.0001***	−0.002***	−0.0001***	−0.002***	−0.0001***	−0.002***	−0.0001***
	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0001)	(0.00002)
% Single parents	0.001***	−0.0001**	0.001***	−0.0001**	0.001***	−0.0001**	0.001***	−0.0001**
	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0001)
% Owners	−0.012***	−0.001***	−0.012***	−0.001***	−0.012***	−0.001***	−0.012***	−0.001***
	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0001)	(0.00002)
% Farmers	0.036***	−0.001***	0.036***	−0.001***	0.036***	−0.001***	0.036***	−0.001***
	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0001)
% Artisans and others	0.007***	0.001***	0.007***	0.001***	0.007***	0.001***	0.007***	0.001***
	(0.0003)	(0.0001)	(0.0003)	(0.0001)	(0.0003)	(0.0001)	(0.0003)	(0.0001)
Constant	0.017***	0.001***	0.017***	0.001***	0.017***	0.001***	0.017***	0.001***
	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0001)	(0.00002)
Observations	2,289,012	2,289,012	2,289,012	2,289,012	2,289,012	2,289,012	2,289,012	2,289,012
R^2	0.032	0.001	0.032	0.001	0.032	0.001	0.032	0.001
Adjusted R^2	0.032	0.001	0.032	0.001	0.032	0.001	0.032	0.001
Residual Std. Error	0.016	0.006	0.016	0.006	0.016	0.006	0.016	0.006
F Statistic	8,274.774***	201.974***	8,289.753***	203.487***	8,280.368***	200.690***	8,314.016***	202.013***

*Notes: Rural areas correspond to the reference density. The variable "Exposed" characterizes the squares for which at least 50% of their area belongs to a 3km buffer zone around at least one polluting site in 2010 (column 1 and 2), 2011 (column 3 and 4), 2012 (column 5 and 6), and 2013 (column 7 and 8). % farmers correspond to the percentage of farmers at the municipality level. % artisans and others correspond to the percentage of artisans, merchants, and business owners at the municipality level. Bootstrap standard errors in parenthesis. ***, **, *, . indicate 0.1%, 1%, 5% and 10% significance level, respectively.*

A.3.2 Buffer zone

Table A.3.4: Variance and Skewness for 2019 FiLoSoFi database

	% Poverty					
	2011		2012		2013	
	Variance	Skewness	Variance	Skewness	Variance	Skewness
	(1)	(2)	(3)	(4)	(5)	(6)
Exposed	−0.002***	−0.0002***	−0.002***	−0.0002***	−0.002***	−0.0002***
	(0.00004)	(0.00002)	(0.00004)	(0.00002)	(0.00004)	(0.00002)
Exposed*peri-urban	0.002***	0.0003***	0.002***	0.0002***	0.002***	0.0002***
	(0.0001)	(0.00003)	(0.0001)	(0.00003)	(0.0001)	(0.00003)
Exposed*urban	0.002***	0.0003***	0.002***	0.0004***	0.002***	0.0004***
	(0.0001)	(0.00003)	(0.0001)	(0.00003)	(0.0001)	(0.00003)
Peri-urban	−0.003***	−0.0003***	−0.003***	−0.0003***	−0.003***	−0.0003***
	(0.00004)	(0.00001)	(0.00004)	(0.00001)	(0.00004)	(0.00001)
Urban	−0.002***	−0.0001***	−0.002***	−0.0001***	−0.002***	−0.0001***
	(0.00004)	(0.00002)	(0.00004)	(0.00002)	(0.00004)	(0.00002)
% Single Parents	−0.0001	−0.0003***	−0.0001	−0.0003***	−0.0001	−0.0003***
	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0001)
% Owners	−0.012***	−0.001***	−0.012***	−0.001***	−0.012***	−0.001***
	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0001)	(0.00002)
% Farmers	0.033***	0.0002*	0.033***	0.0002*	0.033***	0.0002**
	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0001)
% Artisans and others	0.012***	0.001***	0.012***	0.001***	0.012***	0.001***
	(0.0003)	(0.0001)	(0.0003)	(0.0001)	(0.0003)	(0.0001)
Constant	0.017***	0.001***	0.017***	0.001***	0.017***	0.001***
	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0001)	(0.00002)
Observations	2,287,871	2,287,871	2,287,871	2,287,871	2,287,871	2,287,871
R^2	0.030	0.001	0.030	0.001	0.030	0.001
Adjusted R^2	0.030	0.001	0.030	0.001	0.030	0.001
Residual Std. Error	0.015	0.006	0.015	0.006	0.015	0.006
F Statistic	7,852.941***	171.632***	7,856.705***	171.075***	7,858.306***	170.142***

*Notes: Rural areas correspond to the reference density. The variable "Exposed" characterizes the squares for which at least 50% of their area belongs to a 2km buffer zone around at least one polluting site in 2011 (column 1 and 2), 2012 (column 3 and 4), and 2013 (column 5 and 6). % farmers correspond to the percentage of farmers at the municipality level. % artisans and others correspond to the percentage of artisans, merchants, and business owners at the municipality level. Bootstrap standard errors in parenthesis. ***, **, *, . indicate 0.1%, 1%, 5% and 10% significance level, respectively.*

Table A.3.5: Variance and Skewness for 2017 FiLoSoFi database

	% Poverty							
	2010		2011		2012		2013	
	Variance	Skewness	Variance	Skewness	Variance	Skewness	Variance	Skewness
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exposed	−0.002***	−0.0003***	−0.002***	−0.0003***	−0.002***	−0.0003***	−0.002***	−0.0003***
	(0.00005)	(0.00002)	(0.00004)	(0.00002)	(0.00004)	(0.00002)	(0.00004)	(0.00002)
Exposed*peri-urban	0.002***	0.0003***	0.002***	0.0003***	0.002***	0.0003***	0.002***	0.0003***
	(0.0001)	(0.00003)	(0.0001)	(0.00003)	(0.0001)	(0.00003)	(0.0001)	(0.00003)
Exposed*urban	0.002***	0.0004***	0.002***	0.0004***	0.002***	0.0004***	0.002***	0.0004***
	(0.0001)	(0.00003)	(0.0001)	(0.00003)	(0.0001)	(0.00003)	(0.0001)	(0.00003)
Peri-urban	−0.003***	−0.0003***	−0.003***	−0.0003***	−0.003***	−0.0003***	−0.003***	−0.0003***
	(0.00004)	(0.00001)	(0.00004)	(0.00001)	(0.00004)	(0.00001)	(0.00004)	(0.00001)
Urban	−0.002***	−0.0001***	−0.002***	−0.0001***	−0.002***	−0.0001***	−0.002***	−0.0001***
	(0.00004)	(0.00002)	(0.00004)	(0.00002)	(0.00004)	(0.00002)	(0.00004)	(0.00002)
% Single parents	−0.0001	−0.0002***	−0.0001	−0.0002***	−0.00005	−0.0002***	−0.00004	−0.0002***
	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0001)
% Owners	−0.012***	−0.001***	−0.012***	−0.001***	−0.012***	−0.001***	−0.012***	−0.001***
	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0001)	(0.00002)
% Farmers	0.033***	−0.0001	0.033***	−0.0001	0.033***	−0.0001	0.033***	−0.00005
	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0001)
% Artisans and others	0.011***	0.001***	0.011***	0.001***	0.011***	0.001***	0.011***	0.001***
	(0.0003)	(0.0001)	(0.0003)	(0.0001)	(0.0003)	(0.0001)	(0.0003)	(0.0001)
Constant	0.017***	0.001***	0.017***	0.001***	0.017***	0.001***	0.017***	0.001***
	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0001)	(0.00002)
Observations	2,294,716	2,294,716	2,294,716	2,294,716	2,294,716	2,294,716	2,294,716	2,294,716
R^2	0.029	0.001	0.029	0.001	0.029	0.001	0.029	0.001
Adjusted R^2	0.029	0.001	0.029	0.001	0.029	0.001	0.029	0.001
Residual Std. Error	0.016	0.006	0.016	0.006	0.016	0.006	0.016	0.006
F Statistic	7,663.782***	162.718***	7,677.025***	163.733***	7,667.461***	161.598***	7,679.243***	162.313***

*Notes: Rural areas correspond to the reference density. The variable "Exposed" characterizes the squares for which at least 50% of their area belongs to a 2km buffer zone around at least one polluting site in 2010 (column 1 and 2), 2011 (column 3 and 4), 2012 (column 5 and 6), and 2013 (column 7 and 8). % farmers correspond to the percentage of farmers at the municipality level. % artisans and others correspond to the percentage of artisans, merchants, and business owners at the municipality level. Bootstrap standard errors in parenthesis. ***, **, *, . indicate 0.1%, 1%, 5% and 10% significance level, respectively.*

Table A.3.6: Variance and Skewness for 2015 FiLoSoFi database

	% Poverty							
	2010		2011		2012		2013	
	Variance	Skewness	Variance	Skewness	Variance	Skewness	Variance	Skewness
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exposed	−0.002***	−0.0003***	−0.002***	−0.0003***	−0.002***	−0.0003***	−0.002***	−0.0003***
	(0.00005)	(0.00002)	(0.00005)	(0.00002)	(0.00004)	(0.00002)	(0.00005)	(0.00002)
Exposed*peri-urban	0.002***	0.0003***	0.002***	0.0003***	0.002***	0.0003***	0.002***	0.0003***
	(0.0001)	(0.00003)	(0.0001)	(0.00003)	(0.0001)	(0.00003)	(0.0001)	(0.00003)
Exposed*urban	0.002***	0.0004***	0.002***	0.0004***	0.002***	0.0004***	0.002***	0.0004***
	(0.0001)	(0.00003)	(0.0001)	(0.00003)	(0.0001)	(0.00003)	(0.0001)	(0.00003)
Peri-urban	−0.003***	−0.0003***	−0.003***	−0.0003***	−0.003***	−0.0003***	−0.003***	−0.0003***
	(0.00004)	(0.00001)	(0.00004)	(0.00001)	(0.00004)	(0.00001)	(0.00004)	(0.00001)
Urban	−0.002***	−0.0001***	−0.002***	−0.0001***	−0.002***	−0.0001***	−0.002***	−0.0001***
	(0.00005)	(0.00002)	(0.00005)	(0.00002)	(0.00005)	(0.00002)	(0.00005)	(0.00002)
% Single parents	0.001***	−0.0001**	0.001***	−0.0001**	0.001***	−0.0001**	0.001***	−0.0001**
	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0001)
% Owners	−0.012***	−0.001***	−0.012***	−0.001***	−0.012***	−0.001***	−0.012***	−0.001***
	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0001)	(0.00002)
% Farmers	0.036***	−0.001***	0.036***	−0.001***	0.036***	−0.001***	0.036***	−0.001***
	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0001)	(0.0002)	(0.0001)
% Artisans and others	0.008***	0.001***	0.008***	0.001***	0.008***	0.001***	0.008***	0.001***
	(0.0003)	(0.0001)	(0.0003)	(0.0001)	(0.0003)	(0.0001)	(0.0003)	(0.0001)
Constant	0.017***	0.001***	0.017***	0.001***	0.017***	0.001***	0.017***	0.001***
	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0001)	(0.00002)	(0.0001)	(0.00002)
Observations	2,289,012	2,289,012	2,289,012	2,289,012	2,289,012	2,289,012	2,289,012	2,289,012
R^2	0.031	0.001	0.031	0.001	0.031	0.001	0.031	0.001
Adjusted R^2	0.031	0.001	0.031	0.001	0.031	0.001	0.031	0.001
Residual Std. Error	0.016	0.006	0.016	0.006	0.016	0.006	0.016	0.006
F Statistic)	8,166.847***	182.603***	8,178.815***	182.929***	8,177.541***	181.432***	8,187.039***	180.620***

*Notes: Rural areas correspond to the reference density. The variable "Exposed" characterizes the squares for which at least 50% of their area belongs to a 3km buffer zone around at least one polluting site in 2010 (column 1 and 2), 2011 (column 3 and 4), 2012 (column 5 and 6), and 2013 (column 7 and 8). % farmers correspond to the percentage of farmers at the municipality level. % artisans and others correspond to the percentage of artisans, merchants, and business owners at the municipality level. Bootstrap standard errors in parenthesis. ***, **, *, . indicate 0.1%, 1%, 5% and 10% significance level, respectively.*

A.4 Robustness of number of poor

A.4.1 FiLoSoFi database and year of exposure

Table A.4.1: Effects of past exposure to the number of poor households in 2019

	Dependent variable:		
	Number of poor		
	(1)	(2)	(3)
Exposed	0.101***	0.107***	0.085***
	(0.016)	(0.015)	(0.015)
Exposed*peri-urban	0.221***	0.177***	0.200***
	(0.032)	(0.031)	(0.031)
Exposed*urban	4.532***	4.418***	4.645***
	(0.034)	(0.034)	(0.034)
Peri-urban	0.198***	0.213***	0.209***
	(0.019)	(0.019)	(0.019)
Urban	2.999***	3.038***	2.901***
	(0.025)	(0.025)	(0.025)
% Single parents	3.746***	3.740***	3.750***
	(0.071)	(0.071)	(0.071)
% Owners	−16.517***	−16.526***	−16.502***
	(0.030)	(0.030)	(0.030)
% Farmers	−2.614***	−2.611***	−2.616***
	(0.110)	(0.110)	(0.110)
% Artisans and others	−3.828***	−3.835***	−3.826***
	(0.131)	(0.132)	(0.131)
Constant	14.154***	14.161***	14.143***
	(0.029)	(0.029)	(0.029)
Observations	2,287,871	2,287,871	2,287,871
R^2	0.238	0.237	0.238
Adjusted R^2	0.238	0.237	0.238
Residual Std. Error	7.202	7.204	7.201
F Statistic	79,341.320***	79,150.410***	79,450.590***

*Notes: Rural areas correspond to the reference density. The variable "Exposed" characterizes the squares for which at least 50% of their area belongs to a 3km buffer zone around at least one polluting site in 2011 (column 1), 2012 (column 2), and 2013 (column 3). % farmers correspond to the percentage of farmers at the municipality level. % artisans and others correspond to the percentage of artisans, merchants, and business owners at the municipality level. Bootstrap standard errors in parenthesis. ***, **, *, . indicate 0.1%, 1%, 5% and 10% significance level, respectively.*

Table A.4.2: Effects of past exposure to the number of poor households in 2017

	Dependent variable:			
	Number of poor			
	(1)	(2)	(3)	(4)
Exposed	0.100***	0.101***	0.108***	0.090***
	(0.015)	(0.015)	(0.015)	(0.015)
Exposed*peri-urban	0.199***	0.204***	0.168***	0.182***
	(0.030)	(0.030)	(0.030)	(0.030)
Exposed*urban	4.466***	4.337***	4.223***	4.431***
	(0.032)	(0.032)	(0.032)	(0.032)
Peri-urban	0.239***	0.234***	0.246***	0.245***
	(0.017)	(0.018)	(0.018)	(0.018)
Urban	2.852***	2.933***	2.973***	2.846***
	(0.023)	(0.023)	(0.024)	(0.024)
% Single parents	4.201***	4.210***	4.206***	4.207***
	(0.068)	(0.068)	(0.068)	(0.068)
% Owners	−15.389***	−15.399***	−15.408***	−15.387***
	(0.028)	(0.029)	(0.029)	(0.029)
% Farmers	−2.568***	−2.573***	−2.568***	−2.571***
	(0.102)	(0.102)	(0.102)	(0.102)
% Artisans and others	−3.904***	−3.932***	−3.930***	−3.917***
	(0.123)	(0.123)	(0.123)	(0.123)
Constant	13.165***	13.173***	13.179***	13.164***
	(0.027)	(0.027)	(0.027)	(0.027)
Observations	2,294,716	2,294,716	2,294,716	2,294,716
R^2	0.241	0.241	0.240	0.241
Adjusted R^2	0.241	0.241	0.240	0.241
Residual Std. Error	6.792	6.795	6.797	6.794
F Statistic	81,028.530***	80,816.020***	80,614.010***	80,914.890***

*Notes: Rural areas correspond to the reference density. The variable "Exposed" characterizes the squares for which at least 50% of their area belongs to a 3km buffer zone around at least one polluting site in 2010 (column 1), 2011 (column 2), 2012 (column 3), and 2013 (column 4). % farmers correspond to the percentage of farmers at the municipality level. % artisans and others correspond to the percentage of artisans, merchants, and business owners at the municipality level. Bootstrap standard errors in parenthesis. ***, **, *, . indicate 0.1%, 1%, 5% and 10% significance level, respectively.*

Table A.4.3: Effects of past exposure to the number of poor households in 2015

	Dependent variable:			
	Number of poor			
	(1)	(2)	(3)	(4)
Exposed	0.110***	0.112***	0.118***	0.100***
	(0.015)	(0.015)	(0.015)	(0.015)
Exposed*peri-urban	0.193***	0.200***	0.166***	0.184***
	(0.030)	(0.030)	(0.030)	(0.030)
Exposed*urban	4.425***	4.284***	4.176***	4.383***
	(0.032)	(0.032)	(0.032)	(0.032)
Peri-urban	0.244***	0.239***	0.251***	0.248***
	(0.018)	(0.018)	(0.018)	(0.018)
Urban	2.756***	2.844***	2.881***	2.755***
	(0.024)	(0.024)	(0.024)	(0.024)
% Single parents	4.767***	4.773***	4.777***	4.773***
	(0.069)	(0.069)	(0.069)	(0.069)
% Owners	−14.942***	−14.953***	−14.960***	−14.940***
	(0.028)	(0.028)	(0.028)	(0.028)
% Farmers	−2.794***	−2.800***	−2.793***	−2.794***
	(0.103)	(0.103)	(0.103)	(0.103)
% Artisans and others	−4.213***	−4.241***	−4.246***	−4.227***
	(0.121)	(0.121)	(0.121)	(0.121)
Constant	12.771***	12.780***	12.785***	12.770***
	(0.027)	(0.027)	(0.027)	(0.027)
Observations	2,289,012	2,289,012	2,289,012	2,289,012
R^2	0.233	0.232	0.232	0.233
Adjusted R^2	0.233	0.232	0.232	0.233
Residual Std. Error	6.808	6.811	6.813	6.810
F Statistic	77,236.330***	77,012.320***	76,825.220***	77,115.720***

*Notes: Rural areas correspond to the reference density. The variable "Exposed" characterizes the squares for which at least 50% of their area belongs to a 3km buffer zone around at least one polluting site in 2010 (column 1), 2011 (column 2), 2012 (column 3), and 2013 (column 4). % farmers correspond to the percentage of farmers at the municipality level. % artisans and others correspond to the percentage of artisans, merchants, and business owners at the municipality level. Bootstrap standard errors in parenthesis. ***, **, *, . indicate 0.1%, 1%, 5% and 10% significance level, respectively.*

A.4.2 Buffer area

Table A.4.4: Effects of past exposure to the number of poor households in 2019

	Dependent variable:		
	Number of poor		
	(1)	(2)	(3)
Exposed	0.072***	0.077***	0.055***
	(0.021)	(0.020)	(0.021)
Exposed*peri-urban	0.293***	0.263***	0.292***
	(0.038)	(0.038)	(0.038)
Exposed*urban	4.428***	4.143***	4.469***
	(0.036)	(0.036)	(0.036)
Peri-urban	0.231***	0.235***	0.232***
	(0.017)	(0.017)	(0.017)
Urban	4.031***	4.126***	3.988***
	(0.020)	(0.021)	(0.021)
% Single parents	3.745***	3.740***	3.741***
	(0.071)	(0.071)	(0.071)
% Owners	−16.493***	−16.517***	−16.484***
	(0.030)	(0.030)	(0.030)
% Farmers	−2.679***	−2.680***	−2.680***
	(0.110)	(0.110)	(0.110)
% Artisans and others	−3.963***	−3.988***	−3.961***
	(0.131)	(0.131)	(0.131)
Constant	14.153***	14.174***	14.148***
	(0.029)	(0.029)	(0.029)
Observations	2,287,871	2,287,871	2,287,871
R^2	0.238	0.237	0.238
Adjusted R^2	0.238	0.237	0.238
Residual Std. Error	7.203	7.207	7.202
F Statistic	79,262.040***	78,851.080***	79,313.350***

*Notes: Rural areas correspond to the reference density. The variable "Exposed" characterizes the squares for which at least 50% of their area belongs to a 2km buffer zone around at least one polluting site in 2011 (column 1), 2012 (column 2), and 2013 (column 3). % farmers correspond to the percentage of farmers at the municipality level. % artisans and others correspond to the percentage of artisans, merchants, and business owners at the municipality level. Bootstrap standard errors in parenthesis. ***, **, *, . indicate 0.1%, 1%, 5% and 10% significance level, respectively.*

Table A.4.5: Effects of past exposure to the number of poor households in 2017

	Dependent variable:			
	Number of poor			
	(1)	(2)	(3)	(4)
Exposed	0.079***	0.085***	0.094***	0.071***
	(0.020)	(0.019)	(0.019)	(0.019)
Exposed*peri-urban	0.294***	0.280***	0.250***	0.277***
	(0.036)	(0.036)	(0.036)	(0.036)
Exposed*urban	4.286***	4.227***	3.928***	4.240***
	(0.034)	(0.034)	(0.033)	(0.034)
Peri-urban	0.261***	0.262***	0.266***	0.263***
	(0.016)	(0.016)	(0.016)	(0.016)
Urban	3.882***	3.921***	4.022***	3.890***
	(0.019)	(0.019)	(0.019)	(0.019)
% Single parents	4.205***	4.217***	4.212***	4.207***
	(0.068)	(0.068)	(0.068)	(0.068)
% Owners	−15.370***	−15.374***	−15.400***	−15.368***
	(0.029)	(0.029)	(0.029)	(0.029)
% Farmers	−2.628***	−2.629***	−2.629***	−2.630***
	(0.102)	(0.102)	(0.102)	(0.102)
% Artisans and others	−4.028***	−4.052***	−4.074***	−4.045***
	(0.123)	(0.123)	(0.123)	(0.123)
Constant	13.166***	13.170***	13.192***	13.166***
	(0.027)	(0.027)	(0.027)	(0.027)
Observations	2,294,716	2,294,716	2,294,716	2,294,716
R^2	0.241	0.241	0.239	0.241
Adjusted R^2	0.241	0.241	0.239	0.241
Residual Std. Error	6.794	6.795	6.800	6.795
F Statistic	80,841.280***	80,741.320***	80,279.930***	80,753.840***

*Notes: Rural areas correspond to the reference density. The variable "Exposed" characterizes the squares for which at least 50% of their area belongs to a 2km buffer zone around at least one polluting site in 2010 (column 1), 2011 (column 2), 2012 (column 3), and 2013 (column 4). % farmers correspond to the percentage of farmers at the municipality level. % artisans and others correspond to the percentage of artisans, merchants, and business owners at the municipality level. Bootstrap standard errors in parenthesis. ***, **, *, . indicate 0.1%, 1%, 5% and 10% significance level, respectively.*

Table A.4.6: Effects of past exposure to the number of poor households in 2015

	Dependent variable:			
	Number of poor			
	(1)	(2)	(3)	(4)
Exposed	0.089***	0.096***	0.102***	0.082***
	(0.020)	(0.019)	(0.019)	(0.019)
Exposed*peri-urban	0.299***	0.285***	0.262***	0.285***
	(0.036)	(0.036)	(0.036)	(0.036)
Exposed*urban	4.250***	4.188***	3.883***	4.190***
	(0.034)	(0.034)	(0.034)	(0.034)
Peri-urban	0.264***	0.265***	0.268***	0.266***
	(0.016)	(0.016)	(0.016)	(0.016)
Urban	3.780***	3.820***	3.924***	3.792***
	(0.019)	(0.019)	(0.019)	(0.020)
% Single parents	4.761***	4.773***	4.771***	4.767***
	(0.069)	(0.069)	(0.069)	(0.069)
% Owners	−14.916***	−14.921***	−14.947***	−14.917***
	(0.028)	(0.028)	(0.029)	(0.028)
% Farmers	−2.859***	−2.861***	−2.860***	−2.857***
	(0.103)	(0.103)	(0.103)	(0.103)
% Artisans and others	−4.338***	−4.364***	−4.391***	−4.354***
	(0.121)	(0.121)	(0.121)	(0.121)
Constant	12.769***	12.774***	12.795***	12.771***
	(0.027)	(0.027)	(0.027)	(0.027)
Observations	2,289,012	2,289,012	2,289,012	2,289,012
R^2	0.233	0.232	0.231	0.232
Adjusted R^2	0.233	0.232	0.231	0.232
Residual Std. Error	6.810	6.811	6.816	6.811
F Statistic	77,069.780***	76,970.290***	76,505.740***	76,964.800***

*Notes: Rural areas correspond to the reference density. The variable "Exposed" characterizes the squares for which at least 50% of their area belongs to a 2km buffer zone around at least one polluting site in 2010 (column 1), 2011 (column 2), 2012 (column 3), and 2013 (column 4). % farmers correspond to the percentage of farmers at the municipality level. % artisans and others correspond to the percentage of artisans, merchants, and business owners at the municipality level. Bootstrap standard errors in parenthesis. ***, **, *, . indicate 0.1%, 1%, 5% and 10% significance level, respectively.*

A.5 Robustness for growth of poor households

A.5.1 Year of exposure

Table A.5.1: Growth between 2015 and 2019 of the number of poor households for different years of exposure

	Dependent variable:		
	$\Delta NbPoor$		
	(1)	(2)	(3)
Exposed	0.010***	0.010***	0.011***
	(0.001)	(0.001)	(0.001)
Exposed*peri-urban	0.014***	0.013***	0.009***
	(0.003)	(0.003)	(0.003)
Exposed*urban	0.033***	0.037***	0.036***
	(0.003)	(0.003)	(0.003)
Peri-urban	0.050***	0.051***	0.052***
	(0.002)	(0.002)	(0.002)
Urban	0.112***	0.109***	0.109***
	(0.002)	(0.002)	(0.002)
% Single parents	−0.112***	−0.112***	−0.112***
	(0.007)	(0.007)	(0.007)
% Owners	−0.024***	−0.024***	−0.024***
	(0.003)	(0.003)	(0.003)
% Farmers	−0.225***	−0.225***	−0.224***
	(0.010)	(0.010)	(0.010)
% Artisans and others	−0.074***	−0.073***	−0.074***
	(0.012)	(0.012)	(0.012)
Constant	0.070***	0.070***	0.069***
	(0.003)	(0.003)	(0.003)
Observations	2,164,342	2,164,342	2,164,342
R^2	0.007	0.007	0.007
Adjusted R^2	0.007	0.007	0.007
Residual Std. Error	0.636	0.636	0.636
F Statistic	1,581.905***	1,585.802***	1,585.963***

*Notes: Rural areas correspond to the reference density. The variable "Exposed" characterizes the squares for which at least 50% of their area belongs to a 3km buffer zone around at least one polluting site in 2011 (column 1), 2012 (column 2), and 2013 (column 3). % farmers correspond to the percentage of farmers at the municipality level. % artisans and others correspond to the percentage of artisans, merchants, and business owners at the municipality level. Bootstrap standard errors in parenthesis. ***, **, *, . indicate 0.1%, 1%, 5% and 10% significance level, respectively.*

A.5.2 Buffer area

Table A.5.2: Growth between 2015 and 2019 of the number of poor households for different years of exposure

	Dependent variable:			
	$\Delta NbPoor$			
	(1)	(2)	(3)	(4)
Exposed	0.016***	0.017***	0.016***	0.017***
	(0.002)	(0.002)	(0.002)	(0.002)
Exposed*peri-urban	0.014***	0.010***	0.010***	0.009***
	(0.003)	(0.003)	(0.003)	(0.003)
Exposed*Urban	0.019***	0.018***	0.021***	0.020***
	(0.003)	(0.003)	(0.003)	(0.003)
Peri-urban	0.053***	0.053***	0.053***	0.053***
	(0.002)	(0.002)	(0.002)	(0.002)
Urban	0.124***	0.124***	0.123***	0.123***
	(0.002)	(0.002)	(0.002)	(0.002)
% Single parents	−0.113***	−0.112***	−0.113***	−0.112***
	(0.007)	(0.007)	(0.007)	(0.007)
% Owners	−0.023***	−0.024***	−0.023***	−0.023***
	(0.003)	(0.003)	(0.003)	(0.003)
% Farmers	−0.226***	−0.226***	−0.226***	−0.225***
	(0.010)	(0.010)	(0.010)	(0.010)
% Artisans and others	−0.076***	−0.076***	−0.075***	−0.076***
	(0.012)	(0.012)	(0.012)	(0.012)
Constant	0.070***	0.070***	0.070***	0.069***
	(0.003)	(0.003)	(0.003)	(0.003)
Observations	2,164,342	2,164,342	2,164,342	2,164,342
R^2	0.007	0.007	0.007	0.007
Adjusted R^2	0.007	0.007	0.007	0.007
Residual Std. Error	0.636	0.636	0.636	0.636
F Statistic	1,575.925***	1,575.605***	1,578.421***	1,579.294***

*Notes: Rural areas correspond to the reference density. The variable "Exposed" characterizes the squares for which at least 50% of their area belongs to a 2km buffer zone around at least one polluting site in 2010 (column 1), 2011 (column 2), 2012 (column 3), and 2013 (column 4). % farmers correspond to the percentage of farmers at the municipality level. % artisans and others correspond to the percentage of artisans, merchants, and business owners at the municipality level. Bootstrap standard errors in parenthesis. ***, **, *, . indicate 0.1%, 1%, 5% and 10% significance level, respectively.*

A.6 Descriptive statistics for standard of living

Table A.6.1: Statistics of the standard of living

	AverStandLiv							
	Whole sample		Urban		Peri-urban		Rural	
	Exposed	Non-exposed	Exposed	Non-exposed	Exposed	Non-exposed	Exposed	Non-exposed
N	516104	1771767	158945	94089	111403	177200	245756	1500478
%	0,23	0,77	0,63	0,37	0,39	0,61	0,14	0,86
Mean	10.94	10.91	10.94	11.02	11.00	11.05	10.91	10.88
SD	0,27	0,25	0,32	0,30	0,27	0,27	0,22	0,24
Median	10.95	10.91	10.95	11.03	11.01	11.05	10.92	10.89
Mean - Median	-0.01	0,00	-0.01	-0.01	-0.01	0.00	-0.01	-0.01

Notes: AverStandLiv corresponds to the average standard of living in logarithm by geographical unit. The variable "exposed" characterizes the squares for which at least 50% of their area belongs to a 3km buffer zone around at least one polluting site in 2010. SD corresponds to the standard deviation. N corresponds to the number of squares for each considered sample set, and the percentage distinguishes the proportion of exposed and non-exposed squares within the considered sample.