UNIVERSITÁ DEGLI STUDI DI MILANO-BICOCCA
Scuola di Economia e Statistica
Corso di Laurea in Biostatistica

Territorial Socioeconomic Indicators and Mortality in Italian Municipalities: A Panel Data Analysis for Monitoring Territorial Inequalities

Relatore: Prof. Rino Bellocco
Correlatore:
Dott. Gianfranco Alicandro

Tesi di Laurea di:
Matteo Vergani

Matr. N. 892904

Anno Accademico 2022/2023

Acknowledgements

I would like to thank my Supervisor Prof. Rino Bellocco and my Co-Supervisor Dr. Gianfranco Alicandro for having given me the opportunity to take part in a very stimulating project that I believe has been an excellent opportunity for professional growth in my studies and in which they have given me the chance to sharpen my critical thinking and my ability to propose strategies to achieve the purpose of the study.

I would like to thank my family, who have never failed to be there for me, even in these last few years away from home, and without whom I would never have been able to start and complete this journey. I thank them for always being there every single moment of this journey, for supporting me and for rejoicing with me over even the smallest achievement.

I thank all my friends who, despite the last few years when we spent less time together due to distance, were always there for me, who made me feel as if I had never left and with whom I want to share this milestone in my life.

I would like to thank all the people I have met during these years, whose contributions, whether small or great, have made this journey unique.

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Chapter 1

Introduction

Total mortality is a crucial indicator for assessing the health system of a country as it enables the estimation of significant epidemiological indicators, including excess mortality, life expectancy at birth, premature mortality, and years of life lost. Additionally, these indicators facilitate before-after comparisons within the same country, aiding in the evaluation of temporal trends.
Demographic diversity, including sex, age, and socioeconomic conditions, such as education, occupation, and income, are key factors in understanding health disparities within and among countries. Social inequalities, in fact, play a crucial role in explaining spatio-temporal differences in health outcomes. Addressing health inequalities is a priority for several governments and an urgent concern from a public health perspective[1].

In a study based on individual-level data from more than 1.7 million individuals in 48 independent cohorts, where occupational position was used as proxy for socioeconomic status, Stringhini et al. (2017) found that individuals of lower socioeconomic status face a higher mortality risk compared to their higher socioeconomic counterparts. The hazard ratios (HR) mutually adjusted for other lifestyle risk factors were 1.26 for all-cause mortality, 1.29 for cardiovascular mortality and 1.26 for cancer mortality, indicating an excess risk approaching 30%. Interestingly, the association between socioeconomic status and mortality was comparable in strength and consistency across countries to those of six WHO 25$\times$25 risk factor targets for the reduction of premature mortality, including smoking, diabetes, physical inactivity, high alcohol intake, hypertension and obesity. Additionally, the study estimated a decrease in life expectancy of around 2 years for those with low socioeconomic status[2].

Occupational position represents only one of the possible proxies for socio-economic status. Due to its strong relationship between several health outcomes and since it does not change during the life course, education is the most used proxy of socioeconomic position. Several studies have consistently shown that education is an important risk factor for premature mortality[3]. Education exerts its effect on health across multiple dimensions of life, including knowledge, prestige, material resources and social connections. Individuals with lower educational attainment possess a diminished degree of health literacy, have a higher likelihood of engaging in health risk behaviors and a lower likelihood of benefiting from effective treatments when facing illness[4]. Moreover, this disparities is typically more pronounced at younger ages and among men than at older ages and among women.

Socioeconomic factors may also sustain geographical variations in mortality between countries and also within countries. In Italy, higher mortality has been observed in certain regions of the South, such as Campania and Sicily, and some industrialised areas of the North[5]. These differences may, at least in part, explained by the different socioeconomic status of the individuals residing in those areas. Consequently, socioeconomic factors, including education, occupation and income influence individual choices and shape health risks at both individual and community levels. Urban areas exacerbate socioeconomic disparities, with disadvantaged populations often concentrated in the outskirts or inner areas of cities, forming marginalized community areas. Therefore, the relationship between mortality and socioeconomic inequalities has to take into account not only individual features, but also the peculiarity of the areas where people live[5].

Borrell et al. analysed the relationship between socioeconomic indicators in small areas of 16 European cities and mortality. They considered low education, unemployment rates, and a composite deprivation index comprising the two aforementioned indicators, along with the percentage of manual workers and the percentage of foreign residents from low-income countries. The study revealed notable disparities in total mortality across most of the European cities examined, with the greatest inequality observed in Eastern and Northern European cities. In some Western cities (in men) and Southern cities (in women), the disparities were comparatively smaller. The researchers observed that various factors influenced these results, particularly the number and size of small and large areas within cities, as well as their demographic and geographic characteristics[5].

In Italy socioeconomic disparities are smaller than in other European countries, as a consequence of smaller social differences related to risk factors, that could be represented by, for instance, unhealthy practices, restricted access to treatments and health information and resources[6]. Furthermore, socioeconomic differences within countries change over time, impacting mortality risk and trends in subsequent periods. Considerable socioeconomic and cultural changes occur in Italy in the last decades influencing potentially mortality risk and morbidity.

A study by Stringhini et al. showed that over a 40-year period between 1972 and 2011, absolute inequalities in mortality decreased for both men and women. However, relative inequalities among men increased until 2001, followed by a decline in the next decade. Among women, relative inequalities decreased over the whole study period[6].

The reduction of socioeconomic inequalities in mortality and health, in general, poses a significant challenge for health policy. Decreasing the burden of disease in disadvantaged communities has the potential to increase the average health of the entire population. Consequently, monitoring socioeconomic inequalities is crucial for planning and implementing effective health policy interventions. To achieve this, it is essential to utilize valid and interpretable indicators that can quantify the effects and impact of socioeconomic inequalities on health outcomes[4].

To this purpose two indicators have been proposed: the relative index of inequality (RII) and the slope index of inequality (SII). The RII takes into account both the population size and the relative socioeconomic position of the groups. It does so by regressing the morbidity or mortality rate of SES groups on a specific measure of their relative position: the proportion of the population that has a higher position in the social hierarchy. The resulting figure can be interpreted as the ratio of the morbidity and mortality rates of those at the bottom of the social hierarchy compared with those at the top of the hierarchy, estimated on the basis of the systematic association between morbidity or mortality and SES for all groups. A large score on the RII implies large morbidity and mortality differences between high and low positions in the social hierarchy. The SII is the absolute equivalent of the RII. It expresses the health inequality between the top and bottom of the social hierarchy in terms of rate differences instead of rate ratios.

Using these indicators, Tetzlaff et al.[7] analyzed socioeconomic inequalities in cancer mortality and their trend in Germany using an area-level index of deprivation based on education, employment and income. In 2003 they observed an 80% higher cancer mortality risk (RII=1.8) in the most deprived areas compared to the least ones among men and a 50% higher cancer mortality risk (RII=1.5) among women, corresponding to an absolute difference of 84 deaths per 100,000 in women and 185 deaths per 100,000 in men. As declines in cancer mortality were larger in less deprived districts, they documented and increase in the socioeconomic gap over time.

In Italy the COVID-19 pandemic has caused approximately 100,000 excess deaths in 2020, 60,000 in 2021 and 66,000 in 2022[8]. The epidemic outbroke in Lombardy where the first case was identified on February 20, 2020. In the months of March and April, 25,000 excess deaths were registered in that region, representing around 55% of the total excess deaths registered in the whole country (45,000 deaths)[9].

There is cumulating evidence that the pandemic has increased socio-economic inequalities in several countries [6], however limited data exist in Italy. A study conducted at very beginning of the pandemic found an increase in pre-existing socioeconomic inequality between the poorest and the wealthiest municipalities of Lombardy in March 2020, when the mortality rate ratio increased from 1.12-1.33 before the pandemic to 1.61[10].

The objective of this work is to measure and monitor recent trends in socioeconomic inequality among Italian municipalities, using panel data spanning from 2011 to 2022.

Chapter 2

Methods

2.1 Study design

The study involves a panel data analysis based on mortality, population, income and education data of Italian municipalities collected during a period spanning from 2011 to 2022.

2.2 Data source

Daily mortality data in Italian municipalities was available for the period between 1 January 2011 and 31 December 2022, published by the *Istituto Nazionale di Statistica* (ISTAT)[11].
The dataset contains data related to 7901 Italian municipalities, accounting for all administrative changes that occurred during the study period. These data are disaggregated by sex and age groups (0-5, 5-9,. . . , 100+).

Resident population on 1 January of each year in Italian municipalities in the time period between 2010 and 2023 was downloaded from the ISTAT archives [12] [13]. These data were used to compute the mid-year population residing in each municipality disaggregated by sex and age group for the years 2011-2022.
Mid-year population was obtained as Arithmetic mean of the population on 1 January of the year of interest and that of the subsequent year.

Overall taxable income in each municipality related to tax years between 2011 and 2021 was obtained from the archives of the Ministero dell'Economia e delle Finanze[14]. Data for the tax year 2022 was not available and then was replicated from the previous year.

The level of education of the residents of the Italian municipalities were retrieved from the last decennial census implemented by the ISTAT in Italy and relative to the calendar year 2011, i.e. the 15th *Censimento della popolazione e delle abitazioni*. In 2018 the ISTAT launched the permanent population and housing census which provide yearly census statistics on a sampling basis. Data on level of education between 2018 to 2022 were requested to the ISTAT using the dedicated platform on the Institution website[15]. To fill the data gap of the period 2012-2017, 2011 data were replicated for the years 2012-2014 and 2018 data for the years 2015-2017.

2.3 Classification of municipalities based on education and income level of residents

Average taxable income for each municipality was computing for each tax year as the ratio between the overall taxable income in euros and the number of taxpayers in the municipality.

The level of education obtained from the 2011 decennial census archive included the following categories:

1) "Analfabeti";
2) "Alfabeti privi di titolo di studio";
3) "Licenza di scuola elementare";
4) "Licenza di scuola media inferiore o di avviamento professionale";
5) "Diploma di scuola secondaria superiore (2-3 anni)";
6) "Diploma di scuola secondaria superiore (4-5 anni)";
7) "Diploma di accademia di belle arti etc. Conservatorio vecchio ordinamento";
8) "Diploma universitario (2-3 anni) del vecchio ordinamento (incluse le scuole dirette e a fini speciali o parauniversitarie)";
9) "Diploma accademico A.F.A.M. I Liv";
10) "Laurea triennale";
11) "Diploma accademico A.F.A.M. II Liv";
12) "Laurea (4-6 anni) del vecchio ordinamento, laurea specialistica o magistrale a ciclo unico del nuovo ordinamento, laurea biennale specialistica (di II livello) del nuovo ordinamento".

The level of education obtained from the 2018-2022 permanent census archives included the following categories:

- "Nessun titolo di studio" (NED);
- "Licenza di scuola elementare" (PSE);
- "Licenza di scuola media inferiore o di avviamento professionale" (LSE);
- "Diploma di istruzione secondaria di II grado o di qualifica professionale (corso di 3-4 anni) compresi IFTS" (USE_IF);
- "Diploma di tecnico superiore ITS o titolo di studio terziario di primo livello" (BL);
- "Titolo di studio terziario di secondo livello" (ML);
- "Dottorato di ricerca/diploma accademico di formazione alla ricerca" (RDD);
- "Titolo di studio terziario di secondo livello e dottorato di ricerca";.

We grouped municipalities according to average taxable income and the percentage of residents aged ≥ 25 years with attained education below high school diploma, corresponding to a level of the International Standard Classification of Education < 3. Decile of the distribution of these two indicators were used for classifying the municipalities.
Therefore, municipalities were classified for each year in ten groups from 1 to 10, where 1 corresponds to the lowest income level and 10 to the highest income level, while in the classification by education, 1 correspond to the municipalities where lived the lowest numbers of less educated individuals and 10 the municipalities with the highest proportion of less educated individuals.

2.4 Data analysis

The mortality and population dataset were linked using the six alphanumeric code that identifies municipalities, sex, age group and the calendar year of the period considered by the study. Subsequently, the resulted dataset was linked with the income and education datasets using the municipality identification code and the calendar year.

The final data set contained the following variables:

- ID: The ISTAT identification code of the municipality;
- MUN: The name of the municipality;
- SEX (1: Male; 2: Female);

- AGEGROUP: Age groups (10 levels) which are defined modifying the original classification as follows: AGEGROUP$= 1$ represents the age group 0-24, AGEGROUP$= 2$ represents the age group 25-49, AGEGROUP$= 3$ represents the age group 50-54, AGEGROUP$= 4$ represents the age group 55-59, AGEGROUP$= 5$ represents the age group 60-64, AGEGROUP$= 6$ represents the age group 65-69, AGEGROUP$= 7$ represents the age group 70-74, AGEGROUP$= 8$ represents the age group 75-79, AGEGROUP$= 9$ represents the age group 80-84 and AGEGROUP$= 10$ represents the age group 85+;

- EDUC: Proportion of residents with educational attainment below high school (10 levels based on decile of the distribution of the variable);

- INCOME: Average taxable income of the taxpayers living in the municipality (10 levels based on decile of the distribution of the variable);

- TIME: calendar years (values from 2011 to 2022);

- POP: Mid-year resident population;

- DEATHS: Number of deaths from any cause;

In response to the World Health Organization's plea to address socioeconomic disparities in health [16], there has been extensive debate on the interpretation and assessment of socioeconomic inequalities in the last 40 years. One approach involves analysing the socioeconomic factor as an ordered variable, in order to measure the monotonic relationship between the socioeconomic factor and health status - where health improves with rising socioeconomic status. Various techniques have been suggested to capture such socioeconomic gradient, measuring the likelihood of an event (e.g., hazard rate or incidence rate). While straightforward measures comparing two socioeconomic groups offer valuable insights (e.g., incidence rate ratios/differences), they lack comparability across populations with distinct distributions of the socioeconomic indicator. Consequently, more sophisticated measures are needed for meaningful cross-population comparisons.
To this purpose, two indices have been proposed, namely the relative index of inequality (RII) and the slope index of inequality (SII). These metrics facilitate the quantitative evaluation and comparison of socioeconomic inequality and the comparison across populations defined by geographic location, time period, or birth cohort. They consist of a single comprehensive metric of socioeconomic inequality in relative and absolute term.

Mackenbach and Kunst's[4] work provided the first definitions of the RII and SII Following these definitions, the RII is defined as a relative risk:

$$RII_1 := h(1)/h(0), \tag{2.1}$$

where $h(x)$ is the health outcome defined as a function of socioeconomic rank x where 0 and 1 are the position of best-placed and worst-placed individuals, respectively.
Conversely, the SII is defined as an excess risk:

$$SII_1 := h(1) - h(0), \tag{2.2}$$

in order to compute differences in health outcomes.
The initial definitions of the RII and SII offer significant advantages. They are easy to communicate, as the indexes are described as relative risk and excess risk between hypothetical extremes, respectively. However, what they are really intended to measure is the linear association across the entire socioeconomic scale, and not only the ratio or the difference between two extreme socioeconomic levels.

New definitions of the RII and the SII proposed by Moreno-Betancur et al. along with a structured regression framework for their estimation [17] implies the use of log-linear models, of the form $f_\beta(x) = y_0 exp(\beta x)$. Assuming $y = f_\beta(x)$, $exp(\beta)$ indicates the strength of the linear relationship between the socioeconomic rank x and the health outcome y and its direction: $RII > 1$ if the association is positive, < 1 if the association is negative.
Therefore, the RII is obtained as:

$$RII := exp(\beta^*), \tag{2.3}$$

where β^* is the least false parameter, that is the parameter that provides the best approximation of the relationship between x and y by log-linear model.
The new definition of SII involves the use of linear models of the form $g_\alpha(x) = y_0 + \alpha x$. Assuming $y = g_\alpha(x)$, the parameter α indicates the strength and direction of the linear association between socioeconomic rank x and health outcome y in absolute terms. A larger deviation of α from zero indicates a stronger association, where the sign of α specifies the direction of the association. Therefore, the SII is obtained as:

$$SII := \alpha^*, \tag{2.4}$$

where α^* is the least false parameter, representing the parameter that offers the optimal approximation of the association between x and y through a linear model.

The interpretation of RII and SII as the least false parameters involves implementing log-linear and linear models independently of the shape of the observed relation between x and y. Thus, they are not real population parameters, but summary measures of the association with the health outcome across the entire scale of the socioeconomic factor.

Appropriate distributional assumptions need to be specified to obtain estimates of the indexes, which depend on the type of the health outcome. New definitions maintain intact analogies with relative and excess risks:

$$\begin{aligned} RII &= \frac{f_{\beta^*}(1)}{f_{\beta^*}(0)} \\ SII &= g_{\alpha^*}(1) - g_{\alpha^*}(0) \end{aligned} \tag{2.5}$$

allowing to use current regression models for the estimation of relative and excess risks. Thus, the RII and the SII could be interpreted as the expected relative and excess risks comparing the two hypothetical extremes of the scale under the log-linear and linear models, respectively, that provides the optimal approximation of the relation between socioeconomic status and health.

According to Moreno-Betancur et al.[17], when working with event data aggregated by socioeconomic group, the RII and the SII are estimated through the use of Poisson multiplicative and additive regression models respectively in order to represent the relationship between exposure and outcome.
In this scenario, the dataset contains the number of events n for each socioeconomic group k, n_k, and m_k person-time risks. Therefore, the incidence rate in socioeconomic group k is computed as $r_k = n_k/m_k$.
The exposure variable is the socioeconomic rank $x_{(k)}$. Using a multiplicative Poisson regression model, RII can be estimated assuming that n_k is distributed as Poisson variable with mean satisfying the equation:

$$E(n_k) = m_k exp(\beta_0 + \beta x_{(k)}) = exp(\log(m_k) + \beta_0 + \beta x_{(k)}) \tag{2.6}$$

Consequently, the estimate of the RII is:

$$\widehat{RII} = exp(\hat{\beta}), \tag{2.7}$$

where $\hat{\beta}$ is the maximum likelihood.
The SII is computed using an additive Poisson regression model where the response variable n_k is Poisson distributed and its mean satisfies:

$$E(n_k) = m_k(\alpha_0 + \alpha x_{(k)}) = m_k\alpha_0 + \alpha(m_k x_{(k)}) \tag{2.8}$$

The estimate of the SII is given by:

$$\widehat{SII} = \hat{\alpha} \tag{2.9}$$

where $\hat{\alpha}$ is estimated by maximum likelihood and expressed by unit of time.

To enhance the comparability of the RII and SII across different populations, the regression models employed for estimation should be adjusted by covariates. For instance, in the analysis of mortality data, age is an important covariate related to both the socioeconomic position and the risk of death.

The inclusion of the adjustment for age in the models for the estimation of SII may not be enough in order to obtain accurate and comparable estimates, in particular in mortality studies. Being SII is an absolute measure, the SII in mortality studies varies according to the level of health in the population, and thus depends on its age structure.

To compare the SII across populations with different age structures, the definition of *age-adjusted SII* has been proposed. It is a weighted sum of estimated age group-specific indices with the weights corresponding to the relative sizes of age group-specific in a reference population. In this case, the reference population chosen is the WHO World Standard Population Distribution (%), based on world average population between 2000-2025[18], with age groups from "0-4" to "85+". These age groups are consistent with those used in the datasets of the analysis.
Age group-specific SIIs are computed fitting an additive Poisson regression model stratified by age group and assuming different coefficients for the socioeconomic rank $x_{(k)}$ within age groups. Assuming the number of events n_{ks} in socioeconomic group k and age group s is Poisson distributed and its mean satisfies:

$$E(n_{ks}) = \alpha_{0s} m_{ks} + \alpha_s (m_{ks} x_{(k)}), \tag{2.10}$$

where m_{ks} is the person-time risks in socioeconomic group k and age group s.
Considering age group-specific indices $\alpha_1, \ldots, \alpha_S$ and age group-specific weights of the reference population w_s, the age-standardized SII is defined by:

$$\widehat{SII}_{age} = \sum_{s=1}^{S} w_s \hat{\alpha}_s, \tag{2.11}$$

where $\hat{\alpha}_1, \ldots, \hat{\alpha}_S$ are the estimated indices.

In this study, we adapted the regression framework proposed by Moreno-Bentancur to the panel structure which characterizes our data:

- data consist of aggregated events collected longitudinally over a 12-year period (from 2011 to 2022);

- data are clustered in groups defined by the combination of Italian municipality (represented by the ISTAT code) and age group, so it was necessary to consider the correlation structure in order to make a correct inference;

To consider accurately the hierarchical structure of the data, the RII and the SII are estimated using generalized estimating equations (GEE) with a first-order auto-regressive correlation structure (AR-1).

In this study we separately evaluated two socioeconomic indicators, i.e. the level of education and the average taxable income of the residents in the municipalities. To this purpose, the categorical variables EDUC and INCOME and consequently the corresponding ranks are computed. Moreover, the models are fitted separately for men and women in order to obtain separate estimates for each sex.
Considering each combination of the two genders and the two socioeconomic ranks, three different models were fitted:

1) a model where the time variable was treated as a categorical variable with 12 levels to obtain a point estimate for each calendar year;

2) a model where the time variable is treated as a continuous variable in order to obtain an estimate of the linear trend;

3) a model where the time variable is treated as a continuous variable, excluding the calendar years 2020, 2021 and 2022 from the analysis. This exclusion aimed to mitigate the effect of the surge in the mortality rate observed in that year, attributable the outbreak of the pandemic in the country.

The original regression framework was also modified by including and interaction terms between the socioeconomic ranks and time are considered. This allowed to test the statistical significance of the interaction between time and the socioeconomic rank using Wald statistic. Thus, providing evidence of a significance variation in the magnitude of the socioeconomic inequalities over the study period.

Therefore, the specification of the three multiplicative models to estimate the RII were:

1) Time treated as categorical variable:

$$\begin{aligned} E(n_k) = exp\{ \log(m_k) + \beta_0 + \beta_1 AgeGroup_2 + \cdots + \beta_9 AgeGroup_{10} + \\ + \beta_{10} T_{2012} + \ldots + \beta_{20} T_{2022} + \beta_{21} x_{(k)} + \\ + \beta_{22}(x_{(k)} * T_{2011}) + \cdots + \beta_{33}(x_{(k)} * T_{2022})\} \end{aligned} \tag{2.12}$$

where:

- $AgeGroup_j = 1$ if $AgeGroup = j$ and $AgeGroup_j = 0$ otherwise, for $j = 2, \ldots, 10$;
- $T_{2011} = 1$ if $Year = 2011$ and $T_{2011} = 0$ otherwise, $T_{2012} = 1$ if $Year = 2012$ and $T_{2012} = 0$ and so on;
- $x_{(k)}$ represents the educational rank (EDUC_RANK) or the income rank (INCOME_RANK);
- n_k represents the number of deaths in socioeconomic group k;
- m_k represents the mid-year population of residents in socioeconomic group k;

2) Time treated as continuous variable, considering the whole study period:

$$\begin{aligned} E(n_k) = exp(\log(m_k) + \beta_0 + \beta_1 AgeGroup_2 + \cdots + \beta_9 Agegroup_{10} + \\ + \beta_{10} TIME_1 + \beta_{11} x_{(k)} + \beta_{12} TIME_1 * x_{(k)}) \end{aligned} \tag{2.13}$$

where:

- $AgeGroup_j = 1$ if $AgeGroup = j$ and $AgeGroup_j = 0$ otherwise, for $j = 2, \ldots, 10$;
- $TIME_1 = TIME - 2011$ where $TIME = 2011, \ldots, 2022$, so $TIME_1 = 0, \ldots, 11$;
- $x_{(k)}$ represents the educational rank (EDUC_RANK) or the income rank (INCOME_RANK);
- n_k represents the number of deaths in socioeconomic group k;
- m_k represents the mid-year population of residents in socioeconomic group k;

3) Time treated as continuous variable, without considering year 2020. In this case, the specification of the model equals the previous one, but data related to year 2020 was not used to fit the model.

The estimates of the RII for each year of the study period were provided by the combinations of the estimates of the coefficients of socioeconomic rank $x_{(k)}$ and interaction terms between time and socioeconomic rank. As a consequence, the point estimates of RII and the corresponding standard errors are computed as follows:

- the logarithm of the point estimate of the RII for each year of the study period is given by:

$$\log(R\hat{I}I_i) = \hat{\beta}_{21} + \hat{\beta}_i \tag{2.14}$$

where β_i is the coefficient related to the interaction term between the socioeconomic rank and T_i with $i = 2012, \ldots, 2022$.

- the standard error of $\log(\widehat{RII}_i)$ was computed by the combination of variances and covariances related to the coefficients of socioeconomic rank and the interaction term between socioeconomic rank and time variable. Indeed, at first the variance of $\log(\widehat{RII}_i)$ was computed:

$$Var(\log(\widehat{RII}_i)) = Var(\hat{\beta}_{21}) + Var(\hat{\beta}_i) + 2Cov(\hat{\beta}_{21}, \hat{\beta}_i) \tag{2.15}$$

  Then, the standard error of $\log(\widehat{RII}_i)$ was obtained as follows:

$$SE(\log(\widehat{RII}_i)) = \sqrt{Var(\log(\widehat{RII}_i)} \tag{2.16}$$

- the point estimate of the RII for each year of the study period was obtained by applying the exponential transformation to the logarithm of the RII:

$$\widehat{RII}_i = exp(\log(\widehat{RII}_i)) = exp(\hat{\beta}_{21} + \hat{\beta}_i) \tag{2.17}$$

  where β_i is the coefficient related to the interaction term between the socioeconomic rank and T_i with $i = 2012, \ldots, 2022$. As regards year 2011, $\widehat{RII}_{2011} = exp(\log(\widehat{RII}_{2011})) = \hat{\beta}_{21}$;

- the standard error of the point estimate of RII for each year of the study period was computed by applying the delta method to the estimate of the standard error of $\log(\widehat{RII}_i)$ and using the exponential transformation.

The standard error was used to calculate the corresponding confidence intervals with a significance level $\alpha = 0.05$.

With regard to the second and third models, they allowed to estimate the expected annual change in the RII:

- from these models the logarithm of the point estimate of the RII for each year of the study is given by:

$$\log(\widehat{RII}_i) = \hat{\beta}_{11} + j \cdot \hat{\beta}_{12} \tag{2.18}$$

  where β_{11} is the coefficient related to the socioeconomic rank (EDUC_RANK or INCOME_RANK) and β_{12} is the coefficient related to the interaction term between the socioeconomic rank the variable $TIME_1$, assuming values $i = 0, \ldots, 11$ that is to say years between 2011 and 2022.
  The annual change in the logarithm of the RII can be estimated by the coefficient related to the interaction term between the socioeconomic rank and the time variable (β_{12}).

- the standard error of $\log(\widehat{RII}_j)$ was computed by from the variances and covariances related to the coefficients of socioeconomic rank and the interaction term between socioeconomic rank and time variable $TIME_1$. Indeed, at first the variance of $\log(\widehat{RII}_i)$ was computed as:

$$Var(\log(\widehat{RII}_i)) = Var(\hat{\beta}_{11}) + i^2 \cdot Var(\hat{\beta}_{12}) + 2 \cdot i \cdot Cov(\hat{\beta}_{11}, \hat{\beta}_{12}) \tag{2.19}$$

  Then, the standard error of $\log(\widehat{RII}_i)$ was calculated:

$$SE(\log(\widehat{RII}_i)) = \sqrt{Var(\log(\widehat{RII}_i))} \tag{2.20}$$

  where $TIME_1$ assumes values $i = 0, \ldots, 11$ which correspond to years between 2011 and 2022.

- the point estimate of the RII for each year of the study period, applying the exponential transformation to the logarithm of the point estimate of the RII:

$$\widehat{RII}_i = exp(\log(\widehat{RII}_i)) = exp(\hat{\beta}_{11} + j \cdot \hat{\beta}_{12}) \tag{2.21}$$

  where β_{11} is the coefficient related to the socioeconomic rank (EDUC_RANK or INCOME_RANK) and β_{12} is the coefficient related to the interaction term between the socioeconomic rank the variable $TIME_1$, assuming values $j = 0, \ldots, 11$.

- the standard error of the point estimate of the RII for each year of the study period was obtained by applying the delta method to the estimate of standard error $\log(\widehat{RII}_i)$ and using the exponential transformation.

These same procedures were used for the estimation of point estimates and interval estimates in the second and third models. The only one difference was that the third model was fit excluding the calendar years 2020, 2021 and 2022.

To estimate the SII, similarly to what has been done to estimate the RII, separate GEE additive Poisson regression models were fit separtely for each sex, assuming that the dependent variable was Poisson distributed. In this case, the link function was the identity function and in the end the intercept was not included in the models. Then, the specification of the three models were:

1) Time treated as categorical variable:

$$\begin{aligned} E(n_k) = &\alpha_1(m_k * AgeGroup_1) + \ldots + \alpha_{10}(m_k * AgeGroup_{10}) + \\ &\alpha_{11}(m_k * x_{(k)}) * T_{2011} + \cdots + \alpha_{22}(m_k * x_{(k)}) * T_{2022} \end{aligned} \tag{2.22}$$

   where:

- $AgeGroup_j = 1$ if $AgeGroup = j$ and $AgeGroup_j = 0$ otherwise, for $j = 2, \ldots, 10$;
- $T_{2011} = 1$ if $Year = 2011$ and $T_{2011} = 0$ otherwise, $T_{2012} = 1$ if $Year = 2012$ and $T_{2011} = 0$ and so on;
- $x_{(k)}$ represents educational rank (EDUC_RANK) or income rank (INCOME_RANK);
- n_k represents the number of deaths in socioeconomic group k;
- m_k represents the number of the mid-year population of residents in socioeconomic group k;

2) Time treated as continuous variable, considering the whole study period:

$$\begin{aligned} E(n_k) = &\alpha_1(m_k * AgeGroup_1) + \ldots + \alpha_{10}(m_k * AgeGroup_{10}) + \\ &\alpha_{11}(m_k * x_{(k)}) + \alpha_{12}(m_k * x_{(k)}) * TIME_1 \end{aligned} \tag{2.23}$$

where:

- $AgeGroup_j = 1$ if $AgeGroup = j$ and $AgeGroup_j = 0$ otherwise, for $j = 2, \ldots, 10$;
- $TIME_1 = TIME - 2011$ where $TIME = 2011, \ldots, 2022$, so $TIME_1 = 0, \ldots, 11$;
- $x_{(k)}$ represents educational rank (EDUC_RANK) or income rank (INCOME_RANK);
- n_k represents the number of deaths in socioeconomic group k;
- m_k represents the number of the mid-year population of residents in socioeconomic group k;

3) Time treated as continuous variable, without considering the calendar years 2020, 2021 and 2022. In this case, the specification of the model equals the previous one, but data related to years 2020, 2021 and 2022 was not used to fit the model.

The estimates of the SII for each year of the study period were obtained by the combinations of the estimates of the coefficients of socioeconomic rank $x_{(k)}$ (EDUC_RANK or INCOME_RANK) and the interaction term between time and socioeconomic rank. The point estimates of SII and the corresponding standard errors are computed as follows:

- the point estimate of SII for each year of the study period:

$$\widehat{SII}_i = \hat{\alpha}_i \tag{2.24}$$

where α_i is the coefficient related to the interaction term between the socioeconomic rank and T_i with $i = 2011, \ldots, 2022$.

- the standard error of $\widehat{SII}_i$ corresponds to the standard error of the coefficient of the corresponding interaction term between socioeconomic rank and time variable. Indeed,

$$SE(\widehat{SII}_i) = SE(\hat{\alpha}_i) \tag{2.25}$$

The standard errors of the point estimate of SII was used to calculate the corresponding confidence intervals with a significance level $\alpha = 0.05$.
The second and third models allowed to estimate the annual change in SII. To this aim, the following method was used:

- the point estimate of SII for each year of the study period was obtained as follows:

$$\widehat{SII}_i = \hat{\alpha}_{11} + j \cdot \hat{\alpha}_i \tag{2.26}$$

  where α_{11} is the coefficient related to the product term between the socioeconomic rank (EDUC_RANK or INCOME_RANK) and the mid-year population and α_i is the coefficient related to the interaction term between the product term between the socioeconomic rank and the mid-year population and the variable $TIME_1$, assuming values $i = 0, \ldots, 11$ that is to say year between 2011 and 2022.

- the standard error of $\widehat{SII}_i$ considering the combinations of variances and covariances related to related to the product term between the socioeconomic rank (EDUC_RANK or INCOME_RANK) and the mid-year population and the interaction term between socioeconomic rank and time variable $TIME_1$. Indeed, at first the variance of $\widehat{SII}_i$ was computed:

$$Var(\widehat{SII}_i) = Var(\hat{\alpha}_{11}) + i^2 \cdot Var(\hat{\alpha}_{12}) + 2 \cdot i \cdot Cov(\hat{\alpha}_{11}, \hat{\alpha}_{12}) \tag{2.27}$$

  Then, the standard error of $\widehat{SII}_i$ was computed as follows:

$$SE(\widehat{SII}_i) = \sqrt{Var(\widehat{SII}_i)} \tag{2.28}$$

The same procedures were used for the estimation of point estimates and interval estimates in the second and third model. The only difference was that the third model was fit excluding the calendar year 2020.
In this study, we assessed the socioeconomic position at the municipality level. However, in densely populated municipalities, this methodology may not fully reflect the heterogeneous distribution of socioeconomic factors within smaller areas. To assess the potential effect of this bias on the RII and SII estimates, a sensitivity analysis was conducted by restricting the analysis to municipalities with an average population over the study period less than 10,000 residents.

Chapter 3

Results

3.1 Exploratory analysis

The cartograms presented below visually depict the geographic distribution of the education and income levels of residents in Italian municipalities during the study period.

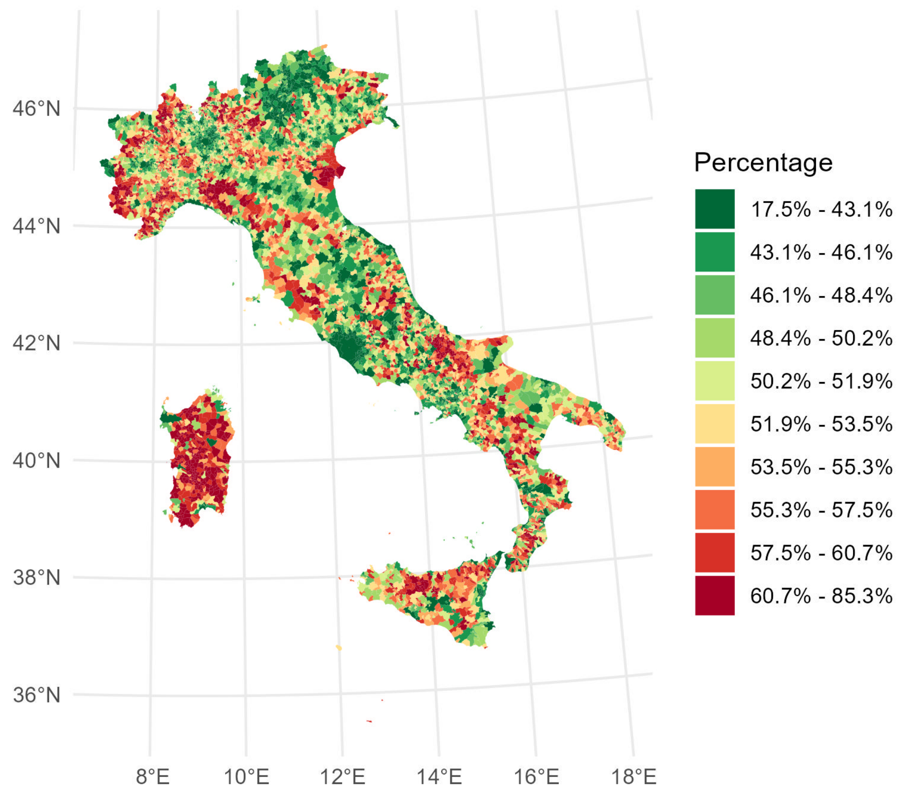

Figure 3.1: Percentage of residents with low educational qualifications (less than high-school diploma) in 2011

Figure 3.1 shows the percentage of residents with a low educational qualification in each Italian municipality for the calendar year 2011 (the first year of study period). The different municipalities are color-coded based on classification which concerns the 10 categories of EDUC variable, defined by deciles of the percentage of residents with a low educational qualification (below high school diploma).
In 2011, Italian municipalities with high percentages of residents with low educational qualifications (highlighted in red shades) were primarily clustered in Sardinia, in southern Italy and in mountainous areas. Conversely, municipalities with low percentages of residents having low educational qualifications (highlighted in red shades) were concentrated in metropolises and large cities, especially in northern and central Italy.

Figure 3.2 presents the distribution of the percentage of residents with low educational qualifications in 2022 (the last year of study period), allowing to conduct a comparison with the 2011 distribution.

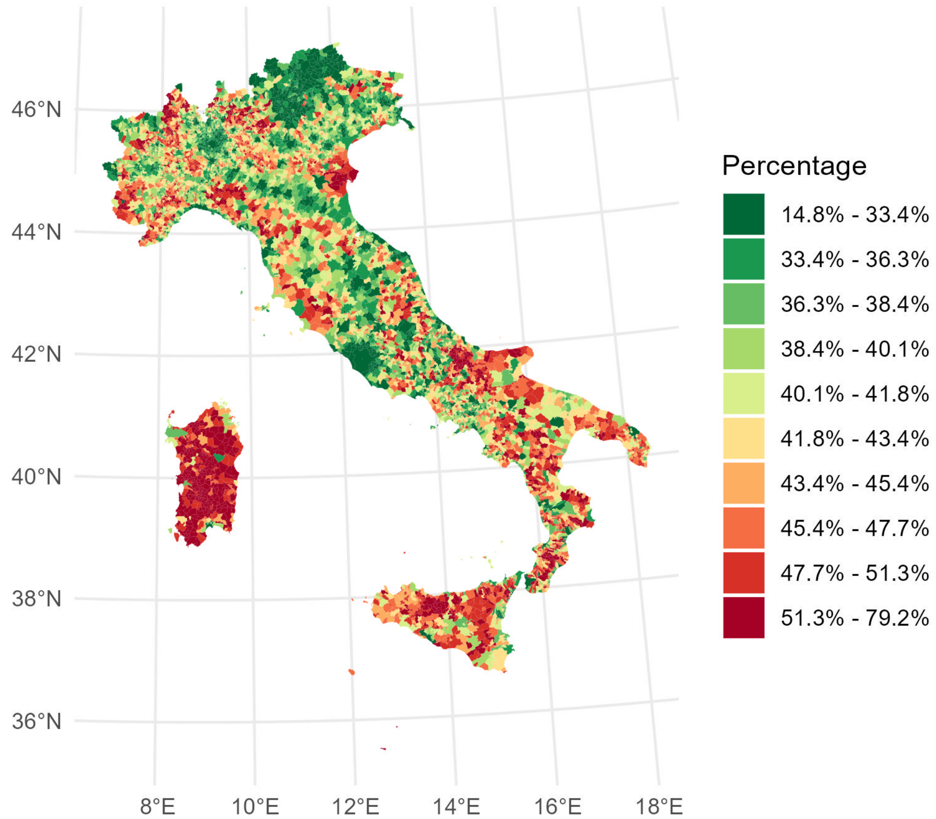

Figure 3.2: Percentage of residents with low educational qualifications (less than high-school diploma) in 2022

Comparing the previous map (Figure 3.1), the distribution of percentages of residents with low educational qualifications in Italian municipalities was quite similar. Besides, Figure

3.2 reveals that the number of Italian municipalities with high percentages of individuals with low educational qualifications has increased in areas where there was already a high concentration of such municipalities in Italy in 2011, while the number of municipalities with low percentages of individuals with low educational qualifications has increased in areas where there was already a high concentration of such municipalities in 2011.

Cartograms were also used to depict the geographic distribution of the average taxable income of residents in Italian municipalities. Figure 3.3 shows the result relative to the calendar year 2011.

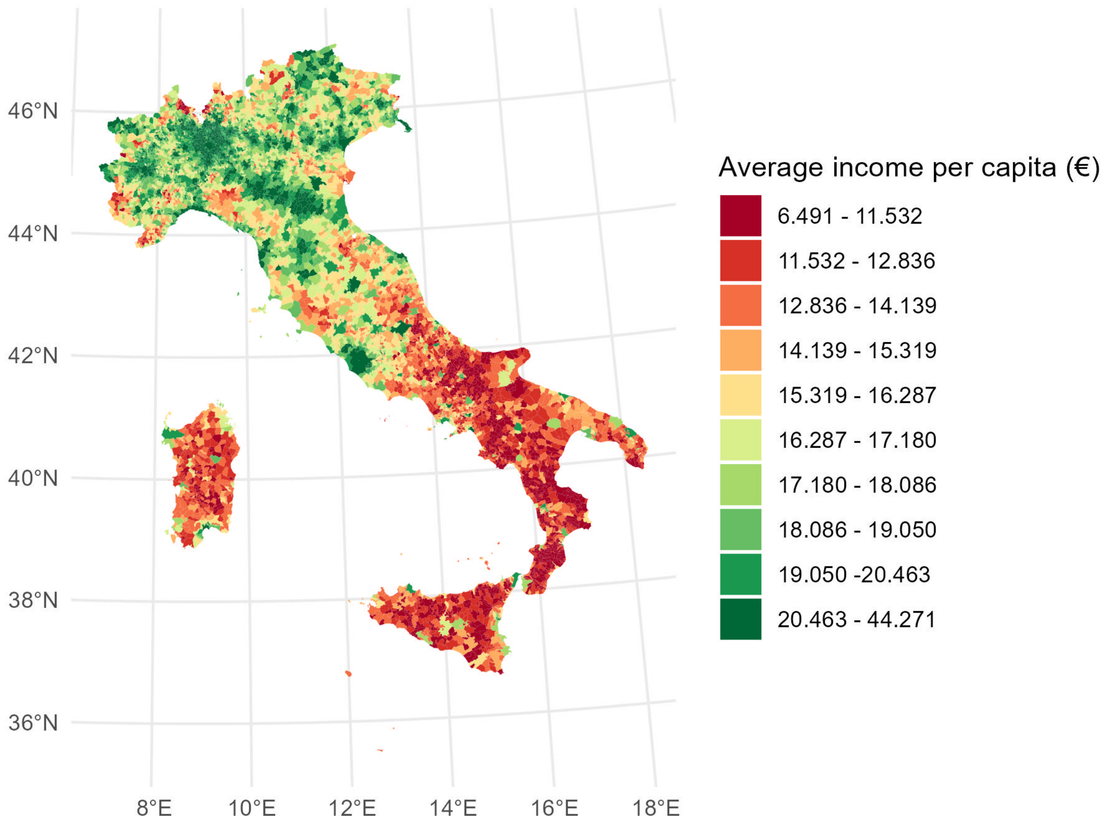

Figure 3.3: Average income per capita in Euro of residents of Italian municipalities in 2011

Figure 3.3 highlights that municipalities characterized by low income levels are mainly concentrated Southern Italy, while those with high income levels are more prevalent in Northern Italy, as well as in Italian major cities and metropolises.

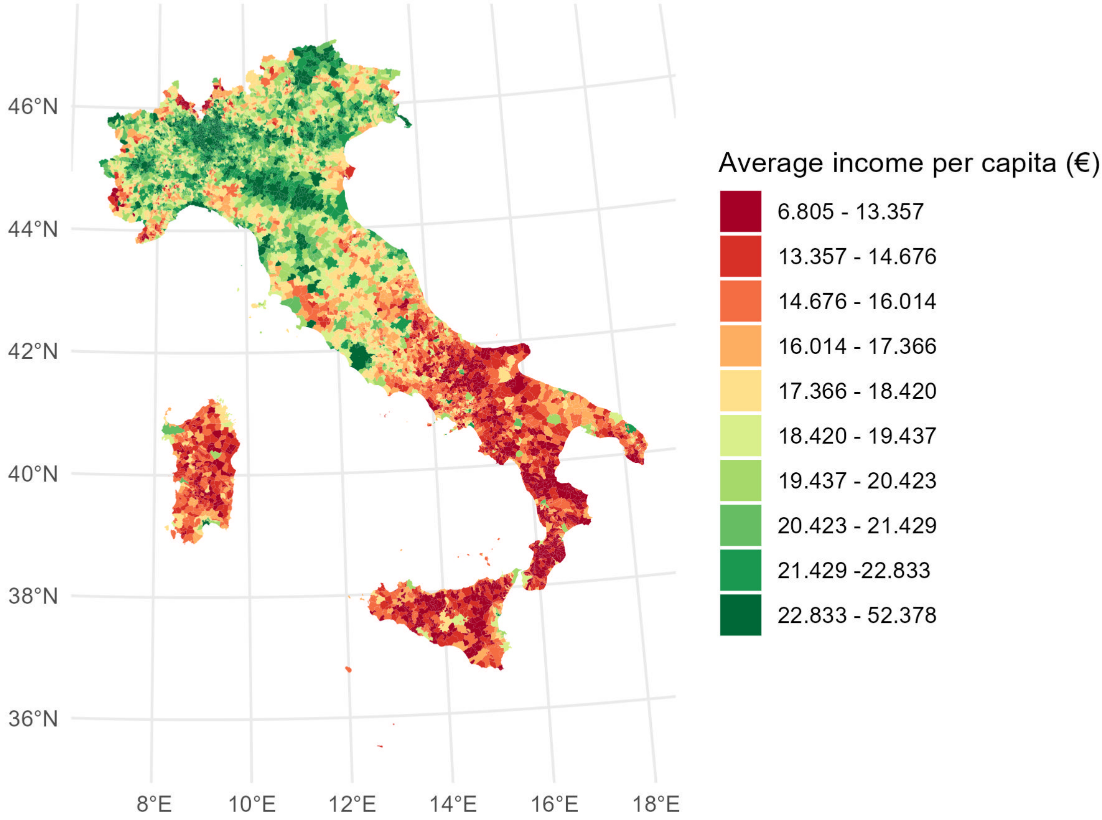

Figure 3.4: Average income per capita in Euro of residents of Italian municipalities in 2022

Figure 3.4 shows the distribution of average income levels per capita of residents in Italian municipalities in 2022. Comparing to Figure 3.3, the number of Italian municipalities with high income levels has increased, remaining mainly concentrated in the Northern and Central regions of Italy. Regarding Southern Italy, the number of municipalities with a low-income level was similar to that observed in 2011.

INCOME										
Year	1	2	3	4	5	6	7	8	9	10
2011	13262 (521.60)	16650 (514.60)	22081 (502.62)	20031 (500.93)	19664 (496.58)	19957 (479.03)	25361 (475.03)	28076 (467.48)	45552 (469.43)	83012 (437.93)
2012	13326 (526.97)	16871 (517.40)	22263 (500.88)	20428 (507.73)	19966 (499.86)	20275 (483.03)	25951 (485.61)	28685 (474.79)	46575 (476.59)	85066 (445.84)
2013	13442 (505.66)	16346 (479.05)	21524 (479.31)	21656 (483.00)	18909 (467.64)	20544 (458.28)	24853 (447.64)	31282 (445.03)	42670 (443.35)	82740 (419.66)
2014	13297 (502.90)	16788 (483.52)	21722 (477.12)	20689 (470.60)	20151 (465.54)	19899 (454.35)	25126 (450.32)	32167 (444.11)	41260 (434.24)	81732 (412.39)
2015	14106 (504.93)	18092 (485.25)	23068 (480.05)	21647 (485.49)	21486 (474.31)	21603 (449.05)	27049 (458.60)	38511 (460.55)	40515 (431.80)	84239 (412.82)
2016	13379 (481.57)	17743 (475.53)	22528 (465.75)	20741 (464.72)	20882 (456.39)	22899 (444.80)	24909 (434.01)	37354 (445.83)	39065 (410.63)	80446 (395.97)
2017	13978 (497.67)	18327 (480.66)	23947 (475.85)	22080 (459.92)	22078 (455.71)	23162 (446.88)	26286 (429.94)	39405 (439.85)	39710 (405.08)	83768 (393.47)
2018	13654 (475.90)	17432 (468.24)	22525 (455.41)	21818 (453.21)	22544 (441.10)	21864 (427.94)	25527 (422.09)	38716 (436.20)	39194 (400.02)	81540 (385.45)
2019	13886 (468.48)	17254 (448.69)	23237 (438.42)	22845 (428.63)	21518 (422.31)	23464 (416.95)	28881 (413.02)	35680 (408.52)	42477 (391.87)	77697 (368.00)
2020	14699 (502.88)	19196 (492.93)	26145 (483.44)	24385 (475.87)	24924 (471.11)	25499 (471.06)	33261 (478.54)	43442 (484.36)	49696 (466.65)	99233 (443.75)
2021	15978 (550.14)	19970 (507.87)	25639 (487.15)	27252 (472.30)	23724 (461.67)	27120 (453.46)	38383 (458.61)	34034 (430.49)	42904 (411.14)	87736 (394.89)
2022	14545 (490.25)	19087 (479.99)	24919 (463.96)	26757 (460.30)	23699 (454.39)	26959 (447.68)	38220 (450.52)	34013 (422.42)	43296 (411.05)	87341 (385.24)

Table 3.1: Number of deaths and age-standardised all-causes mortality rates per 100,000 persons-year (in brackets) in male population within groups of variable INCOME

Firstly, Table 3.1 shows the number of deaths and the age-standardised all-causes mortality rates per 100,000 persons-years, between brackets, in the male population of Italian municipalities within the categories of the variable INCOME during the study period between 2011 and 2022. In category 10 (linked to higher income levels) the highest number of deaths is observed in all years of the study period, and, on the other hand, the lower age-standardised all-causes mortality rates were observed. Quite the opposite, in category 1 (related to lower income levels) the lowest number of deaths was observed and the highest age-standardised all-causes mortality rates was observed in all years between 2011 and 2022.

When analysing the age-standardised all-causes mortality rates for all categories of the INCOME variable from a different perspective, a decreasing trend between the years 2011 and 2019 is observed. Then, in 2020, when the COVID-19 pandemic occurred, all age-standardised all-causes mortality rates increased considerably, especially for categories related to higher income levels. Thereafter, in 2021 the death rates decreased, except for the first three categories, for which they increased again, and in 2022 they decreased for all categories.

INCOME										
Year	1	2	3	4	5	6	7	8	9	10
2011	12701 (319.43)	15909 (314.33)	21323 (308.98)	19756 (306.26)	19479 (295.24)	20648 (289.57)	27030 (296.25)	30010 (283.42)	49142 (289.43)	94447 (274.52)
2012	12962 (321.04)	16283 (317.41)	22036 (316.75)	20554 (314.93)	20673 (306.75)	21271 (295.10)	27711 (298.27)	30834 (288.88)	51280 (299.18)	97162 (279.48)
2013	12619 (297.73)	15874 (295.70)	21034 (296.77)	21216 (294.44)	19536 (291.62)	21161 (278.27)	26856 (280.65)	33998 (280.25)	46307 (278.88)	93511 (263.15)
2014	12840 (306.25)	16538 (293.27)	21330 (294.56)	20525 (291.44)	20621 (286.41)	20810 (278.12)	26545 (277.05)	34570 (276.07)	44761 (271.01)	92945 (260.55)
2015	14034 (314.36)	18726 (316.22)	23956 (311.03)	22157 (312.34)	22580 (298.31)	23861 (288.28)	29505 (290.00)	42939 (293.90)	44288 (271.15)	98979 (269.11)
2016	13140 (300.60)	17395 (293.71)	22344 (293.48)	21055 (294.23)	21637 (283.53)	24281 (281.09)	26361 (271.04)	41142 (283.94)	42758 (259.97)	92266 (253.42)
2017	13957 (308.03)	18421 (306.80)	24241 (304.67)	22850 (300.43)	23277 (292.12)	25421 (288.56)	28704 (278.06)	44172 (288.77)	44156 (262.26)	96618 (256.24)
2018	13652 (296.44)	17297 (290.39)	22459 (287.89)	22119 (290.45)	23775 (282.56)	23896 (277.18)	27759 (269.83)	42557 (278.56)	43518 (257.52)	94111 (251.31)
2019	13727 (295.76)	17625 (286.15)	23546 (288.48)	23755 (285.79)	22459 (271.90)	25530 (269.03)	31776 (269.16)	38926 (261.43)	46545 (253.74)	88745 (240.36)
2020	14402 (313.81)	18890 (302.48)	25633 (302.53)	24106 (297.52)	25524 (295.09)	27115 (298.45)	35501 (300.75)	46219 (306.37)	52870 (291.96)	109469 (277.02)
2021	15629 (346.85)	19879 (320.74)	25588 (314.22)	27360 (306.98)	24206 (296.60)	27939 (287.07)	41171 (300.35)	35997 (274.10)	46048 (268.64)	96940 (253.14)
2022	14897 (318.45)	19640 (310.40)	25741 (307.76)	27617 (307.27)	24753 (293.87)	29050 (291.10)	42631 (301.29)	36840 (276.70)	47174 (267.69)	100648 (254.93)

Table 3.2: Number of deaths and age-standardized all-causes mortality rates per 100,000 persons-year (in brackets) in female population within groups of variable INCOME

Afterwards, similarly to Table 3.1, Table 3.2 presents the number of deaths and age-standardised all-causes mortality rates in female population within categories of INCOME variable during the study period. When examining the data in Table 3.1 for the male population, it is evident that the female population has a higher number of deaths in the top 5 income categories, especially for category 10. Throughout the study period, it is clear that the female population consistently experiences lower age-standardised all-causes mortality rates in all categories of INCOME variable.

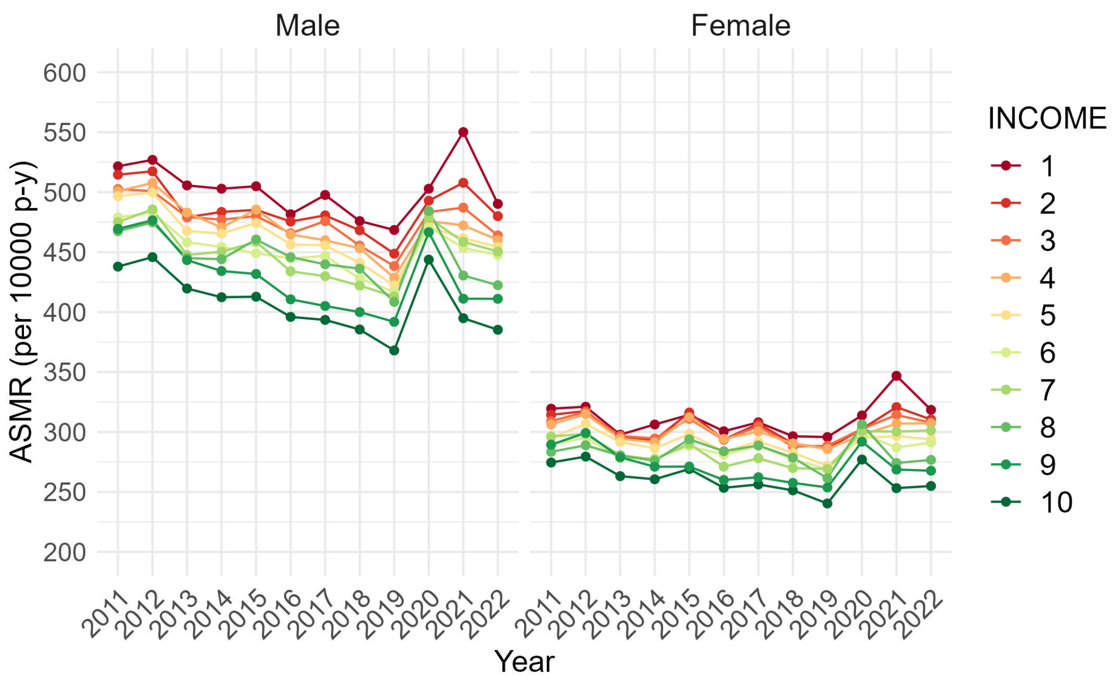

Figure 3.5: Comparison of male and female age-standardised mortality rates within category 1 and 10 of INCOME variable

Figure 3.5 allows to compare the age-standardised all-causes mortality rates between the ten categories of INCOME variable within men and women during the study period. Analysing the plot, it is evident how within categories male mortality rates were higher than female ones in all years of the study period and, from another point of view, in both genders mortality rates of category 1 is the highest on than the corresponding mortality rates of all other categories in all years between 2011 and 2022.

Table 3.3 shows number of deaths and age-standardised all-causes mortality rates in the male population in municipalities grouped according to decile of percentage of residents with low educational qualification.

	EDUC									
Year	1	2	3	4	5	6	7	8	9	10
2011	98165 (448.48)	49200 (480.93)	30732 (469.50)	26875 (477.67)	21395 (471.62)	19197 (495.93)	16392 (499.57)	13956 (493.37)	11077 (504.87)	6657 (532.92)
2012	99943 (453.54)	50538 (492.11)	31114 (474.63)	27733 (488.86)	21871 (480.02)	19616 (503.25)	16370 (494.45)	14304 (499.13)	11346 (510.69)	6571 (508.57)
2013	98934 (429.30)	49464 (460.83)	30581 (442.97)	26719 (447.40)	21631 (453.30)	19043 (469.29)	16298 (472.06)	13667 (465.32)	11082 (488.89)	6547 (506.40)
2014	98598 (424.33)	49192 (454.49)	30630 (441.21)	26987 (450.23)	21333 (444.33)	18854 (462.96)	16205 (466.78)	13895 (472.99)	10874 (473.81)	6263 (480.12)
2015	89260 (418.95)	49069 (437.56)	30714 (447.73)	37660 (472.21)	22672 (464.80)	22684 (464.62)	19760 (478.38)	16370 (483.68)	14188 (482.28)	7939 (510.78)
2016	86122 (402.32)	47328 (419.12)	29615 (430.62)	36312 (455.67)	22135 (449.25)	21975 (453.06)	19059 (460.93)	15863 (465.55)	13900 (468.50)	7637 (479.12)
2017	90156 (401.34)	49435 (418.85)	30494 (421.50)	37954 (456.01)	23133 (450.64)	22861 (449.49)	19910 (462.99)	16493 (465.49)	14264 (462.95)	8041 (493.48)
2018	87328 (388.75)	48635 (413.28)	30062 (417.67)	37004 (445.13)	22513 (439.90)	22182 (438.60)	19529 (456.49)	16016 (456.27)	13895 (455.49)	7650 (468.25)
2019	92103 (376.93)	42058 (393.60)	32415 (402.21)	36828 (424.90)	23799 (424.38)	21484 (417.51)	18640 (435.16)	17721 (437.15)	13881 (445.37)	8010 (461.09)
2020	108383 (434.03)	48038 (459.90)	39490 (475.36)	40260 (488.61)	30145 (491.72)	24687 (495.34)	23810 (491.54)	19371 (510.85)	16837 (501.46)	9459 (501.56)
2021	93606 (400.51)	51138 (425.32)	36457 (439.70)	39493 (457.75)	30859 (466.45)	23516 (458.66)	22012 (472.98)	18787 (491.15)	16963 (502.28)	9909 (518.17)
2022	93346 (392.73)	50868 (417.22)	36137 (431.50)	39561 (453.99)	29933 (444.32)	23224 (446.92)	21728 (458.11)	18279 (470.95)	16266 (472.18)	9494 (485.73)

Table 3.3: Number of deaths and age-standardised mortality rates per 100,000 persons-year (in brackets) in male population within groups of variable EDUC

Throughout the study period, the municipalities with the lowest percentage of residents with low educational qualifications (category 1) consistently exhibited the highest number of deaths and the lowest age-standardised all-causes mortality rates. On the other hand, the category with the highest percentage of residents with low educational qualifications (category 10) presented the lowest number of deaths and the highest age-standardised all-causes mortality rates in all years of the study period. Moreover, across all categories of EDUC variable, a decreasing trend of age-standardised all-causes mortality rates was observed between 2011 and 2019. However, in 2020, during the outbreak of COVID-19 pandemic, these rates increased considerably, before subsequently decreasing and then they decreased in 2021 and 2022.

	EDUC									
Year	1	2	3	4	5	6	7	8	9	10
2011	109540	52408	31925	27596	21745	19264	16690	14147	10999	6131
	(281.65)	(299.23)	(286.74)	(293.64)	(284.34)	(298.47)	(301.99)	(297.92)	(300.47)	(287.67)
2012	112281	54004	33152	28568	22803	20105	17149	14803	11349	6552
	(284.68)	(305.13)	(293.46)	(302.49)	(297.10)	(308.38)	(306.64)	(305.08)	(304.70)	(304.50)
2013	109600	52892	32130	27982	22256	19471	16597	14118	10880	6186
	(269.78)	(287.00)	(277.69)	(283.78)	(279.88)	(289.48)	(286.81)	(286.48)	(285.20)	(279.44)
2014	109513	52523	32284	27373	21796	19574	16647	14345	11042	6388
	(266.34)	(285.15)	(274.31)	(275.56)	(271.67)	(289.64)	(287.17)	(283.98)	(281.18)	(284.07)
2015	103228	54090	33059	41020	24726	23891	21155	17265	14722	7869
	(271.47)	(278.45)	(284.33)	(304.89)	(297.99)	(299.08)	(305.73)	(308.75)	(304.05)	(298.50)
2016	97906	51274	31460	39080	23012	22530	19736	16142	13766	7473
	(257.70)	(265.65)	(271.84)	(291.81)	(281.87)	(283.10)	(286.36)	(289.84)	(287.30)	(282.96)
2017	102958	54545	33178	41234	24592	24208	21052	17351	14956	7743
	(260.50)	(270.80)	(275.80)	(295.65)	(290.46)	(292.83)	(298.79)	(300.25)	(298.97)	(282.93)
2018	100098	53291	32007	39880	23935	23167	20344	16505	14409	7507
	(253.45)	(265.89)	(267.22)	(286.52)	(279.81)	(280.76)	(286.72)	(287.50)	(286.66)	(278.86)
2019	104487	45604	34745	40011	25184	22327	19371	18630	14382	7893
	(244.93)	(256.44)	(263.48)	(279.11)	(274.05)	(270.10)	(278.51)	(287.56)	(281.53)	(273.29)
2020	119565	51051	41349	41768	30898	25633	24075	19194	16979	9217
	(273.57)	(290.91)	(298.14)	(307.04)	(309.04)	(314.91)	(303.98)	(311.78)	(309.34)	(293.10)
2021	103316	54116	38018	41649	31272	24423	22529	19204	16744	9486
	(256.96)	(274.44)	(286.81)	(300.65)	(296.07)	(299.98)	(305.14)	(311.09)	(312.02)	(307.32)
2022	106586	56143	38712	42770	31775	24656	22665	19077	16861	9746
	(258.29)	(276.68)	(282.92)	(301.86)	(295.50)	(293.44)	(300.73)	(302.52)	(303.10)	(307.26)

Table 3.4: Number of deaths and age-standardised mortality rates per 100,000 persons-year (in brackets) in female population within groups of variable EDUC

Table 3.4 describes the number of deaths and age-standardised all-causes mortality rates per 10,000 (between brackets) in the female population within categories of EDUC variable. Similarly to male data, category 1 (linked to the lowest percentages of residents with low educational qualification) presents the highest number of deaths and the lowest age-standardised all-causes mortality rates for all categories in all years of the study period. Conversely, category 10 related to the highest percentages of residents with low educational qualification presents the highest age-standardised all-causes mortality rates during the whole study period.

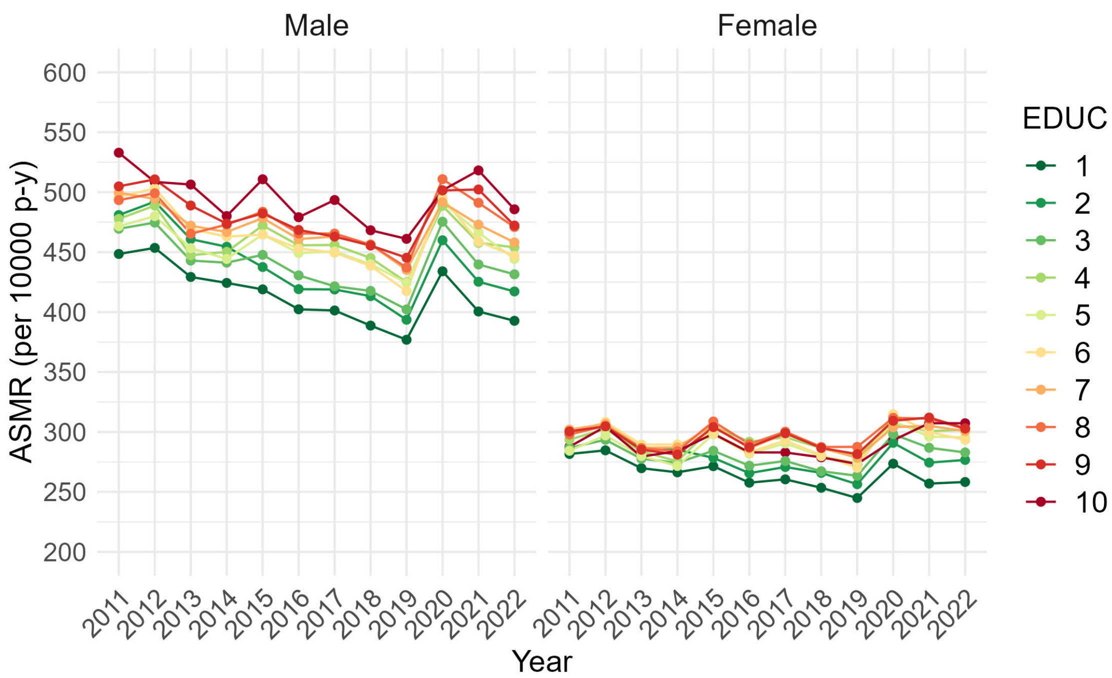

Figure 3.6: Comparison of male and female age-standardised mortality rates within category 1 and 10 of EDUC variable

Figure 3.6 enables a visual comparison of the trends of the age-standardised all-causes mortality rates between the ten categories defined by the EDUC variable for the male and female populations. The figure shows that, irrespective of the EDUC category, male mortality rates consistently exceeded female throughout the entire study period.

Table 3.5 describes the Pearson correlation coefficient between education and income inequalities (EDUC_RANK and INCOME_RANK, respectively) over the study period.

Year	Correlation
2011	0.51
2012	0.51
2013	0.50
2014	0.49
2015	0.58
2016	0.58
2017	0.59
2018	0.58
2019	0.59
2020	0.59
2021	0.59
2022	0.59

Table 3.5: Pearson correlation coefficient between education and income inequalities, by calendar year

Throughout the study period, the correlation coefficient between education and income inequalities increased between 2011 and 2015 and remaining stable around 0.59 in the next years up to 2022.

3.2 Main analysis

3.2.1 RII

Table 3.6 shows the point estimates of the RII and the corresponding 95% confidence intervals for education-related and income-related inequalities, in female and male population.

	Women				Men			
	EDUC		INCOME		EDUC		INCOME	
Year	RII	95% CI	RII	95% CI	RII	95% CI	RII	95% CI
2011	1.07	(1.05 - 1.09)	1.16	(1.14 - 1.18)	1.13	(1.11 - 1.16)	1.18	(1.16 - 1.20)
2012	1.09	(1.07 - 1.12)	1.16	(1.14 - 1.19)	1.12	(1.10 - 1.14)	1.16	(1.14 - 1.18)
2013	1.08	(1.05 - 1.10)	1.15	(1.12 - 1.17)	1.13	(1.11 - 1.15)	1.18	(1.16 - 1.20)
2014	1.10	(1.07 - 1.12)	1.18	(1.15 - 1.20)	1.12	(1.10 - 1.14)	1.19	(1.17 - 1.21)
2015	1.16	(1.14 - 1.18)	1.20	(1.18 - 1.22)	1.18	(1.16 - 1.20)	1.20	(1.18 - 1.22)
2016	1.14	(1.12 - 1.17)	1.19	(1.16 - 1.21)	1.19	(1.17 - 1.21)	1.21	(1.19 - 1.23)
2017	1.19	(1.16 - 1.21)	1.24	(1.21 - 1.26)	1.21	(1.19 - 1.24)	1.26	(1.24 - 1.28)
2018	1.17	(1.14 - 1.19)	1.18	(1.16 - 1.21)	1.21	(1.19 - 1.23)	1.22	(1.20 - 1.24)
2019	1.19	(1.17 - 1.22)	1.23	(1.21 - 1.26)	1.21	(1.19 - 1.23)	1.24	(1.22 - 1.26)
2020	1.15	(1.11 - 1.18)	1.06	(1.03 - 1.09)	1.16	(1.14 - 1.19)	1.06	(1.03 - 1.08)
2021	1.25	(1.22 - 1.28)	1.32	(1.29 - 1.35)	1.27	(1.24 - 1.29)	1.32	(1.29 - 1.34)
2022	1.20	(1.17 - 1.23)	1.24	(1.22 - 1.27)	1.22	(1.20 - 1.24)	1.24	(1.22 - 1.26)

Table 3.6: RII estimates and 95% confidence intervals related to education and income inequalities, by sex and calendar year

Among women, the RII related to low education was 1.07 in 2011, indicating a 7% relative excess mortality associated to low educational attainement. This estimate corresponded to the lowest value of the RII observed during the study period, whereas the highest value was observed in 2021, reaching 1.25. In terms of income inequalities, the RII in 2011 was 1.16 in 2011 and the highest value was observed in 2021 (RII: 1.32). Except for the 2020, income inequalities consistently exceeded educational inequalities.
Among men, the RII linked to low educational attainement was 1.13, indicating a 13% relative excess mortality related to low education. The lowest value for the point estimate of the RII was observed in 2014 (RII: 1.12), while the highest was documented in 2021 (RII: 1.27). In 2011, the RII related to low income was 1.18, with the lowest value observed in 2020 (RII: 1.06) and the highest one in 2021 (RII: 1.32). Similar, to what has been observed among women, income inequalities were higher than educational inequalities, with the sole exception being the year 2020.

Figure 3.7 shows the results obtained using model 2, where the year variable was included in the model as a continuous variable.

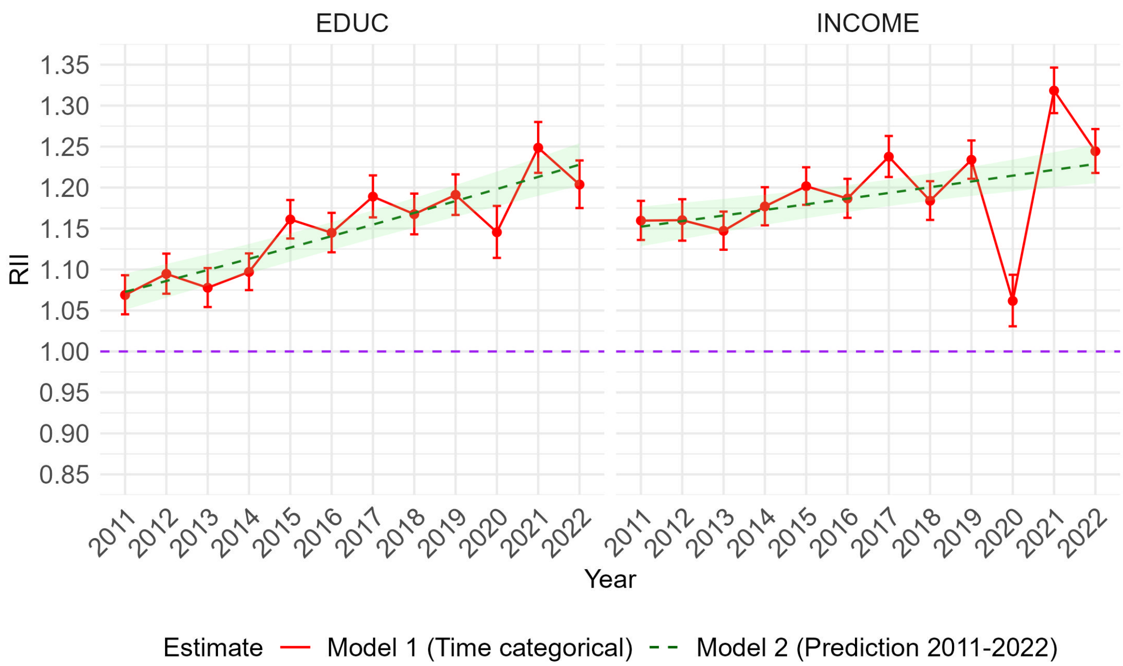

Figure 3.7: Trends in the RII estimates and 95% confidence intervals related to educational and income inequalities over the study period, among women.

In the female population, a rising trend in the RII was observed over the study period in terms of both educational and income inequalities.This indicates that the excess mortality associated to both low educational attainment and low income increased over the study period. The slope of the predicted lines indicates that the increase was more pronounced for educational inequality ($\hat{\beta}_{12} = 0.0123$, p-value < 0.001) than for income inequality ($\hat{\beta}_{12} = 0.0058$, p-value < 0.001). The corresponding annual percent changes in the RII were 1.24% (95% CI: 0.97% ; 1.50%) for educational inequalities and 0.59% (95% CI: 0.31% ; 0.86%) for income inequalities.

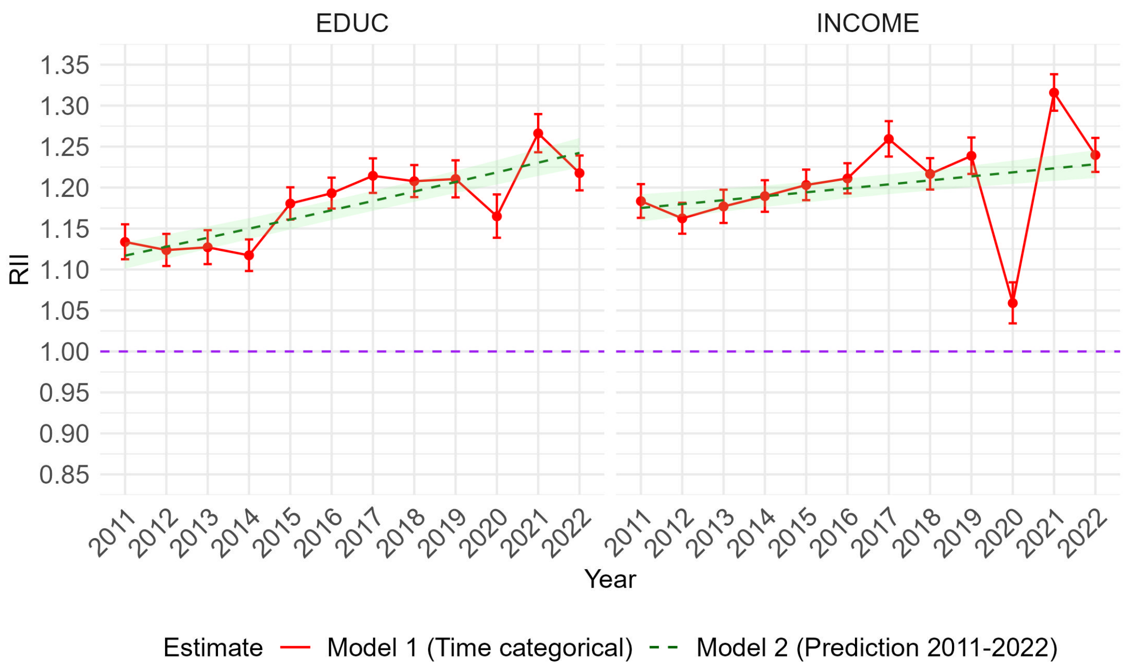

Figure 3.8: Trends in the RII estimates and 95% confidence intervals related to educational and income inequalities over the study period, among men.

A similar pattern was observed in the male population. The RII increased over the study period for both educational and income inequalities. The slope of the predicted lines linked to inequalities in education ($\hat{\beta}_{12} = 0.0097$, with a p-value < 0.001) was more than twice the corresponding slope related to income inequalities ($\hat{\beta}_{12} = 0.0040$, p-value < 0.001). The corresponding annual percent changes in the RII were 0.97% (95% CI: 0.78% ; 1.16%) for educational inequalities and 0.40% (95% CI: 0.23%; 0.58%) for income inequalities.

Since in 2020, there was a substantial drop in the estimate of the RII for both educational and income inequalities, observed exclusively in that year, we fit a model (model 3) excluding data related to the calendar years 2020, 2021 and 2022. The results of this analysis are shown in Figure 3.9 for the female population and 3.10 for the male population.

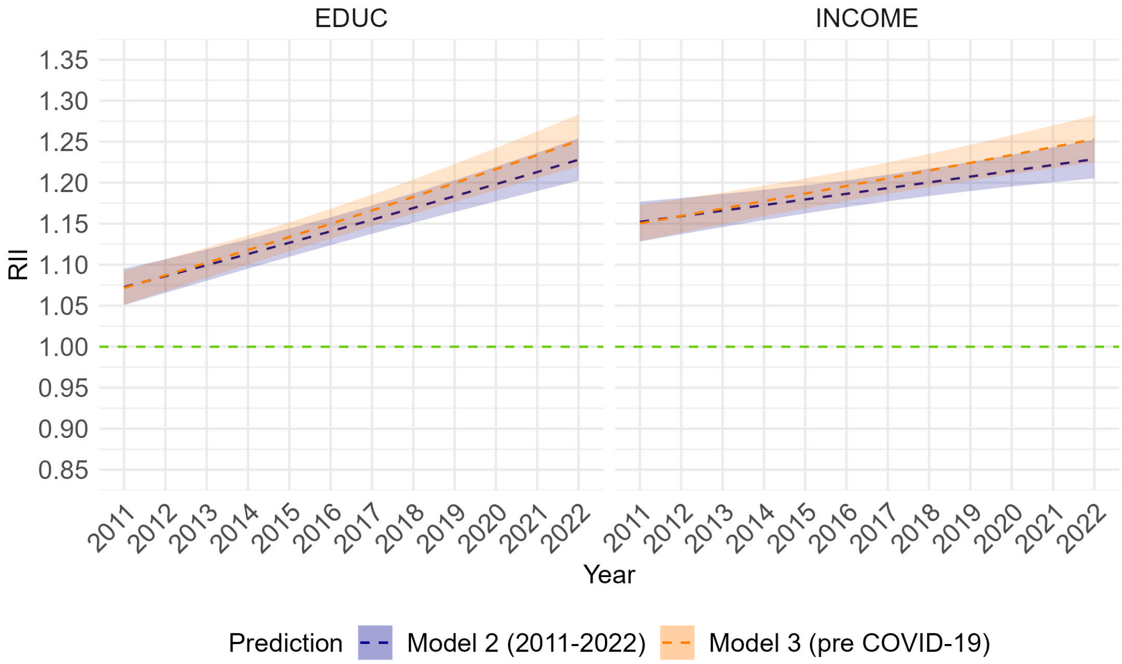

Figure 3.9: Comparison of the RII trends estimated frombetween the prediction of Model 2 (including all years) and Model 3 (considering only pre-pandemic data) in the female population

In the female population, the slope of the regression line for the RII related to educational inequalities slightly increased (from 0.0123 to 0.0141, pvalue< 0.001), corresponding to an annual percent change of 1.24% in Model 2 and 1.42% (95% CI: 1.13%; 1.70%) in Model 3. Conversely, removing the 2020, 2021 and 2022 data, substantially increased the estimate of the slope of the regression line for the RII related to income inequality (from 0.0058 to 0.0077, pvalue< 0.001). Thus, providing an annual increment of 0.59% estimated from Model 2 and of 0.78% (95% CI: 0.52; 1.04%) from Model 3.

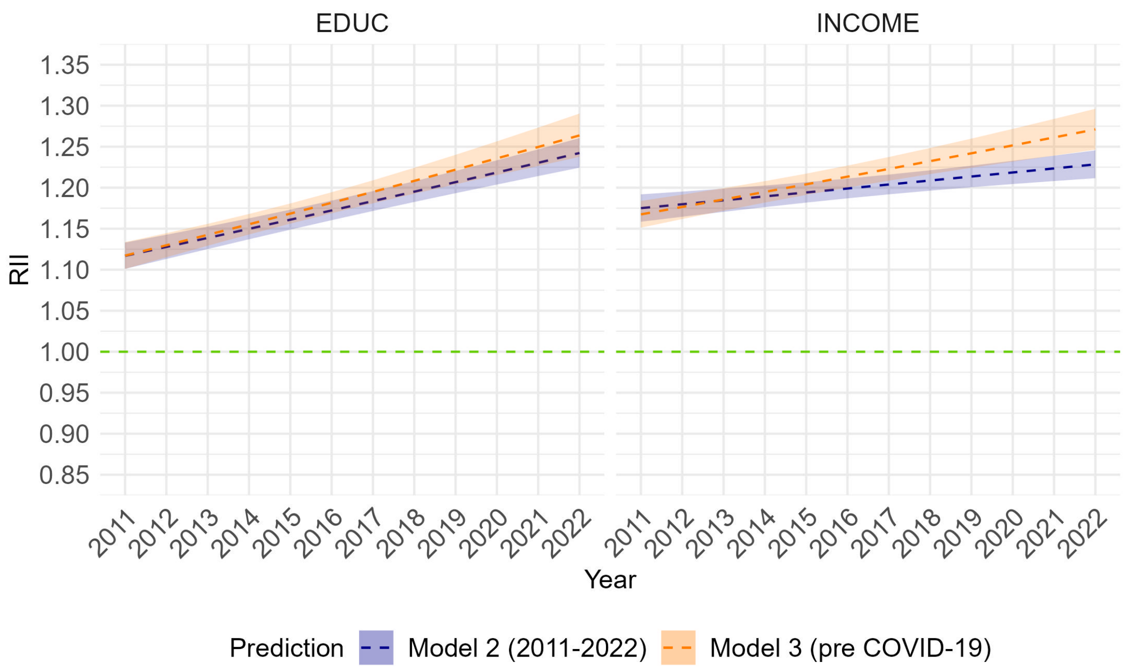

Figure 3.10: Comparison of the RII trends estimated from Model 2 (including all years) and Model 3 (considering only pre-pandemic data) in the male population

In the male population, the slope of the regression line of the RII related to low education changed from 0.0097 (annual percent change: 0.97%) to 0.0112 (pvalue< 0.001, annual percent change: 1.13%, 95% CI: 0.87%; 1.39%). Similarly to what was observed among females, removing the pandemic data, induced a more pronounced effect on the estimate of the slope for the RII related to low income, which varied from 0.0040 (annual percent change: 0.40%) in Model 2 to 0.0077 (pvalue< 0.001, annual percent change: 0.78%, 95% CI: 0.54%; 1.01%) in Model 3.

3.2.2 SII

Table 3.7 shows the point estimates of the SII (per 100,000 p-y) and the corresponding 95% confidence intervals for education-related and income-related inequalities, in female and male population.

	Women				Men			
	EDUC		INCOME		EDUC		INCOME	
Year	SII	95% CI	SII	95% CI	SII	95% CI	SII	95% CI
2011	16.65	(13.89 - 19.42)	19.91	(17.40 - 22.42)	47.91	(43.91 - 51.92)	45.83	(42.18 - 49.49)
2012	17.29	(14.61 - 19.97)	18.65	(16.28 - 21.03)	40.03	(36.25 - 43.81)	40.10	(36.62 - 43.57)
2013	9.44	(6.81 - 12.07)	13.26	(10.81 - 15.72)	31.29	(27.52 - 35.06)	32.65	(29.29 - 36.02)
2014	5.32	(2.70 - 7.94)	9.40	(6.95 - 11.84)	22.42	(18.68 - 26.17)	25.40	(21.99 - 28.82)
2015	11.52	(8.98 - 14.06)	14.27	(11.78 - 16.76)	28.84	(25.35 - 32.32)	30.22	(26.83 - 33.62)
2016	7.12	(4.56 - 9.68)	10.47	(7.96 - 12.99)	18.54	(15.13 - 21.94)	21.13	(17.80 - 24.46)
2017	8.64	(6.05 - 11.24)	11.78	(9.22 - 14.34)	17.78	(14.43 - 21.13)	21.17	(17.84 - 24.50)
2018	4.35	(1.83 - 6.86)	7.62	(5.16 - 10.08)	16.56	(13.17 - 19.95)	19.86	(16.55 - 23.17)
2019	-0.31	(-2.75 - 2.13)	3.85	(1.44 - 6.26)	9.30	(5.79 - 12.80)	11.89	(8.44 - 15.33)
2020	4.78	(2.36 - 7.21)	6.62	(4.21 - 9.03)	18.72	(15.16 - 22.28)	18.51	(15.04 - 21.99)
2021	9.24	(6.70 - 11.78)	13.06	(10.49 - 15.63)	22.58	(18.87 - 26.28)	26.07	(22.39 - 29.75)
2022	3.01	(0.47 - 5.55)	6.35	(3.83 - 8.87)	12.52	(9.05 - 15.98)	16.39	(12.93 - 19.85)

Table 3.7: SII estimates (per 100,000 p-y) and 95% confidence intervals related to education inequalities and income inequalities, among women and men

In the female population, the SII in 2011 was 16.65 per 100,000 persons-year, indicating an absolute excess risk related to low education of about 17 deaths per 100,000 individuals in one year. The highest point estimate of SII was reached in 2012, when the estimate was 17 per 100,000 persons-year, while the lowest point estimate was reached in 2019 when the SII was below 0, indicating no excess. The SII related to low income was higher than that estimated for low education. The highest value was observed in 2011, and the lowest value recorded in 2018 (3.85 deaths per 100,000 person-years).

In the male population, the point estimate of the SII linked to low education was equal to 47.91 per 100,000 persons-year in 2011, indicating an absolute excess risk of approximately 48 deaths per 100,000 individuals in one year. The highest point estimate of SII was reached in 2011, while the lowest point estimate of SII was reached in 2019, when the SII was 9.30 deaths per 100,000 person-years.

With the only exception for the year 2020, the SII related to income inequalities was higher than that estimated for educational inequality. The point estimate of the SII was equal to 45.83 per 100,000 persons-year in 2011 and it approached 12 deaths per 100,000 person-years in 2019. In all combinations of sex and income- or education-related inequalities, a decreasing trend of the SII was observed between 2011 and 2019. However, in 2020 and 2021, during in the second year outbreak of the COVID-19 pandemic, the estimates of the SII increased considerably, changing the decreasing trend observed in the previous period. However, in 2022, they returned to the levels observed in the pre-pandemic period (Figure 3.11) trend before subsequently decreasing in 2022.

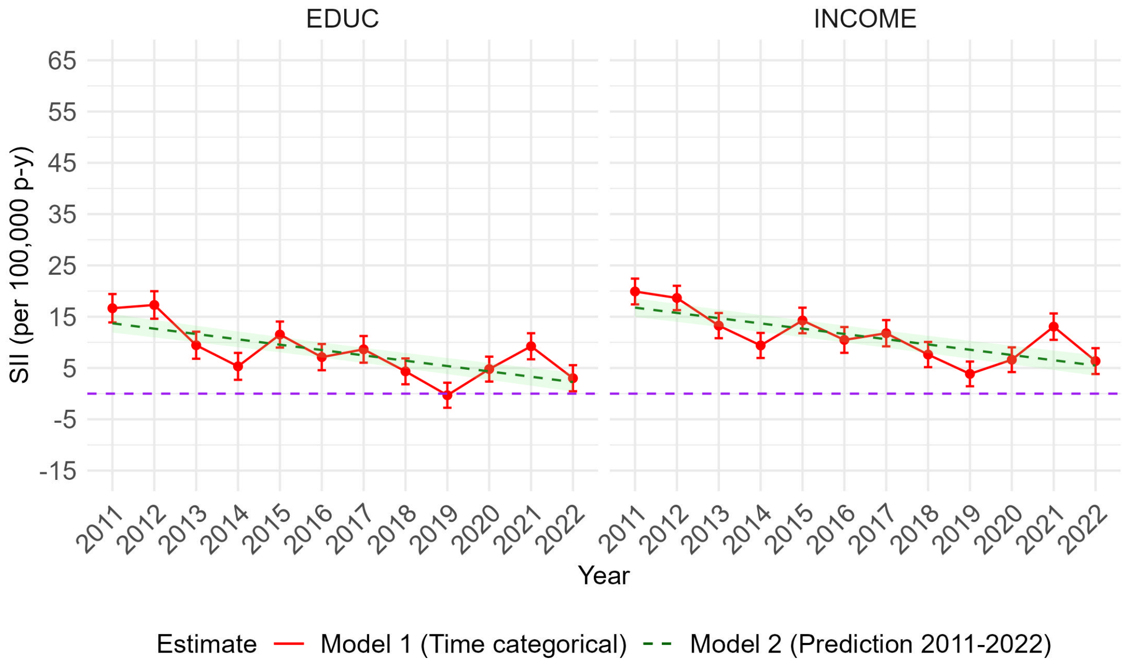

Figure 3.11: Trends in the SII estimates and 95% confidence intervals related to educational and income inequalities over the study period, among women

The magnitude of the decreasing trend in the SII was similar between education and income-related inequalities. The slope of the regression lines indicated an annual decrease in the absolute number of excess deaths of 1 unit in 100,000 individuals in one year ($\hat{\alpha}_{12}$ for educational inequalities $-1.04 \cdot 10^{-5}$, pvalue< 0.001, 95% CI: [$-1.24 \cdot 10^{-5}$;$-8.46 \cdot 10^{-6}$]; $\hat{\alpha}_{12}$ for income inequalities $-1.03 \cdot 10^{-5}$, pvalue< 0.001, 95% CI: [$-1.20 \cdot 10^{-5}$;$-8.54 \cdot 10^{-6}$]). This implies an annual decrease in the excess risk by almost 1 unit in 100,000 individuals in one year.

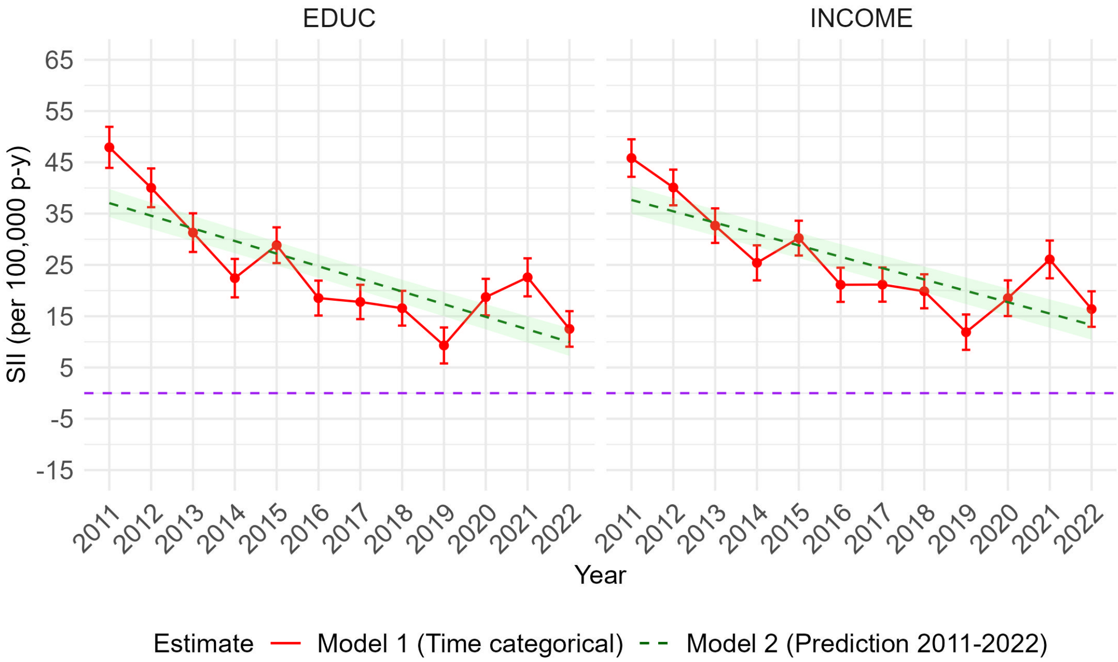

Figure 3.12: Trends in the SII estimates and 95% confidence intervals related to educational and income inequalities over the study period, among men.

Similar results were obtained in the male population (Figure 3.12), where the slope of the regression lines indicated an annual decrease in the absolute number of excess deaths associated to low income or education of 2.2 and 2.5 deaths per 100,000 person-years ($\hat{\alpha}_{12}$ for educational inequalities $-2.46 \cdot 10^{-5}$, pvalue< 0.001, 95% CI: $[-2.73 \cdot 10^{-5}$;$-2.20 \cdot 10^{-5}]$; $\hat{\alpha}_{12}$ for income inequalities $= -2.21 \cdot 10^{-5}$, pvalue< 0.001, 95% CI: $[-2.44 \cdot 10^{-5}$;$-1.99 \cdot 10^{-5}]$). This implies an annual decrease in the excess risk by almost 2 unit in 100,000 individuals in one year.

Figure 3.13 enables the comparison between the point estimates and the corresponding confidence intervals of the RII in education-related and income-related inequalities obtained by both Model 2 and Model 3 in female population.

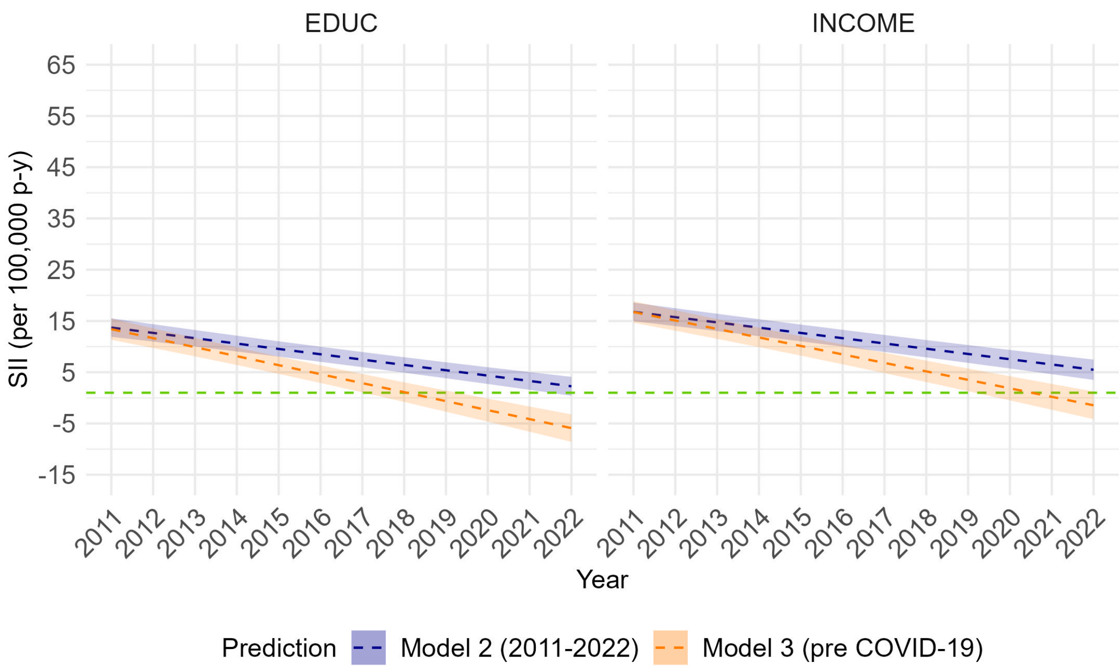

Figure 3.13: Comparison of the SII trends estimated from Model 2 (including all years) and Model 3 (related to pre-pandemic data) in the female population

Excluding data from the pandemic years 2020-2022 substantially changed the estimate of the annual decrease in the SII in both the female and male populations. In the female population, the estimate for educational inequalities changed from $-1.04 \cdot 10^{-5}$ in Model 2 to $-1.75 \cdot 10^{-5}$ (95% CI: [$-2.05 \cdot 10^{-5}$;$-1.46 \cdot 10^{-5}$]) in Model 3, while the estimate for income inequalities changed from $-1.03 \cdot 10^{-5}$ to $-1.65 \cdot 10^{-5}$ (95% CI: [$-1.91 \cdot 10^{-5}$;$-1.40 \cdot 10^{-5}$]).

Figure 3.14 enables the comparison between the point estimates and the corresponding confidence intervals of the RII in education-related and income-related inequalities obtained by both Model 2 and Model 3 in male population.

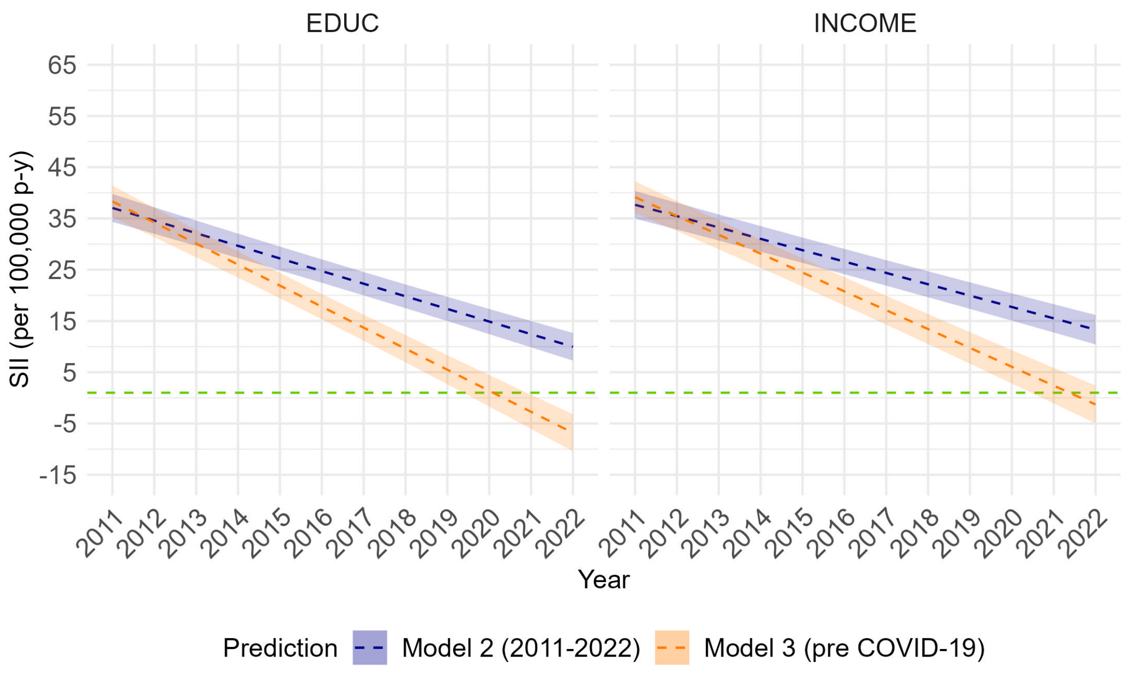

Figure 3.14: Comparison of the SII trends estimated from Model 2 (including all years) and Model 3 (considering only the pre-pandemic data) in the male population.

In the male population, the estimate for educational inequalities changed from $-2.46 \cdot 10^{-5}$ in Model 2 to $-4.10 \cdot 10^{-5}$ (95% CI: [$-4.51 \cdot 10^{-5}$;$-3.69 \cdot 10^{-5}$]) in Model 3, while the estimate for income inequalities changed from $-2.21 \cdot 10^{-5}$ to $-3.68 \cdot 10^{-5}$ (95% CI: [$-4.05 \cdot 10^{-5}$;$-3.32 \cdot 10^{-5}$]).

3.3 Sensitivity Analysis

3.3.1 RII

Table 3.8 shows the point estimates of the RII and the corresponding 95% confidence intervals for education-related and income-related inequalities, in female and male population, considering only the Italian municipalities with population below 10,000 residents.

	Women				Men			
	EDUC		INCOME		EDUC		INCOME	
Year	RII	95% CI	RII	95% CI	RII	95% CI	RII	95% CI
2011	1.06	(1.03 - 1.09)	1.12	(1.09 - 1.15)	1.14	(1.12 - 1.17)	1.16	(1.14 - 1.19)
2012	1.10	(1.07 - 1.13)	1.11	(1.08 - 1.13)	1.15	(1.12 - 1.17)	1.14	(1.11 - 1.16)
2013	1.07	(1.04 - 1.10)	1.09	(1.06 - 1.11)	1.15	(1.12 - 1.18)	1.18	(1.15 - 1.21)
2014	1.11	(1.08 - 1.14)	1.14	(1.11 - 1.17)	1.14	(1.11 - 1.16)	1.17	(1.14 - 1.19)
2015	1.12	(1.09 - 1.15)	1.13	(1.10 - 1.15)	1.18	(1.15 - 1.21)	1.18	(1.15 - 1.20)
2016	1.11	(1.08 - 1.13)	1.13	(1.10 - 1.15)	1.19	(1.16 - 1.22)	1.19	(1.16 - 1.21)
2017	1.15	(1.12 - 1.18)	1.19	(1.16 - 1.22)	1.25	(1.22 - 1.28)	1.28	(1.25 - 1.31)
2018	1.12	(1.09 - 1.15)	1.10	(1.08 - 1.13)	1.20	(1.17 - 1.23)	1.20	(1.17 - 1.23)
2019	1.16	(1.13 - 1.19)	1.17	(1.15 - 1.20)	1.23	(1.20 - 1.27)	1.24	(1.21 - 1.27)
2020	1.07	(1.05 - 1.10)	0.92	(0.90 - 0.94)	1.16	(1.13 - 1.18)	0.96	(0.94 - 0.98)
2021	1.18	(1.15 - 1.21)	1.25	(1.22 - 1.28)	1.28	(1.25 - 1.31)	1.32	(1.29 - 1.35)
2022	1.16	(1.14 - 1.19)	1.16	(1.14 - 1.19)	1.25	(1.23 - 1.28)	1.22	(1.20 - 1.25)

Table 3.8: RII estimates and 95% confidence intervals related to education inequalities and income inequalities, for women and men, considering only the Italian municipalities with population below 10,000 residents.

In the female population, the estimates of the RII obtained in the sensitivity analysis were generally lower than that obtained in the main analysis for both educational and income inequalities (Figure 3.15).
Conversely, estimates for the male population almost overlapped, with the only exception being income inequality in 2020, when the RII fell below the unity in the sensitivity analysis (Figure 3.16).

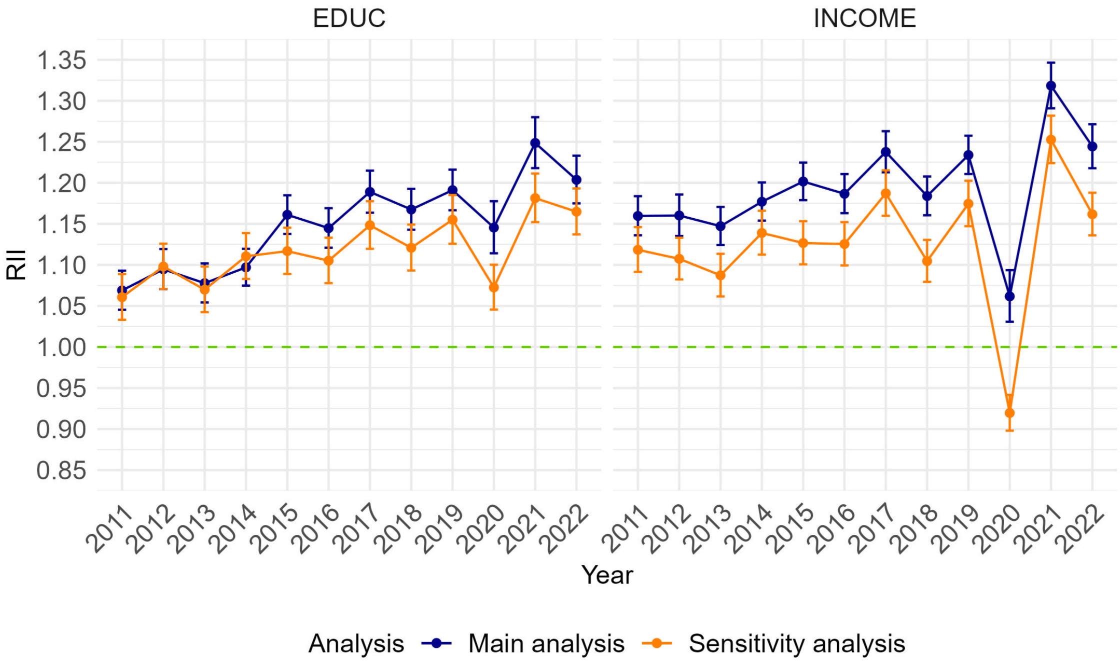

Figure 3.15: Comparison between the estimates of the RII obtained in the main analysis and in the sensitivity analysis among the female population

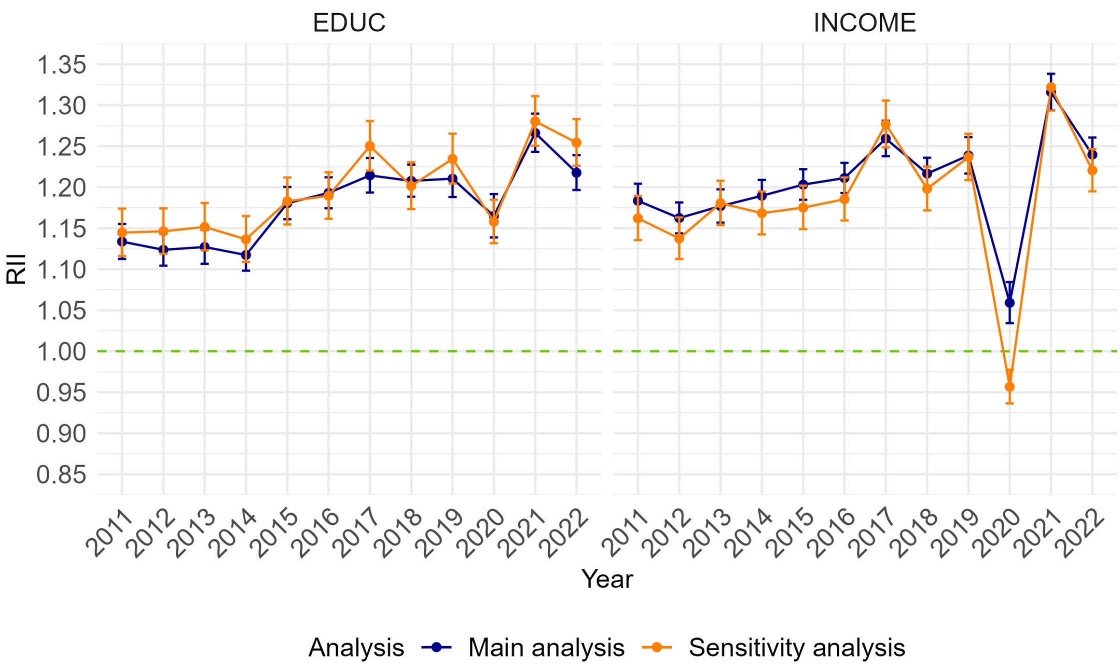

Figure 3.16: Comparison between the estimates of the RII obtained in the main analysis and in the sensitivity analysis among the male population.

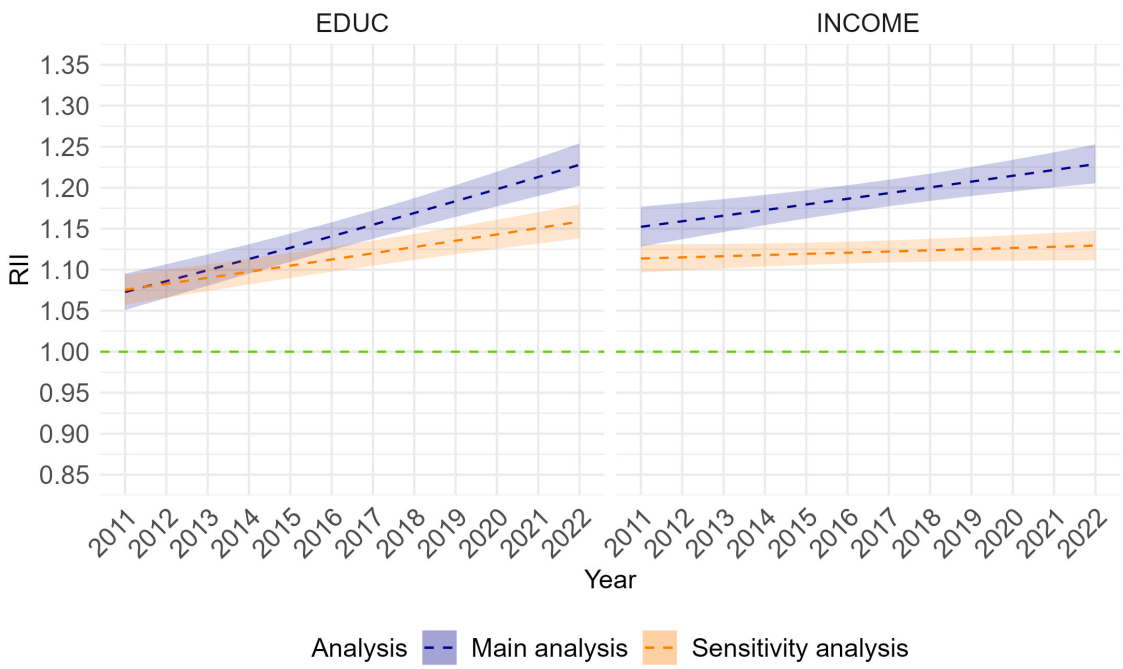

Figure 3.17: Comparison between the RII trends estimated in the main analysis and in the sensitivity analysis in the female population

Analysing Figure 3.17, among women the increase in the RII related to educational inequalities as estimated in the sensitivity analysis was lower than that obtained in the main analysis (0.68% and 95% CI:[0.48%;0.88%] in sensitivity analysis vs 1.24% and 95% CI:[0.97%;1.51%] in main analysis). This was also observed for income inequality (0.13% and 95% CI:[-0.06%;0.31%] in sensitivity analysis vs 0.59% and 95% CI:[0.31%;0.86%] in main analysis).

In contrast, considering Figure 3.18, comparable estimates were obtained among the male population for both educational inequalities (0.88% and 95% CI:[0.69%;1.08%] in sensitivity analysis vs 0.97% and 95% CI:[0.78%;1.16%] in main analysis) and income inequalities (0.20% and 95% CI:[0.02%;0.38%] in sensitivity analysis vs 0.40% and 95% CI:[0.23%;0.59%] in main analysis).

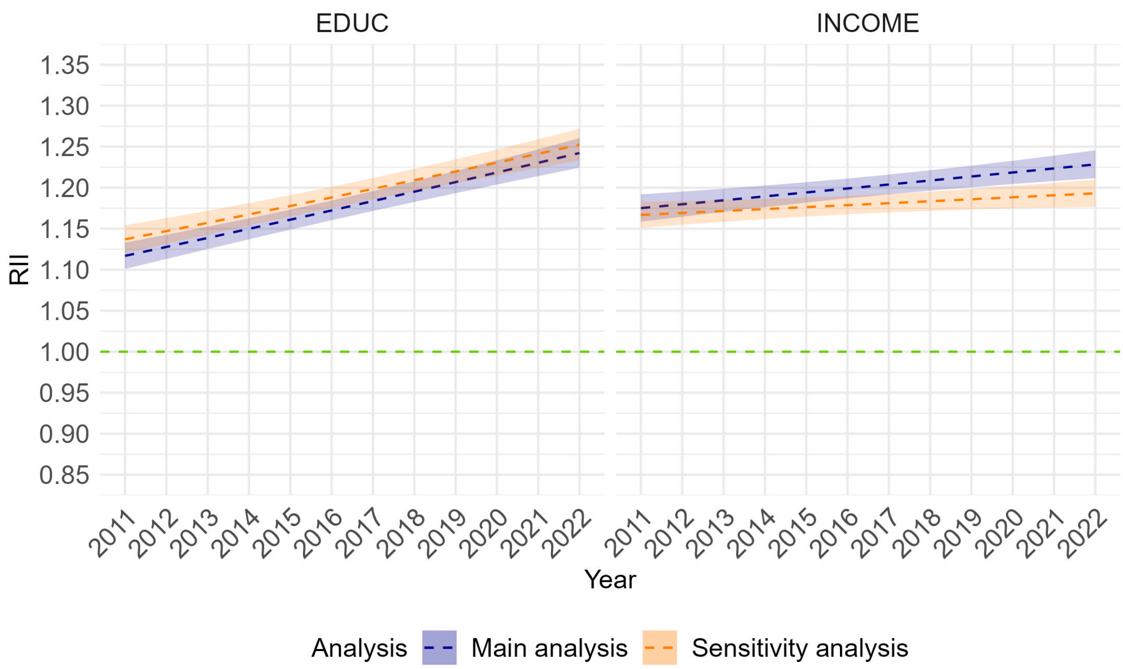

Figure 3.18: Comparison between the RII trends estimated in the main analysis and in the sensitivity analysis in the male population.

3.3.2 SII

Table 3.9 shows the point estimates of the SII (per 100,000 p-y) and the corresponding 95% confidence intervals for education-related and income-related inequalities, in female and male population, considering only the Italian municipalities with population below 10,000 residents.

	Women				Men			
	EDUC		INCOME		EDUC		INCOME	
Year	SII	95% CI	SII	95% CI	SII	95% CI	SII	95% CI
2011	23.19	(19.64 - 26.75)	24.44	(21.06 - 27.82)	57.01	(52.16 - 61.86)	53.50	(49.00 - 58.00)
2012	21.97	(18.49 - 25.44)	21.08	(17.86 - 24.29)	49.26	(44.66 - 53.87)	47.34	(43.01 - 51.68)
2013	17.58	(14.19 - 20.97)	17.89	(14.66 - 21.13)	43.63	(38.92 - 48.34)	42.88	(38.45 - 47.30)
2014	13.78	(10.50 - 17.07)	14.59	(11.46 - 17.73)	33.73	(29.28 - 38.17)	32.94	(28.78 - 37.11)
2015	16.52	(13.13 - 19.90)	16.56	(13.34 - 19.77)	39.37	(34.81 - 43.93)	37.50	(33.18 - 41.82)
2016	15.20	(11.70 - 18.70)	15.45	(12.01 - 18.90)	31.26	(26.73 - 35.79)	29.81	(25.52 - 34.09)
2017	14.66	(11.24 - 18.08)	15.89	(12.59 - 19.19)	31.16	(26.72 - 35.61)	30.63	(26.36 - 34.90)
2018	11.04	(7.70 - 14.39)	10.75	(7.61 - 13.89)	25.61	(21.32 - 29.90)	25.73	(21.60 - 29.86)
2019	6.77	(3.57 - 9.97)	8.18	(5.05 - 11.31)	23.05	(18.59 - 27.52)	20.67	(16.48 - 24.86)
2020	12.66	(9.43 - 15.89)	11.36	(8.28 - 14.44)	34.31	(29.94 - 38.69)	29.14	(25.00 - 33.27)
2021	15.19	(11.84 - 18.55)	16.68	(13.42 - 19.94)	32.62	(28.20 - 37.04)	33.34	(29.02 - 37.65)
2022	9.97	(6.68 - 13.25)	10.01	(6.88 - 13.13)	25.13	(20.72 - 29.54)	23.56	(19.35 - 27.77)

Table 3.9: SII (per 100,000 p-y) estimates and 95% confidence intervals related to education inequalities and income inequalities, for women and men, considering only the Italian municipalities with population below 10,000 residents.

Evaluating Figure 3.19 and Figure 3.20, the estimates of the SII obtained from the sensitivity analysis were higher than those obtained in the main analysis for both educational and income inequality and for both men and women.

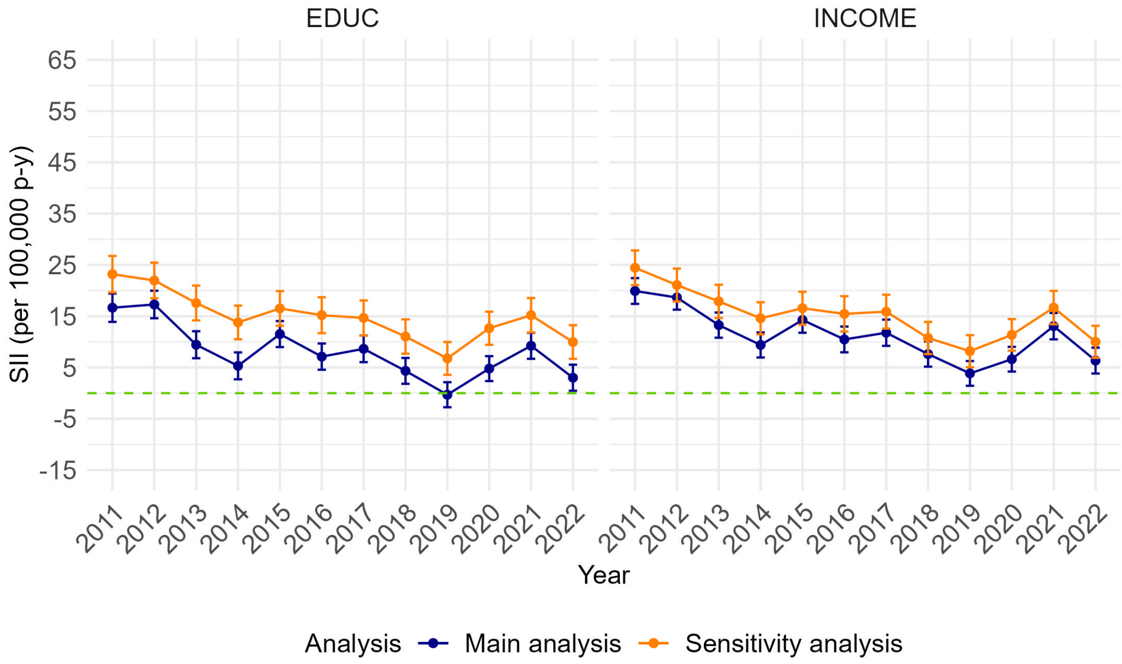

Figure 3.19: Comparison between the estimates of the SII obtained in the main analysis and in the sensitivity analysis among the female population.

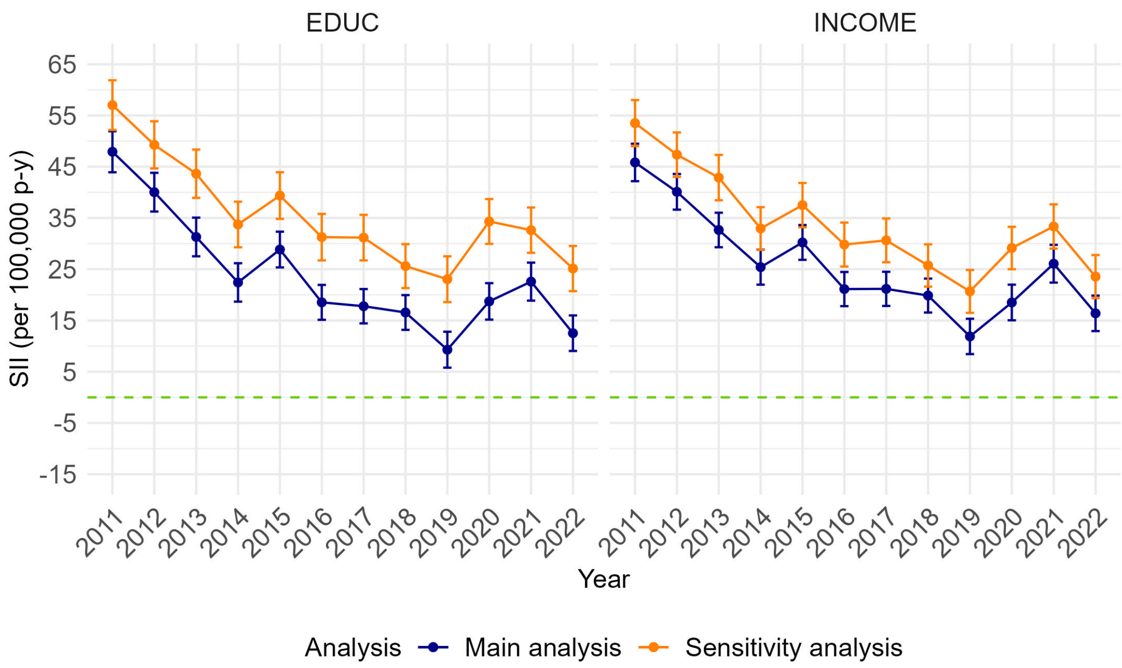

Figure 3.20: Comparison between the estimates of the SII obtained in the main analysis and in the sensitivity analysis among the male population

However, the magnitude of the annual decrease observed in the main analysis was comparable to that observed in the sensitivity analysis (Figure 3.21 and Figure 3.22).

When evaluating educational inequalities, the estimated annual decrease was $-1.04 \cdot 10^{-5}$ (95% CI: [$-1.24 \cdot 10^{-5}$;$-8.46 \cdot 10^{-6}$]) in the main analysis and $-1.03 \cdot 10^{-5}$ (95% CI: [$-1.28 \cdot 10^{-5}$;$-7.75 \cdot 10^{-6}$]) in the sensitivity analysis among women, whereas among men, it was $-2.28 \cdot 10^{-5}$ (95% CI: [$-2.62 \cdot 10^{-5}$;$-1.94 \cdot 10^{-5}$]) in the sensitivity analysis and $-2.46 \cdot 10^{-5}$ (95% CI: [$-2.73 \cdot 10^{-5}$;$-2.20 \cdot 10^{-5}$]) in the main analysis.

Regarding income inequalities, the estimated annual decrease was $-1.03 \cdot 10^{-5}$ (95% CI: [$-1.20 \cdot 10^{-5}$;$-8.54 \cdot 10^{-6}$]) in the main analysis and $-1.04 \cdot 10^{-5}$ (95% CI: [$-1.29 \cdot 10^{-5}$;$-7.95 \cdot 10^{-6}$]) in the sensitivity analysis among women, whereas, among men, it was $-2.26 \cdot 10^{-5}$ (95% CI: [$-2.58 \cdot 10^{-5}$;$-1.93 \cdot 10^{-5}$]) in the sensitivity analysis and $-2.21 \cdot 10^{-5}$ (95% CI: [$-2.44 \cdot 10^{-5}$;$-1.99 \cdot 10^{-5}$]) in the main analysis.

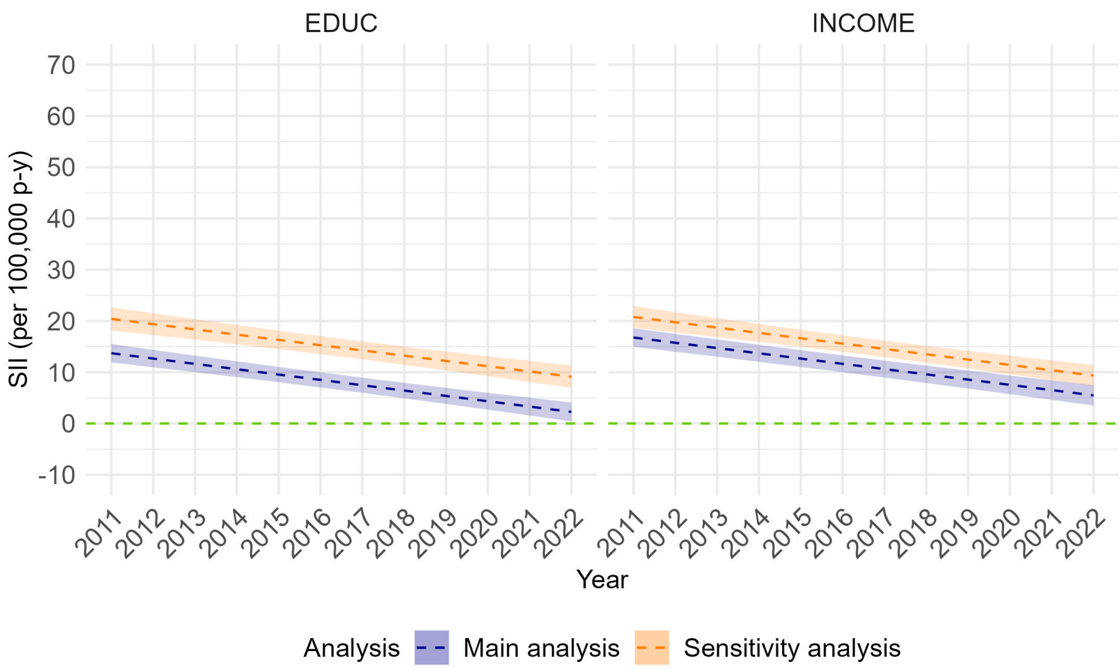

Figure 3.21: Comparison between the SII trends estimated in the main analysis and in the sensitivity analysis in the female population.

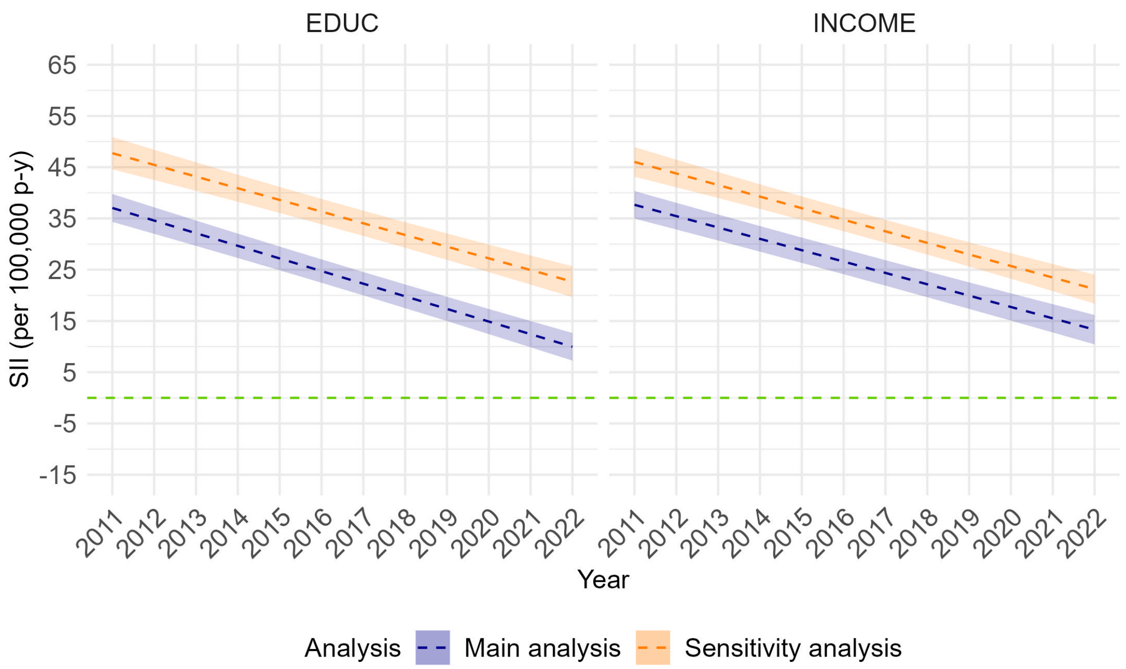

Figure 3.22: Comparison between the SII trends estimated in the main analysis and in the sensitivity analysis in the male population.

Chapter 4

Discussion

The study provides recent evidence of the trend of socioeconomic inequality in mortality in Italian municipalities. Two area-level indicators, namely the average income of the taxpayers in the municipality and the education attainment of the residents, were used as a proxy of the socioeconomic position of the municipality. From 2011 to 2022, mortality was consistently higher in municipalities with lower average incomes and educational levels among residents. In absolute terms, there was an overall reduction in socioeconomic inequality, attributable to a general decline in total mortality in the country. Nevertheless, the study found an annual increase in relative educational inequality in total mortality among Italian municipalities from 2011 to 2022 of 1% in men and 1.2% in women. A similar, albeit smaller, increase was also observed for income inequality, with an annual percent increase of 0.4% in men and 0.6% in women.

The decrease in socioeconomic inequality in absolute terms was also documented in a comprehensive multi-cohort study conducted in different European countries, including Finland, Norway, Sweden, Scotland, England and, France, Switzerland, Spain (Barcelona), Italy (Turin), Slovenia, and Lithuania[19]. This study evaluated changes in mortality inequalities over a two decade period (1990 and 2010) across Europe. Most European countries analysed displayed a more substantial reduction in mortality among lower-educated individuals compared to their highly educated counterparts, resulting in an overall decline in absolute inequality of up to 35%, particularly in men. Conversely, relative inequalities widened almost universally due to smaller percentage declines in lower socioeconomic groups.

Examining the Turin cohort, data revealed an increase in relative inequality from 1990-1994 to 2005-2009, with a mortality ratio between high and low educated individuals rising from 1.47 to 1.70 among men, while no appreciable differences were found among women. The study found that the reductions in absolute inequalities were mainly driven by improvements in prevention and treatment for conditions like ischaemic heart disease, smoking-related causes, and medical intervention amenable causes.

In a different study, based on the same cohort of the city of Turin[20], Stringhini et al. examined long-term trends in educational inequalities in all-cause and cause-specific mortality. The data, covering a period of 40 years, showed a significant decline in overall and cause-specific mortality for both men and women in all educational groups. Absolute inequalities in mortality substantially decreased over the study period for both sexes, while relative educational inequalities in mortality remained generally stable among men and tended to narrow among women. The study supports the hypothesis that educational inequalities in mortality have decreased in southern European countries. The decline in absolute inequalities was observed for all causes of death, particularly in cardiovascular disease and alcohol-related mortality among men, and for all causes, cardiovascular disease, and smoking-related mortality among women. However, despite the positive trends, large inequalities in mortality were still observed at the end of the study period, especially among men.

Our study did not observe a consistent increase in socioeconomic inequality during the COVID-19 pandemic. This finding diverges somewhat from a study[10] employing a similar design, which reported a higher increase in mortality in March 2020 in economically disadvantaged municipalities compared to more wealthy ones in Lombardy, the Italian region most severely impacted by the pandemic. However, this increase was limited to that month, as in the subsequent months the differences between the poorest and wealthiest municipalities returned to pre-pandemic levels.
In contrast, our study noted a decrease in relative inequalities in 2020. This could be attributed to the fact that a significant number of the wealthiest municipalities in Italy were situated in the northern part of the country, including the Lombardy region, where mortality rates were notably elevated during the first wave of the pandemic (March-April 2020).

Increasing area-level socioecomic inequalities were also documented in a study by Brandily et al.[21]. They analyzed the impact of COVID-19 on mortality inequalities in France, focusing in particular on the income gradient. The study found that the epidemic caused 2.6 more deaths per 10,000 inhabitants on average in the poorest municipalities in 2020, relative to a baseline of 8.7 in non-poor municipalities, representing a 30% higher effect in the poorest municipalities. The study found a clear income gradient in excess mortality rates during 2020, with the poorest municipalities experiencing a significantly higher increase in excess mortality compared to the richer municipalities. This gradient persisted over the two distinct waves of the epidemic, indicating a consistent impact of COVID-19 on mortality inequalities.

The difference between our results and those reported in the French study may be attributed to several factors, encompassing the type and stringency of the containment measures to control the spread of the pandemic that may disproportionally benefit the low and the high socioeconomic groups as well as the socioeconomic background of the country.

Our study has also some limitations. The area-level indicators were computed on relatively large areas, as mortality for smaller areas, such as census blocks, were not available. This limitation may prevent our analysis to capture the granularity of the relationship between area-level indicators and total mortality, particularly in main Italian cities. In an effort to address this issue, we conducted a sensitivity analysis by excluding municipalities with a population size greater than 10,000 inhabitants. This exclusion did not materially change the main findings of our study; indeed, the estimates of the sensitivity analysis supported a more pronounced increase in relative inequalities. Additionally, municipalities were grouped according to the average income of taxpayers or educational level of the residents. While the first indicator was available for each year of the study period, the second one was only available for the year 2011, when the decennial census was conducted in Italy, and for the period 2018-2021, during which a survey-based permanent census was implement. Consequently, some misclassification of the municipalities may have occurred in the period when data were not available (2012-2017).

The study's strengths lie in the use of the two most important epidemiological indicators to measure socioeconomic inequalities and health outcomes – specifically, the RII and the SII. These indicators facilitate the quantification of socioeconomic inequality by computing a single summary measure - the RII for estimating socioeconomic inequalities in relative terms and the SII to estimate socioeconomic inequality in absolute terms. Additionally, our study makes a significant contribution to the existing knowledge by adapting the regression framework proposed by Moreno-Betancur et al.[17]. This adaptation allows us to estimate the RII and the SII within a panel data structure, where repeated measurements at different time points are clustered within municipality.

Chapter 5

Conclusions

The study finds evidence of decreasing disparities in mortality between poorer and wealthier Italian municipalities, as well as and among municipalities with varying proportions of less educated individuals. While this holds true in absolute terms, relative disparities have increased over the past decade.

The reduction in mortality inequalities in absolute terms is likely attributable to population-wide behavioral changes and improvements in prevention and treatment, rather than explicit policies targeting health inequalities. This overall reduction in mortality rate, however, was relatively lower among disadvantaged groups. Thus, suggesting that they have benefited less from the preventive strategies and effective treatments available to counter the occurrence and consequence of chronic diseases, including cardiovascular diseases and cancer.

The study's finding has two major implications. Firstly, it highlights that the different distribution of socioeconomic factors in Italian municipalities partly explains the well-known territorial differences in mortality across the country. Secondly, it emphasizes the need for a larger redistribution of healthcare and welfare resources to achieve greater declines in relative mortality in lower socioeconomic groups.

In conclusion, the persistent reduction in mortality in Italy has contributed to reduce the excess mortality in the most disadvantages areas. However, in relative terms, mortality risks remain higher in the poorer and less educated municipalities. The increase in relative inequalities call for tailored public health interventions to reduce mortality in socioeconomically disadvantaged municipalities in Italy.

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