Research Article

# Cancer Mortality Among Women in the European Union: A Comprehensive Analysis of Economic, Social, and Health Factors

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**This study takes a unique and comprehensive approach to assess the inequality of gender's effect on mortalities' cancer in twenty-seven European Union (EU) countries in 2013-2021. It utilizes Pooled Ordinary Least Squares and Quantile Regression models to explore gender-specific variations in cancer mortality, identifying key factors and establishing connections between gender inequality indicators and mortality rates. The findings are not only significant but also intriguing, revealing the substantial influence of indicators like women's average years of schooling, contributing to a 55.0277 increase in women's cancer mortality. Conversely, Gross National Income per capita among women correlates with a -0.0003 reduction in women's cancer mortality. Lifestyle factors such as engagement in daily cooking/housework, avoidance of smoking/harmful drinking, and participation in physical activities/consumption of fruits and vegetables are associated with mortality reductions. In contrast, unmet medical examination needs, positive health perceptions, education/training, ministerial positions, assembly memberships, and leisure activities are linked to increased women's cancer mortality. The urgency of addressing healthcare gender gaps is underscored by these findings, guiding interventions, policies, and gender equity support in alignment with UN SDGs. This study uniquely focuses on the EU context, employing an interdisciplinary approach to explore mechanisms linking gender inequality and cancer mortality.**

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## 1. Introduction

Gender inequality affects geographic, socioeconomic, and cultural factors, creating barriers to healthcare access[1]. Women in countries with different incomes are impacted differently by cancer. One explanation can be gender inequality or other causes, such as the degradation of the environment or deprivation (e.g., Cesario[2]). Literature supports that gender inequality can contribute to a substantial increase in women's cancer[3]. The magnitude of this discrepancy goes beyond social boundaries.[4][5].

The intricate interplay of gender inequality with a range of factors leads to variations in the consequences of cancer. Elements such as socioeconomic conditions, educational gaps, access to healthcare, and societal norms collectively contribute to women's susceptibility to cancer. These factors shape the diagnosis trajectory, treatment options, and eventual survival rates.

Donington and Colson[3] further underscore the multifaceted impact of gender inequality on cancer, stressing physiological differences, behavioral influences, lifestyle choices, and equal access to medical care. Jolidon[6] and Willems et al.[7] also illustrate that widespread macro-level gender inequality detrimentally affects programs. Willems et al.[7] revealed the importance of some factors in health disparities associated with gender. This perspective highlights the advantages of policies that promote women's political participation, autonomy, family roles, and broader empowerment.

Furthermore, women's access to health care can be stimulated by augmented self-rule and the ability to make their own decisions[8]. On the other hand, unfavorable situations tend to hinder the capacity to decide on health choices and family[9]. There is also a tendency to perpetuate gender discrimination that is rooted in procreative health and social and cultural conditions that can compromise the health of women[10]. Varying levels of gender inequality are evident in the European context. In 2013, for example, Hungary (0.251) and Romania (0.315) had significant gender inequality. On the other hand, Denmark (0.039), the Netherlands (0.042), Finland (0.062), Germany (0.079), and Portugal (0.098) had lower gender inequality values. Despite concentrated efforts, Hungary (0.222) and Romania (0.283) revealed persistent high levels of inequality. These countries shed light on unique aspects of gender inequality within Europe, including gender pay gaps, occupational segregation, leadership representation, and work-life balance dynamics (See **Figure 1** below).

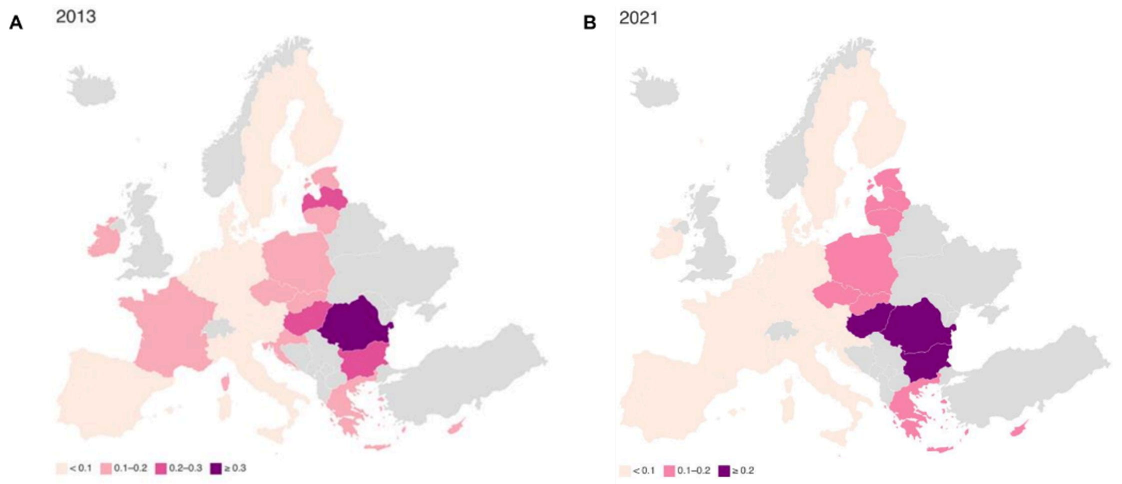


**Figure 1.** The Gender Inequality Index (GII) was evaluated across 27 European Union countries from 2013 to 2021 (A-B). This index represents the degree of gender inequality in these nations during the specified period. The map provided in this study was created by the authors, based on data from the United Nations Development Programme (UNDP, 2022).

Gender inequality remains a pressing concern in European nations, spanning education, employment, decision-making, healthcare, and societal interactions. Educational opportunities for women often remain limited, hindering their entry into male-dominated fields. This inequality is reflected in persistent employment disparities, job-related discrimination, and gender pay disparities. Even though there is some progress, women continue to be underrepresented in political positions and economic decision-making roles compared to men. Healthcare reveals evident gaps in service access and reproductive health, compounded by gender-based violence and discrimination. Achieving an equitable, inclusive, and just society demands commitment, initiative, and encouragement (e.g., EIGE[11]; European Commission[12]).

European countries are working toward cultivating gender equality and empowering women via legislation, policymaking, and incentivizing recognition. The cumulative result of these efforts is a reduction in gender inequality, declining from 0.126 in 2013 to 0.100 in 2021 (See **Figure 2** below).

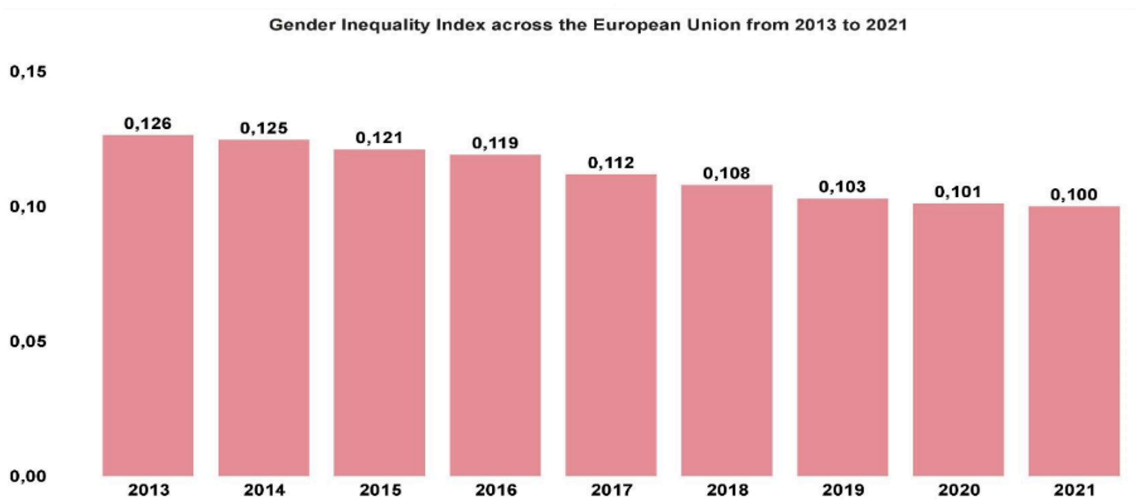


**Figure 2.** The Gender Inequality Index in the EU was analyzed for the years 2013 to 2021. The map displayed in this study was created by the authors, using data obtained from the United Nations Development Programme (UNDP, 2022).

Gender inequality intersects with a pressing EU issue: cancer mortality, mainly among women. Cancer-related deaths are a notable public health concern within the EU. In 2013, certain EU countries showed high women's cancer mortality. Hungary, Denmark, Slovakia, the Netherlands, Slovenia, Ireland, Croatia, Czechia, Poland, Latvia, Sweden, Estonia, Germany, and Belgium. Conversely, Greece, Bulgaria, Cyprus, Portugal, and Spain had relatively lower cancer mortality (See **Figure 3** below).

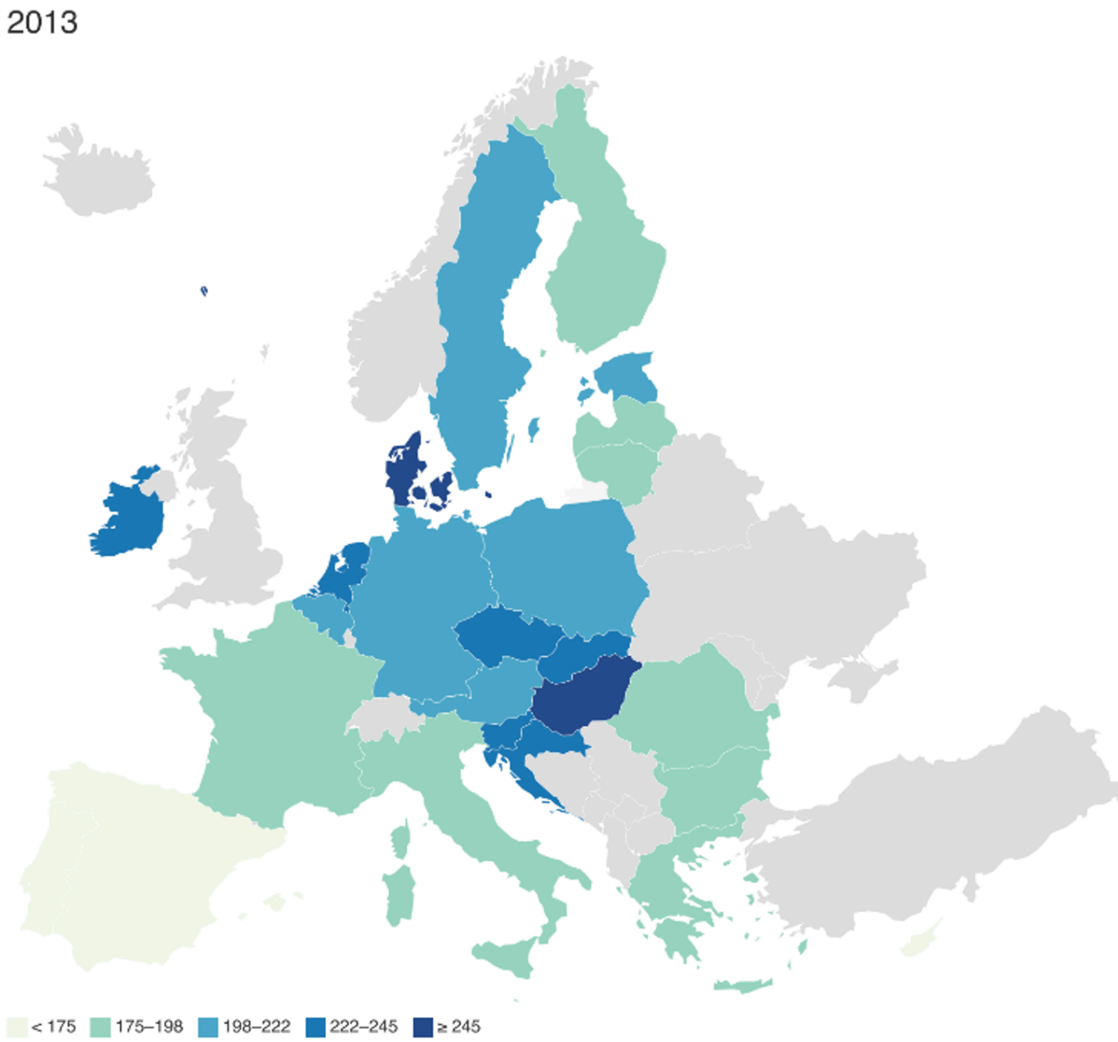


**Figure 3**. Cancer-Related Mortality in Women across the EU countries in 2013. The map presented was created by the authors using data provided by Eurostat (2023a).

By 2021, for instance, France, Germany, Belgium, Sweden, Estonia, Luxembourg, and Austria lowered women's cancer mortality rates. However, Slovakia, Hungary, Poland, Latvia, Ireland, Denmark, Czechia, and Croatia face high cancer mortality. The EU's cancer mortality rate among women dropped significantly from 262 in 2013 to 241 in 2021 due to various initiatives (See Figure 4 below).

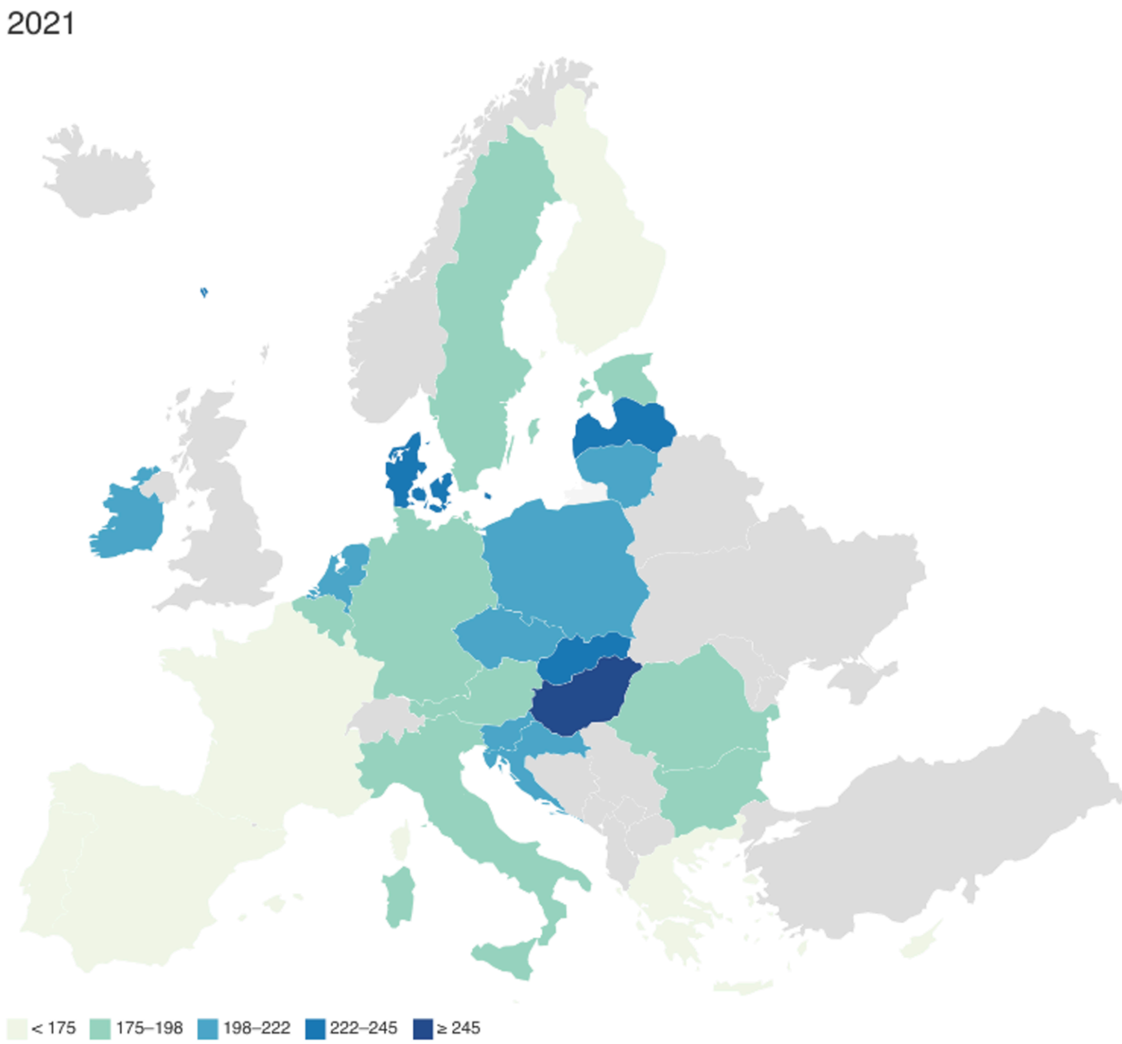


**Figure 4**. Cancer-Related Mortality in Women across the EU countries in 2021. The map presented was created by the authors using data provided by Eurostat (2023a).

Breast cancer stands as the primary cause of cancer-related deaths (28.75%) among EU women in 2020. Closely is lung cancer (27.18%), followed by colorectal cancer (21.60%) and pancreatic cancer (13.94%) (See **Figure 5** below).

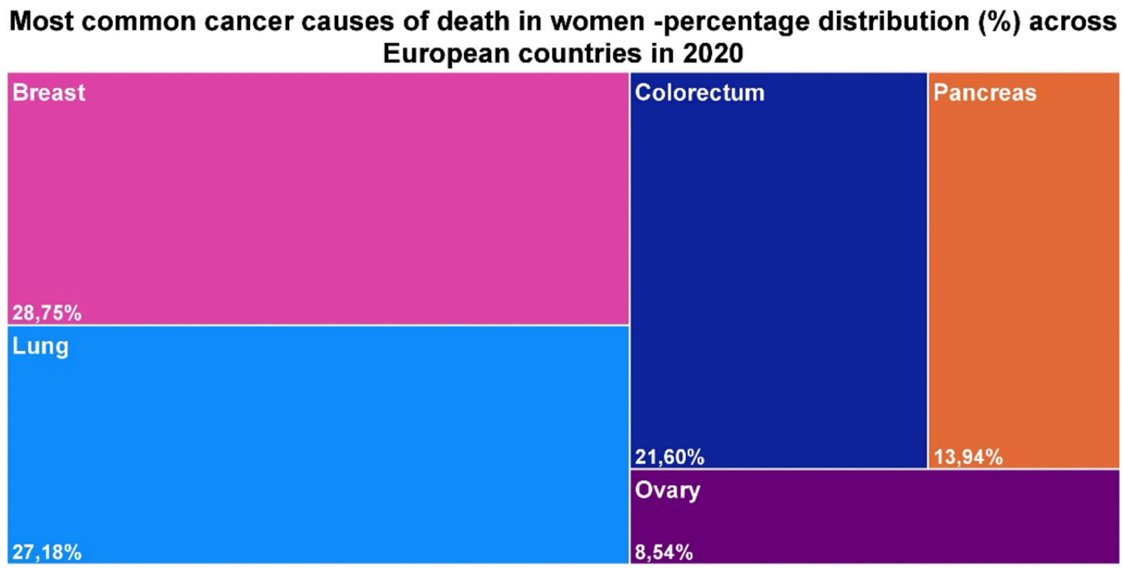


**Figure 5.** Most common causes of cancer-related deaths in women – percentage distribution (%) across the EU in 2020. The map was created by the authors using data from the European Cancer Information System (ECIS, 2023).

Cancer death distribution varies across age groups. For those aged 0-44 years, breast cancer makes up 31% of deaths. In the 45-64 age group, lung cancer becomes the primary cause, contributing to 24% of deaths. Women aged 65 and older show a 16% mortality rate due to breast cancer (See **Figure 6** below).

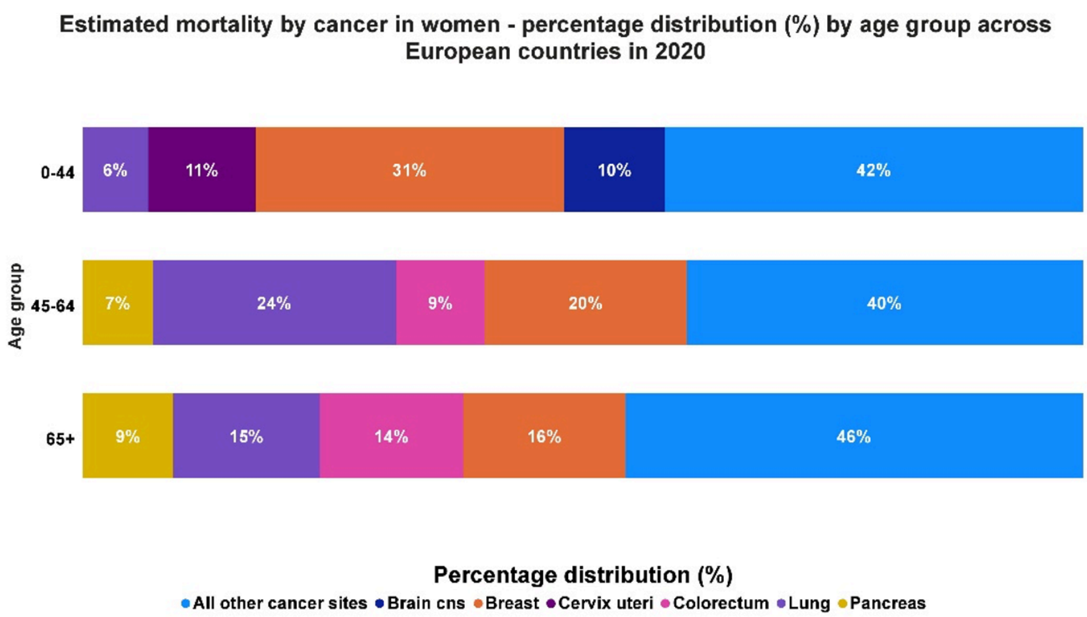


**Figure 6.** Estimated mortality from cancer in women – percentage distribution (%) by age group across the EU in 2020. The map was created by the authors using data from the European Cancer Information System (ECIS, 2023).

The distribution of cancer mortality among EU women in 2020 shows some significant behaviors. Breast cancer was revealed to be the most mortal (16.53%), followed by lung cancer (15.61%), colorectal cancer (12.40%), pancreatic cancer (8.01%), and other cancer (26.58%) (See **Figure 7** below).

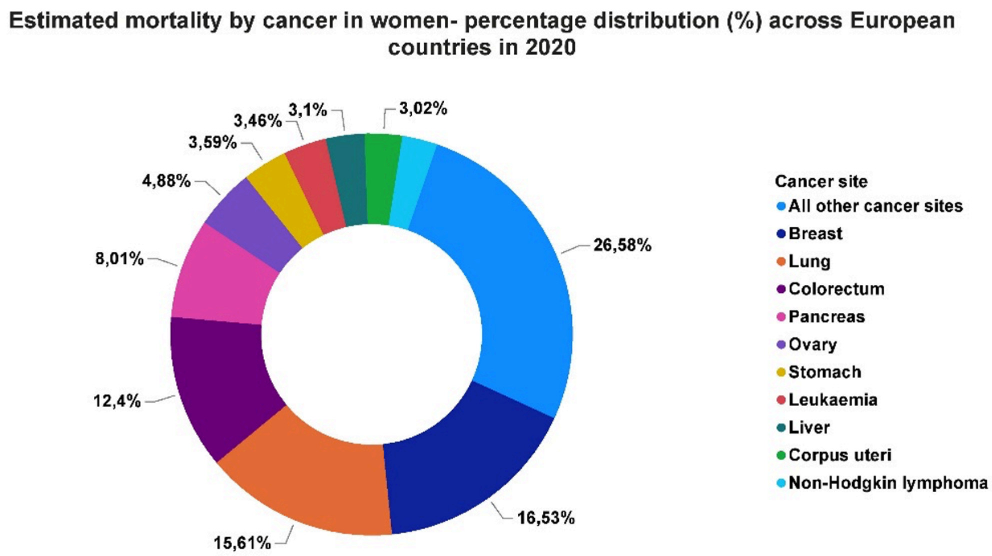


**Figure 7.** Estimated mortality from cancer in women – percentage distribution (%) across the EU in 2020. The map was created by the authors using data from the European Cancer Information System (ECIS, 2023).

When it comes to mortality rates, the EU's age-standardized rate for breast cancer is 34.1 per 100,000 population, followed by lung cancer at 33.2 and colorectal cancer at 24.5 per 100,000 population (See **Figure 8** below).

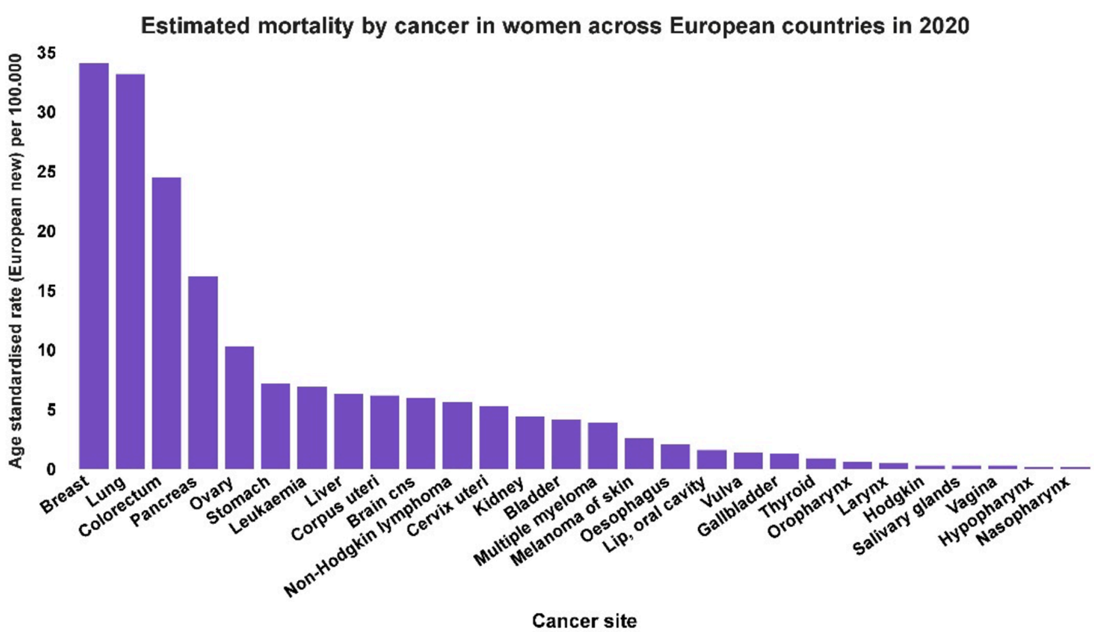


**Figure 8.** Estimated cancer mortality in women across the EU in 2020. The map was created by the authors using data from the European Cancer Information System (ECIS, 2023).

The levels of cancer mortality among EU women highlight the urgency of exploring gender-based vulnerability to cancer mortality in the EU due to interactions involving biological, behavioral, social, and systemic factors. It calls for a comprehensive strategy, including gender-sensitive healthcare, improved screening and treatment access, and addressing social determinants. The literature recognizes gender-related factors in understanding cancer mortality, highlighting disparities rooted in socioeconomic indicators and gender (e.g., Donington and Colson[3]; OECD[5]; Jolidon[6]; Koengkan and Fuinhas[13]; Vaccarella et al.[4]). It briefly mentions the potential impact of women's political participation but fails a deep analysis of EU female cancer mortality's link to gender inequality. Studies mention political participation, education, income, and health access, but a detailed exploration of gender inequality's role in cancer mortality is missing. Consequently, this investigation addresses the following question: "To what extent does gender inequality impact women's cancer mortality in the EU?" Below are the main potential hypotheses that can address this inquiry:

- Hypothesis 1: Gender disparity significantly influences the mortality rates of female cancer patients in the European Union by exacerbating disparities in educational attainment, socioeconomic status, healthcare accessibility, and high-risk behaviors. Increased gender inequality may compound limited access to education and awareness, amplifying unhealthy behaviors and impeding healthcare access, ultimately contributing to elevated cancer mortality rates among women.
- Hypothesis 2: Gender inequality within the EU is not found to have a substantial impact on cancer mortality rates among women. This implies that reduced levels of gender inequality, as indicated by minimized disparities in socioeconomic status, access to healthcare, and risk behaviors, do not correlate with increased mortality rates among women with cancer in EU nations.

The research investigates the potential impact of gender inequality indicators on cancer mortality rates among women in the European Union between 2013 and 2021 to address the research gap and validate either of these hypotheses. To fulfill our objectives, our research aims to employ advanced econometric methods, including Pooled Ordinary Least Squares (OLS) regression and Quantile regression (QREG).

The selected methodology provides quantitative analysis and examines large-scale trends. It recognizes limitations such as the attenuation of individual-level variations by aggregated data, the availability of accurate data, its extensiveness, and the nature of the study. The research emphasizes a notable gap in the existing literature concerning the relationship between gender discrimination and the cancer death penalty.

Understanding this relationship is essential for addressing gender disparities in healthcare, informing evidence-based interventions, policies, and practices, and promoting gender equity and social justice following the United Nations' Sustainable Development Goals (SDGs). Furthermore, this study seeks to offer innovative contributions by concentrating on the EU context and employing an interdisciplinary approach incorporating sociological, public health, and epidemiological perspectives.

This paper provides a comprehensive overview of the relevant literature in the following section. Section 3 explains the research data and the methodologies utilized. Section 4 scrutinizes the empirical findings, and Section 5 extensively discusses the consequences of the results. Finally, Section 6 offers a comprehensive conclusion.

## 2. Literature review

There are many academic studies on the causes of death rates. However, most studies exclude causes of death and gender-differentiated mortality. For example, gender differentiation in lung and breast cancer deaths is higher than in other cancer types[14]. Despite this, the number of studies examining cancer-related deaths in women has been increasing in recent years. Some studies use the Gender-Related Development Index (GDI) to indicate gender disparity[15]. However, the GDI is not a measure of gender inequality and should not be interpreted independently of the Human Development Index (HDI)[16].

As expected, the literature supports the idea that an increase in HDI causes a decrease in cancer deaths[17], which is generally valid in low—and middle-income countries. Although studies on gender-differentiated mortality rates typically examine the issue regarding biological differences, fewer studies focus on the relationship between socioeconomic variables—such as education, income, and social status—and deaths.

Numerous studies examining education and mortality rates conclude that there is an inverse relationship between the two variables (e.g.,[18]). Some of these studies emphasize that the impact of schooling rate on both genders is similar[19]; however, these results vary according to the education level and the development of the countries.

Gender differences in income can also affect mortality rates due to access to primary and secondary health services. The increased decision-making autonomy of women as they earn their income positively affects health services utilization[20], and studies show that high socioeconomic status increases women's screening[21], which facilitates early diagnosis and prevents cancer deaths[22]. However, adequate access to screening and health services is not independent of hospital expenditures and insurance costs. For this reason, poverty's negative effect on health is mentioned[23]. Indeed, Gakidou et al.[24] show that only 19% of women in developing countries are screened for cervical cancer while, in developed countries, this rate rises above 60%. Then, increasing primary care investments to prevent the emergence of diseases is also associated with lower cancer deaths[25]. The increase in secondary care investments, which will expand the screening process, and the increase in the rate of the insured population cause a decrease in social inequalities and, consequently, cancer-related deaths[26].

Furthermore, studies examining income inequality and cancer deaths find a positive correlation between the two variables[25] and support that lower income is associated with higher mortality rates[27]. However, these general results do not apply to some types of cancer. For instance, investigations using income and education as socioeconomic indicators show that breast cancer-related mortality rates are higher among women in the high strata compared to the lower strata (e.g.,[27][18][14]). However, as social inequalities decrease, the relationship between education and breast cancer decreases[21]. Unlike breast cancer, low-income women have an increased incidence of lung cancer[28].

As previously stated, most studies on the relationship between socioeconomic status (SES) and mortality rates use education and social classes as indicators[19][29]. However, SES is not easy to calculate because selected variables can affect SES. Then, studies examining the relationship between SES and health inequality may show inconsistent results due to the difficulty of collecting individual SES data, changes in SES over time, and misclassification of social groups[30]. In addition, many investigations examining the relationship between SES and health outcomes use simple correlation analyses, examining a small set of variables[31].

Detailed indices on women's status have been created recently. Therefore, few studies have examined the relationships between political participation, reproductive rights, representation, and female mortality rates. Research using data from the Institute for Women's Policy Research in the USA shows that women's political participation is associated with lower female mortality rates[32]. Bhalotra and Clots-Figueras[33] also argue that women's political representation reduces death rates in India because women attach more importance to healthcare equality than men. Women are expected to draw the most attention to the differentiation of death rates by gender, thanks to their power of representation.

Daily life habits can also adversely affect health quality and increase cancer rates. In recent years, the rate of smoking among women has increased compared to men. Accordingly, there has been an increase in cancer diagnoses among women (e.g.,[34]), especially in highly educated and upper social class women[35]. However, there are no precise results in the literature as to the effect of smoking on cancer deaths. Behaviors such as physical activity and eating habits also, directly and indirectly, affect both SES and health outcomes. According to Ford et al.[36], women with higher SES can devote more free time to themselves and are involved in more physical activity at home. Although there are no definite results on their effects, it is known that fruit and vegetable intake can reduce some cancer risks[37].

Although a healthy diet reduces the risk of cancer, it is supported by research that foods categorized as unhealthy[38] and obesity due to unhealthy diet increase the risk of cancer[39]. Just as unhealthy diets are typical in low-income areas of society, exposure to harmful particulate matter is often high in regions with low house prices, polluted air, and non-environmentally friendly industrial facilities[40][29]. Studies conclude that tiny and harmful airborne particles are associated with female cancer deaths (e.g., Prada et al.[41]).

The literature review acknowledges the importance of gender-related factors in understanding cancer mortality rates. It highlights the differences in mortality rates for various types of cancer-based on socioeconomic indicators and gender. It also briefly discusses the influence of women's political participation and representation on reducing female mortality rates. However, the literature review does not extensively explore or analyze the specific impact of gender inequality on cancer mortality in women within the EU during the specified time frame. While it mentions studies that touch on various gender-related aspects, such as political participation and representation, it does not delve deeply into the complex interplay between gender inequality and cancer mortality rates.

To address this gap effectively, research emphasizing gender-related metrics and robust data analysis is crucial. This holistic approach seeks to illuminate the intricate mechanisms through which gender inequality influences the outcomes of cancer mortality among European women. Consequently, this investigation endeavors to fill this void by conducting an empirical analysis centered around data-driven insights.

## 3. Data and methods

### *3.1. Research outline*

This research delves into the 27 EU member states[1] women's cancer mortality rates induced by gender inequality. Selecting these countries provides diverse representation, capturing socioeconomic, cultural, and healthcare variations. Analyzing multiple countries improves statistical power and facilitates comparisons. This approach comprehensively examines gender inequality's impact on cancer mortality.

The study employed longitudinal data covering 2013 to 2021, intending to obtain comprehensive and consistent data. This procedure helped mitigate variations in data collection methodologies and reporting accuracy while also allowing for the generation of statistically significant findings within the period's historical and sociopolitical landscape.

### *3.2. Variables and sources*

The study uses cancer-related deaths in women, "Dc_w" as the dependent variable. Table 1 below presents the selected variables for this empirical analysis.

| Abbreviation | Description | Unit of measure | Source |
|---|---|---|---|
| Dependent variable | | | |
| Dc_w | Cancer-related deaths in women (total, under 65 years and 65 years or older) | Rate | Eurostat[42] |
| Independent variable | | | |
| Mys_w | Mean Years of Schooling | Rate | UNDP[43] |
| PM2.5 | Exposure to Fine particulate matter (PM2.5) | Rate | OECD Data (2023) |
| Gni_pc_w | Gross National Income per capita among women | Euro | UNDP[43] |
| Bcc_w | Breast cancer and cervical cancer screenings in women | Rate | Eurostat[44] |
| Hc_ex | Total healthcare expenditure | Million euro per capita | Eurostat[44] |
| Pdc_w | Women engaging in daily cooking and housework activities (%, 18+ population) | Rate | EIGE[45] |
| Pdsd_w | Women who do not smoke and are not engaged in harmful drinking (%, 16+ population) | Rate | EIGE[45] |
| Pdpfv_w | Women who engage in physical activities and consume fruits and vegetables (%, 16+ population) | Rate | EIGE[45] |
| Pumex_w | Women with unmet needs for medical examinations (%, 16+ population) | Rate | EIGE[45] |
| Sphg_w | Women who self-perceive their health as good or very good (%, 16+ population) | Rate | EIGE[45] |
| Ppet_w | Women who participate in formal or non-formal education and training (%, 15+ population) | Rate | EIGE[45] |
| Sm_w | The share of women serving as ministers (%) | Rate | EIGE[45] |
| Smp_w | The proportion of women serving as members of parliament (%) | Rate | EIGE[45] |
| Smra_w | The proportion of women serving as members of regional assemblies (%) | Rate | EIGE[45] |
| Wds_w | Women who engage in sporting, cultural, or leisure activities outside of their home at least daily or several times a week (%, 15+ workers) | Rate | EIGE[45] |

**Table 1.** Variables description

The chosen independent variables are carefully selected to examine the theoretical relations, and each variable was rigorously justified based on existing scientific research and evidence.

I. "Mys_w" and "Ppet_w": Are linked to improved health outcomes and lower cancer mortality rates among women. Previous studies (e.g., Raghupathi and Raghupathi[46]; Vaccarella et al.[4]) have demonstrated a positive association between higher levels of education ("Mys_w") and women who participate in formal or non-formal education and training ("Ppet_w") with better health outcomes, including reduced cancer mortality.
II. "PM2.5": Represents fine particulate matter pollution associated with adverse health effects, including increased cancer risks. Scientific studies (e.g., Prada et al.[41]) have shown the link between exposure to PM2.5 and elevated cancer incidence and mortality rates.
III. "Gni_pc_w": Reflects economic well-being and access to healthcare services among women. Studies (Fletcher[47]) have established the relationship between higher gross national income per capita and improved healthcare infrastructure, which can contribute to better cancer outcomes.

IV. "Bcc_w": Focuses on breast and cervical cancer, emphasizing the importance of early detection and reduced mortality rates among women. Research (Yang et al.[48]) has shown that adequate breast and cervical cancer screening programs improve survival rates and lower mortality.
V. "Hc_ex" represents healthcare expenditures and highlights the importance of healthcare services in cancer outcomes. Previous studies (e.g., Akinyemiju et al.[49]) have demonstrated the significant role of access to healthcare services in reducing cancer mortality rates.
VI. "Pdc_w": Emphasizes the association between daily cooking and housework activities and lower cancer mortality rates among women. Research (e.g., Chen et al.[50]) has consistently shown the benefits of regular physical activity and a healthy lifestyle in reducing cancer risk and improving survival.
VII. "Pdsd_w": Relates to reduced cancer risks through lower smoking and drinking (Anand et al.[51]; Lugo et al., 2017) have demonstrated the link between tobacco and alcohol consumption and increased cancer incidence and mortality.
VIII. "Pdpfv_w": Emphasizes the benefits of regular physical activity and a healthy diet in lowering cancer mortality among women. Existing research (e.g., Schnohr et al.[52]) supports the positive impact of physical activity and a nutritious diet on reducing cancer risks and improving survival.
IX. "Pumex_w": Addresses barriers to accessing healthcare services and potential delays in cancer diagnosis among women. Studies have highlighted the importance of timely access to healthcare and its influence on cancer outcomes (e.g., Quintal et al.[53])
X. "Sphg_w": Highlights the association between positive self-perceived health in women and lower cancer mortality rates. Research (Korn et al.[54]) has shown that individuals with a positive self-perception of health tend to engage in healthier behaviors and have improved health outcomes, including lower cancer mortality.
XI. "Sm_w," "Smp_w," and "Smra_w": Reflect women's political representation, which has been linked to improved health outcomes and lower cancer mortality rates. Studies (Reeves et al.[55]) have demonstrated the positive impact of gender equality in political representation on cancer mortality.
XII. "Wds_w": Represents women's engagement in regular physical and leisure activities (Schnohr et al.[52]).

Our investigation has encompassed various variables, including socioeconomic, environmental, lifestyle, and healthcare factors. The focus on women's mortality is of the utmost importance, given the distinct effects of gender inequality on women's health, socioeconomics, and risk behaviors.

### *3.3. Pooled OLS estimation*

The general Pooled OLS specification is specified by E1. (1).

$$y_{it} = \beta_0 + \beta_1 x_{1it} + \beta_2 x_{2it} + \cdots + \beta_n x_{12it} + \varepsilon_{it} \tag{1}$$

where, $x_1, \cdots, x_{12}$ are the independent variables, $\beta_1, \cdots, \beta_{12}$ the regression coefficients reveal the statistical relationship between the independent variables and the dependent variable, and the error term captures the unexplained variability or residual variation in the dependent variable that is not accounted for by the independent variables.

### *3.4. QREG estimation*

This study utilized QREG estimation, an econometric technique that helps assess the robustness of Pooled OLS results. Unlike OLS, which focuses solely on the mean, QREG analyzes how variations in covariates impact different percentiles of the explained variable. This characteristic makes QREG robust to outliers and allows distinct patterns in data. This approach is particularly valuable for understanding complex relationships, skewed distributions, and specific segments of the response distribution. The linear quantile regression can be expressed by Eq. (2).

$$Q(y \mid x; \tau) = \beta_{0,\tau} + \beta_{1,\tau} x + \varepsilon \tag{2}$$

This empirical investigation employed the 25th, 50th, 75th, and 95th quantiles for a robustness check. This QREG technique ensures reliable analysis by examining relationships across response distribution segments, revealing potential asymmetry and heterogeneity. The median offers central tendency insight with outlier resistance, while the 95th quantile scrutinizes extreme outcomes, ensuring consistent conclusions across the distribution and enhancing model reliability. QREG's ability to estimate different quantiles accommodates data variations, revealing insights into extreme values and tail behavior. Comparing QREG and OLS results allows for robustness assessment, significantly when data deviates from normality or contains outliers. This approach enriches understanding variable relationships and ensures a holistic data evaluation.

### *3.5. Preliminary tests*

It is crucial to conduct preliminary tests to comprehend variable characteristics in the economic model before the pooled OLS and QREG estimators' regressions. Therefore, the following preliminary tests were conducted to assess the variables' properties.

I. Summary statistics and histograms: The mean, standard deviation, range, quartiles, and histograms.

II. Pairwise Correlation [56]: The pairwise correlation was calculated to measure the linear association between variables.

III. Normality tests: This test determines skewness and kurtosis [57] to infer a normal distribution. H0: The variable is normally distributed.

IV. Pesaran's [58] Panel Unit Root test (Cross-sectionally Augmented IPS) assesses the stationarity of variables in panel data.

V. Wooldridge's test for autocorrelation in panel data [59]: The test examines autocorrelation in the residuals, with the null stating no autocorrelation.

VI. Breusch-Pagan/Cook-Weisberg's test [60][61]: The test examines heteroskedasticity in residuals. The null states no heteroskedasticity. Test for Heteroskedasticity:

Conducting initial tests yielded valuable insights into variable traits and identified non-normality, autocorrelation, or heteroskedasticity that may impact subsequent Pooled OLS and QREG regressions. Notably, such tests are widely employed in econometrics [62].

### *3.6. Stata commands*

The Stata commands employed in this study encompassed sum, histogram, pwcorr, sktest, vif, multipurt, xtserial, hettest, reg, reg robust, and qreg, quantile (.25.5.75.95) (See **Figure 9** below).

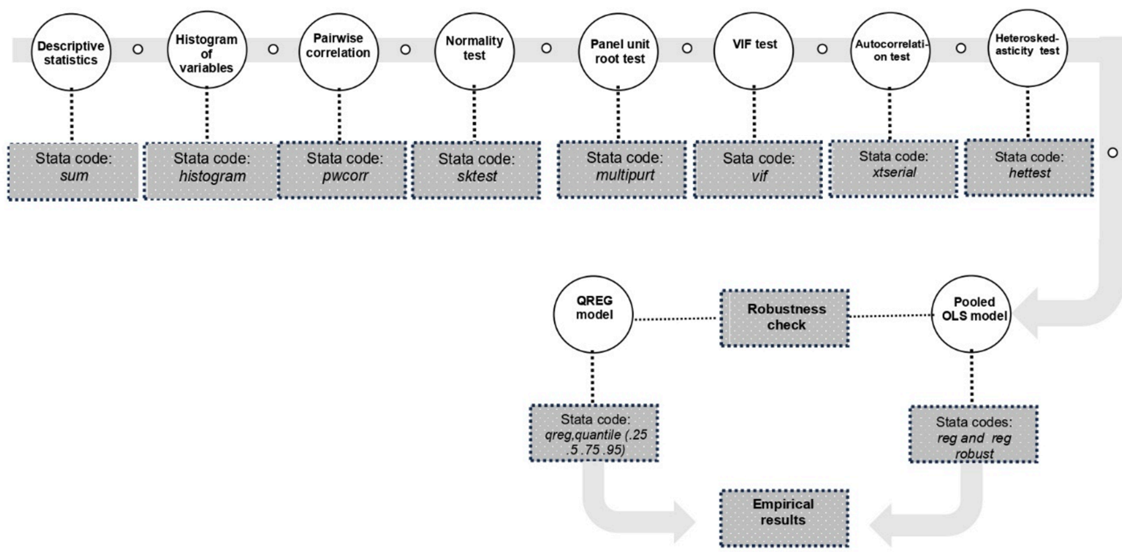


**Figure 9**. *Stata commands. The authors developed this figure.*

## 4. Results

This section includes information on data properties, pretesting of variables, estimation results, and specification tests for the estimation. Variables' descriptive statistics were computed and are exposed in Table 2 below.


doi.org/10.32388/12YVRJ.2

| Variables | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Dc_w | 216 | 200.1289 | 28.07403 | 140.36 | 268.56 |
| Mys_w | 243 | 2.4802 | 0.1018 | 2.1603 | 2.6487 |
| PM2.5 | 243 | 2.5660 | 0.3823 | 1.6741 | 3.2946 |
| Gni_pc_w | 243 | 32518.08 | 11339.21 | 15135.71 | 71316.82 |
| Bcc_w | 243 | 33.98156 | 30.50838 | 0 | 84.3 |
| Hc_ex | 241 | 9.5900 | 1.6147 | 6.6783 | 13.0168 |
| Pdc_w | 243 | 76.4609 | 8.96420 | 0 | 90 |
| Pdsd_w | 242 | 4.2779 | 0.0813 | 4.0253 | 4.4426 |
| Pdpfv_w | 243 | 35.1358 | 14.6471 | 0 | 70 |
| Pumex_w | 228 | 1.5657 | 0.81914 | 0 | 3.0910 |
| Sphg_w | 242 | 4.1345 | 0.1831 | 3.6375 | 4.4308 |
| Ppet_w | 242 | 2.7835 | 0.4390 | 0.6931 | 3.8066 |
| Sm_w | 243 | 26.0493 | 13.2555 | 0 | 59 |
| Smp_w | 243 | 26.2222 | 10.1541 | 0 | 48 |
| Smra_w | 243 | 27.1687 | 10.5611 | 0 | 49 |
| Wds_w | 242 | 3.1156 | 0.6180 | 1.7917 | 4.0943 |

**Table 2.** Descriptive statistics

Moreover, pairwise correlation and VIF statistics (see Tables 3 and 4 below) were performed and revealed that correlation and multicollinearity are not a concern to the estimation.

| | | | | | | | Pairwise Correlation | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Variables** | **(A)** | **B)** | **(C)** | **(D)** | **(E)** | **(F)** | **(G)** | **(H)** | **(I)** | **(J)** | **(K)** | **(L)** | **(M)** |
| Dc_w (A) | 1.000 | | | | | | | | | | | | |
| Mys_w (B) | 0.4063*** | 1.000 | | | | | | | | | | | |
| PM2.5 (C) | 0.2215*** | -0.0582 | 1.000 | | | | | | | | | | |
| Gni_pc_w (D) | -0.0310 | 0.2766*** | -0.5336*** | 1.000 | | | | | | | | | |
| Bcc_w (E) | 0.3204*** | 0.2617*** | -0.1070* | 0.2336*** | 1.000 | | | | | | | | |
| Hc_ex (F) | -0.0929 | -0.2193*** | -0.1715** | 0.3552*** | -0.0790 | 1.000 | | | | | | | |
| Pdc_w (G) | -0.2617*** | -0.0770 | -0.2132*** | 0.2435*** | 0.1542** | 0.1360** | 1.000 | | | | | | |
| Pdsd_w (H) | -0.1781** | -0.2999*** | 0.0795 | -0.5158*** | -0.1537** | -0.2320*** | -0.1250** | 1.000 | | | | | |
| Pdpfv_w (I) | 0.1493* | 0.3677*** | -0.5677*** | 0.6898*** | 0.2710*** | 0.2264*** | 0.2884*** | -0.4697*** | 1.000 | | | | |
| Pumex_w (J) | 0.1660* | 0.0122 | 0.0419 | -0.4472*** | -0.1655** | -0.2470*** | -0.0607 | 0.2128** | -0.2790*** | 1.000 | | | |
| Sphg_w (K) | -0.1653* | -0.1205** | -0.1306*** | 0.4771*** | 0.0530 | 0.3687*** | 0.1706** | -0.4679*** | 0.3256*** | -0.3386*** | 1.000 | | |
| Ppet_w (L) | 0.0970 | 0.2808*** | -0.5285*** | 0.5638*** | 0.1964** | 0.1217** | 0.1838*** | -0.1233*** | 0.6394*** | -0.1216* | 0.2166*** | 1.000 | |
| Sm_w (M) | -0.2012** | 0.1061* | -0.3709*** | 0.4619*** | -0.0655 | 0.5050*** | 0.2956*** | -0.2919*** | 0.4416*** | -0.1395** | 0.2359*** | 0.5169*** | 1.000 |
| Smp_w (N) | -0.1872** | 0.0529 | -0.4880*** | 0.4925*** | -0.0356 | 0.5439*** | 0.3819*** | -0.1841*** | 0.4754*** | -0.2113** | 0.1989 *** | 0.5533*** | 0.7472*** |
| Smra_w (O) | -0.2641*** | 0.0685 | -0.4963*** | 0.4052*** | -0.0037 | 0.4764*** | 0.3889*** | -0.2265*** | 0.4231*** | -0.1585** | 0.2219*** | 0.5846*** | 0.7671*** |
| Wds_w (P) | 0.1168*** | 0.2802*** | -0.5081*** | 0.6735*** | 0.4130*** | 0.3331*** | 0.3592 | -0.3945*** | 0.7026*** | -0.2550*** | 0.3936 | 0.7652*** | 0.5260*** |

**Table 3.** Pairwise Correlation

***Notes**: ***, **, and * denote statistically significant at the 1%, 5%, and 10% levels, respectively.*

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| Variables | VIF test | Mean VIF |
|---|---|---|
| Dc_w | N/a | 3.13 |
| Mys_w | 1.85 | |
| PM2.5 | 3.14 | |
| Gni_pc_w | 4.25 | |
| Bcc_w | 1.54 | |
| Hc_ex | 2.34 | |
| Pdc_w | 1.46 | |
| Pdsd_w | 2.43 | |
| Pdpfv_w | 4.15 | |
| Pumex_w | 1.62 | |
| Sphg_w | 1.87 | |
| Ppet_w | 4.58 | |
| Sm_w | 3.19 | |
| Smp_w | 3.90 | |
| Smra_w | 4.95 | |
| Wds_w | 5.73 | |

**Table 4**. VIF test

***Notes**: N/a means "Not applicable."*

Table 5 below displays the variables' test of normal distribution.


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| Variables | Skewness/kurtosis | | | |
|---|---|---|---|---|
| | Pr(Skewness) | Pr(Kurtosis) | Prob>chi2 | |
| Dc_w | 0.0609 | 0.010 | 0.0105 | * |
| Mys_w | 0.0000 | 0.4952 | <0.0001 | *** |
| PM2.5 | 0.0027 | 0.1707 | 0.0077 | * |
| Gni_pc_w | 0.0000 | 0.0605 | <0.0001 | *** |
| Bcc_w | 0.0000 | 0.0000 | <0.0001 | *** |
| Hc_ex | 0.2182 | 0.0000 | <0.0001 | *** |
| Pdc_w | 0.0000 | 0.0000 | <0.0001 | *** |
| Pdsd_w | 0.1503 | 0.6871 | 0.3246 | |
| Pdpfv_w | 0.0421 | 0.8557 | 0.1227 | |
| Pumex_w | 0.0193 | 0.0225 | 0.0083 | * |
| Sphg_w | 0.0000 | 0.5561 | <0.0001 | *** |
| Ppet_w | 0.0395 | 0.0000 | <0.0001 | *** |
| Sm_w | 0.0367 | 0.0058 | <0.0001 | *** |
| Smp_w | 0.2005 | 0.0000 | <0.0001 | *** |
| Smra_w | 0.0010 | 0.0236 | <0.0001 | *** |
| Wds_w | 0.2197 | 0.0000 | <0.0001 | *** |

**Table 5.** Skewness/kurtosis test

***Notes:*** ****, * denote statistically significant at 1% and 10%, respectively.*

The tests show that variables Pdsd_w and Pdpfv_w do not follow a normal distribution. The evidence that variables Dc_w, PM2.5, and Pumex_w follow a normal distribution is weak. For the remaining variables, the tests support a normal distribution. Moreover, the autocorrelation test of Wooldridge and the test of heteroskedasticity tests of Breusch-Pagan / Cook-Weisberg – are presented in Table 6 below – which reveal the presence of heteroskedasticity.

| Wooldridge test for autocorrelation in panel data | Breusch-Pagan / Cook-Weisberg test for heteroskedasticity |
|---|---|
| F(1,26) = 2.440 | chi2(1) = 9.89** |

**Table 6.** Wooldridge and Breusch-Pagan / Cook-Weisberg tests

***Notes:*** *** denotes statistically significant at 5% levels; $H_0$ of Wooldridge test: no first-order autocorrelation; $H_0$ of Breusch-Pagan / Cook-Weisberg test: constant variance.*

The second-generation unit root test and the variable histogram were also performed. The outcomes of both tests are not presented but are available upon request.

Following preliminary tests, this study executes the Pooled OLS regression. As mentioned earlier, this regression constitutes the central model of our empirical investigation, and the outcomes are presented in Table 7 below.


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| Explanatory variables | Explained variable (Dc_w) | | | | |
|---|---|---|---|---|---|
| | | Pooled OLS | | Robust Pooled OLS | |
| | Coefficient | t | Significance | t | Significance |
| Mys_w | 55.0277 | 3.28 | *** | 3.69 | *** |
| PM2.5 | 15.5570 | 2.60 | ** | 2.74 | *** |
| Gni_pc_w | −0.0003 | -1.65 | | -1.70 | * |
| Bcc_w | 0.1418 | 2.68 | *** | 2.47 | ** |
| Hc_ex | 5.4938 | 4.55 | *** | 4.28 | *** |
| Pdc_w | −0.8992 | −4.47 | *** | −4.86 | *** |
| Pdsd_w | −87.2914 | −3.65 | *** | −3.78 | *** |
| Pdpfv_w | 0.2785 | 1.60 | | 1.73 | * |
| Pumex_w | 6.6875 | 3.38 | *** | 3.27 | *** |
| Sphg_w | −39.9806 | −4.29 | *** | −4.63 | *** |
| Ppet_w | 18.8653 | 3.09 | *** | 3.51 | *** |
| Sm_w | −0.4403 | -2.50 | ** | -2.77 | *** |
| Smp_w | 0.10610 | 0.42 | | 0.49 | |
| Smra_w | -1.1209 | −4.14 | *** | −4.25 | *** |
| Wds_w | 11.7107 | 2.37 | ** | 2.25 | ** |
| Constant | 516.3015 | 3.81 | *** | 3.80 | *** |
| Number of obs | 227 | 227 | | | |
| F(10,211) | 17.59 | 31.27 | | | |
| Prob > F | < 0.001 *** | < 0.001 *** | | | |
| $R^2$ | 0.5556 | 0.5556 | | | |
| Adj $R^2$ | 0.5241 | n.a. | | | |
| Root MSE | 19.162 | 19.162 | | | |

**Table 7.** Pooled OLS estimations

***Notes:** ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively; n.a. means "Not applicable."*

The outcomes of the Pooled OLS robust regression reveal notable associations. The variable "PM2.5" is linked to a 15.5570 increase in cancer mortality among women, as represented by the dependent variable "Dc_w." Similarly, the variable "Bcc_w" exhibits a 0.1418 increase in women's cancer mortality, while "Hc_ex" demonstrates a 5.4938 increase. Furthermore, gender inequality indicators, such as "Mys_w," exhibit a substantial impact, contributing to a 55.0277 increase in cancer mortality among women (Dc_w). On the other hand, the variable "Gni_pc_w" correlates with a reduction of -0.0003 in women's cancer mortality. Additionally, "Pdc_w," "Pdsd_w," and "Pdpfv_w" are associated with reductions in women's cancer mortality by -0.8992, -87.2914, and an increase of 0.2785, respectively. Meanwhile, "Pumex_w," "Sphg_w," "Ppet_w," "Sm_w," "Smra_w," and "Wds_w" are linked to increases of 6.6875, -39.9806, 18.8653, -0.4403, -1.1209, and 11.7107 in women's cancer mortality, respectively.

Following the execution of the Pooled OLS regression, it becomes imperative to verify the stability of the outcomes obtained from the preceding model. The investigation employed QREG models to ensure this robustness assessment, and the outcomes are presented in Table 8. As part of this empirical inquiry, the approach selected for the robustness assessment involves employing the 25th, 50th, 75th, and 95th quantiles.

| Independent variables | Dependent variable (Dc_w) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Quantiles | | | | | | | | | | | |
| | .25Q | | | .5Q | | | .75Q | | | .95Q | | |
| Mys_w | 88.1095 | <0.001 | *** | 41.1732 | 0.102 | | 13.79452 | 0.497 | | 34.7266 | <0.001 | *** |
| PM2.5 | 14.6251 | 0.037 | ** | 30.6473 | <0.001 | *** | 27.7872 | <0.001 | *** | 37.8619 | <0.001 | *** |
| Gni_pc_w | −0.0002 | 0.447 | | 0.0000 | 0.874 | | 0.0003 | 0.283 | | −0.0001 | 0.873 | |
| Bcc_w | −0.0082 | 0.894 | | 0.0829 | 0.297 | | 0.2770 | <0.001 | *** | 0.2539 | <0.001 | *** |
| Hc_ex | 4.8701 | <0.001 | *** | 2.0373 | 0.261 | | 4.4088 | <0.001 | *** | 0.4395 | 0.627 | |
| Pdc_w | −1.2173 | <0.001 | *** | −1.5693 | <0.001 | *** | −1.0573 | <0.001 | *** | −0.6067 | <0.001 | *** |
| Pdsd_w | -22.5621 | 0.420 | | −40.2808 | <0.001 | *** | −43.3806 | 0.135 | | −51.6931 | <0.001 | *** |
| Pdpfv_w | 0.3200 | 0.118 | *** | 0.4751 | 0.070 | * | 0.0198 | 0.925 | | 0.1767 | 0.177 | |
| Pumex_w | 8.2161 | <0.001 | *** | 10.6309 | <0.001 | *** | 12.7632 | <0.001 | *** | 11.3479 | <0.001 | *** |
| Sphg_w | −45.6901 | <0.001 | *** | −54.4367 | <0.001 | *** | -26.9202 | <0.001 | *** | -28.2145 | <0.001 | *** |
| Ppet_w | 11.23136 | 0.116 | | 4.7683 | 0.602 | | 18.6004 | <0.001 | *** | 23.3084 | <0.001 | *** |
| Sm_w | −0.4208 | 0.042 | ** | −0.5210 | 0.049 | ** | −0.2987 | 0.162 | | −0.0022 | <0.001 | *** |
| Smp_w | −0.2054 | 0.489 | | 0.3121 | 0.413 | | 0.7483 | <0.001 | *** | 0.2625 | 0.168 | |
| Smra_w | −0.3289 | 0.299 | | -.3703 | 0.362 | | -2.1013 | <0.001 | *** | -2.0477 | <0.001 | *** |
| Wds_w | 7.3813 | 0.202 | | 15.0190 | 0.043 | ** | 24.3554 | <0.001 | *** | 26.2964 | <0.001 | *** |
| Constant | 217.1116 | 0.171 | | 432.1564 | 0.034 | ** | 322.644 | <0.001 | *** | 296.7569 | <0.001 | *** |

**Table 8.** QREG model

***Notes:** ***, **, * denote statistically significant at 1%, 5%, and 10%, respectively.*

The results from Table 8 show the results of Quantile Regression. The outcomes generally support the results already achieved by the pooled OLS regression but with the signal of the parameter of screening for breast and cervical cancer in women turning negative. Indeed, this change of signal to negative is expected for this variable. Furthermore, this estimation indicates that all variables are statistically highly significant, at least in quantile, except for Gross National Income per capita among women (not statically significant at all quantiles). Finally, Figure 10 summarizes the findings of this research.


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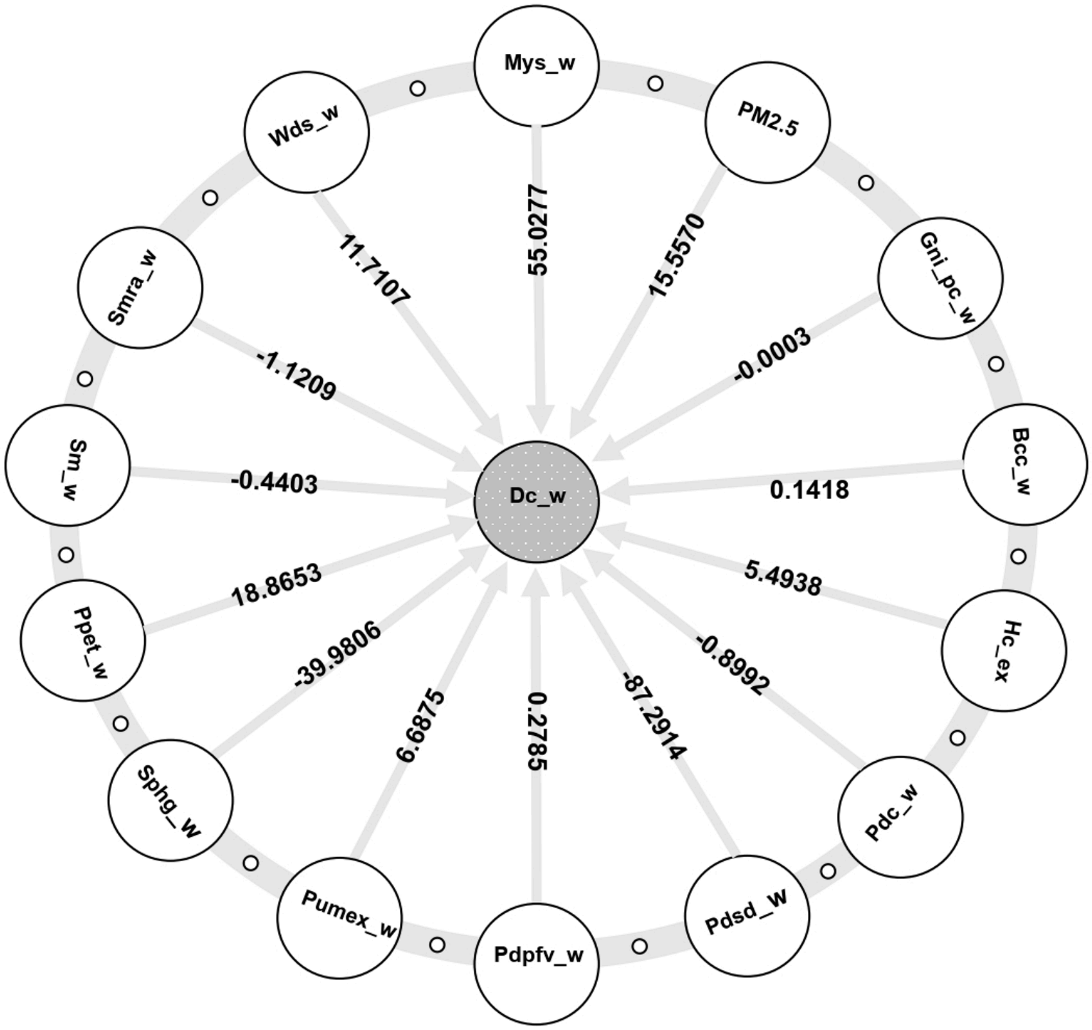


**Figure 10**. *The authors created this figure to summarize the empirical results from Table 1.*

## 5. Discussion

This section offers potential explanations for the observed empirical results. However, it is important to note that further studies may be necessary to confirm these findings definitively. Based on the findings presented, this investigation raises the following question: What plausible explanations could be for these results?

The results demonstrate the unexpected influence of the "Mys_w" and "Ppet_w" on cancer mortality in women in the EU. Contrary to expectations, higher values of these variables are associated with increased cancer mortality rates by 55.0277 and 18.8653, respectively (e.g., Raghupathi and Raghupathi[46]; Vaccarella et al.[4]).

The EU has a relatively high proportion of women with tertiary education, indicating a greater likelihood of women having a university degree than men[63]. However, disparities exist, with Romania having the lowest percentage of women aged 25-34 with tertiary education (25%) and Ireland having the highest (62%). Other countries show varied rates: Italy at 29%, Hungary at 32%, Slovakia at 39%, Finland at 40%, and Portugal at 44%[63]. Contributing to low education levels among women in these countries are factors such as entrenched historical gender norms, economic disparities that prioritize male education, and cultural beliefs that limit women's progress. These challenges are exacerbated by early marriages, restricted access to quality education, and persistent gender stereotypes.

This unexpected impact on cancer mortality rates could be attributed to the low proportion of women with high education in most EU countries. Previous studies have shown an association between low education levels in women and higher cancer mortality rates (e.g., Barcelo et al.[64]; Vaccarella et al.[4]). Women with lower levels of education are more likely to face challenges in accessing healthcare, be exposed to risk factors for cancer, lack awareness of cancer symptoms, and possess limited knowledge about cancer prevention (e.g., Barcelo et al.[64]; Kamanga and Stones[65]).

Furthermore, the correlation between limited educational attainment and inadequate nutritional habits (e.g., Assari and Lankarani[66]), reduced physical activity[67], lower rates of breast and cervical cancer screenings among women[65], as well as restricted income levels[66], collectively contribute to the escalated mortality rates from cancer among women with lower educational backgrounds. This connection finds support in the outcomes of "Bcc_w," "Pdpfv_w," "Pumex_w," and "Wds_w." In summary, the unexpected relationship between education and cancer mortality in EU women suggests that the low proportion of highly educated women in most countries may play a role. This aligns with previous studies that have identified the association between low education levels in women and increased cancer mortality rates (e.g., Barcelo et al.[64]; Kamanga and Stones[65]).

The impact of PM2.5 on cancer mortality rates among EU women is significant, with a coefficient of 15.5570. PM2.5 exposure is known to pose a cancer risk, and women residing in urban areas in the EU are more exposed to PM2.5 than those in rural areas[68][69]. This increased exposure likely contributes to the elevated cancer mortality rates among women[68][69]. In 2019, Bulgaria (19.6 μg/m3) and Poland (19.3 μg/m3) had high PM2.5 levels in urban areas within the EU, followed by Romania (16.4 μg/m3) and Croatia (16 μg/m3). Conversely, Finland (5.1 μg/m3) and Sweden (5.8 μg/m3) exhibited lower PM2.5 concentrations in urban areas[70]. Studies have established a link between PM2.5 exposure and cancer mortality in women (e.g.,[41]). This outcome may be associated with lower education levels and income, which compel women to reside in areas characterized by poor air quality due to limited housing choices or financial constraints, elevating their exposure to PM2.5[71]. Furthermore, women's restricted access to healthcare can pose significant barriers to timely cancer screening, diagnosis, and treatment[65]. This situation often results in the detection of cancer at a more advanced and less treatable stage, ultimately contributing to increased cancer mortality associated with PM2.5 exposure.

The "Gni_pc_w" influences a reduction of -0.0003 in women's cancer mortality. This decrease is linked to higher Gross National Income per capita in EU countries. These nations tend to possess superior healthcare systems, allocate more resources for prevention, and encourage healthier lifestyles. This lowers cancer mortality rates[47]. This outcome is likely due to policies targeting the gender pay gap, which grant women more financial resources for investing in health, including better food choices, preventive care, and quitting smoking, resulting in decreased cancer mortality for EU women.

The findings show that "Bcc_w" leads to a significant increase in cancer mortality among women by 0.1418. This unexpected impact may be due to the low rates of breast and cervical cancer screenings among women in certain EU countries. Some EU member-states (e.g., Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, France, Germany, Hungary, Italy, Latvia, Lithuania, Luxembourg, Poland, and Slovakia), have shown almost no women, aged 50 to 69, screenings for cancer of breast and cervical in both 2010 and 2020. Notably, these countries have participation rates below 70% for breast cancer screening and below 50% for cervical cancer screening[72].

The low rate of screening for breast and cervical cancer among women aged 50 to 69 in the EU can be attributed to several factors. These include limited awareness and access to screening, financial barriers to costly procedures, language barriers affecting communication with healthcare providers, and cultural beliefs that discourage participation. To improve screening rates among EU women, addressing these barriers through increased awareness, affordability, improved accessibility, language support, and cultural sensitivity[72][48]. This negative impact also might be associated with insufficient investment in screening services and programs for breast and cervical cancers in some EU countries[73].

Time constraints and heavy workloads also significantly impact these trends. Kamanga and Stones[65] suggest that demanding jobs, family obligations, and commitments make it hard for women to prioritize health check-ups, including cancer screenings. Moreover, Kamanga and Stones[65] also note that a lack of education about early detection contributes to these rates. Some women do not grasp screening benefits or risks, lowering their priority. Moreover, access limitations, cultural norms, personal beliefs, and healthcare system inefficiencies deter women from screenings[65].

The findings indicate that "Hc_ex" increases cancer mortality among women by 5.4938 (e.g., Akinyemiju et al.[49]). This unexpected impact on cancer mortality rates could be attributed to low healthcare expenditure per capita in certain EU countries.

Contrary to expectations, several EU countries had relatively low healthcare expenditure levels in 2020, e.g., Croatia, Hungary, Latvia, Poland, and Romania[74]. This low expenditure can increase death from cancer in several ways, including healthcare inadequacy, tardy diagnosis, and postponed treatment, as well as scarce investment in covering and deterrence (e.g., Allemani et al.[75]; Jemal et al.[76]). Indeed, the influence of "Bcc_w" on the increase in cancer mortality among women indicates healthcare expenditure patterns.

The results show that "Pdc_w" leads to a reduction of -0.8992 in cancer mortality among women (e.g., Chen et al.[50];). Engaging in everyday cooking and housework activities among EU women can potentially lower cancer mortality rates through several mechanisms, e.g., encourage a healthier diet by enabling control over ingredients and cooking methods, resulting in well-rounded and nutritious meals. Moreover, housework involves physical movement, and increasing physical activity levels is linked to reduced cancer risks. Additionally, these activities might act as stress-relievers, potentially lowering chronic stress levels associated with elevated cancer risk[77].

The results show that "Pdsd_w" is linked to a significant decrease of 87.2914 in women's cancer mortality. This decrease can be attributed to the prevalence of low smoking or engaging in damaging drinking behaviors. It is well-established that abstaining from smoking and excessive alcohol consumption significantly reduces female cancer mortality (Anand et al.[51]; Lugo et al. 2017).

However, trends in the EU show a decline in the proportion of women who abstain from smoking and harmful drinking despite policies and campaigns aimed at reducing alcohol and tobacco consumption[78][79]. Continued promotion of healthy behaviors and awareness of the risks associated with smoking and harmful drinking are crucial to reducing cancer mortality rates among EU women further.

The results indicate that "Pdpfv_w" influences the increase of 0.2785 in cancer mortality in women. The capacity of women who engage in physical activities and consume fruits and vegetables to increase cancer mortality could be related to low levels of physical activity and fruit and vegetable consumption among women[80]. Socio-cultural norms can discourage women from participating in physical activities (e.g., European Commission[81]; Baskin and Galligan[82]). This finding could also be attributed to the lower education level. Individuals with less education frequently lack proper nutrition education[66].

Consequently, such misinformation can significantly influence their actual intake of these food groups. In this context, the lower levels of education in certain EU countries could contribute to this intake. Furthermore, insufficient education contributes to limited activity engagement[67]. Scarce earnings may also be a contributing factor to this outcome. According to Assari and Lankarani[66], income insufficiencies may induce people to choose cheaper but inadequate food. Indeed, processed foods are usually affordable and caloric, which incentivizes their use.

Furthermore, time constraints and workloads could be influencing these results. As Palmer et al.[83] pointed out, women frequently manage multiple roles, including paid employment and significant caregiving responsibilities for their families. This encompasses meal preparation and planning, which can become more challenging when faced with time limitations and restricted resources, resulting in a preference for convenience foods over cooking and meal preparation that incorporate fruits and vegetables. Moreover, these time constraints and workloads also impact women's engagement in physical activities[84]. The link between lower engagement in physical activities among EU women and its potential influence on cancer mortality is supported by the "Wds_w."

The outcomes indicate that "Pumex_w" significantly increases cancer mortality among women in the EU by 6.6875. In the EU, different age groups reported varying percentages of unmet medical needs. Expenses, distance, and waiting lists were prevalent reasons among older age groups[85].

The specific reasons for unmet medical needs varied across EU countries. Expensiveness is frequently appointed as the main reason (Austria, Belgium, France, Italy, Latvia, Portugal, and Romania). In Estonia, Ireland, Poland, Slovenia, Slovakia, and Sweden, long waiting is the main problem. Some countries, such as Czechia, Denmark, Germany, Hungary, and the Netherlands, assume a passive posture[85].

The results indicate that "Sphg_w" significantly reduces cancer mortality among women in the EU by -39.9806. This reduction is associated with women who perceive their health as good or very good.

In the EU, 66% of women self-perceive their health as good or very good. Countries with the highest percentages of women with positive self-perceived health include Ireland, Greece, Cyprus, Luxembourg, Belgium, the Netherlands, Italy, Norway, Austria, and Sweden. Conversely, countries with the lowest percentages of women with positive self-perceived health are Lithuania, Latvia, Estonia, Hungary, Germany, Slovakia, and Croatia[86]. Korn et al.[54] also support the finding that individuals with a positive self-perception of health tend to engage in healthier behaviors and have improved health outcomes, including lower cancer mortality.

The results indicate that "Sm_w" and "Smra_w" significantly reduce cancer mortality among women by -0.4403 and -1.1209, respectively. This reduction can be attributed to gender-responsive policies and healthcare decision-making led by women in positions of power, which can prioritize gender-specific health issues, including cancer prevention[55].

Women in political leadership positions can result in policy initiatives supporting cancer prevention programs, early detection strategies, and improved healthcare infrastructure. This promotes awareness, education, and access to cancer screening and treatment services for women, leading to better health outcomes and potentially reducing cancer mortality rates. Gender equality and women's empowerment in society also play a role in women's healthcare-seeking behaviors, as empowered women prioritize their health, engage in preventive measures, and make informed healthcare decisions[45].

The proportion of women in the European Parliament was approximately 40% in 2021[87]. The representation of women in national parliaments varies among EU countries. Countries with higher proportions of women in national parliaments include Sweden, Finland, Belgium, and Spain, while countries with lower proportions include Malta, Cyprus, Hungary, and Greece[88].

"Wds_w" significantly raises cancer mortality among EU women by 11.7107. This increase is tied to their infrequent participation in outdoor activities like sports, culture, or leisure, leading to a sedentary lifestyle and higher cancer risk. Factors including societal norms, time constraints, limited access, and gender stereotypes contribute to this reduced engagement (e.g., Park et al.[89]). Other factors, such as time constraints and workloads, may influence these results, as Palmer et al.[83] highlighted in the preceding discussion concerning "Pdpfv_w."

Considering the empirical findings and the potential rationales behind them, this study does not find a reason to reject $H_1$. Increased gender inequality could potentially curtail educational opportunities and awareness, amplify unhealthy behaviors, and impede healthcare accessibility, thereby potentially contributing to elevated cancer mortality rates.

## 6. Conclusion and policy implications

This study aimed to evaluate the impact of gender inequality indicators on cancer-related deaths among women in 27 EU countries from 2013 to 2021. The findings provide key insights into how gender inequality factors contribute to varying cancer mortality rates.

The study reveals significant associations between higher education and women's participation in formal or non-formal education and training with increased cancer mortality rates. This unexpected result could be attributed to the low proportion of women with high education in several EU countries, which might limit their access to healthcare and preventive measures. Additionally, particulate matter (PM2.5) emerged as a significant risk factor, with higher levels of exposure linked to increased cancer mortality, especially in urban areas.

The research also shows that higher Gross National Income per capita is associated with lower cancer mortality rates, highlighting the role of economic factors in improving women's health outcomes. Daily cooking and housework activities were found to reduce cancer mortality, likely due to increased physical activity and healthier dietary habits.

Breast and cervical cancer screenings were linked to increased mortality, likely reflecting low participation rates in certain countries. Healthcare expenditure per capita also showed a positive correlation with increased cancer mortality, indicating that countries with lower healthcare spending face challenges in early detection and treatment.

Positive self-perceived health significantly reduces cancer mortality among women, emphasizing the importance of mental and physical well-being. Furthermore, political representation of women at ministerial and parliamentary levels is associated with lower cancer mortality, suggesting that women's leadership in policy-making can enhance health outcomes.

In conclusion, addressing gender inequality in education, healthcare access, economic status, and political representation is critical to reducing cancer mortality rates among women. Policy interventions should focus on empowering women through education, improving access to healthcare, and addressing environmental risk factors such as PM2.5 exposure. These steps are essential for promoting equitable health outcomes and reducing gender disparities in cancer mortality.

### *6.1. Policy Implications*

The implications derived from this study underscore the critical necessity for policy interventions to reduce gender-based health disparities and enhance the overall well-being of EU women. Policymakers should prioritize implementing gender-responsive healthcare policies that address the unique health needs of EU women. The identified disparities highlight the urgency of implementing targeted interventions and policies that comprehensively address the multifaceted factors influencing divergent health outcomes related to cancer mortality among EU women. To this end, policy recommendations are proposed to guide policymakers in fostering positive change.

Firstly, promoting women's empowerment through education, economic opportunities, and political participation can improve health-seeking behaviors and equitable health outcomes. This approach can increase cancer screenings, risk management, and healthy lifestyles among women. With national and EU financing, educational institutions, healthcare providers, and community groups may conduct awareness seminars and initiatives in EU countries to reduce cancer mortality among women. Increased health literacy among women will encourage greater participation in cancer screenings and ultimately lead to better health outcomes.

Secondly, policies should ensure that all women have access to the healthcare system. This requires policies that eliminate financial barriers to screenings and cancer treatments. Furthermore, expanding government-funded healthcare programs, subsidizing cancer-related costs, and adopting new delivery methods such as telemedicine can remove obstacles to widespread healthcare access and early cancer diagnosis.

Thirdly, more stringent environmental regulations, particularly those aimed at reducing air pollution, can lower cancer risks. Collaborations among governments, environmental agencies, local authorities, and private stakeholders can help reduce indoor air pollution. Moreover, a gender-responsive policy environment can be created through quotas or incentives for female political participation, leadership training, and mentoring. Leadership programs, awareness campaigns, and capacity-building projects can benefit from government budgets and EU support, making cancer prevention and treatment policies more equitable and effective.

Fourthly, targeted actions are needed to ensure equitable healthcare access and risk reduction for disadvantaged and vulnerable groups. Policymakers should collaborate with non-governmental organizations, community groups, and healthcare practitioners to create culturally sensitive initiatives that meet these groups' specific needs. Adequate healthcare budgets and public-private collaborations will be crucial for the success of these programs.

Finally, investing in healthcare infrastructure and increasing per capita healthcare expenditure is imperative to enhance healthcare quality, reduce screening times, and prioritize preventive measures and early detection programs. Policymakers should also encourage physical activity and healthy behaviors through comprehensive awareness campaigns, community-based programs, and incentivized initiatives.

### *6.2. Study Limitations*

Several limitations can arise from this study. Firstly, it is crucial to comprehend how interventions impact inequalities and how to develop strategies to eliminate them. Interventions typically aim to create equitable living conditions, reduce risk factors, and improve access to early detection. Examples include fiscal policies, air quality regulation, access to healthy food and clean water, suitable housing, occupational safety measures, and vaccination against cancer-causing agents. Effective solutions require multidisciplinary research and engagement with affected communities and stakeholders. Secondly, the reliance on existing data sources introduces the potential for inaccuracies and limitations in the scope of variables considered.

Thirdly, caution is needed when generalizing the EU-focused findings to other regions due to varied cultural, economic, and societal impacts on gender inequality. Fourthly, due to data constraints, the study may have overlooked some relevant factors such as cultural norms, individual behaviors, genetic predispositions, environmental exposures, and regional variations in healthcare infrastructure.

Lastly, the study heavily relied on quantitative analysis, which provides statistical insights but may overlook qualitative differences.

### *6.3. Future Research*

Several avenues for further research are recommended to build upon the insights gained and contribute to informed policy decisions. Future studies should consider examining gender inequalities in cancer-related death rates in women through longitudinal analysis. Additionally, conducting comparative studies across diverse geographical and cultural contexts can shed light on context-specific disparities in women's health concerning cancer-related deaths in Europe.

In future research endeavors, including qualitative and quantitative methodologies can provide a more comprehensive understanding of women's experiences, perspectives, and barriers to accessing healthcare and adopting healthy habits. Furthermore, future investigations may benefit from incorporating a more extensive range of variables and factors to provide a more in-depth exploration of cancer mortality among women.

## Statements and Declarations

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## Footnotes

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