Comparative Analysis of Direct Costs of Cancer and Risk Factors in Europe

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Abstract
This study explores the direct costs and risk factors associated with cancer across European Union member states, emphasizing the economic and public health implications. A Cancer Risk Factors Index (CRFI) is developed to quantify and compare the impact of various determinants, including obesity, smoking, alcohol consumption,

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socioeconomic conditions, and pollution. Using data from Eurostat and other authoritative sources, we analyze the correlation between CRFI scores, healthcare expenditures, and cancer mortality rates. Results reveal significant disparities in cancer risk factors and healthcare investments across countries, with lower CRFI scores generally associated with higher healthcare spending and improved outcomes. The findings underscore the importance of comprehensive public health strategies and targeted interventions to address modifiable risk factors, reduce cancer-related mortality, and promote equitable healthcare access.

Keywords: direct costs of cancer, risk factors, Europe, healthcare expenditures, cancer mortality

JEL Classification: I00; I10; I18

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1. Introduction

Cancer is a leading cause of morbidity and mortality worldwide, with significant personal, societal, and economic consequences (Bray et al., 2018). Understanding the costs associated with cancer is crucial for informing healthcare policy, resource allocation, and economic planning. To this end, a substantial body of research has examined the various costs of cancer, including direct medical costs, indirect costs, and out-of-pocket expenses.

From an economic perspective, costs related to cancer can be included in three major categories: direct costs, indirect costs and out-of-pocket expenses. Direct medical costs refer to the expenses incurred for cancer-related healthcare services, such as physician visits, hospitalizations, diagnostic tests, and treatment (Luengo-Fernandez et al., 2013). These costs can vary widely depending on factors like cancer type, stage at diagnosis, treatment modalities, and healthcare system characteristics. Several studies have attempted to quantify the direct costs of cancer, with estimates ranging from tens of thousands to hundreds of thousands of dollars per patient, depending on the country and healthcare context (Torkki et al., 2022; Lana et al., 2020; Mariotto et al., 2011; Yabroff et al., 2011).

Indirect costs, on the other hand, encompass the productivity losses and foregone earnings associated with cancer (Bradley et al., 2008). These include absenteeism from work, reduced work hours, and premature mortality. The indirect costs of cancer can be substantial, often exceeding the direct medical costs, and have significant implications for individuals, families, and society as a whole (Bradley et al., 2008).

Out-of-pocket expenses refer to the costs borne by patients and their families, including copayments, deductibles, and expenses not covered by insurance (Zafar & Abernethy, 2013). These expenses can create significant financial burdens, especially for low-income and uninsured individuals, and may lead to delays in seeking care or financial hardship (Zafar et al. 2013).

This study makes several contributions to understanding cancer risk factors across European Union member states. First, the paper presents the Cancer Risk Factors Index (CRFI) that quantifies and compares the impact of multiple cancer determinants including obesity, smoking, alcohol consumption, socioeconomic conditions, and pollution on cancer outcomes. Second, using data from Eurostat and other authoritative sources, we analyze correlations between CRFI scores, healthcare expenditures, and cancer mortality rates. Third, the research reveals substantial disparities in cancer risk factors and healthcare investments across EU countries, with lower CRFI scores generally associated with higher healthcare spending and improved health outcomes.

The rest of the paper is organized in five main sections. The literature review section outlines the major research avenues and trends in the research regarding cancer costs and is followed by a Methods section that explains the building blocks of CRFI. Further, the Results section presents the main findings around the CRFI, the Discussion section highlights the implications of our findings, and the last section concludes and puts forward ideas for further research.

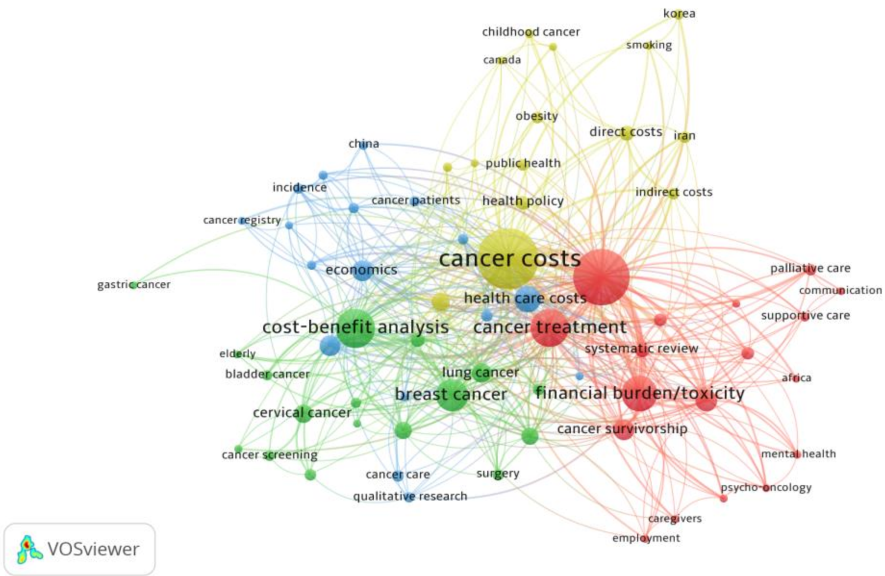
2. Literature review: Major research directions and trends in cancer cost research

The bibliometric analysis of research on the costs of cancer presents a thorough examination of the progression and extent of studies within this domain, which shows the patterns, significant contributors, global dispersion, and thematic advancements. The 1,200 publications spanning the years 1919 to 2024 identified in the Scopus database reveal a significant expansion of research in the field, especially since the early 2000s. In particular, the last decade has seen a surge in research endeavours, with 2018 standing out as the most productive year for research on cancer costs. This pattern highlights the growing recognition of the financial consequences of cancer and the necessity for thorough economic assessments. The research domain is led by the United States, with a contribution of almost 40% of the total publications, followed by United Kingdom and Canada, which reflects the presence of research funding and infrastructure in these nations.

The research on costs of cancer is interdisciplinary in nature, with contributions from medical, health economics, and social science disciplines. One notable discovery is the considerable contribution of pharmaceutical corporations in financing research on cancer costs, which underlines the industry's focus on the financial dimensions of cancer therapy, while also giving rise to potential conflicts of interest.

We identified the most relevant primary research paths and patterns in the examination of cancer expenses through bibliometric techniques, specifically co-occurrence analysis utilizing VoSViewer software. The key findings from the co-occurrence analysis are summarized in Figure no.1 and further detailed below.

Figure 1. Map of co-occurrence



(1) Interdisciplinary nature of research: keywords related to medical and clinical aspects frequently co-occur with terms from health economics, policy, and social sciences, revealing a comprehensive approach to the economic burden of cancer, integrating insights from various disciplines to address its complexity;

(2) Several main research themes have been identified, as follows: (i) Financial toxicity: refers to the financial burden and distress experienced by cancer patients due to the high costs of treatment. Research in this area examines out-of-pocket costs, insurance coverage gaps, and the overall economic impact on households. Studies highlight the need for policy interventions to reduce financial barriers to cancer care and improve the affordability of treatments; (ii) Economic evaluations of cancer treatments include cost-effectiveness analyses and budget impact assessments, which are critical for informing healthcare decision-making. Research in this area aims to identify treatments that provide the best value for money, ensuring that healthcare resources are used efficiently. Cost-effectiveness analyses help policymakers prioritize funding for treatments that offer the greatest health benefits relative to their costs.; (iii) Policy impact on cancer costs: Research in this area examines how different policy interventions, such as insurance reforms, pricing regulations, and reimbursement policies, affect the economic burden on patients and healthcare systems. Studies analyse the impact of policies on access to care, treatment affordability, and overall healthcare spending.

(3) Pharmaceutical economics. These studies examine the economic impact of pharmaceuticals, including drug pricing, access to medications, and the cost-effectiveness of new cancer therapies, driven by the high costs associated with novel cancer treatments and the significant role of pharmaceutical companies in funding this research.

(4) Healthcare and cost management. These studies analyse hospital stays, outpatient services, and the economic impact of different treatment modalities. The goal is to identify cost-saving measures and improve the efficiency of cancer care delivery.

(5) Geographic and demographic variations. These studies aim to identify disparities in cancer treatment costs and outcomes, across different geographies and demographic categories (low-

versus high-income regions, racial or ethnic groups, age, gender, etc.), which can inform targeted interventions and policy decisions.

(6) The most prevalent emerging research directions are: (i) Incorporating patient-reported outcomes and measures of financial well-being into economic evaluations of cancer treatments; (ii) The value-based care and alternative payment models in healthcare that aim to improve the quality and affordability of care; (iii) The use of real-world evidence and advanced data analytics, based on large datasets from electronic health records, insurance claims, and patient registries to generate insights into the economic impact of cancer care.

3. Methods

We develop a comprehensive index for evaluating the impact of cancer risk factors at the national level in EU countries. Thus, we created a "Cancer Risk Factors Index" (CRFI) to understand the relative importance of different cancer risk factors at the national level and guide targeted interventions for cancer prevention in EU countries.

Based on the literature review and cancer reports this index several categories of factors are considered: obesity, alcohol and tobacco use, physical activity, pollution, socio-economic conditions, and diet. These categories of factors and associated indicators are detailed in Table 1.

Based on Eurostat data for the most recent period (2019, 2020, 2021 or 2022) we calculated the CRFI for each EU member country. To normalize the sub-factors effectively we use the Min-Max normalization method. It scales each value to a range between 0 and 100. This method is straightforward and maintains the distribution's relationships, making it suitable for comparison across different sub-factors.

Table 1. Cancer Risk Factors Index (CRFI) and data sources

Category	Sub-Factor	Description (Eurostat code)	Impact on Cancer (References)
1. Obesity tendency (OB)	OB2: Prevalence of Overweight	Percentage of adults (18+) with a BMI between 25 and 29.9 [hlth_ehis_bm1e__custom_11172597]	Overweight status increases cancer risk, but to a lesser degree than obesity (Bhaskaran et al., 2014)
2. Alcohol and Tobacco Use (AT)	AT1: Alcohol Consumption	Frequency of heavy episodic drinking (weekly) [hlth_ehis_al3e$defaultview]	Alcohol consumption is strongly linked to liver, colorectal, and breast cancers (LoConte et al., 2018)
	AT2: Tobacco Smoking Prevalence	Percentage of adults (15+) who are daily smokers [hlth_ehis_sk3e__custom_11140379]	Smoking is a leading cause of lung cancer and is linked to other cancers (IARC, 2012)
	AT3: Daily exposure to smoking	Daily exposure to tobacco smoke indoors – At least 1 hour per day [hlth_ehis_sk4e__custom_11140189]	Declining smoking rates are correlated with lower lung cancer mortality (Jemal et al., 2018)
3. Sports Activity (SA)	SA1: Physical Activity	Percentage of adults performing health-enhancing physical activity [hlth_ehis_pe9e__custom_11172934]	Regular physical activity reduces the risk of colon, breast, and endometrial cancers (Moore et al., 2016)

Category	Sub-Factor	Description (Eurostat code)	Impact on Cancer (References)
			Sedentary behavior is linked to higher risks of colorectal, endometrial, and lung cancers (Schmid & Leitzmann, 2014) Increasing physical activity rates are associated with reduced cancer risk (de Rezende et al., 2018)
4. Socio-Economic Conditions (SEC)	SEC1: At risk of poverty rate	Percentage of the population living below the poverty line (cut-off point: 60% of median equivalized income after social transfers) [tessi010__custom_11140589]	Poverty is associated with higher cancer mortality due to limited access to healthcare and late diagnosis (Moss et al., 2020)
	SEC2: Education Level	Percentage of adults with higher education Tertiary educational attainment [sdg_04_20__custom_11182781]	Higher education levels are linked to better health behaviors and lower cancer risk (Ward et al., 2004)
	SEC3: Preventive healthcare expenditures	Preventive healthcare expenditure in PPS per inhabitant [hlth_sha11_hc]	Access to healthcare ensures early detection and treatment, reducing mortality (Singh & Jemal, 2017)
5. Pollution (POL)	POL1: Greenhouse emissions	Net greenhouse gas emissions - Tonnes per capita [sdg_13_10__custom_11182667]	Air pollution is linked to lung cancer and other respiratory tract cancers (Loomis et al., 2013)

Source: authors based on the literature review

Thus, to normalize using Min-Max Method we calculated for each sub-factor the minimum (min) and maximum (max) values across all countries, then we applied the following formula to each country's sub-factor value:

$$Normalized\ value\ = \frac{Actual\ value\ -\ Min\ value}{Max\ value\ -\ Min\ value} * 100$$

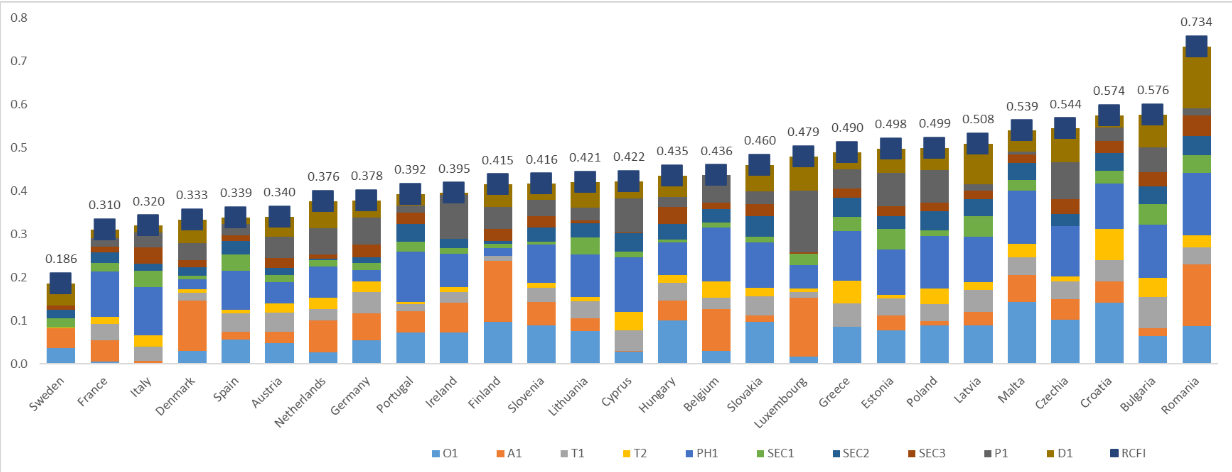
This formula scales the values to a range of 0 to 100, where 0 corresponds to the minimum observed value and 100 to the maximum. A normalized score closer to 100 indicates a higher impact of that sub-factor on cancer risk (depending on whether the sub-factor is positively or negatively correlated with risk). If a sub-factor is inversely related to cancer risk (e.g., education level), we reversed the scale by subtracting the normalized value from 100 to interpret the risk correctly.

For the aggregated score we multiplied the normalized sub-factor scores by their weights and summed the results. However, in this case we considered every category the same weight, so it was equivalent to an arithmetic average of values for each category. After determining the aggregate scores for each country, we rank countries based on CRFI, where a higher score indicates a greater overall impact of cancer risk factors.

4. Results

The aggregated index for EU Member States reflects some important aspects based on the values of the subfactors (see Figure no 2 and Annex 1 for details)[2]. To demonstrate the validity of the index we correlated the CRFI values for EU Member States with two important aspects of the disease and general healthcare issue: Cancer mortality (ASR per 100.000 persons – data from WCFR.org) and healthcare expenditures from all the sources excluding out-of-pocket money from the patient households. The first indicator is correlated with the effect of cancer disease, while the second indicator is correlated with the general (private and public) effort to reduce the risk factors.

Figure 2. Cancer Risk Factor Index (CRFI) results



Source: own calculations

The scatter plot in Figure no 3 displays the relationship between the values of CRFI and cancer mortality rates in EU Member States. The horizontal axis represents CRFI, which measures the combined impact of various risk factors associated with cancer. The vertical axis represents cancer mortality rates. There is a positive relationship between the two variables. Romania, Hungary, and Slovakia are examples of countries with both high CRFI values and cancer mortality rates, while Sweden, Luxembourg and Finland exhibit low CRFI values and cancer mortality rates.

However, we can identify Malta as an outlier with a significantly low cancer mortality rate compared to its CRFI value. Efficient screening programs, advanced treatments, and accessibility to healthcare could mitigate the impact of risk factors on mortality rates. At the same time, many countries are clustered in the middle range for both CRFI and cancer mortality rates, including France, Ireland, Germany, and Austria.

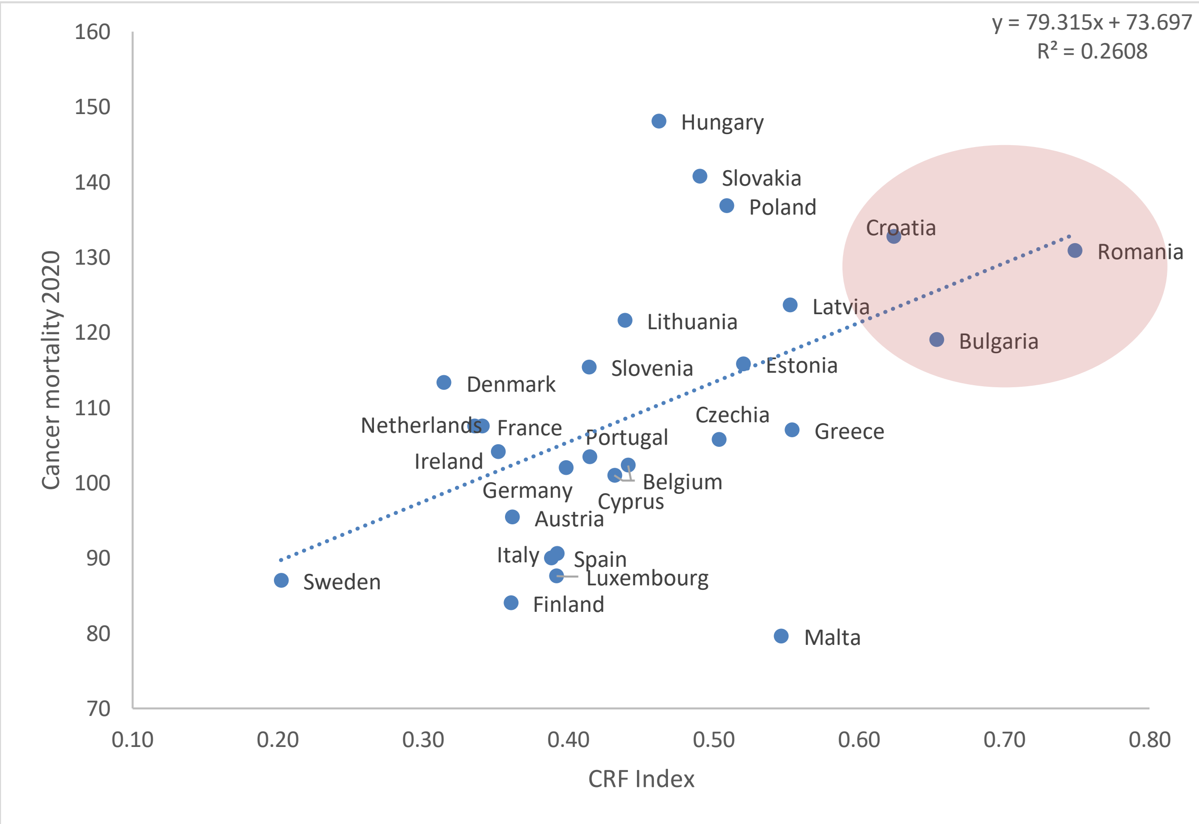
Also, countries with effective public health campaigns promoting healthy lifestyles and cancer prevention strategies may have lower mortality rates. These measures could include anti-smoking campaigns, vaccination programs, or healthy diet promotions. Lifestyle differences

[2] The codes for every subfactor are Share of overweight persons (O1), Excessive drink habits (A1), Tobacco smoking prevalence (T1), Exposure to smoking (T2), Sedentary behavior (PH1), Poverty rate (SEC1), Preventive expenditures (SEC2), Education level (SEC3), Emissions per capita (P1), Fruits and vegetables consumption (D1).

such as diet, exercise, smoking rates, and alcohol consumption could vary significantly between countries. Socioeconomic status, which affects access to healthcare and healthy lifestyle options, also plays a significant role. Lastly, environmental influences such as pollution, exposure to carcinogens, and urbanization can vary widely and impact cancer rates differently across countries.

However, all these factors imply massive expenditures per capita and investment from both public and private sources. This fact is shown in Figure no 4 where is a solid and strong negative relationship between the value of index and the health expenditures per capita at PPP. Countries like Germany, Sweden, and the Netherlands, which typically have robust healthcare systems, are seen towards the higher end of healthcare spending and lower end of CRFI. On the opposite end, countries such as Romania, Bulgaria, and Latvia have higher CRFI values and lower healthcare spending, indicating possible gaps in healthcare funding or access, which could impact overall health outcomes negatively.

Figure 3. Relationship between Cancer Risk Factor Index (CRFI) and Cancer Mortality

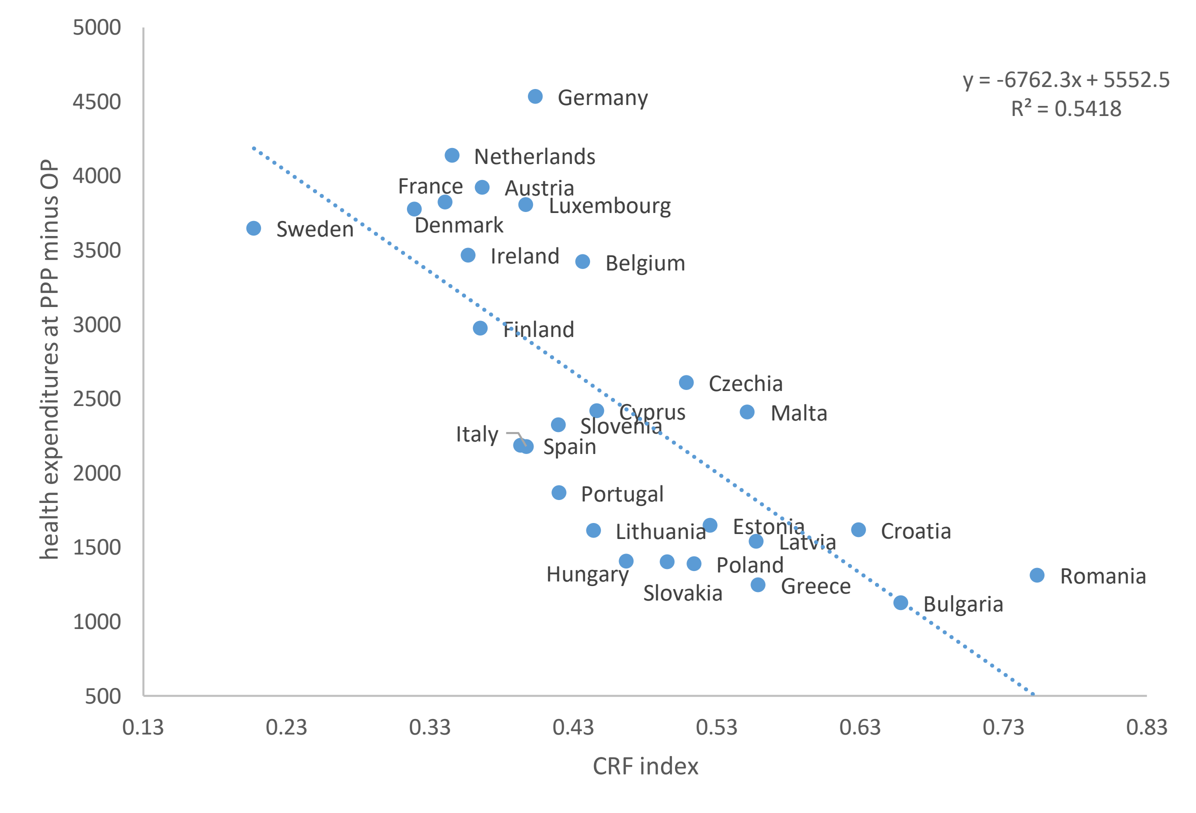


Source: own calculations and wcfr.org

The graph suggests that countries with lower CRFI values tend to invest more in healthcare, potentially contributing to better health outcomes through prevention and early intervention strategies. Conversely, higher-risk countries might be under-investing relative to their needs, possibly due to economic constraints, lower fiscal revenues, or different governmental policy priorities. Some countries, like Malta and Cyprus, despite having low healthcare expenditures, manage to maintain lower CRFI values, possibly due to other mitigating factors like lifestyle, environmental conditions, or more efficient health system management.

Overall, this plot highlights the complex relationship between healthcare investment and cancer risk factors, suggesting that higher investments in healthcare might be associated with lower aggregate risk factors for cancer across the EU.

Figure 4. Cancer Risk Factor Index (CRFI) and Cancer Mortality Rate



Source: own calculations based on Eurostat data

5. Discussion

Health statistics provide crucial insights into the well-being of populations, guiding policy decisions and resource allocation. By examining data from diverse sources such as the Global Health Observatory (GHO), ECHI Data Tool, Healthcare Expenditure Statistics from EU member states, and the Peterson Centre on Healthcare in corroboration with Cancer Registries such as European Network of Cancer Registries one can explore how investments in healthcare correlate with health outcomes, the efficiency of spending in various healthcare systems, and how economic factors influence healthcare budgets.

Universal access to quality healthcare at an affordable cost is one of the core values of EU health system and is regarded as a basic need. However, both public and private expenditure on healthcare varies significantly across EU Member States. Starting from an bird-eye view, like health expenditure as percentage of GDP, or health expenditure per capita, policymakers can see a clearer picture and can optimize data-driven policy decisions on healthcare delivery together with fiscal sustainability.

The third largest source of healthcare funding was generally household out-of-pocket payments. In 2020, the share of out-of-pocket payments accounted for more than one-third of total healthcare expenditure in Bulgaria (35.5 %), Malta (34.1 %, 2019 data) and Greece (33.4 %). The Netherlands, France and Luxembourg were the only EU Member States where household out-of-pocket payments accounted for less than one-tenth of healthcare expenditure, with shares of 9.3 %, 8.9 % and 8.4 %, respectively.

Direct costs for cancer include all medical expenditures related to the diagnosis, treatment, and care of cancer. These costs cand included: hospital and clinic visits, costs of chemotherapy, radiation therapy, and other medications, diagnostic tests like MRIs and CT scans, surgical procedures and outpatient care. These expenses are the actual payments made to healthcare providers and for medications required for cancer treatment.

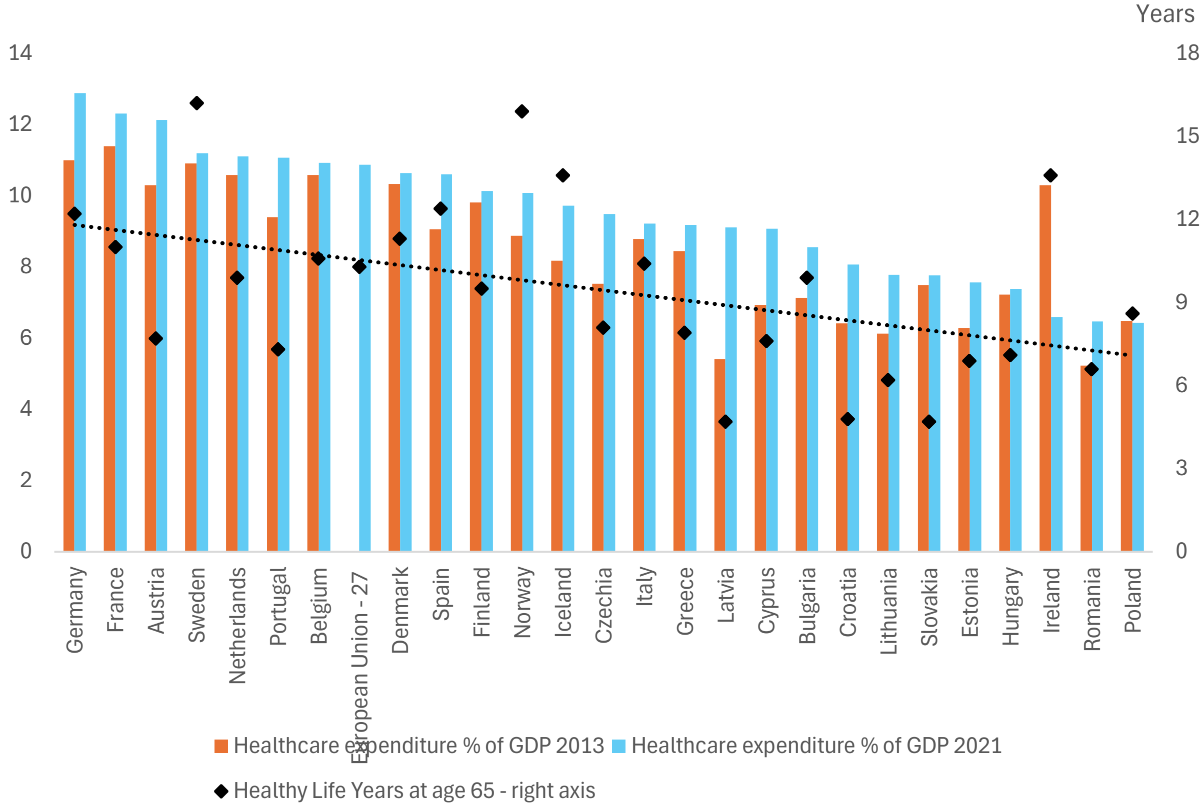
There is a very large variation in how each country represents in official records and statistical databases the direct costs of cancer. Some countries do not even have an overall representation, making the analysis of cost-effectiveness even harder to grasp. Not even in the EU, despite statistical homogenization efforts, there is not a unitary representation of the direct costs of cancer across member states (IHE Report 2019). According to the IHE Report 2019, there are multiple data sources for each country with differing methodologies of estimation of overall direct costs of cancer. Some studies include such expenditure categories as: hospitalization, ambulatory care, chemotherapy, radiotherapy, medical consultations, and medicine, while screening and primary prevention are not included (e.g. Portugal). Others include expenditure on: inpatient care, specialized outpatient care, cancer medicines, as well as screening, primary care, palliative care, and other services (e.g. Sweden).

Indirect costs involve losses not directly billed by healthcare but nevertheless impact the economy and the patient's financial situation. These costs include lost productivity due to absence from work or reduced ability to work, loss of income due to disability or death, travel and accommodation expenses for treatment at distant facilities, and informal care costs, which may include expenses related to family or friends providing care without compensation

The distinction between direct and indirect costs is significant in understanding the total economic burden of cancer on individuals and society. These costs reflect not only the significant healthcare expenses associated with cancer treatment but also the broader economic impacts such as lost productivity and personal financial stress, which can be substantial.

The most noticeable aspect of the Figure no 5 is that healthcare expenditure as a percentage of GDP has increased in all EU Member states. There is only one exception, that is Ireland, but the relative decrease as a per of GDP is the fact that GDP has increased at a very high pace given the fact that Ireland is home to many tech giants. The main reason behind this increase is the aging population that requires more health services and medications, in combination with the fact that the population is becoming more aware of the benefits brought by investments in health, thus putting pressure on policy makers.

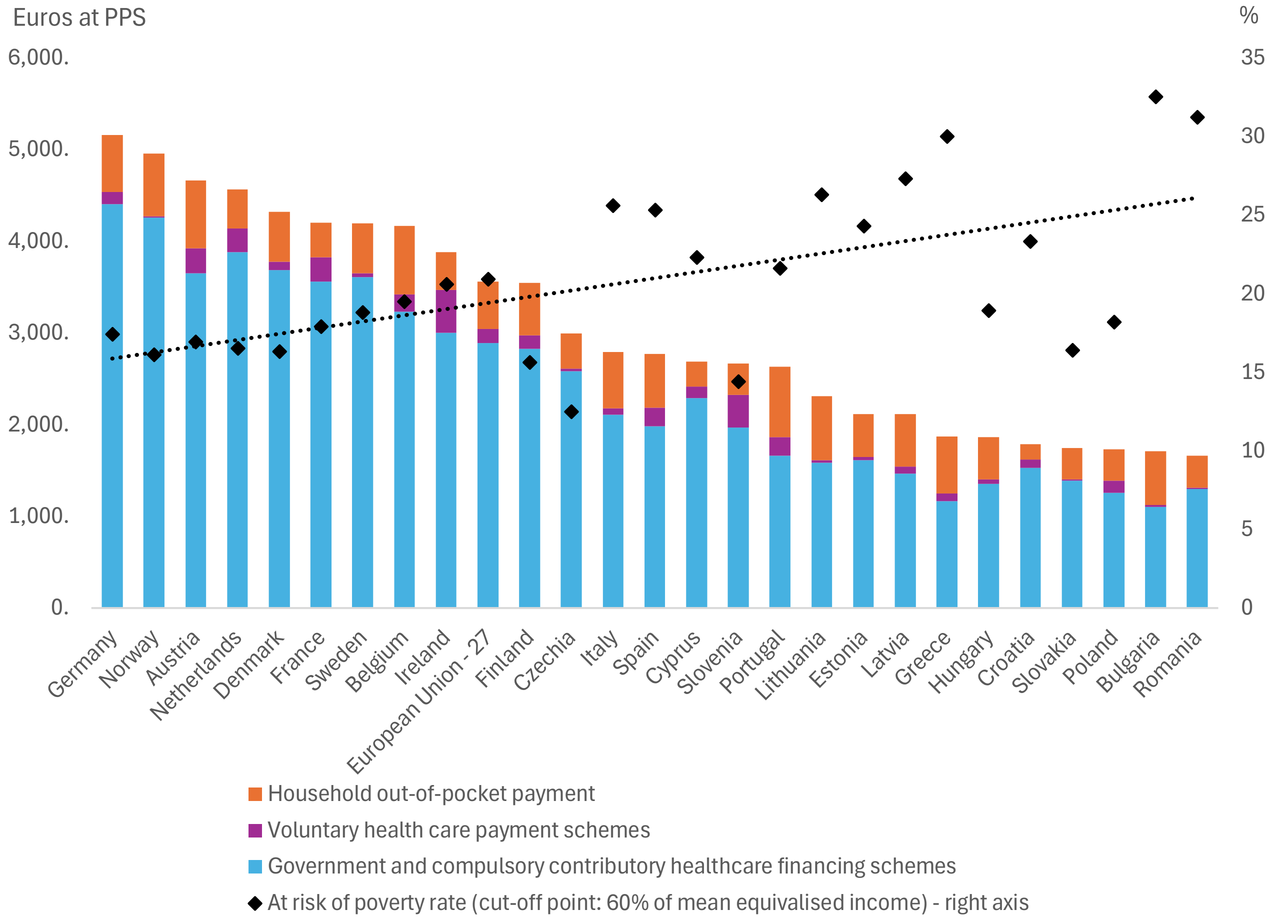
Figure 5. Healthcare expenditure % of GDP and healthy life years at 65



Note: *Last data available for Healthy Life Years at age of 65 is from 2019.
Source: Eurostat and European Core Health Indicators data tool

Another important and relevant aspect is the number of healthy years that a person is expecting to live after retirement, that is generally at 65 in EU Member states. Even if a state's health expenditures are not the only factor that influences the hope of a healthy life in retirement, the level of pollution, the general level of stress of the population, as well as the eating habits and the attitude towards sports are also very important, the state's expenditure on health probably plays one of the most important roles in determining healthy life expectancy. It can be seen from the Figure no 5 that there is a correlation between the size of these expenses and the number of healthy years that a person who has reached the age of 65 can hope for.

Figure 6. Structure of Healthcare financing schemes and population at risk of poverty



Source: Eurostat and European Core Health Indicators data tool

It is quite clear that the majority of healthcare is provided by public funds, either government schemes or compulsory contributory healthcare financing schemes, as it can also be observed that wealthier states allocate more funds for medical care. Although there are many types of voluntary medical insurance, they are very little used in most states and have a low share in the total healthcare financing schemes, although in some states such as Romania or Bulgaria this type of instrument is almost non-existent or insignificantly used (Figure no 6).

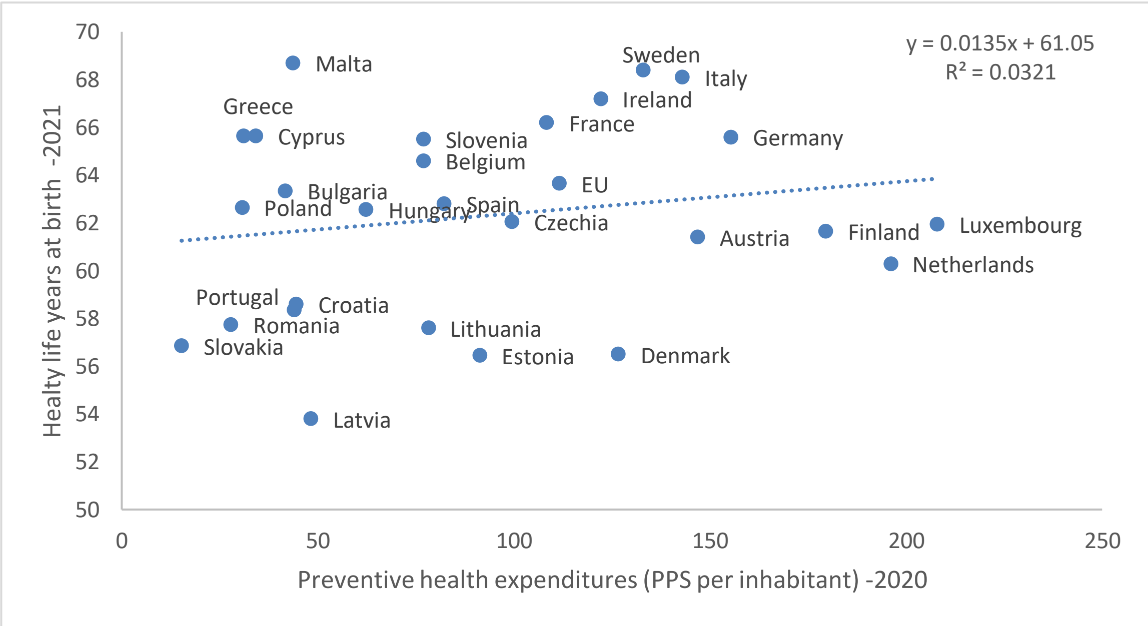
Moreover, in addition to the fact that voluntary medical insurance is not used in these two previously mentioned states, out of pocket expenses have a significant role in the total medical expenses per capita, approximately 21% in Romania and 34% in Bulgaria. If we correlate this aspect with the rates of at risk of poverty (which is also an indicator that shows us the inequalities in a society), which are the highest in Romania and Bulgaria, we can draw the conclusion that it is very difficult for a person from these two states to manage to cover the necessary medical expenses from out-of-pocket money.

Figure no 7 and figure no 8 show the correlation between preventive healthcare expenditures and healthy life years both at birth and after 65 years across EU countries. Preventive Healthcare Expenditures are considered at PPS Per Inhabitant (2021 data). The adjustment for purchasing power standards (PPS) makes it possible to compare different countries' expenditures directly by eliminating differences in price levels.

Data shows that there is a large variation between countries in terms of expenditures, from 208 PPS in Luxembourg to 15 PPS in Slovakia, but also in terms of healthy life years at birth and after 65 years. For example, Austria spends 146.7 PPS on preventive healthcare per inhabitant and has an expectancy of 63.60 healthy life years at birth. In contrast, Romania spends 27.8 PPS per inhabitant on preventive healthcare and has a lower expectancy of healthy life years at 57.75.

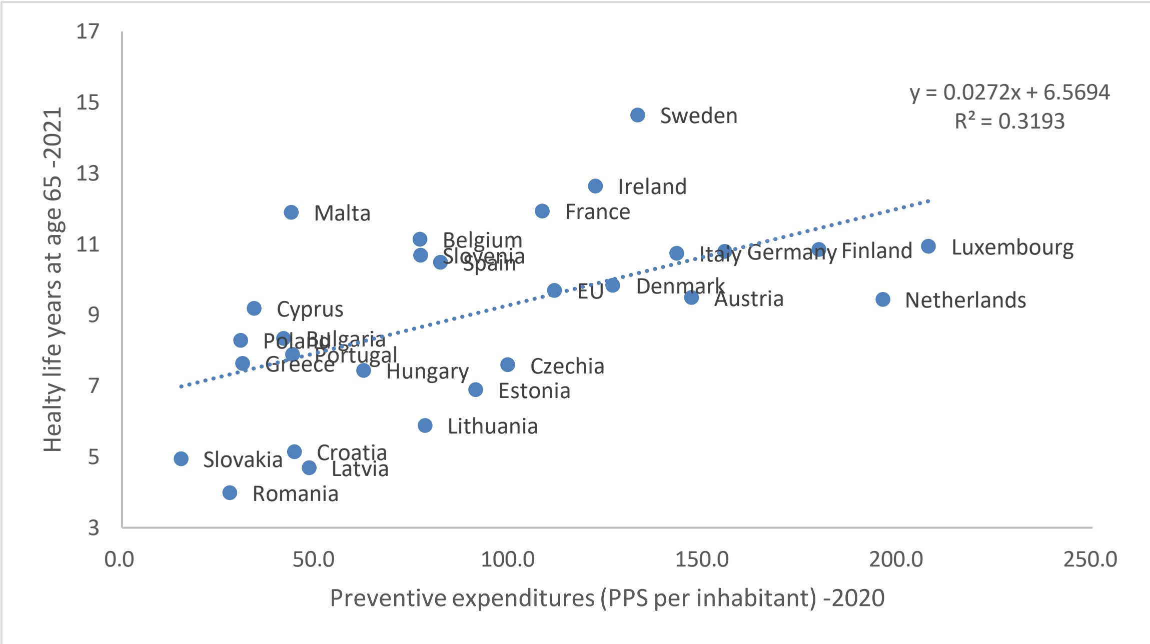
However, even that this variation is not so clear when is linked with the Healthy life years at birth, there is a stronger relationship between the healthcare expenditure with prevention and Healthy life years after 65 years (R-squared coefficient close to 31%), which enforce the hypothesis that usually, the effects of healthcare prevention have a long- and very long-term impact, especially after a threshold.

Figure 7. Correlation between preventive healthcare expenditures in EU Member States and healthy life years at birth



Source: authors' compilation on Eurostat data

Figure 8. Correlation between healthy life years after 65 years and the preventive healthcare expenditures in EU Member States



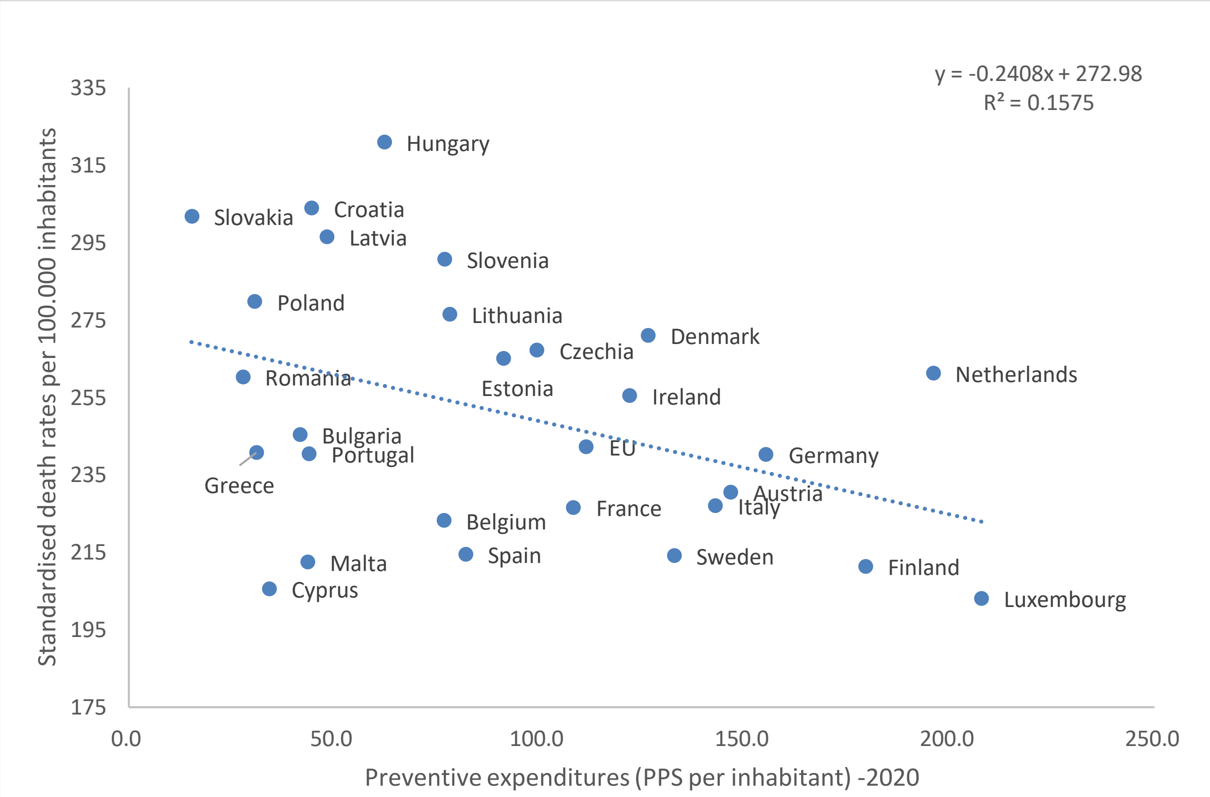
Source: authors' compilation on Eurostat data

In terms of differences, there are several studies that explore differences in preventive healthcare expenditures and healthy life years (HLY) among EU countries, focusing on various explanatory factors, from healthcare expenditures and infrastructure across EU countries, to individual economic status and educational level (primary school, secondary or tertiary), and general regional economic development disparities or labour market performances. See for example, Jagger et al., (2008) which show that HLYs range significantly more than life expectancies. Factors such as GDP and expenditure on elderly care were positively associated with higher HLYs, while long-term unemployment was negatively associated, particularly in men. The study suggests that improving population health is crucial for increasing older people's participation in the labor force across all EU countries (Jagger et al., 2008). Also, based on a difference-in-difference (DiD) analysis and data envelopment analysis (DEA), Jakovljevic et al. (2016) found that countries that joined the EU in 2004 showed significant health expenditure growth and longevity increase, suggesting a strong performance in balancing these aspects compared to other sub-regions

Additionally, a comparative study across eight European countries highlighted the impact of education on disability-free life expectancy (Mäki et al., 2013). There were significant educational differences in disability-free life expectancy in all countries, with highly educated individuals expected to live longer and healthier lives. This variance was more pronounced in certain countries, illustrating how education levels can influence health outcomes (Mäki et al., 2013). In another study, Albulescu (2022) analysed the health expenditures in the European Union countries. The paper assessed the convergence process in health care expenditure across selected EU countries over 50 years. It analysed public and private health expenditures, revealing mixed findings on convergence and highlighting the heterogeneity of health care systems across the EU. The study emphasizes the need for common solutions to enhance the convergence processes in EU health care systems.

For cancer, Figure no 9 plots the relationship between preventive health expenditures per inhabitant (in purchasing power standards, PPS) and standardized death rates per 100,000 inhabitants caused by malignant neoplasms (cancer) in 2020 across EU member states. The trend line indicates a negative correlation between these variables, respectively a higher preventive health expenditures per inhabitant are associated with lower standardized death rates from malignant neoplasms (negative correlation coefficient of -0.24).

Figure 9. Relationship between preventive health expenditures per inhabitant and standardized death rates across EU member states

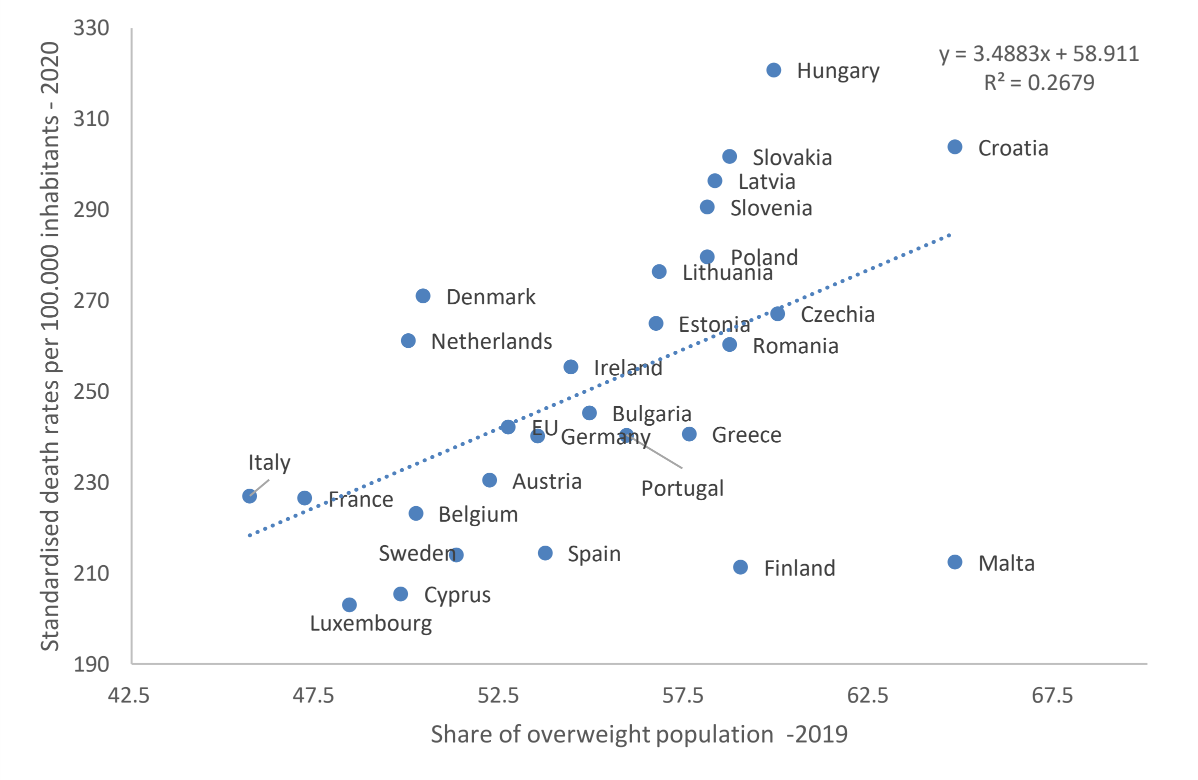


Source: authors' compilation on Eurostat data

Moreover, the R-squared value is 0.1575. This means that almost 16% of the variation in death rates from malignant neoplasms across EU states can be explained by differences in preventive health spending. This is a relatively low value, suggesting that other factors not captured in this Figure also play significant roles in influencing cancer mortality rates (aspects of healthcare quality, access to treatment, environmental factors, and lifestyle differences among populations).

A large body of studies collectively underline that while preventive healthcare spending is crucial, a comprehensive understanding of cancer mortality rates must also consider broader social, environmental, and lifestyle factors. These elements play a critical role in shaping the health outcomes of populations, suggesting that interventions need to address these diverse determinants.

Figure 10. Share of the overweight population in 2019 and the standardized death rates

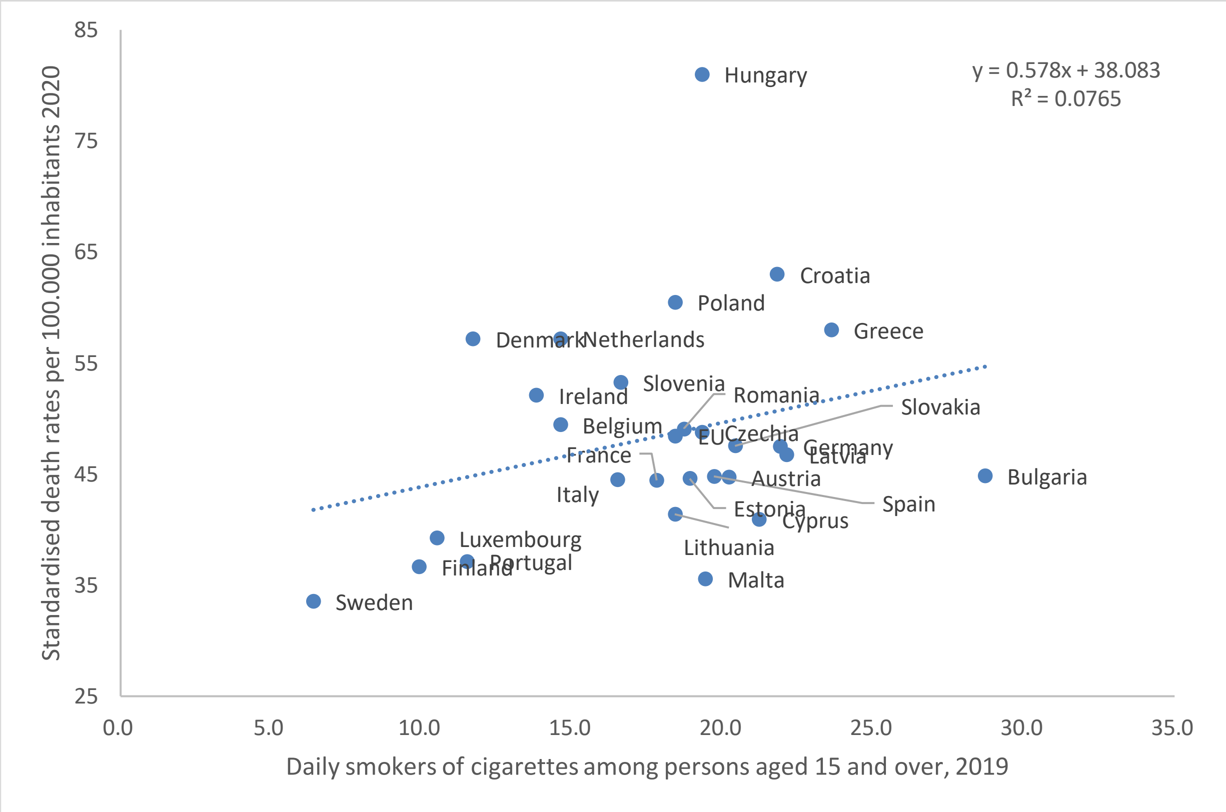


Source: authors' compilation on Eurostat data

For example, a study by Belpomme et al. (2007) highlights the significant role of environmental carcinogens, including air pollution, chemicals, and electromagnetic fields, which may contribute to the rising incidence of cancer alongside traditional lifestyle factors. Also, analysing socio-environmental patterns and cancer mortality, Pou et al. (2018) emphasized the interplay of quality of life, urban-related resources, and environmental exposures with cancer outcomes, while Weiderpass (2010) discussed how major behavioural and environmental risk factors, such as diet, physical inactivity, and exposure to pollutants, contribute significantly to global cancer mortality, with a notable impact of modifiable lifestyle choices (see also Coughlin and Smith, 2015 on the role of diet, obesity, and chemical exposures). A corelation between the share of the overweight population in 2019 and the standardized death rates is presented in Figure no. 10.

In the next paragraphs we analysed some of these factors that are available from the Eurostat database related to tobacco consumption, tobacco exposure and obesity. The scatter plot below shows the relationship between the share of the overweight population in 2019 and the standardized death rates from malignant neoplasms (cancer) per 100,000 inhabitants in 2020 across EU member states. The plotted trend line suggests a positive correlation between the share of the overweight population and the cancer death rates, while the R-squared coefficient indicates that approximately 26.79% of the variation in the cancer death rates across the EU member states can be explained by the variation in the percentage of the overweight population.

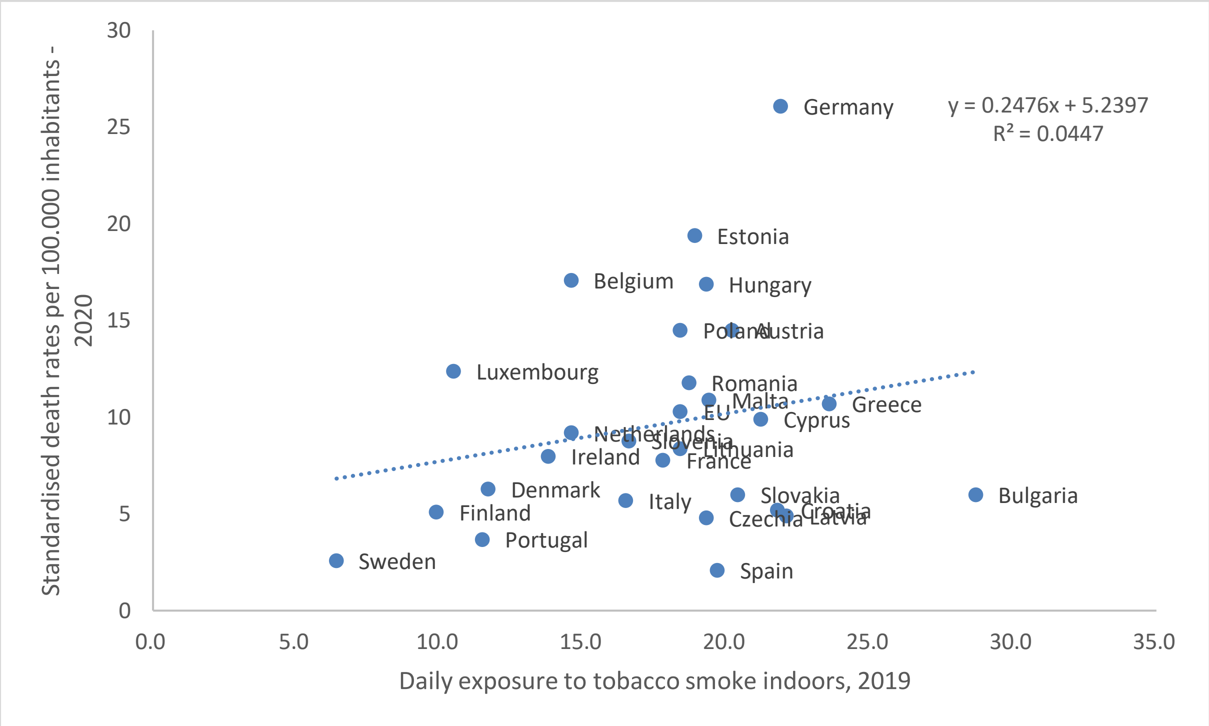
Figure 11. Smoking rates and the standardized death rates from malignant neoplasms of the trachea, bronchus, and lung



Source: authors' compilation on Eurostat data; Note: Data for Belgium and Netherlands are for 2014

Figure no 11 highlight the relationship between the daily smoking rates among persons aged 15 and over in 2019 and the standardized death rates from malignant neoplasms of the trachea, bronchus, and lung per 100,000 inhabitants in 2020 across various EU member states. The Figure highlights a positive but relatively weak association between smoking rates and lung cancer mortality among EU member states. Also, there is a weak link between the daily exposure to tobacco smoke indoors (at least one hour per day) and the death rates (Figure no. 12). The low R^2 value implies that other factors play a more significant role in influencing lung cancer mortality rates than smoking alone, as also was the case for obesity.

Figure 12. Tobacco smoke exposure indoors and the standardized death rates from malignant neoplasms of the trachea, bronchus, and lung

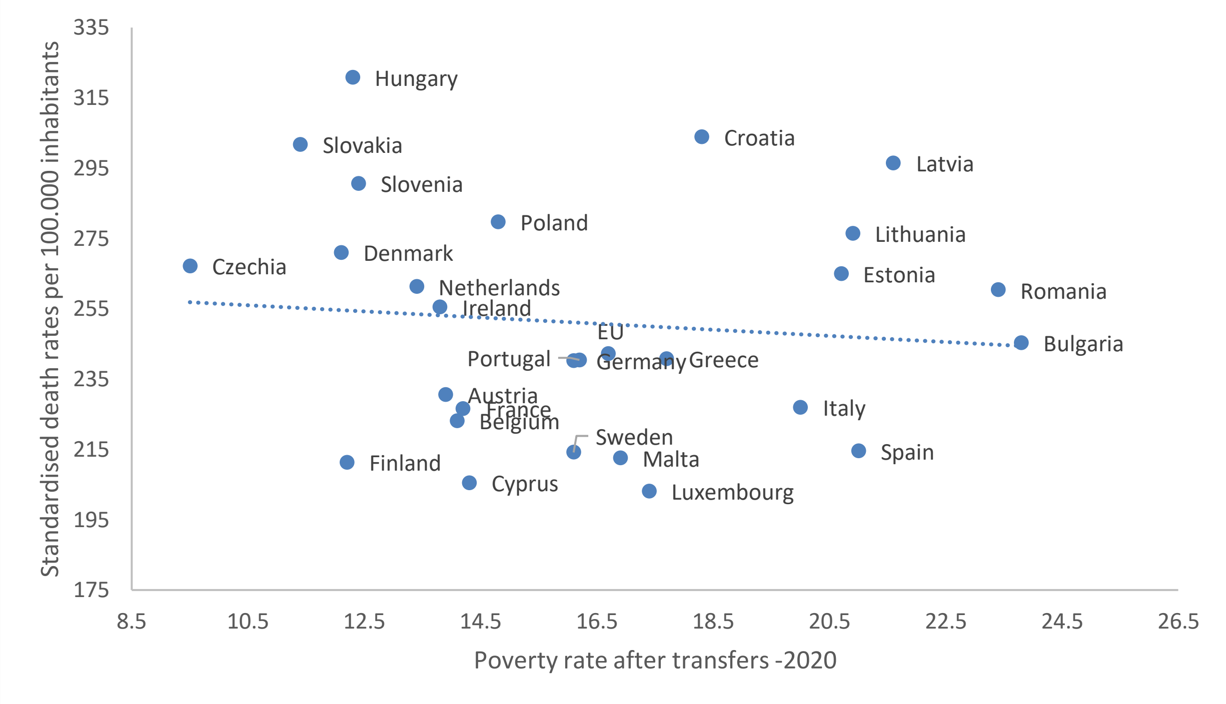


Source: authors' compilation on Eurostat data; Note: Data for Belgium and Netherlands are for 2014

The last perspective of the cancer mortality is by socio-economic factors, respectively poverty rates among EU Member States. Several studies provide insights into how income and living conditions, particularly poverty rates, can significantly influence cancer mortality rates (Figure no 13). The social, structural, and behavioural challenges associated with persistent poverty contribute to higher vulnerability to cancer (Moss et al., 2020), while individuals in high-poverty areas are more likely to be diagnosed with cancer at a distant stage, which leads to higher mortality rates.

This is partly due to disparities in access to cancer screening and early detection services (Boscoe et al., 2016). Ward et al. (2004) shows that factors contributing to these disparities include lower access to healthcare, higher prevalence of risk factors such as tobacco use, and inadequate screening. Moreover, as poverty is generally associated with social exclusion, this independently increases the risk of cancer mortality as there is a lack of community and social support in mitigating cancer risks (Marcus et al., 2017).

Figure 13. Death rates and poverty correlation in Europe



Source: authors' compilation on Eurostat data; Note: Data for Belgium and Netherlands are for 2014

6. Conclusions

This study highlights the significant disparities in cancer risk factors and healthcare expenditures across European Union member states, emphasizing the need for tailored public health policies. The Cancer Risk Factors Index (CRFI) provides a comprehensive framework for evaluating and comparing the influence of obesity, smoking, alcohol consumption, socioeconomic conditions, and environmental factors on cancer outcomes. Countries with lower CRFI scores tend to exhibit higher healthcare spending, reflecting robust public health systems and proactive investments in cancer prevention and treatment. Conversely, higher CRFI scores in certain nations underscore the challenges posed by underfunded healthcare systems, socioeconomic inequalities, and gaps in public health initiatives.

The findings underscore the importance of prioritizing preventive healthcare strategies, such as smoking cessation programs, public awareness campaigns on diet and exercise, and early cancer screening initiatives. Addressing disparities in healthcare access and funding, particularly in low-income countries, remains critical to reducing cancer mortality rates and improving health outcomes. Moreover, our analysis suggests that long-term investments in healthcare infrastructure and preventive measures yield significant benefits, extending healthy life expectancy and reducing the economic burden of cancer.

Future efforts should focus on integrating socio-economic, lifestyle, and environmental considerations into national healthcare strategies. Policymakers must leverage data-driven insights to allocate resources effectively and promote equitable access to healthcare services. This study reinforces the value of a holistic approach to cancer prevention and treatment, underscoring the pivotal role of public health systems in mitigating cancer risks and ensuring better outcomes for all populations**.**

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Annex 1. Scores for factors and subfactors covered by the Cancer Risk Factors Index (CRFI)

	Obesity	Alcohol	Tobacco		Physical inactivity	Socio-economic conditions			Pollution	Diet	
	Share of overweight persons	Excessive drink habits	Tobacco smoking prevalence	Exposure to smoking	Sedentary behavior	Poverty rate	Preventive expenditures	Education level	Emissions per capita (CO2)	Fruits and vegetables consumption	TOTAL
	O1	A1	T1	T2	PH1	SEC1	SEC2	SEC3	P1	D1	
Belgium	0.031	0.097	0.026	0.037	0.125	0.011	0.032	0.015	0.062	0.000	**0.436**
Bulgaria	0.065	0.019	0.071	0.045	0.123	0.048	0.041	0.032	0.057	0.075	**0.576**
Czechia	0.102	0.048	0.041	0.012	0.117	0.000	0.027	0.034	0.086	0.078	**0.544**
Denmark	0.031	0.116	0.017	0.009	0.023	0.008	0.020	0.016	0.039	0.054	**0.333**
Germany	0.055	0.062	0.050	0.023	0.027	0.017	0.013	0.029	0.062	0.040	**0.378**
Estonia	0.077	0.034	0.040	0.008	0.105	0.047	0.029	0.023	0.078	0.056	**0.498**
Ireland	0.072	0.070	0.024	0.013	0.076	0.014	0.021	0.000	0.101	0.004	**0.395**
Greece	0.086	0.000	0.055	0.051	0.116	0.032	0.044	0.022	0.044	0.040	**0.490**
Spain	0.057	0.017	0.043	0.009	0.090	0.038	0.031	0.013	0.026	0.015	**0.339**
France	0.005	0.050	0.037	0.017	0.104	0.020	0.025	0.013	0.019	0.020	**0.310**
Croatia	0.142	0.049	0.049	0.071	0.106	0.029	0.040	0.028	0.030	0.028	**0.574**
Italy	0.000	0.008	0.032	0.026	0.113	0.037	0.016	0.038	0.034	0.016	**0.320**
Cyprus	0.028	0.001	0.047	0.044	0.125	0.014	0.043	0.001	0.078	0.040	**0.422**
Latvia	0.089	0.032	0.050	0.018	0.106	0.046	0.039	0.021	0.014	0.093	**0.508**
Lithuania	0.077	0.029	0.038	0.011	0.098	0.040	0.032	0.006	0.030	0.060	**0.421**
Luxembou	0.018	0.135	0.013	0.008	0.054	0.027	0.000	0.003	0.143	0.078	**0.479**
Hungary	0.101	0.045	0.041	0.019	0.074	0.007	0.036	0.039	0.023	0.048	**0.435**
Malta	0.143	0.062	0.042	0.031	0.123	0.024	0.041	0.019	0.006	0.048	**0.539**
Netherlan(	0.027	0.074	0.026	0.026	0.071	0.016	0.003	0.010	0.061	0.062	**0.376**
Austria	0.048	0.026	0.044	0.021	0.050	0.017	0.015	0.023	0.049	0.047	**0.340**
Poland	0.089	0.011	0.038	0.037	0.121	0.013	0.044	0.019	0.075	0.051	**0.499**
Portugal	0.073	0.049	0.016	0.005	0.117	0.023	0.041	0.026	0.017	0.025	**0.392**
Romania	0.087	0.143	0.039	0.029	0.143	0.041	0.045	0.048	0.017	0.143	**0.734**
Slovenia	0.089	0.056	0.033	0.012	0.088	0.007	0.032	0.026	0.038	0.037	**0.416**
Slovakia	0.097	0.015	0.045	0.020	0.105	0.013	0.048	0.027	0.030	0.061	**0.460**
Finland	0.097	0.142	0.011	0.000	0.018	0.009	0.007	0.028	0.052	0.051	**0.415**
Sweden	0.036	0.046	0.000	0.001	0.000	0.022	0.019	0.010	0.000	0.052	**0.186**

Source: authors' own calculations

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