4PCAN

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List of Abbreviations

CAGR – Compound Annual Growth Rate

COVID-19 – Coronavirus Disease 2019

EU – European Union

EUR – Euro

FCTC – Framework Convention on Tobacco Control

FE – Fixed Effects

FTE – Full-time Equivalent

GBD – Global Burden of Disease

GDP – Gross Domestic Product

GNDI – Gross National Disposable Income

GVA – Gross Value Added

HCA – Human Capital Approach

HPV – Human Papillomavirus

IARC – International Agency for Research on Cancer

IHME – Institute for Health Metrics and Evaluation

ILOSTAT – International Labour Organization Statistics

OECD – Organisation for Economic Co-operation and Development

OLS – Ordinary Least Squares

PIT – Personal Income Tax

RE – Random Effects

UNESCO – United Nations Educational, Scientific and Cultural Organization

VAT – Value Added Tax

WHO – World Health Organization

Executive summary

This comprehensive economic analysis quantifies the indirect costs of cancer-related premature mortality across eight European countries, examining both macroeconomic burden and behavioural intervention pathways for cancer risk reduction. The research employs quantitative methodologies to assess productivity losses, fiscal revenue impacts, and policy intervention effectiveness within the framework of the 4P-CAN Horizon Europe project on personalized cancer primary prevention.

The study addresses three primary research objectives: (1) establishing a harmonized framework for measuring indirect economic costs of cancer mortality among the economically active population (ages 20-64); (2) analysing consumption elasticities for alcohol and tobacco as modifiable cancer risk factors; and (3) developing evidence-based policy scenarios to optimize fiscal interventions for cancer prevention.

The analysis encompasses Romania, Moldova, France, Belgium, Bulgaria, Portugal, North Macedonia, and Montenegro over the period 2015-2023, utilizing a triangulated approach combining macroeconomic assessment with microeconomic modelling. The methodological framework integrates the Human Capital Approach (HCA) for productivity loss estimation with panel data econometric models examining price and income elasticities of alcohol and tobacco consumption.

Data sources include national statistical institutes, WHO databases, IARC registries, and Eurostat indicators, ensuring cross-country comparability while accounting for diverse healthcare contexts and economic structures. The temporal analysis incorporates compound annual growth rates (CAGR) for workforce dynamics and labor productivity, enabling forward-looking projections and policy scenario development.

The indirect economic burden of cancer mortality among working-age populations reveals substantial heterogeneity across the eight European countries analysed, with annual losses ranging from €16 million in Montenegro to €3.52 billion in France. This variation reflects not merely disease burden but the complex interaction between mortality rates, labor productivity levels, and demographic characteristics. France demonstrates the highest absolute economic impact despite maintaining a low crude mortality rate (107 per 100,000 active persons), generating annual gross value added losses of €2.6 billion and fiscal revenue losses of €904 million. Conversely, Romania exhibits elevated average mortality rates (152 per 100,000) resulting in €564 million total annual losses, while countries like Moldova, Bulgaria, and Portugal show intermediate profiles where modest absolute losses mask significant relative economic impacts within their national contexts.

A critical discovery across multiple countries reveals that economic costs are escalating significantly faster than underlying mortality rates, creating a dynamic amplification effect driven by rising wages and productivity improvements. In Moldova, while cancer mortality increased by 20% between 2019-2023, total economic losses surged by 58%, exemplifying how economic development paradoxically increases vulnerability to health-related economic shocks. This pattern appears consistently across Eastern European countries, where Romania experienced post-2020 acceleration with fiscal losses growing from €105 million to €147 million despite relatively modest mortality increases. The fiscal component, consistently representing 15-25% of total indirect costs, encompasses personal income tax, social security contributions, and value-added tax losses that compound the productivity impacts.

The microeconomic analysis reveals critical insights into consumption patterns for major cancer risk factors, with tobacco expenditures demonstrating significant income sensitivity (elasticity +0.695) while both tobacco and alcohol exhibit inelastic price responses (tobacco: -0.234; alcohol: -0.306), indicating that taxation alone produces only moderate consumption reductions.

The combination of strong income effects and weak price sensitivity for tobacco underscores a fundamental policy challenge: economic prosperity without intervention drives increased tobacco consumption and cancer risk through improved affordability. This finding necessitates income-indexed taxation strategies where tax rates automatically adjust to exceed income growth, preventing economic development from undermining public health objectives and ensuring that fiscal interventions maintain effectiveness over time.

Intervention scenario modelling demonstrates that comprehensive cancer control strategies generate substantial economic returns, with potential annual benefits ranging from €309 million in France to €32 million in Bulgaria under the most ambitious prevention framework. The cumulative five-year economic gains across all countries could exceed €4.22 billion under comprehensive interventions, compared to €1.6 billion for treatment-focused approaches alone. These projections establish that cancer control investments function as economic development strategies rather than purely health expenditures, particularly in high-mortality countries like Romania and Bulgaria where elevated baseline rates and rising productivity create optimal conditions for intervention cost-effectiveness. The analysis reveals that each prevented cancer death carries increasingly significant economic value as countries develop, making prevention investments progressively more attractive from both humanitarian and fiscal perspectives.

Objectives and scope of the deliverable

This report aims to assess the indirect economic costs of cancer in selected European countries by estimating the productivity and fiscal losses resulting from premature cancer mortality among the working-age population (20 to 64 years). Aligned with the goals of the 4P-CAN project, the analysis provides quantitative evidence on the macroeconomic burden imposed by cancer-related deaths, contributing to the broader understanding of how cancer prevention and control strategies can yield economic benefits.

The research builds on a harmonised cross-country dataset covering the period 2015–2023 and applies the Human Capital Approach (HCA) to evaluate losses in economic output and public revenue. This method quantifies the potential economic contributions lost due to premature death, drawing on demographic data, national labour productivity indicators, and fiscal structures specific to each country. The resulting estimates reflect both the decline in gross value added (GVA) caused by reduced workforce participation and the fiscal losses generated through uncollected personal income tax, social security contributions, and value-added tax.

Complementing this macroeconomic perspective, the report also investigates the behavioural dimensions of cancer risk through an analysis of alcohol and tobacco consumption patterns. Using panel data econometric models, the study estimates income and price elasticities for these products across five countries with time series data available, enabling an evaluation of how excise tax policies may influence consumption behaviour and, by extension, cancer risk exposure. These results serve as the empirical foundation for the development of fiscal policy scenarios aimed at cancer prevention.

General observations

The country-level datasets used to estimate the indirect economic burden of cancer-related premature mortality exhibit a commendable degree of structural harmonization, enabling rigorous comparative analysis across diverse national healthcare contexts such as Romania, Moldova, France, Portugal, Montenegro, Belgium, Bulgaria and North Macedonia.

Each dataset follows a consistent framework, reporting essential indicators including total and working-age (20–64 years) population, crude cancer mortality rates specific to the active population, and the estimated number of cancer-related deaths within the labour force. This uniformity is essential for the application of the human capital approach (HCA),

which relies on comparable demographic and economic inputs to quantify productivity losses attributable to mortality.

Data are derived from a triangulated array of sources, including national statistical institutes, WHO databases, and the International Agency for Research on Cancer (IARC), supplemented by economic indicators from Eurostat, ILOSTAT, OECD or National banks (for exchange rate data).

The inclusion of compound annual growth rates (CAGR) for both workforce size and labour productivity reflects the temporal dynamics and avoid static cost estimations. This temporal sensitivity is useful for projecting long-term economic implications, informing policy responses grounded in forward-looking fiscal planning and estimating the impact of different types of healthcare policies implemented by the governments.

The mortality data underscore significant differences across countries. France, while exhibiting lower crude mortality rates among its working-age population, incurs a higher absolute number of premature cancer deaths due to its larger labour force. In contrast, countries like Romania, Bulgaria and Moldova face dual pressures: elevated mortality rates among active individuals and declining labour force participation amid migration and declining birth rates (negative natural growth rate of population).

This combination amplifies both the direct health burden and the structural economic risks, as shrinking workforces reduce productive capacity while simultaneously increasing the relative weight of health-related economic losses.

Some **limitations** are evident at the level of data access and methodologies, implying the use of some proxies or auxiliary calculations (annual monetary productivity, working time). Some of these calculations likely rely on auxiliary datasets or embedded computations in order to attribute an economic value to lost labour potential. For example, in the case of Moldova, we derived the hourly average labour productivity for each year based on the nominal GDP divided by the total employment and then divided by the total annual number of hours worked obtained from ILOSTAT (Wages and Working Time Statistics (COND) Database).

In sum, the data infrastructure provides a solid foundation for estimating the macroeconomic impact of cancer mortality in working-age populations. However, it also invites the national authorities to further refinement in both transparency and standardisation aspects, particularly as such models could have an important impact in terms of informing strategic health investment decisions and labour market impact planning at the national and European levels.

Methodology Description

The Human Capital Approach (HCA) is a well-established method in health economics for estimating the indirect costs of illness and premature death. It values productivity losses by estimating the potential future earnings lost due to morbidity or mortality, assuming that an individual would have continued contributing to the economy having not been ill or deceased (see for example: Johns & Baltussen, 2004). In addition to the broader economic loss in productivity, premature mortality also results in fiscal losses for the government. These losses represent reduced tax (personal income tax and VAT) and social contribution revenues that the deceased would have paid over their remaining working years. Figure 1 is a schematic overview of how both fiscal losses and gross value-added losses are aggregated by the human capital approach.

Figure 1. Indirect economic costs of cancer mortality
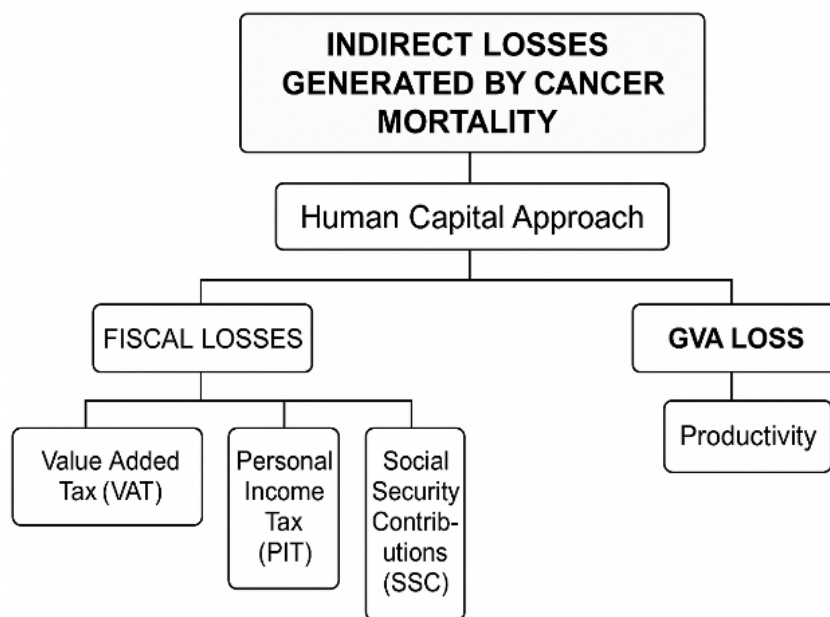
Source: authors' design

Hanly et al. (2015) is particularly well represented, as the author uses labour force datasets, mortality rates, and national productivity indicators and apply them across European countries in order to obtain the economic losses due to premature cancer deaths using the human capital approach. Also, the Global Burden of Disease (GBD) studies by the Institute for Health Metrics and Evaluation (IHME) regularly apply variants of this methodology for broader disease cost estimations.

The objective of this methodological approach is to quantify the **indirect economic costs** of cancer-related premature mortality in the active population (20–64 years), based on annual data at the national level.

Key Indicators

- **Active Population (20–64 years):** It indicates the segment of the labour force affected by cancer-related mortality.
- **Crude Mortality Rate (Cancer, Active Population)**: Expressed per 100,000 active people. Allows estimation of the annual number of premature deaths due to cancer.
- **Estimated Deaths**: $Deaths = (Crude\ Mortality\ Rate\ at\ 100{,}000) \times Active\ Population$
- **Productivity Proxy (per Worker)**: Based on **average hourly productivity** x **number of working hours per year**. For non-eurozone countries productivity was initially expressed in local currency and converted to EUR using **annual average exchange rates** from national banks.
- **Indirect Cost Estimate (Gross value added per Year t)**:
  $$Indirect\ Cost = Annual\ Deaths\ (active\ patients)\ x\ Hourly\ labor\ Productivity\ x\ Annual\ average\ number\ of\ hours$$
- **Fiscal costs:** the sum of Social contributions, Personal income tax and VAT amounts uncollected by the state budget. The social contributions and PIT were derived from the difference between gross and net average wages per year, while the uncollected VAT was calculated based on the average consumption propension and the standard VAT rate for every country considered.

Evolution of Crude Mortality Rate in Relation to Fiscal Revenue Loss and GDP Productivity Loss – Cross – Country comparison

A cross-sectional analysis of average cancer-related mortality rates among active individuals (aged 20–64 years old) and their associated economic impacts for the period 2015–2023 reveals striking disparities between Western and Eastern European countries, both in health outcomes and in economic vulnerability.

France emerges as the country with the highest estimated indirect economic burden, recording an average annual gross value added (GVA) loss of €2.6 billion and a fiscal revenue loss of €904 million, leading to a cumulative average annual economic loss of approximately €3.52 billion. This substantial figure is primarily driven by France's large working-age population and high productivity per worker. Notably, this burden is incurred despite France having one of the lowest average 2015-2023 mortality rates among active

persons (107 per 100,000), suggesting that the economic value of each premature death is particularly high in high-income economies due to elevated wage and output levels.

In contrast, Romania, while exhibiting a significantly higher average cancer mortality rate (152 per 100,000 active persons) in the same period registers a total annual economic loss of approximately €564 million, with GVA loss accounting for €466 million and fiscal loss at €98 million. Romania's elevated mortality burden, paired with more modest productivity levels, positions it as a high-risk country in relative terms, where gains in cancer prevention and treatment could deliver substantial cost-effectiveness for public budgets and economic output.

Similarly, countries such as Belgium and Portugal display intermediate profiles. Belgium's lower average mortality rate (87) still yields nearly €600 million in total annual economic losses, underscoring the amplifying role of high productivity levels. Portugal, with a mortality rate of 116, reports €248 million in GVA loss and €71 million in fiscal loss, resulting in €319 million in total losses.

In Eastern and Southeastern Europe, the overall economic burden is markedly lower in absolute terms but not necessarily in relative impact. Moldova, Montenegro[1], and North Macedonia display average mortality rates ranging from 110 to 129 per 100,000, with relatively modest total economic losses (ranging between €16–€29 million annually). These figures are reflective of both smaller population sizes and lower average productivity levels. However, they mask deeper structural vulnerabilities: in economies with limited fiscal capacity and lower resilience, even modest absolute losses can represent a substantial proportion of national GDP or tax revenue. A summary of GVA, Fiscal and Total losses can be found in Table 1.

From a policy standpoint, these findings confirm that cancer mortality among the working-age population constitutes a dual threat—both to health systems and to macroeconomic sustainability. The magnitude of indirect economic costs is not solely a function of mortality rates but is highly influenced by labour productivity, wage structures, and demographic profiles. As such, strategic investments in cancer prevention and early intervention programs—particularly in countries with high mortality and rising fiscal pressures—should be recognised not only as public health priorities but also as economic imperatives.

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[1] Due to data limitation, estimates for Montenegro covers only 2022 and 2023

Table 1 Average economic indirect costs caused by cancer mortality

	Average mortality rate (active persons at 100000)	Average 2015–2023 (mil. EUR)		
		GVA loss	Fiscal loss	Total
Romania	152	466	98	564
Moldova	129	26	3	29
France	107	2616	904	3520
Belgium	87	424	172	597
Bulgaria	138	79	18	97
Portugal	116	248	71	319
North Macedonia	110	19	5	24
Montenegro*	127*	14*	2*	16*

Source: authors estimates; * due to data limitation, estimates for Montenegro covers only 2022 and 2023

The cross-country analysis offers valuable insight into broad patterns and structural disparities across Europe. However, to fully understand the economic and policy implications of cancer-related mortality, it is essential to examine national dynamics in greater detail. The following country chapters provide focused case studies that explore how these economic costs have evolved over time, revealing the interplay between health system resilience, demographic change, and labor market pressures in each national context.

Romania

An analysis of the Romanian data from 2015 to 2023 reveals important dynamics between cancer-related mortality in the active population (20–64 years) and the broader economic losses incurred through diminished fiscal revenues and reduced GDP output.

Throughout the period under review, the crude mortality rate among active individuals initially exhibited a modest decline, reflecting gradual improvements in healthcare access and early detection efforts up to 2019. However, from 2020 onward, a notable reversal is observed, with mortality rates climbing sharply. This pattern is presented in Figure 2 and is consistent with broader health system stresses, potentially exacerbated by the COVID-19 pandemic, delayed diagnoses, and treatment disruptions, all of which likely intensified cancer mortality trends.

Figure 2 Cancer mortality in Romania for active persons (2015–2023)
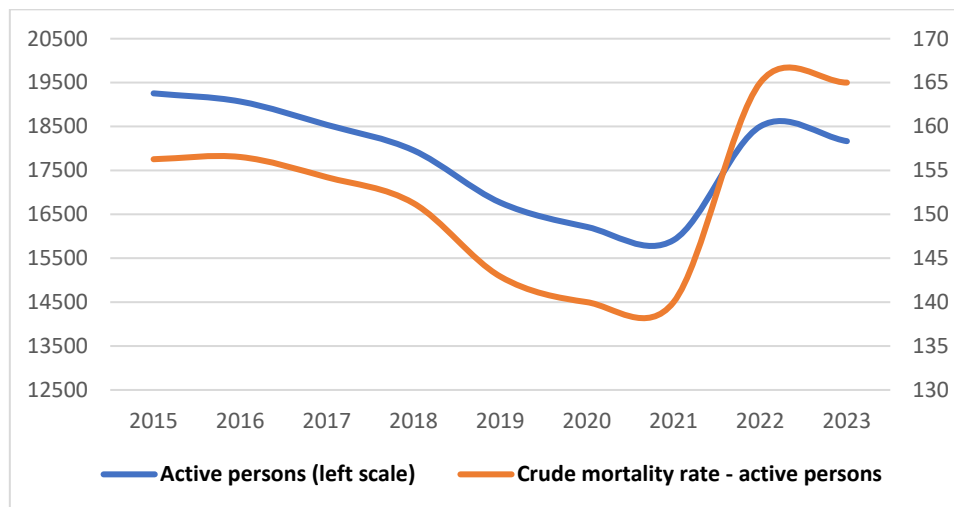
Source: authors estimate

In parallel, the estimated fiscal revenue losses—representing the diminished public tax intake due to premature deaths among economically active individuals—demonstrated a gradual but persistent increase from 2015 to 2019 (social contributions, PIT and VAT). During this initial phase, fiscal losses grew from approximately €53 million in 2015 to over €105 million in 2019. Following the mortality trend shift, fiscal losses accelerated markedly, reaching €133 million by 2022 and surpassing €147 million by 2023.

This suggests a nonlinear relationship wherein small deteriorations in mortality among active individuals can produce amplified fiscal consequences, reflecting both lost income tax contributions and diminished consumption tax bases.

The annual GDP loss attributable to lost productivity mirrors this trajectory, as can be seen in Figure 3. From a baseline of approximately €36 million in 2015, GDP losses rose steadily, reaching over €436 million by 2019. Post–2020, this trend steepened dramatically, with GDP productivity losses escalating to €615 million in 2022 and close to €700 million in 2023. The sharp rise in productivity losses relative to mortality rate changes underscores the compounding effects of labour market shrinkage: as active labour supply contracts due to health shocks, the marginal productivity of remaining workers rises, thus amplifying the economic value of each premature loss.

Figure 3 Economic indirect costs of cancer mortality in Romania (2015–2023)
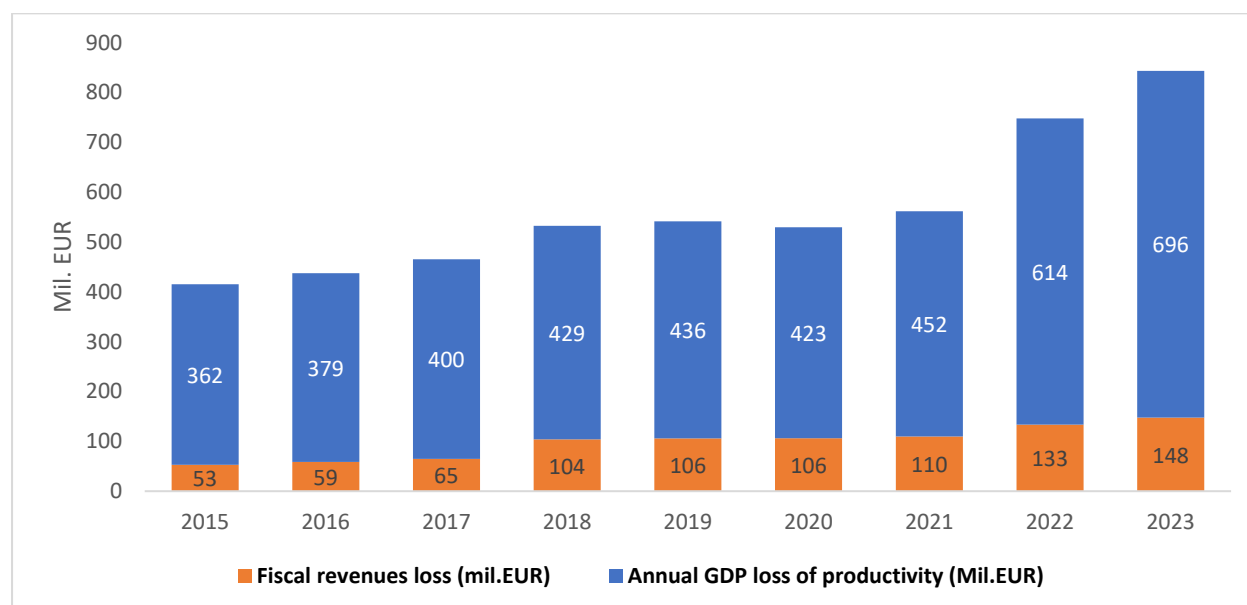
Source: authors estimate

Importantly, this analysis reveals that the indirect economic costs of cancer mortality are increasing at a faster rate than the crude mortality rate itself. This divergence is critical for policymakers: it highlights that improving survival rates among the working-age population yields not only health benefits but also significant fiscal and economic returns. Moreover, the data suggests that economic vulnerability to health shocks is intensifying over time, driven by structural demographic trends, including population aging and declining labour force participation.

In conclusion, the evolution of the crude cancer mortality rate among Romania's active population is closely and increasingly tied to substantial fiscal revenue and GDP productivity losses. These findings emphasize the urgent need for integrated public health and economic policy strategies that prioritise cancer prevention, early detection, and treatment as mechanisms to safeguard not only individual health but also national economic resilience.

Moldova

The analysis of Moldavian data for the 2015-2023 mirrors largely the Romanian situation, showing significant dynamics between cancer-related mortality in the active population (20-64 years) and economic losses due to lower fiscal revenues and reduced GDP. In a nutshell, the data and our calculations indicate that the indirect economic costs of cancer mortality are increasing at a faster rate than crude mortality rates, highlighting the compounding economic effects of health system challenges and demographic shifts.

Throughout the period under analysis, the crude mortality rate among active individuals (aged 20-64) initially showed a promising decline, falling from 130.99 per 100,000 individuals in 2015 to 122.58 per 100,000 individuals in 2018. Figure 4 summarises this downward trend reflected gradual improvements in healthcare access, early detection programs, and treatment protocols implemented during the mid-2010s. However, after 2018, a concerning reversal emerged. Mortality rates stabilised at 120 per 100,000 individuals from 2019-2021, before experiencing a sharp deterioration to 144 per 100,000 individuals in both 2022 and 2023. This 20% increase represents a significant departure from the earlier positive trajectory and likely reflects multiple converging factors including health system stresses exacerbated by the COVID-19 pandemic, as well as resource constraints.

Figure 4 Cancer mortality in Moldova for active persons (2015-2023)
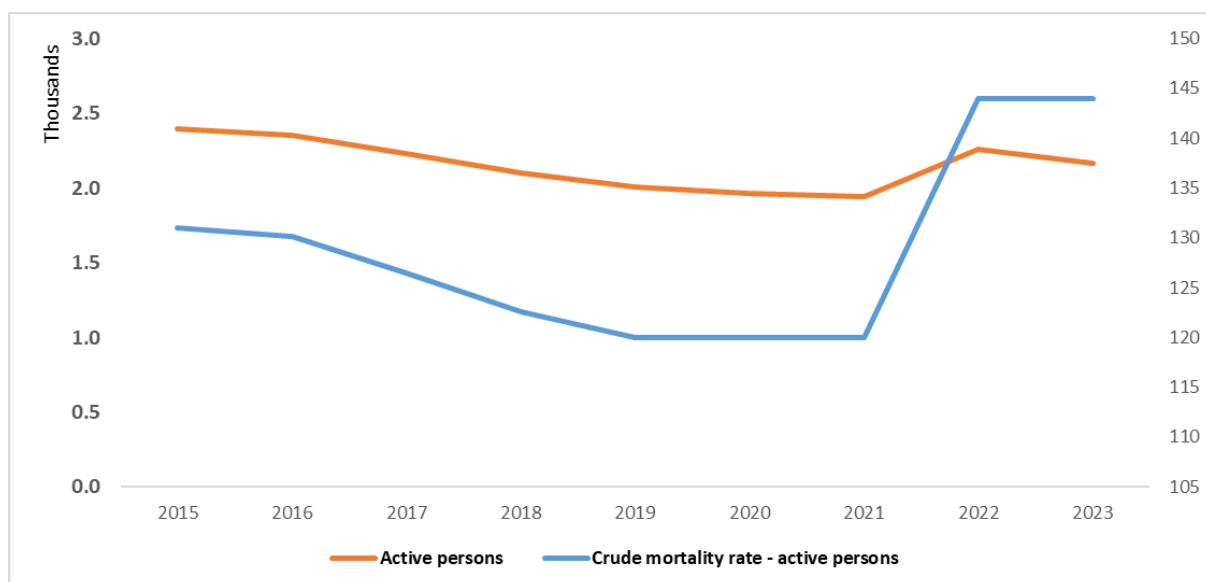
Source: authors estimate

The number of affected persons in the active population peaked at 4,903 individuals in 2016, declined to 4,547 by 2021, but then surged dramatically to 5,207 in 2022 and 5,059 in 2023. This pattern mirrors the mortality rate trends and underscores the substantial human cost of the health system challenges experienced during the post-2019 period.

The estimated fiscal revenue losses, which reflect the diminished public tax intake due to premature deaths among economically active individuals, show a concerning upward trajectory throughout the period under analysis. These losses encompass social security contributions, personal income tax (PIT), and value-added tax (VAT) from reduced consumption.

During the initial period from 2015 to 2018, fiscal losses grew gradually from approximately €1.98 million to €2.56 million, reflecting both demographic changes and modest

economic growth. However, the period from 2019 onward witnessed an acceleration in fiscal losses, reaching €2.78 million in 2019 and continuing to climb to €2.97 million in 2021.

The most dramatic increase in fiscal losses occurred in the final two years of analysis, in 2022 and 2023, when they reached €4.21 million (2022) and €4.81 million (2023) – this represents a 143% increase from 2015.

The composition of these losses reveals important insights: social security contributions and personal income tax losses grew from €1.08 million in 2015 to €2.43 million in 2023, while VAT losses from reduced consumption increased from €0.89 million to €2.38 million over the same period. This demonstrates that cancer mortality affects government revenues through multiple channels, with both direct wage-related taxes and indirect consumption taxes suffering substantial impacts.

The annual GDP loss attributable to lost productivity mirrors and amplifies the fiscal revenue trajectory. From €19.88 million in 2015, GDP losses initially fluctuated, reaching €20.40 million in 2016 and climbing to €25.22 million by 2018. During this period, productivity losses represented a relatively stable share of national GDP, close to 0.3% of GDP.

Following 2018, GDP productivity losses demonstrated increased volatility, declining to €24.15 million in 2019 and €23.80 million in 2020, before recovering to €26.67 million in 2021. However, the final two years witnessed a dramatic acceleration, with productivity losses reaching €36.14 million in 2022 and €37.79 million in 2023, representing a 90% increase from 2015 levels.

The sharp rise in productivity losses relative to mortality rate changes underscores the compounding effects of labour market dynamics. As active labour supply contracts due to health issues diminishes, the marginal productivity of remaining workers rises, thus amplifying the economic value of each premature loss in the active population. Additionally, Moldova's improving labour productivity, which increased from €4.49 per hour in 2015 to €9.03 per hour in 2023, means that each lost worker represents an increasingly economic contribution.

When combining fiscal revenue and GDP productivity losses, the total economic impact reveals the full magnitude of cancer mortality costs. Total economic losses grew from €21.85 million in 2015 to €42.60 million in 2023, representing a cumulative loss of €264.23 million over the nine-year period, as can be seen in Figure 5.

Figure 5 Economic indirect costs of cancer mortality in Moldova (2015–2023)
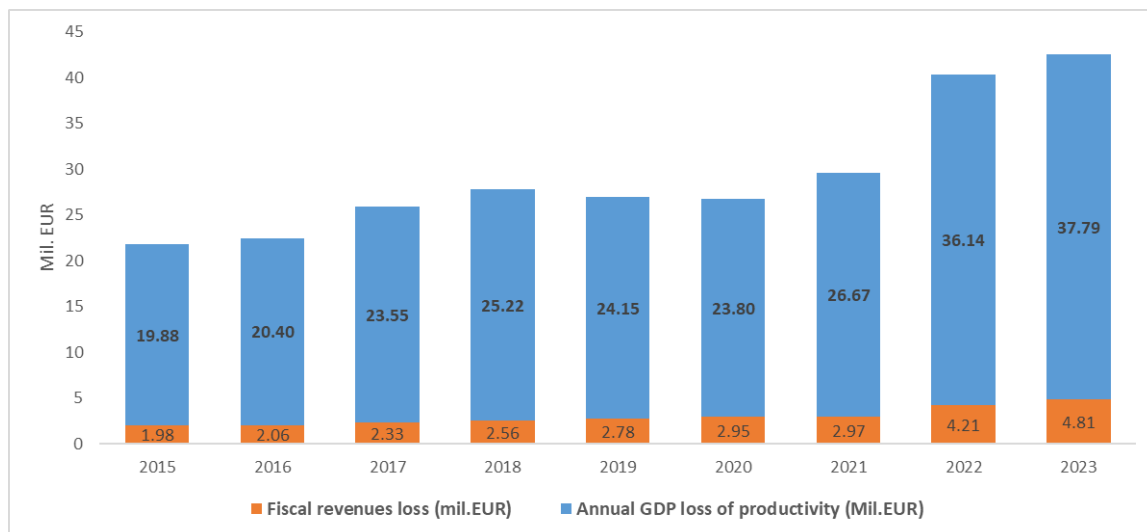
Source: authors estimate

The analysis reveals that indirect economic costs are increasing at a rate significantly exceeding the crude mortality rate changes. While mortality rates increased by 20% between 2019 and 2023, economic losses surged by over 58% during the same period. This divergence needs to be well understood for policymakers as it highlights that improving the survival rates among the working-age population offers not only health benefits but also substantial fiscal and economic returns.

Simultaneously, rising wages and productivity amplify the economic value of each lost worker. Average gross earnings increased from €217 per month in 2015 to €622 per month in 2023, while hourly productivity grew from €4.49 to €9.03. These improvements, while positive for living standards, also mean that cancer mortality represents an increasingly costly economic loss.

The evolution of cancer mortality rates among Moldova's active population is closely and increasingly tied to substantial fiscal revenue and GDP productivity losses. The data reveals that the country's economic vulnerability to health shocks was intensifying over time, driven by demographic contraction, rising productivity, and wage growth that amplifies the cost of each premature death. Moreover, there are compound effects where modest improvements in cancer survival could yield disproportionate economic benefits. Conversely, deteriorating mortality rates produce amplified economic costs, as demonstrated in the 2022–2023 period (post-COVDI19 shock). Furthermore, cancer mortality affects government finances through multiple channels - direct wage taxes, social contributions, and indirect consumption taxes - requiring comprehensive policy responses that address both healthcare and economic dimensions. Finally, the €264.23 million in cumulative losses over nine years provides a compelling economic justification for substantial investments in cancer prevention, early detection, and treatment

infrastructure. Even modest improvements in survival rates would generate significant returns on investment.

The findings emphasize the urgent need for integrated public health and economic policy strategies that prioritise cancer prevention, early detection, and treatment as mechanisms to safeguard not only individual health but also national economic resilience. Given Moldova's shrinking active population and rising productivity, each successful intervention to reduce cancer mortality yields increasingly valuable economic returns. Policymakers must recognise that investments in cancer care represent not just humanitarian imperatives but critical economic infrastructure that protects Moldova's fiscal sustainability and economic growth potential. Future policy development should prioritise comprehensive cancer control strategies that integrate prevention, early detection, treatment, and survivorship care while recognising the substantial economic returns such investments generate for Moldova's long-term economic stability and growth.

France

France is among countries that are determined to fight against cancer. France launched a new National Cancer Strategy 2021-30, with a funding of EUR 1.74 billion over five years – an increase of 20% on the previous strategy. The Strategy is structured around four key priorities, aligned with those from the Europe's Beating Cancer Plan (Prevention, Early Detection, Diagnosis and Treatment, Quality of Life) (OECD, 2025). Each pillar has its own contribution to indirect cost, by reducing the impact of cancer on the productivity, on absenteeism rate or invalidity. Many studies underline, for example, the role of risk factors in improving the active life and in diminishing the health system burden of the disease (Miszczyńska et al. 2025; Franklin et al. 2024; Noël Racine et al. 2022).

According to the OCDE data (2025), the overall cancer mortality rates is lower in France than the EU average. France has a healthcare system that ensures widespread availability of high-quality cancer care (radiotherapy equipment supply exceeds the EU average, the number of medical oncologists has doubled since 2012, and the public expenditure on cancer care is increasing, reaching EUR 22.6 billion in 2022, mostly due to the rising of drug costs) (OECD, 2025, p. 3).

The crude mortality rate among active individuals, presented in Figure 6, in France exhibited a slow decline until 2021 (from 112 in 2015 to 99 in 2021) and registered an increase to 114 in 2022 and 2023. The rise is broadly credited to COVID-19 pandemic, that overstrained the health systems all over the world, causing significant delays in the screening, detection and treatment of many diseases, including cancer.

Figure 6 Cancer mortality in France for active persons (2015 – 2023)
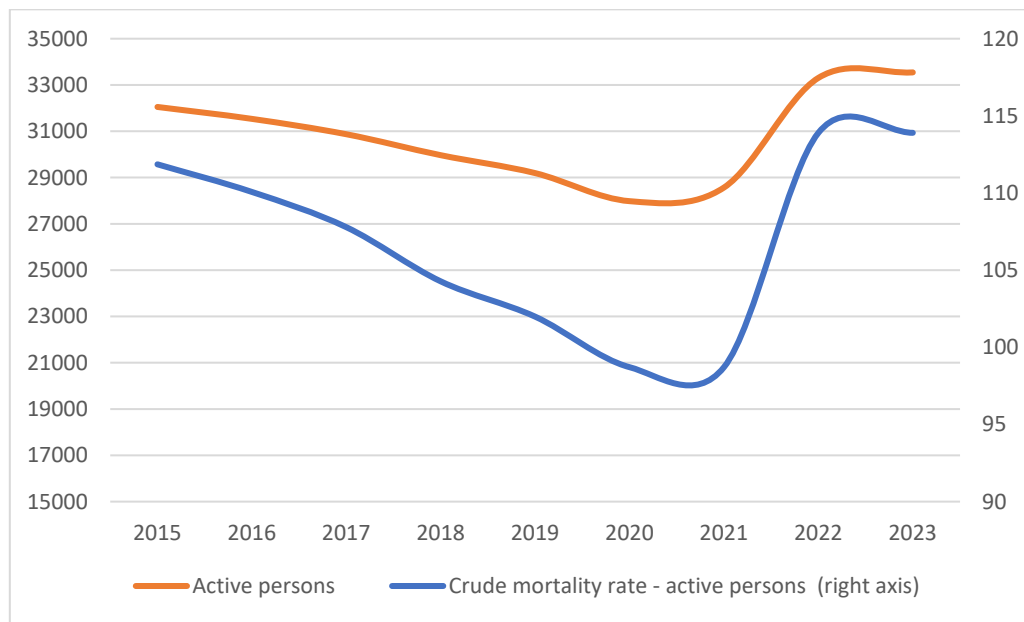
Source: authors estimate

The estimated fiscal revenue losses - representing the diminished public tax intake due to premature deaths among economically active individuals—display a gradual decrease until 2020 (social contributions, PIT and VAT), from almost 935 mil euros in 2015, to 775.2 mil euros in 2020, when it reached the lowest level. It started to increase in 2021, to 837.6 mil euros (still not exceeding the 2015 level), and reaching 1077.8 mil euro in 2023 (Figure 7). This evolution is consistent with the costs generated by the blockage of the health system during the pandemic.

Figure 7 Economic indirect costs of cancer mortality in France (2015–2023)
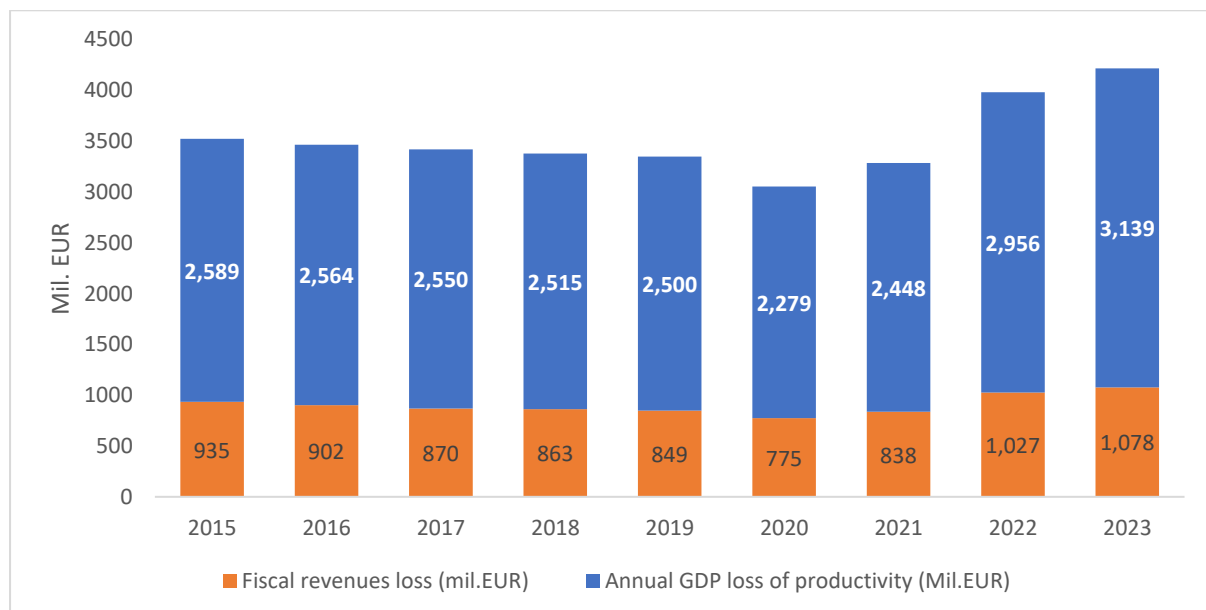
Source: authors estimate

The annual GDP loss attributable to lost productivity reflects similar evolution. In absolute terms (mil euros), it registered a slow decrease during 2015 – 2021. From 2022 it started to grow, exceeding the value for 2015 in 2022. However, in relative terms (% of the GDP), the percentage remained below the 2015 value, even in the face of more substantial increases in absolute value in 2023. It seems that constant productivity growth has counteracted the negative effects generated by health shocks (see Figure 8).

Figure 8 Annual loss of Productivity
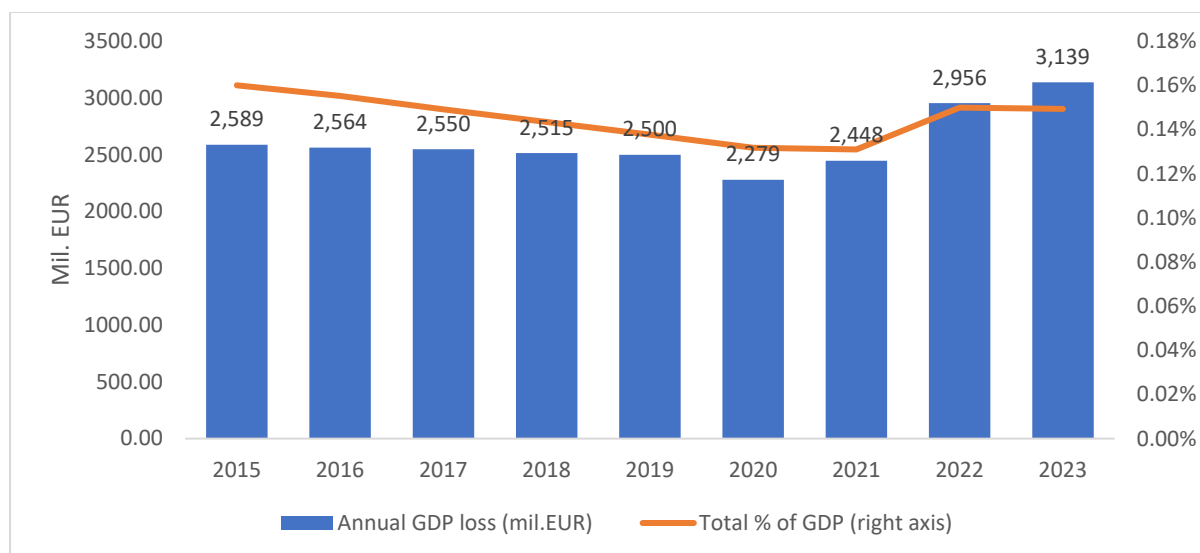
Source: authors estimate

A rise in the crude mortality rate among active persons directly affects a country's GDP and fiscal situation. When economically active people die prematurely, the labour force shrinks, reducing overall output, and negatively affect the GDP growth. At the same time, the government loses income tax revenues and social contributions, while facing higher public spending on healthcare. In time, this imbalance leads to fiscal losses, intensifies the economic burden of premature mortality, weaken economic resilience and increases pressure on public finances.

As Figure 9 suggest, at least before COVID-19 pandemic, the pace of the cancer crude mortality rate to active persons decreased at a higher rhythm comparing to the GDP and fiscal losses evolution. This marked a positive trend, demonstrated by the improvements in the French Health System: better prevention, early detection, innovations in treatments, better drugs etc. However, after COVID-19 pandemic, fiscal and GDP losses impact started to increase, as well as crude mortality rate, being consistent with the fact other factors generated by the consequences of the heath system obstruction during the pandemic, or by the rising in the treatment costs are driving the economic stress.

Figure 9 Evolution of the cancer crude mortality rate to active persons and the GDP and fiscal losses (2015–2023)
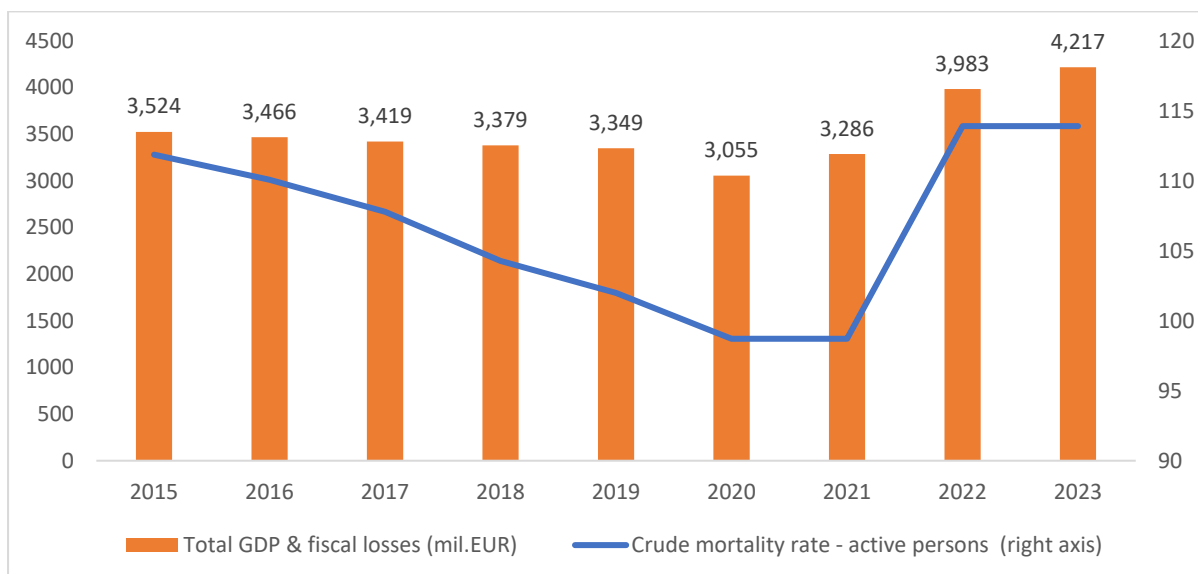
Source: authors estimate

It is estimated that cancer will have a major impact on the workforce in France. During 2023-50 on average, there is expected to be a loss of 169 full-time equivalent workers (FTEs) per 100 000 people in France due to the need to reduce employment because of cancer, as well as 38 FTEs per 100 000 due to absenteeism and 43 FTEs per 100 000 due to presenteeism (Presenteeism refers to lost productivity that occurs when employees are not fully functioning in the workplace because of an illness, injury or other condition) (OCDE, 2025, p. 5). This is a sign that public health, in general, and economic policies must adapt to address to the rest of the consequences of cancer disease, such as long-term care and productivity loss.

Bulgaria

The analysis of Bulgarian health and economic data spanning 2015-2023 examines the profound relationship between cancer mortality in the economically active population (ages 20-64) and the resulting fiscal and productivity losses. The findings reveal a disturbing pattern (Figure 10) where economic costs associated with cancer mortality are escalating more rapidly than mortality rates themselves, indicating Bulgaria's growing economic vulnerability to health-related demographic shifts and healthcare system pressures.

Bulgaria's cancer mortality trajectory among the active population reveals concerning fluctuations with an alarming recent deterioration. Beginning from 141.62 deaths per 100,000 active individuals in 2015, crude mortality rates demonstrated initial improvement, declining to 131.77 per 100,000 by 2017. This brief positive trend suggested that healthcare system reforms and improved access to cancer treatments were beginning to yield results.

However, the period from 2018 onwards tells a more troubling story. Mortality rates began climbing again, reaching 137.09 per 100,000 in 2019, before experiencing some stabilisation around 133.99 per 100,000 during 2020-2021. The most concerning development occurred in 2022-2023, when mortality rates surged to 148.1 per 100,000, representing a 10.5% increase from 2015 levels and marking the highest rates recorded throughout the analysis period.

Figure 10 Cancer mortality in Bulgaria for active persons (2015–2023)
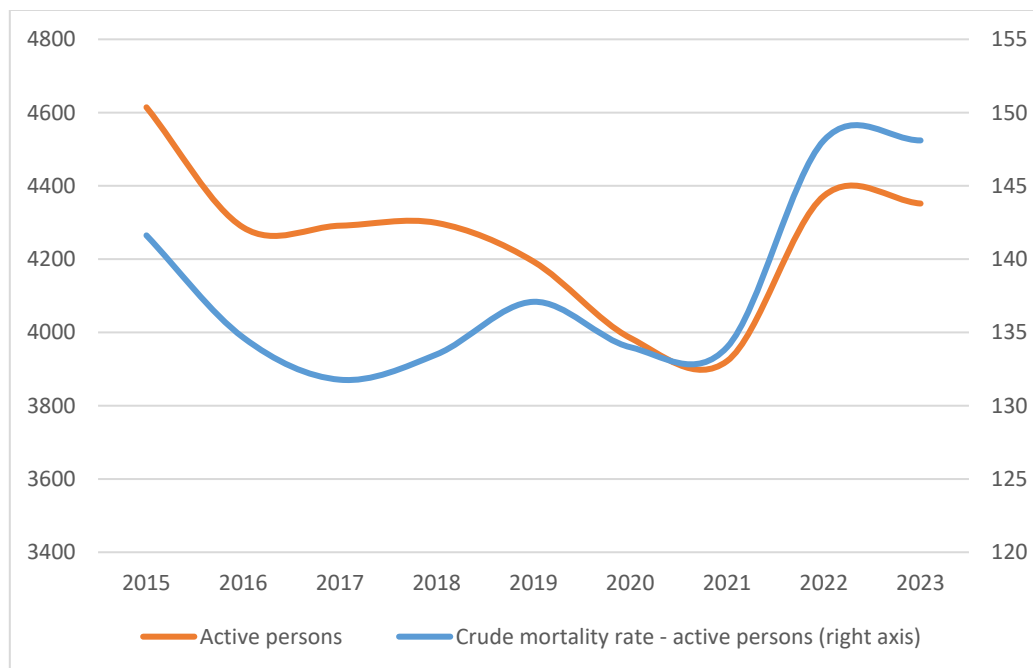
Source: authors estimate

The absolute number of cancer-affected individuals in the active population tells a parallel story of concern. Starting with 17,504 affected persons in 2015, the numbers fluctuated between approximately 16,650-17,450 through 2021, before jumping to 17,827 in 2022 and stabilising at 17,731 in 2023. This pattern reflects not only mortality trends but also Bulgaria's changing demographic composition and healthcare system challenges. Considering both Romania's and Moldova's cases, this further suggests regional healthcare system vulnerabilities that may be linked to pandemic-related disruptions, resource constraints, and delayed diagnosis protocols that became prevalent across Eastern Europe during this period.

The fiscal consequences of cancer mortality among Bulgaria's active population have grown substantially, creating mounting pressure on public finances. Total fiscal revenue losses encompassing social security contributions, personal income tax, and consumption-related VAT have demonstrated a persistent upward trajectory throughout the analysis period.

From a baseline of €12.95 million in fiscal losses during 2015, the burden increased gradually to €15.84 million by 2018. This initial period reflected steady but manageable growth in line with Bulgaria's economic development and wage increases. However, the acceleration phase began in 2019, with fiscal losses reaching €17.28 million and continuing their climb to €19.29 million in 2021. The most dramatic escalation occurred during 2022–2023, when fiscal losses surged to €24.61 million and €27.54 million respectively. This represents a remarkable 113% increase from 2015 levels, demonstrating how cancer mortality's fiscal impact has more than doubled over the analysis period (Figure 11).

Figure 11 Economic indirect costs of cancer mortality in Bulgaria (2015–2023)
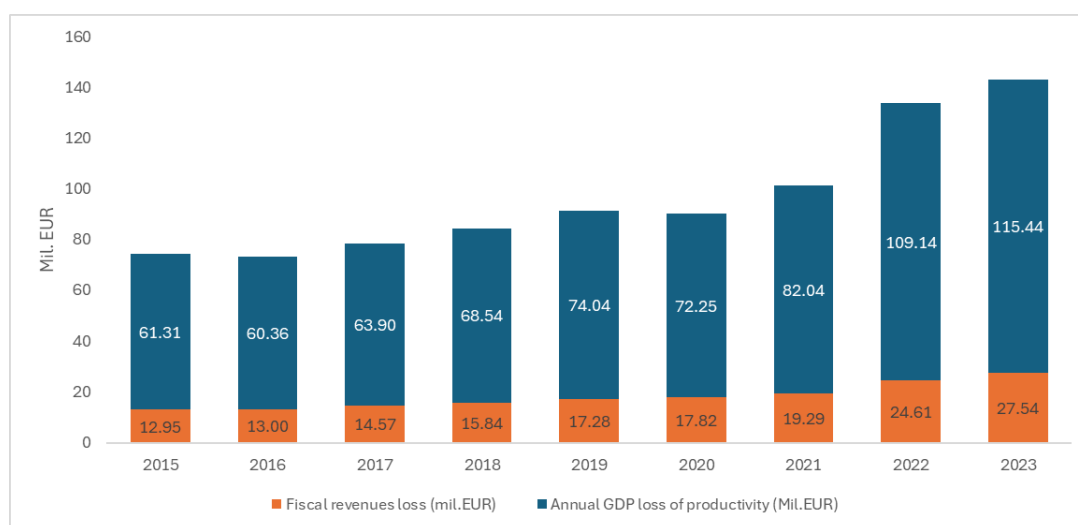
Source: authors estimate

Breaking down these losses by component reveals important insights into the country's fiscal mechanisms. Social security contributions and personal income tax losses increased from €10.14 million in 2015 to €21.84 million in 2023, actually more than doubling over the period. Simultaneously, VAT losses from reduced consumption grew from €2.80 million to €5.70 million, reflecting both the direct consumption impact of lost workers and the multiplier effects of reduced economic activity.

Bulgaria's GDP productivity losses due to cancer mortality present an even more striking picture of economic vulnerability. Beginning from €61.31 million in 2015, productivity losses initially fluctuated, declining to €60.36 million in 2016 before climbing steadily to €74.04 million by 2019. The period 2020–2021 witnessed some moderation, with losses falling to €72.25 million in 2020 and rising to €82.04 million in 2021. However, the final two years of analysis revealed an explosive growth, with productivity losses reaching €109.14 million in 2022 and €115.44 million in 2023. This represents an 88% increase from 2015 levels and reflects the compounding effects of Bulgaria's rising labour productivity on the economic value of each lost worker.

The relationship between productivity growth and economic losses is particularly pronounced in Bulgaria's case. Average hourly productivity increased from €8.08 in 2015

to €16.39 in 2023, more than doubling over the period. This substantial productivity enhancement means that each cancer-related death now represents a substantially larger economic loss than in previous years, creating a scenario where even stable mortality rates would generate growing economic costs.

Combining fiscal and productivity losses reveals the comprehensive economic impact of cancer mortality in Bulgaria. Total economic costs surged from €74.25 million in 2015 to €142.97 million in 2023, representing a cumulative burden of €869.90 million over the nine-year analysis period. The growth trajectory shows distinct phases: modest increases through 2018 (reaching €84.37 million), accelerated growth during 2019-2021 (peaking at €101.33 million), and explosive expansion during 2022-2023. The final two years alone account for €276.73 million in economic losses, representing nearly one-third of the total nine-year burden.

This economic burden consistently represents approximately 0.24-0.31% of Bulgaria's GDP throughout the period, indicating that cancer mortality among the active population imposes a measurable toll on national economic performance. While this percentage appears modest, the absolute amounts represent substantial resources that could otherwise contribute to economic growth and development.

Bulgaria's demographic landscape amplifies the economic impact of cancer mortality. The active population contracted from 3.26 million in 2015 to 2.94 million in 2023, representing a 9.8% decline. This demographic compression means that each lost worker represents an increasingly significant portion of the available labour force. Simultaneously, Bulgaria's economic development has accelerated the value of human capital. Average gross earnings expanded from €545 monthly in 2015 to €1,198 monthly in 2023, while net earnings grew from €362 to €780 over the same period. This wage growth, combined with productivity improvements, creates a situation where cancer mortality represents an ever-escalating economic cost.

The evolution of cancer mortality costs in Bulgaria yields several critical insights for policy development: (i) As productivity and wages continue growing, the economic consequences of health system failures become increasingly severe, creating a compelling case for preventive healthcare investments; (ii) As the analysis reveals that economic costs are growing substantially faster than mortality rates, indicating multiplicative rather than linear relationships between health outcomes and economic impacts, this suggests that even modest improvements in cancer survival could generate disproportionately large economic benefits; (iii) Cancer mortality affects government finances through multiple simultaneous channels - direct wage taxes, social contributions, and consumption taxes - which requires comprehensive and integrative policy responses that address both healthcare and economic dimensions of the challenge; (iv) The €869.90 million cumulative economic loss over nine years provides substantial justification for significant investments in cancer prevention, early detection, and treatment infrastructure.

Overall, Bulgaria's experience with cancer mortality costs demonstrates that health system performance increasingly determines economic outcomes as countries develop. The 88% increase in productivity losses and 113% increase in fiscal losses over the analysis period underscore that traditional approaches to healthcare investment may be inadequate for addressing the scale of economic consequences generated by cancer mortality.

The dramatic acceleration in costs during 2022-2023 serves as a critical warning about the economic consequences of healthcare system stress. The pandemic period's legacy appears to include lasting impacts on cancer outcomes that continue generating substantial economic costs well beyond the immediate health crisis. Future policy development should prioritise comprehensive cancer control strategies that recognise the substantial economic returns generated by improved survival rates. Given Bulgaria's rising productivity and wages, each successful intervention to reduce cancer mortality yields increasingly valuable economic benefits, making healthcare investments not just social imperatives but critical economic infrastructure investments.

Portugal

The analysis of Portuguese cancer mortality data reveals a critical public health and economic challenge with far-reaching implications for the nation's fiscal stability and economic development. Between 2015 and 2023 (Figure 12), Portugal experienced an important deterioration in cancer mortality among its economically active population, accompanied by escalating indirect economic costs that significantly outpaced the underlying mortality trends.

Portugal's cancer mortality trajectory among the economically active population presents a complex pattern of gradual deterioration punctuated by sharp increases. There are three distinct phases that reflect broader challenges within the Portuguese healthcare system and societal pressures. During the initial period from 2015 to 2017, crude mortality rates demonstrated a steady upward pressure, rising from 112 per 100,000 to 117 per 100,000 active individuals. This 4% increase occurred despite Portugal's ongoing healthcare reforms and EU-supported improvements in cancer screening programs. The gradual nature of this increase suggests structural challenges in cancer care delivery, possibly related to healthcare access disparities between urban and rural areas, or delays in implementing comprehensive cancer control strategies.

Figure 12 Cancer mortality in Portugal for active persons (2015–2023)
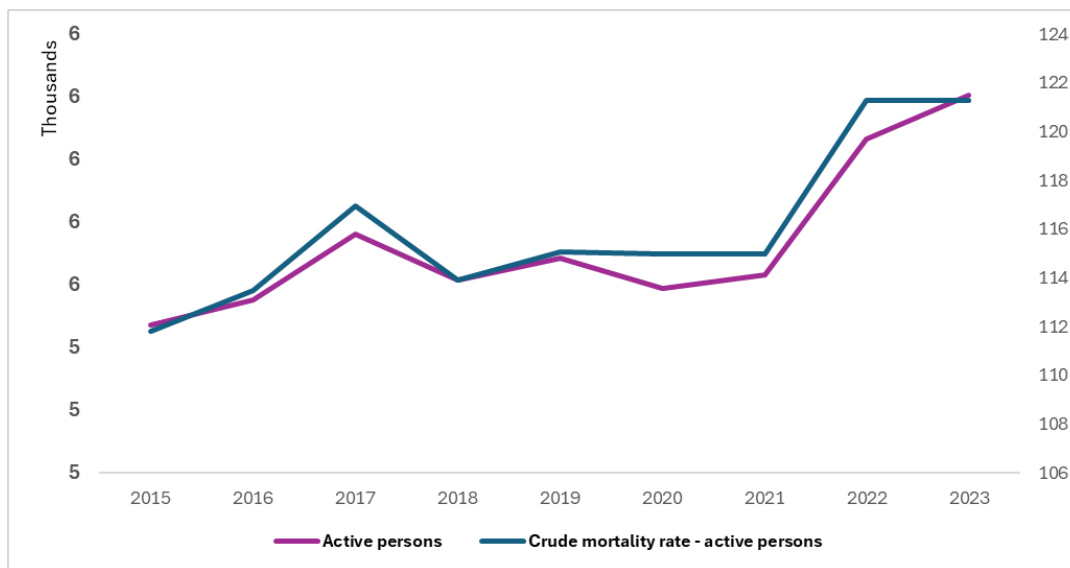
Source: authors' estimate

The period from 2017 to 2021 witnessed a decline in crude mortality rates, as they reached 114 per 100,000 individuals in 2020 and slightly increasing to 115 per 100,000 by 2021. This timeframe coincides with the COVID-19 pandemic's impact on healthcare systems globally, and this data shows the remarkable resilience of the Portuguese health system faced with a large array of pandemic challenges.

However, an alarming development occurred in the final two years of analysis, with mortality rates surging to 121 per 100,000 in 2022 and 2023, which represents a 5% increase from 2021 levels and may suggest that the pandemic's delayed effects on cancer outcomes became fully manifest in subsequent years.

In absolute terms, the number of cancer deaths among active individuals increased from approximately 26,880 in 2015 to 35,010 in 2023. This 30% increase in affected persons reflects not only higher mortality rates but also Portugal's expanding active population, which grew by 4.5% over the same period. The combination of a growing workforce and deteriorating health outcomes creates a particularly challenging situation for economic planning and healthcare resource allocation.

The fiscal consequences of cancer mortality in Portugal's active population demonstrate a concerning trajectory that significantly outpaces the underlying mortality trends. These losses encompass multiple revenue streams, including social security contributions, personal income tax, and value-added tax from reduced consumption, creating a compound effect on government finances.

Fiscal revenue losses grew from €60.0 million in 2015 to €93.2 million in 2023, representing a 55.2% increase that substantially exceeds the 24.6% increase in mortality rates. This amplification reflects the dynamic nature of Portugal's tax system and the country's economic development trajectory during the analysis period.

The composition of fiscal losses reveals important insights into the mechanisms through which cancer mortality affects government revenues. Social security contributions and personal income tax losses constitute the largest component, growing from €49.5 million in 2015 to €76.9 million in 2023. This 55.3% increase reflects both higher mortality rates and the substantial growth in Portuguese wages over the period.

Portugal's average gross earnings increased by 36.5% during the analysis period, rising from €1,791 monthly in 2015 to €2,446 monthly in 2023. This wage growth, while positive for living standards, amplifies the fiscal impact of each cancer death among active workers. Higher wages generate proportionally higher tax contributions, meaning that the fiscal cost of premature mortality increases even when mortality rates remain constant.

Value-added tax losses from reduced consumption patterns add another dimension to the fiscal impact. These losses grew from €10.5 million in 2015 to €16.2 million in 2023, representing a 54.2% increase. The VAT component reflects the broader economic ripple effects of cancer mortality, as deceased individuals can no longer participate in consumer spending that drives economic activity and tax generation.

The acceleration of fiscal losses in the final years of analysis is particularly notable. Between 2021 and 2023, fiscal losses increased by 25.8%, far exceeding the 15.6% increase in mortality rates during the same period. This suggests that Portugal's improving economic conditions paradoxically increase the country's vulnerability to health-related fiscal losses.

The productivity losses attributable to cancer mortality among Portugal's active population represent the largest component of indirect economic costs, reflecting the substantial economic value generated by workers in their prime productive years. These losses demonstrate both the immediate impact of premature deaths and the long-term consequences for Portugal's economic development trajectory.

Annual GDP productivity losses increased from €213.8 million in 2015 to €319.5 million in 2023, representing a 49.5% surge over the nine-year period. This growth rate significantly exceeds the underlying mortality rate increase, highlighting how Portugal's improving labour productivity amplifies the economic cost of each cancer death, as can be seen in Figure 13.

Figure 13 Economic indirect costs of cancer mortality in Portugal (2015–2023)
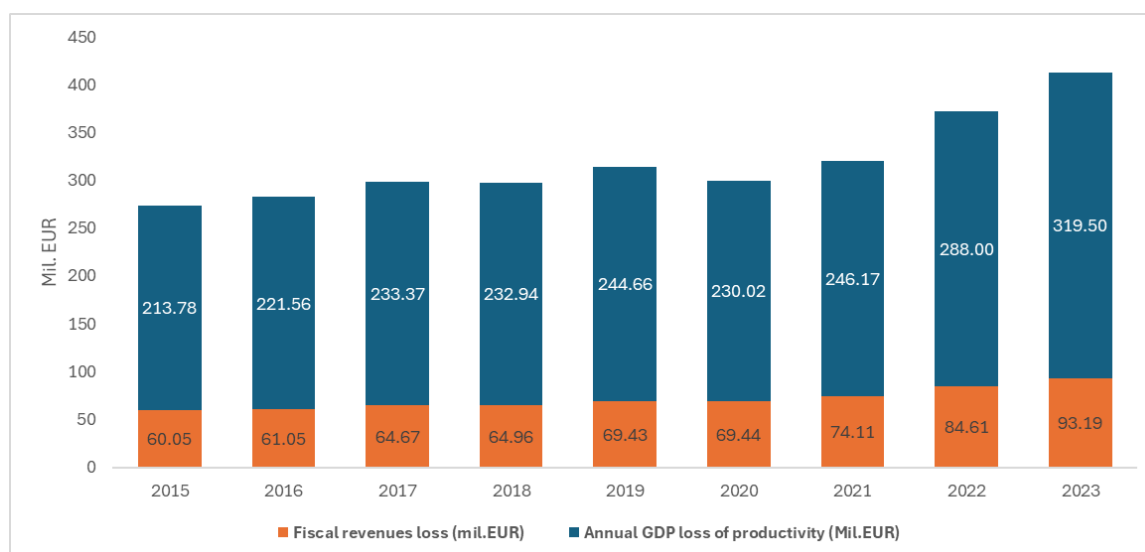
Source: authors' estimate

Portugal's hourly labour productivity experienced remarkable growth during the analysis period, increasing by 40.0% from €22.56 per hour in 2015 to €31.58 per hour in 2023. This productivity enhancement, driven by technological improvements, skills development, and economic restructuring, represents positive economic development. However, it simultaneously increases the economic value of each worker, making cancer mortality increasingly costly in economic terms.

The productivity loss trajectory reveals interesting patterns that reflect broader economic dynamics. Losses grew consistently through 2019, reaching €244.7 million, before declining to €230.0 million in 2020. This temporary reduction likely reflects the economic disruptions of the pandemic year, when overall productivity and economic activity contracted. However, losses resumed their upward trajectory from 2021 onwards, reaching their peak in 2023.

The relationship between productivity losses and mortality rates reveals important insights for policymakers. While mortality rates increased by 24.6% over the full period, productivity losses grew by 49.5%, demonstrating a near two-to-one amplification effect. This suggests that Portugal's economic development creates increasing vulnerability to health-related productivity losses, making investments in cancer prevention and treatment increasingly economically attractive.

Portugal's relatively small but its growing active population adds another dimension to these productivity considerations. The active population grew from 4.89 million in 2015 to 5.11 million in 2023, representing a 4.5% increase. This expansion means that more individuals are contributing to economic productivity, but also that the absolute number of potential cancer deaths is increasing, creating additional pressure on both healthcare systems and economic resources.

When combining fiscal revenue losses and GDP productivity impacts, the total economic burden of cancer mortality in Portugal reveals the full magnitude of this public health challenge. Total annual economic losses went up from €273.8 million in 2015 to €412.7 million in 2023, representing a cumulative impact of €2.87 billion over the nine-year analysis period.

The economic burden relative to Portugal's overall economic output provides important context for understanding the significance of these losses. As a percentage of GDP, cancer mortality costs remained relatively stable, fluctuating between 0.12% and 0.15% throughout the period. This stability might suggest that the economic impact of cancer is manageable, but it masks the underlying dynamics driving these costs.

The apparent stability in GDP percentage terms reflects Portugal's strong economic growth during much of the analysis period. Nominal GDP increased from €179.4 billion in 2015 to €267.9 billion in 2023, representing a 49.3% increase. This robust economic growth helped absorb the increasing cancer mortality costs without dramatically altering their relative share of economic output.

However, this perspective obscures the accelerating nature of the problem. The absolute increase in economic losses of €138.9 million annually represents substantial resources that could otherwise contribute to economic development, public services, or private consumption. These losses compound over time, creating an increasingly significant drag on Portugal's economic potential.

Portugal's demographic and economic characteristics create important vulnerabilities to cancer mortality costs. The country's aging population and declining birth rates mean that the active workforce represents an increasingly critical component of economic output. Each cancer death among this population therefore carries disproportionate economic consequences, as fewer workers must support a growing dependent population. Moreover, the economic structure of Portugal, with its emphasis on tourism, manufacturing, and services, requires a healthy and productive workforce to maintain competitiveness. Cancer mortality erodes this foundation, creating both immediate productivity losses and longer-term competitiveness challenges as the economy loses experienced workers in their prime productive years.

Concluding, Portugal faces an escalating economic challenge from cancer mortality among its active population, with indirect costs growing at rates substantially exceeding underlying mortality trends. The €2.87 billion in cumulative economic losses over the 2015-2023 period, combined with the 50.7% increase in annual losses, demonstrates that this issue requires urgent policy attention.

The economic analysis reveals that Portugal's positive economic development increases the country's vulnerability to health-related economic losses. Each cancer death in the active population carries increasingly significant economic consequences, making investments in cancer control increasingly attractive from both humanitarian and economic perspectives. The substantial divergence between mortality rate increases

(24.6%) and economic loss escalation (50.7%) indicates that Portugal cannot afford to treat cancer mortality as solely a health issue. The economic implications require integrated policy responses that recognise cancer control as essential economic infrastructure protecting Portugal's fiscal sustainability and development potential.

Future policy development must prioritise comprehensive cancer control strategies that integrate prevention, early detection, treatment, and survivorship care while recognising the substantial economic returns such investments generate. The analysis demonstrates that Portugal's economic development trajectory makes cancer control investments increasingly economically compelling, offering both immediate fiscal benefits and long-term economic protection.

Belgium

The number of persons affected by cancer remained relatively stable from 2015 to 2020, fluctuating slightly around 26,000–27,000. However, there is a marked increase in 2022 and 2023, reaching nearly 29,000 cases.

The mortality rate in the working-age population followed a downward trend until 2020, declining from 97 to 79 deaths per 100,000. In 2022–2023, it rebounded to approximately 89 deaths per 100,000, indicating either a true increase in mortality or an artifact of reporting and delayed diagnoses during the COVID-19 years Figure 14.

Figure 14 Crude mortality rate – active persons in Belgium
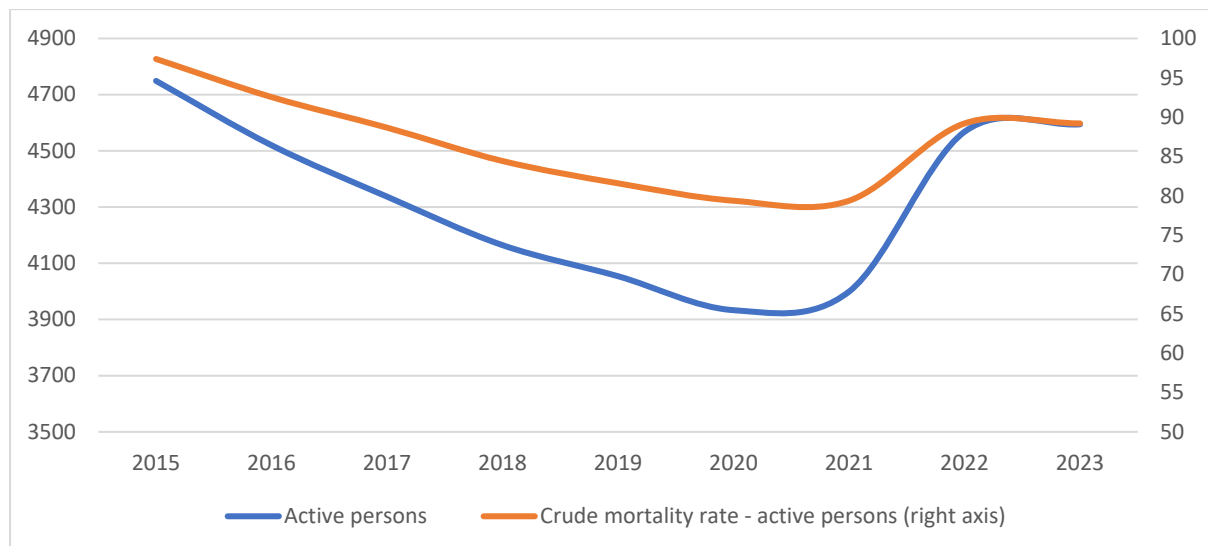
Source: authors estimate

Losses to the national economy from reduced productivity due to cancer ranged from €426 million in 2015 to a peak of €518 million in 2023. The slight but persistent increase reflects the indirect effects of reduced labour participation.

Total losses combining productivity, fiscal revenue, and indirect economic effects grew from approximately €608 million in 2015 to €731 million in 2023 (see Figure 15). The stable upward trend aligns with the increase in the number of affected persons and indicates the expanding financial footprint of cancer on the national budget and healthcare system.

Figure 15 Fiscal revenues and annual GDP loss in Belgium (2015–2023)
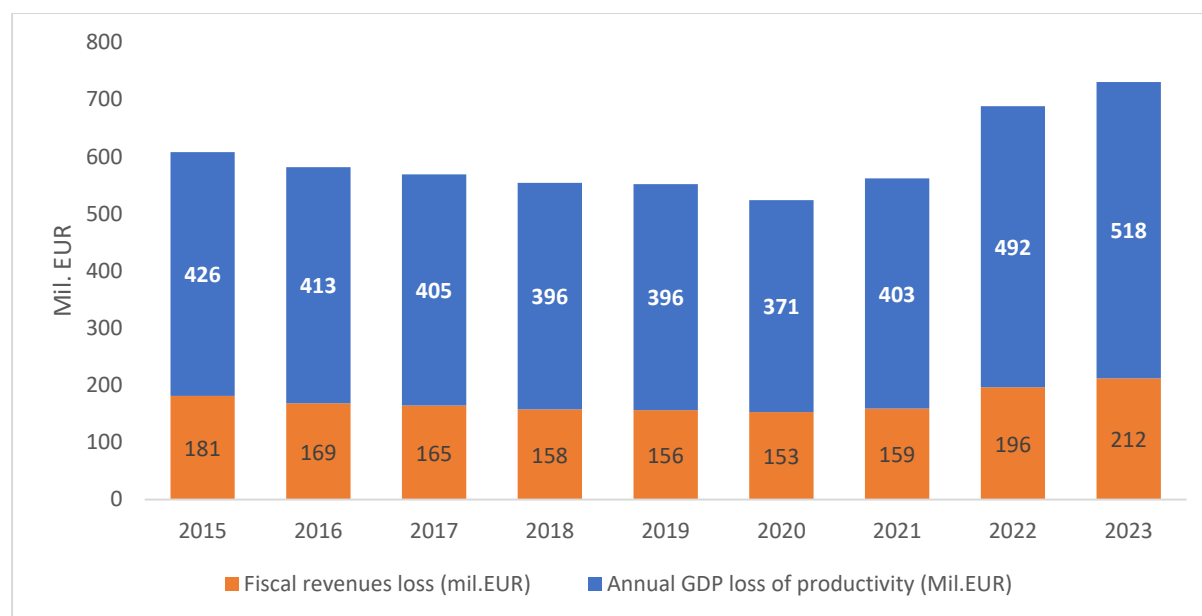
Source: authors estimate

The evolution of cancer indicators in Belgium from 2015 to 2023 reveals a complex interplay between improved healthcare outcomes until COVID–19 crisis (e.g., declining mortality), increased diagnosis rates, and rising economic burden in absolute values. While mortality has decreased over the years, the economic impact continues to grow. These findings underscore the importance of continuous investment in prevention, early detection, and patient support systems.

Montenegro

The economic burden of cancer mortality in Montenegro[2] demonstrates a concerning upward trajectory across the examined period, with both productivity losses and fiscal revenue reductions showing notable increases between 2022 and 2023 in absolute values. The data reveals that the most substantial economic impact stems from productivity losses, which represent the foregone economic output due to premature

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[2] due to data limitation, estimates for Montenegro covers only 2022 – 2023

mortality from cancer, with an estimated crude mortality rate among active persons (20–64 years) of 127.

Figure 16 Fiscal revenues and annual GDP loss in Montenegro (2015–2023)
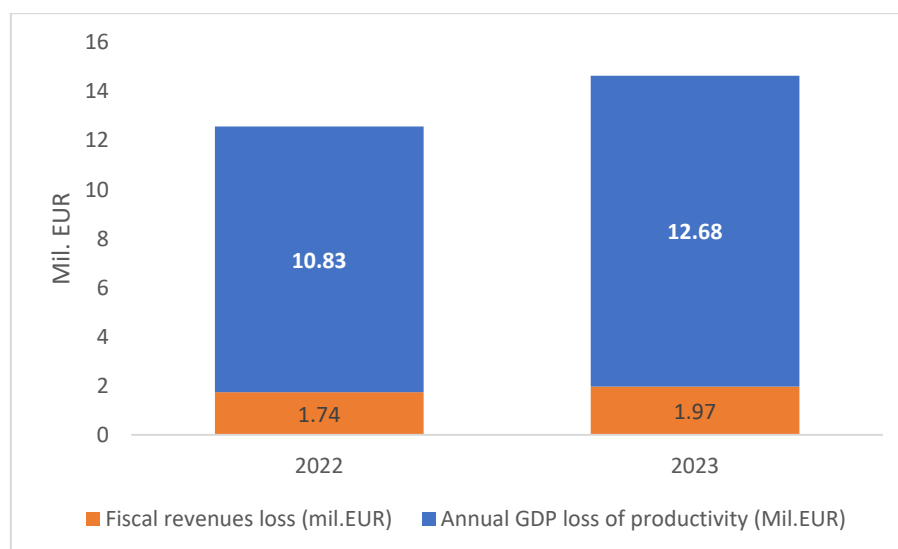
Source: authors estimate

The combined economic impact reveals that cancer mortality imposed a total estimated burden of 12.57 million EUR in 2022, escalating to 14.65 million EUR in 2023 (Figure 16). This represents an overall increase of 16.5% year-over-year, underscoring the accelerating economic consequences of cancer-related deaths in Montenegro. The productivity losses consistently accounted for approximately 86% of the total economic burden across both years, highlighting the predominant role of human capital losses in the overall economic impact of cancer mortality.

North Macedonia

The economic burden of cancer mortality in North Macedonia reveals a relative stability until 2020, followed by a dramatic escalation in recent years, with a pronounced shift toward substantially higher economic impacts in terms of GDP (productivity) and fiscal losses.

During the baseline period from 2015 to 2021, North Macedonia experienced relatively stable economic losses from cancer mortality, with total annual costs ranging between 20.5 and 22 million EUR. The productivity losses consistently dominated the economic burden, accounting for approximately 80–85% of total costs throughout this period. Fiscal revenue losses during these years remained relatively contained, fluctuating between 3.83 and 4.77 million EUR, while productivity losses (gross value added) showed modest variations between 16 and 18 million EUR (Figure 17).

However, the landscape underwent a dramatic transformation after 2021, when total losses surged to more than 31 million EUR, representing a 40.1% increase from the previous year. This escalation continued into 2023, reaching close to 35 million EUR, which constitutes a 56.5% increase compared to 2021 levels. The acceleration was particularly pronounced in productivity losses, which increased from 17.46 million EUR in 2021 to 27.11 million EUR in 2023—a 55.3% rise over just two years.

The demographic and epidemiological context underlying these economic trends is highlighted by concurrent changes in the active population and mortality patterns. The active population data reveals a corresponding trajectory, maintaining relative stability through the mid-2010s before experiencing a sharp upward trend beginning in 2021. Concurrently, the crude mortality rate among active persons followed a similar pattern, suggesting that both population growth and increased mortality rates contributed to the observed economic burden escalation.

The fiscal impact estimates also demonstrated accelerated growth during this recent period, increasing from 4.77 million EUR in 2021 to 7.69 million EUR in 2023, representing a 61.2% increase.

Figure 17 Fiscal revenues and annual GDP loss in North Macedonia (2015–2023)
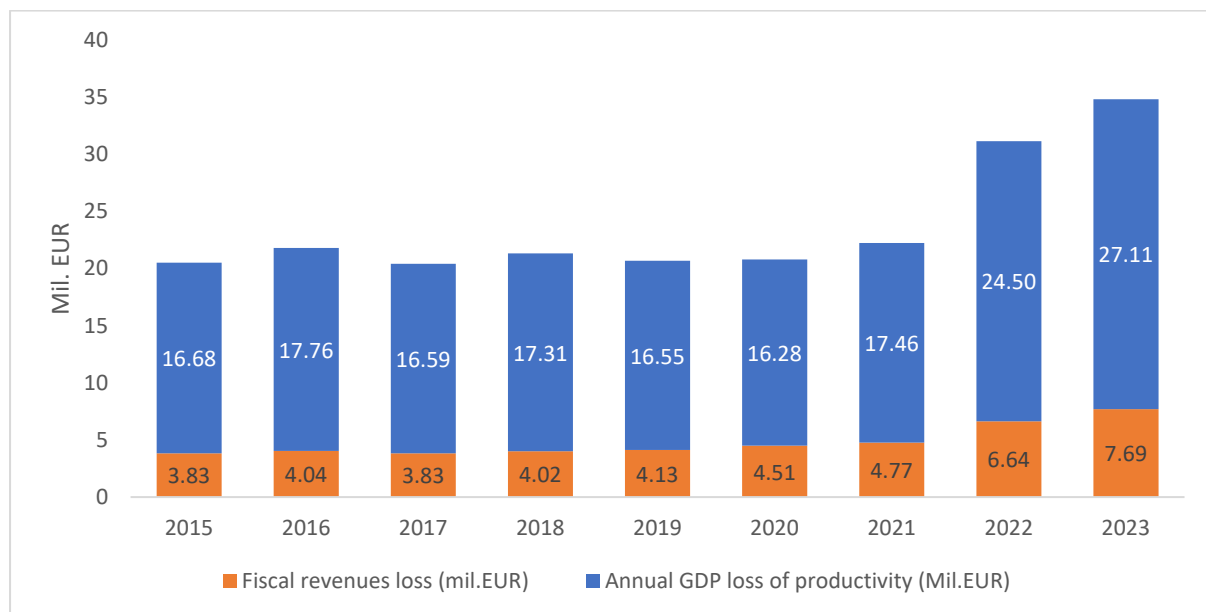
Source: authors estimate

Figure 18 Active persons and cancer crude mortality in North Macedonia (2015–2023)
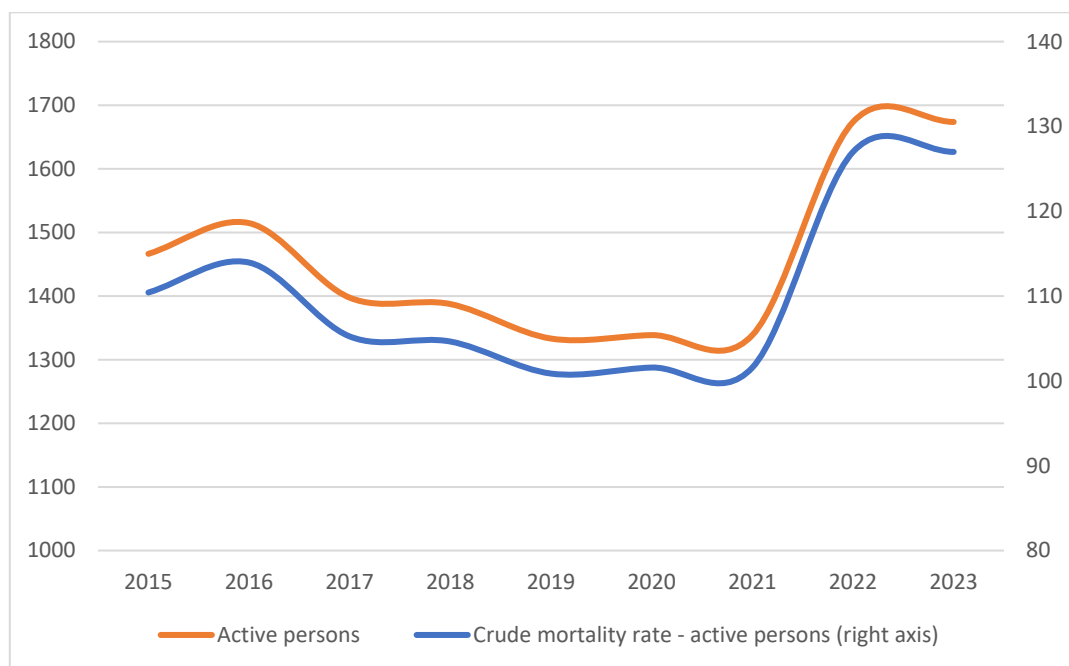
Source: authors estimate

In parallel to macroeconomic estimations of productivity and fiscal losses, the report also explores cancer-related behavioral risk factors—namely alcohol and tobacco consumption—through a microeconomic lens. This complements the HCA by simulating how taxation policies on these products can reduce incidence rates and generate dual public health and fiscal gains. The following sections detail the estimation of price and income elasticities, and the construction of fiscal policy scenarios across five countries.

The impact of alcohol and tobacco expenditures on individual spending and implications for cancer risk reduction policies

Introduction

Alcohol and tobacco consumption are widely recognised as major modifiable risk factors that significantly contribute to the global burden of cancer incidence and mortality. According to the World Health Organization (WHO, 2018), alcohol is a causal factor in more than 200 disease and injury conditions, including several types of cancer such as those of the oral cavity, liver, breast, and colorectum. Similarly, tobacco use remains the leading preventable cause of cancer deaths, being directly responsible for approximately 22% of global cancer deaths each year (WHO, 2020).

Public health strategies to reduce the prevalence of these risk factors increasingly emphasize the use of economic instruments, particularly excise taxation, as powerful tools to influence consumption behaviours. The WHO Framework Convention on Tobacco Control (WHO FCTC, 2003) and the WHO Global Alcohol Action Plan (WHO, 2022) both advocate for substantial increases in taxation as part of a comprehensive approach to reduce the affordability, and thus the consumption, of tobacco and alcohol products. Empirical evidence supports the effectiveness of such measures: studies have shown that higher tobacco taxes lead to significant reductions in smoking prevalence, especially among youth and low-income populations (Chaloupka et al., 2012; IARC, 2011). Similarly, systematic reviews indicate that increases in alcohol taxes are associated with decreases in overall alcohol consumption and alcohol-attributable harm (Wagenaar, Salois, & Komro, 2009).

While a majority of nations (53%) within the WHO European Region have implemented elevated tobacco taxation policies, only six countries have successfully reduced cigarette affordability since 2020. From a public health economics perspective, policymakers should implement tax structures that exceed income growth rates to achieve optimal health outcomes. The fundamental economic principle underlying effective tobacco taxation is that price increases beyond consumers' purchasing power growth will decrease market demand for tobacco products, thereby serving as a demand-side intervention for tobacco control (WHO, 2024).

In this context, understanding the responsiveness of alcohol and tobacco expenditures to changes in income and prices—conceptualised as income and price elasticities—is critical for designing effective fiscal and health policies. Elasticities inform the potential

impact of taxation policies not only on consumption levels but also on public revenues and equity considerations. The International Agency for Research on Cancer (IARC, 2011) and the OECD (2021) both stress that setting taxes without knowledge of these behavioural responses may undermine the effectiveness of fiscal interventions aimed at reducing cancer risk factors.

Moreover, the interplay between economic development, disposable income, and the affordability of harmful products requires careful monitoring. In middle- and high-income countries, rising incomes can offset the effects of taxation unless tax rates are periodically adjusted to maintain or increase real prices relative to income growth (WHO, 2017). This dynamic underscore the importance of continuous economic evaluation to ensure that fiscal measures keep pace with socioeconomic trends that may otherwise erode their preventive impact.

Therefore, robust empirical evidence on how alcohol and tobacco expenditures react to income variations and taxation policies is essential. Such insights contribute not only to the optimization of fiscal tools but also to the broader objectives of cancer control strategies, aiming to reduce preventable morbidity and mortality worldwide.

Figure 19 illustrates the dynamic interplay between disposable income, spending on behavioural risk factors (alcohol and tobacco), and cancer prevention policies. As economic capacity increases, a portion of disposable income may be allocated toward harmful consumption such as alcohol and tobacco, both of which are major modifiable risk factors for cancer. This increased exposure raises population-level cancer risk, which in turn justifies the use of policy levers—primarily taxation and regulation—as interventions. These policy measures aim to reduce the affordability and consumption of harmful products. The resulting decrease in consumption feeds back into the system by lowering future behavioural risk, thus forming a preventive feedback loop that connects economic behaviour with public health outcomes.

Figure 19 Alcohol and tobacco spending and policy levers
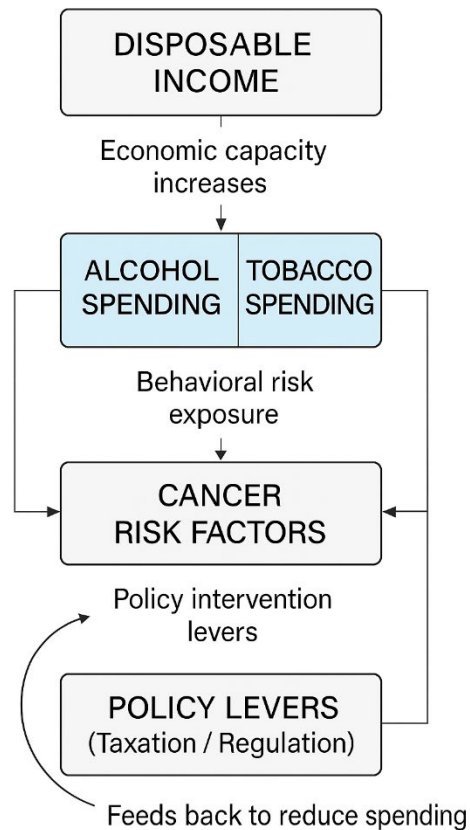
Source: authors work

This section of the report presents a panel data analysis investigating the relationship between disposable income, price changes, and individual expenditures on alcohol and tobacco across five European countries — Belgium, Bulgaria, France, Portugal, and Romania — over the period 2012–2024 (the only countries with complete available datasets). The objective is to assess how taxation-induced price changes may influence consumption behaviours and, by extension, contribute to cancer prevention efforts.

Data and Methodology

This study employs panel data regression models with fixed effects to examine the relationship between disposable income, price changes, and individual expenditures on alcohol and tobacco across five European countries: Belgium, Bulgaria, France, Portugal, and Romania, over the period 2011–2024. The dataset is structured as an unbalanced panel, reflecting variations in the availability of observations across years and countries.

Panel data techniques offer distinct advantages in this context by allowing the analysis to control for both cross-sectional (*country-specific*) and temporal (*year-specific*) variations. Importantly, panel data provides more informative data, greater variability, reduced collinearity among explanatory variables, and higher degrees of freedom, thus enhancing the efficiency of econometric estimations (Hsiao, 2014).

The independent variables include the logarithm of gross national disposable income per capita (GNDI) and the lagged logarithm of price changes for Alcohol and Tobacco, respectively. Country-specific fixed effects were incorporated to control for unobserved, time-invariant heterogeneity among countries, while the use of lagged price variables addresses potential simultaneity bias, ensuring that consumption decisions are influenced by prior price changes rather than contemporaneous shocks.

The econometric models estimated can be expressed in the following general form:

$$\log(\text{Expenditure}_{it}) = \beta 0 + \beta 1 \log(\text{GNDI}_{it}) + \beta 2 \log(\text{PriceChange}_{i,t-1}) + \alpha_i + \epsilon_{it}$$

where:

> i indexes the country (Belgium, Bulgaria, France, Portugal, Romania)
>
> t indexes the year (2012–2024)
>
> log(Expenditure) denotes the logarithm of alcohol or tobacco expenditure
>
> log(GNDI) represents the logarithm of gross national disposable income per capita
>
> $\log(\text{PriceChange}_{,t-1})$ refers to the lagged logarithm of the change in the relevant price index for alcohol or tobacco
>
> α captures unobserved country-specific effects
>
> ϵ is the idiosyncratic error term

Fixed Effects Estimation

The fixed effects (FE) estimator is chosen over alternative methods (such as random effects) based on theoretical considerations and empirical diagnostics (e.g., Hausman tests, omitted here for concision). The FE approach controls for unobserved heterogeneity that is constant over time but varies across countries — such as cultural norms, health policies, enforcement levels of taxation, or general attitudes toward alcohol and tobacco use (Wooldridge, 2010).

By introducing country-specific intercepts (αi), the fixed effects model effectively removes the influence of all time-invariant characteristics, isolating the within-country variation in income and price changes that drive expenditure dynamics. This is particularly relevant in public health economics where persistent institutional and cultural factors play significant roles in shaping behaviours but are difficult to measure directly (Baltagi, 2008). Mathematically, fixed effects estimation relies on the "*within transformation*" — demeaning all variables by their country-specific means — thus eliminating αi before applying Ordinary Least Squares (OLS) to the transformed data.

In choosing the appropriate panel data estimator, a critical methodological decision concerns whether to model unobserved heterogeneity across countries as fixed or random. The choice between fixed effects (FE) and random effects (RE) has important implications for the validity of the estimated coefficients and the reliability of the policy conclusions derived from the model. In this study, the fixed effects estimator was preferred over the random effects estimator based on both theoretical considerations and the likely characteristics of the data.

First, the core assumption underlying the random effects model — that the unobserved individual-specific effects (αi) are uncorrelated with the explanatory variables — is unlikely to hold in the context of alcohol and tobacco expenditure. Country-specific factors such as regulatory environments, enforcement of excise taxes, cultural attitudes toward substance use, and national public health campaigns are persistent over time and are likely correlated with both income levels and consumer price dynamics. If the random effects assumption of no correlation is violated, the RE estimator becomes inconsistent, leading to biased and misleading results (Wooldridge, 2010). In contrast, the fixed effects model allows the unobserved heterogeneity to be freely correlated with the regressors. It accounts for these persistent differences by controlling for all time-invariant country-specific factors, thus providing consistent and unbiased estimates of the effects of income and price changes on alcohol and tobacco expenditures (Baltagi, 2008).

Second, the theoretical justification is further supported by empirical testing. Although the Hausman test, which formally compares the FE and RE estimators, is not presented here due to data limitations, previous studies examining consumption behaviours across countries have consistently favoured fixed effects due to the inherent correlation between institutional factors and economic variables (Cheng & Hoekstra, 2013; Grossman et al., 1994). Therefore, to avoid the risk of omitted variable bias and to obtain credible estimates of the income and price elasticities, the fixed effects estimator is employed as the preferred methodological approach.

Model Diagnostics

Several diagnostic measures are employed to assess the adequacy of the panel models:

- R-squared and Adjusted R-squared statistics gauge the proportion of variance explained by the model, accounting for the degrees of freedom.
- F-statistics and associated p-values test the joint significance of the regressors.
- Durbin-Watson statistics evaluate potential autocorrelation in residuals, which could bias standard errors.
- Information criteria (Akaike, Schwarz, Hannan-Quinn) inform about model fit relative to model complexity.

Although fixed effects correct for time-invariant heterogeneity, the models assume no perfect multicollinearity among regressors and no serial correlation in errors across time for the same unit. Robust standard errors or Driscoll–Kraay corrections may be considered in future research to further adjust for heteroskedasticity and autocorrelation. More details about the model specifications and informational criteria can be found in Annex 1

Results

Alcohol Expenditure Analysis

The estimated equation for alcohol expenditures is:

LOG(A_EXP) = 1.90 + 0.077*LOG(GNDI) − 0.306*LOG(*PRICEA*(−1)) + [CX=F]

Key findings for alcohol expenditures:

- The income elasticity of alcohol expenditure is positive (0.0772) but not statistically significant (p = 0.7820), suggesting a weak relationship between income changes and alcohol spending.

- The price elasticity is smaller than 1 and negative (−0.3060), consistent with economic theory, but also not statistically significant (p = 0.2025).

- The overall model is statistically significant (Prob(F-statistic) = 0.0044) and explains approximately 45% of the variance in alcohol expenditure (R-squared = 0.4473).

Tobacco Expenditure Analysis

The estimated equation for tobacco expenditures is:

$$LOG(T\_EXP) = 0.715 + 0.695*LOG(GNDI) - 0.23*LOG(PRICET(-1)) + [CX=F]$$

Key findings include for the tobacco model:

- The income elasticity of tobacco expenditure is positive (0.6950) and statistically significant (p = 0.0126), indicating that increases in disposable income are associated with substantial increases in tobacco spending.

- The price elasticity is smaller than 1 and negative (-0.2339), as expected, but not statistically significant (p = 0.1397).

- The model is globally significant (Prob(F-statistic) = 0.0453) but explains a smaller share of variance compared to alcohol (R-squared = 0.3158).

Thus, tobacco consumption exhibits a strong positive response to income growth but shows limited immediate sensitivity to price increases over the observed period.

Building on these empirical elasticity estimates, the next section applies the findings in a forward-looking scenario framework. By simulating the potential effects of various excise tax policies on alcohol and tobacco consumption, the analysis explores how fiscal instruments could contribute to cancer prevention and influence long-term economic outcomes. These policy scenarios are grounded in real-world behavioral parameters and aim to support evidence-based public health strategy design.

Conclusions and implications

The results reveal distinct patterns in the responsiveness of alcohol and tobacco expenditures to economic factors. First, the tobacco expenditures are far more sensitive to changes in income than alcohol expenditures. This suggests that as living standards improve, without adequate public health interventions, tobacco consumption — and thus tobacco-related cancer risks — may rise disproportionately.

Secondly, in both models, *the price elasticity of demand is negative and quite low* (e.g. inelastic demand at price changes), indicating that price increases — such as those resulting from higher excise taxes — have the potential to reduce consumption, but not so large. However, the lack of statistical significance suggests that price increases alone may not produce immediate or strong reductions in spending, especially in contexts where consumption habits are deeply entrenched, or households' income increase with a high pace (e.g. increasing affordability for consumers).

Third, these findings emphasize the need for complementary strategies alongside taxation to achieve meaningful reductions in alcohol and tobacco use. Public education campaigns, smoking cessation programs, restrictions on advertising, and stricter regulation of sales could enhance the effectiveness of price-based interventions.

Particularly for tobacco, the strong income effect points to the importance of maintaining high taxation levels relative to income growth to offset rising consumption trends (see also Bayly et al., 2019: Levy et al., 2016; Pierce et al, 2012).

Hower, our study has also some limitations. The limited number of countries and relatively small number of observations constrain the generalizability of the results. Additionally, the absence of statistically significant price effects suggests that further research, using larger datasets and more granular price measures – quarterly or monthly–, is warranted.

In conclusion, this analysis provides evidence that disposable income levels play a significant role in shaping individual spending on tobacco, with weaker but directionally similar effects observed for alcohol. Price increases, while aligned with theoretical expectations, did not show immediate significant effects on expenditures in the countries studied. These findings highlight the complex relationship between economic conditions, consumption behaviours, and public health risks. They underscore the necessity of integrating fiscal measures with broader public health strategies to effectively reduce alcohol and tobacco use and, ultimately, to lower the burden of cancer across diverse national contexts.

Policy interventions and scenarios

The relationship between economic prosperity and public health presents one of the most complex challenges in contemporary policy design. While rising incomes generally correlate with improved health outcomes, they can paradoxically undermine efforts to reduce consumption of cancer-causing due to the *affordability* improvement.

According to the World Health Organization, tobacco and alcohol consumption account for a substantial proportion of preventable cancer deaths across Europe, with tobacco alone responsible for approximately 22% of global cancer mortality. The International Agency for Research on Cancer emphasizes that the window for implementing effective prevention policies is narrowing as consumption patterns become entrenched and healthcare systems face increasing treatment burdens. The economic cost of inaction extends beyond individual suffering to encompass substantial healthcare expenditures, productivity losses, and intergenerational health disparities that undermine broader social development objectives.

Building on the estimated income and price elasticities derived from the panel regressions, we developed a set of forward-looking policy scenarios to assess the potential effects of excise tax increases on individual spending for alcohol and tobacco. The scenarios are designed to simulate plausible fiscal interventions over a three-year horizon, capturing both behavioural responses to price changes and anticipated income growth trends.

To model these scenarios, we assume a moderate annual increase in gross national disposable income (GNDI) of 2,5-4%, reflecting stable economic growth across the five countries included in the study for elasticities (Romania, Bulgaria, Portugal, France and Belgium). Three distinct excise tax policy configurations were considered, corresponding to different annual price increases (see Table 2 for every scenario).

The simulations incorporate the estimated elasticities from the empirical models. Specifically, **the price elasticity of demand is −0.2339 for tobacco and −0.3060 for alcohol**, indicating that both products are price inelastic, but that alcohol is slightly more sensitive to price changes. On **the income side**, tobacco exhibits a statistically significant **positive elasticity of +0.6950**, suggesting a strong responsiveness to income growth, while **alcohol** displays a weaker, statistically insignificant elasticity of **+0.0772**.

This scenario-based modelling exercise illustrates that excise tax policies—especially when combined with broader public health interventions—can play a critical role in curbing the consumption of alcohol and tobacco and, by extension, in reducing the burden of cancer. However, the effectiveness of such measures is contingent on the scale of the tax increase, the income dynamics of the population, and the degree of product-specific price sensitivity.

Analytical framework and methodological approach

Scenario 1. Moderate progressive taxation

The first scenario embodies a philosophy of measured progression, recognising that policy sustainability often requires balancing optimal outcomes with political and economic constraints. This approach implements gradual but sustained increases in tobacco and alcohol excise taxes over a three-year period, with tobacco taxes rising cumulatively by 36.6% and alcohol taxes by 28.2%. The scenario reflects a judgment that sustained moderate pressure on consumption may prove more effective over time than dramatic interventions that risk political backlash or economic disruption. This approach recognises that cancer prevention operates on long time horizons, where consistent policy implementation across multiple political cycles may matter more than the magnitude of initial interventions.

Scenario 2. Aggressive taxation strategy

The second scenario represents a different calculation about the urgency of cancer prevention and the appropriate use of fiscal policy tools. Based on the empirical evidence that substantial price increases are necessary to overcome income effects and achieve meaningful consumption reductions, this approach implements dramatic taxation increases: 72.5% for tobacco and 54.6% for alcohol over three years. It reflects a public health imperative that prioritiszes maximum immediate impact on consumption patterns,

accepting higher political and economic risks in pursuit of optimal health outcomes. This approach interprets the empirical evidence as demonstrating that incremental measures are insufficient to address the scale of the cancer prevention challenge, particularly given the offsetting effects of income growth. However, these benefits come with substantial implementation challenges, including heightened risks of illicit trade, cross-border purchasing, and regressive distributional effects that require comprehensive mitigation strategies.

Scenario 3. Adaptive dynamic taxation linked with income growth

The third scenario represents a paradigmatic departure from traditional static policy approaches, implementing a dynamic taxation policy amid changing economic conditions. Rather than setting fixed taxation increases, this framework establishes base rates that automatically adjust based on national disposable income growth patterns, ensuring that the real burden of taxation increases over time rather than eroding through economic development.

The adaptive dynamic taxation framework directly addresses the core empirical finding about income elasticity by incorporating income growth as a parameter. The automatic adjustment mechanism—for example, taxation increases equal to 1.5 times the gross national disposable income growth rate—ensures that affordability improvements are systematically prevented while providing predictable revenue streams for integrated cancer prevention infrastructure.

This scenario represents the evolution from evidence-based policy (where research informs initial design) to evidence-responsive policy (where research continuously shapes implementation). The framework includes systematic elasticity re-estimation at a regular period (for example, 18-24 months), allowing policy parameters to adapt to changing behavioural patterns, technological innovations, and socio-economic conditions that might alter the effectiveness of fiscal interventions.

BOX 1. Detailed information on Scenario 3. A proposal

This scenario explicitly links taxation policy to comprehensive cancer prevention strategy. It could be supplemented with additional coordinated interventions to split the revenues to:
- Primary prevention: 30% of additional revenue toward education and awareness
- Secondary prevention: 25% toward screening program expansion
- Treatment infrastructure: 25% toward oncology care capacity
- Research and evaluation: 20% toward policy effectiveness monitoring

The allocation formula—30% primary prevention, 25% secondary prevention, 25% treatment infrastructure, and 20% research and evaluation—emerges from epidemiological evidence about the relative cost-effectiveness of interventions at different stages of the cancer trajectory. This distribution reflects the principle that prevention is not only more humane than treatment but also more economically efficient in the long term.

Advantages:
- Self-adjusting mechanism maintains policy effectiveness
- Revenue stability for long-term cancer prevention planning
- Reduced need for frequent legislative intervention

Source: authors work

Basic assumptions for scenario modelling (2026–2028)

- Forecast horizon: 3 years (T+1 to T+3 → 2026 to 2028)
- Income growth (GNDI): +2,5-4% annually in nominal terms (moderate income growth assumption)
- Baseline Consumption: Current expenditure levels as reference point
- Tax policy lever: Annual excise tax increase causing an increase in final prices
- Price elasticity: Tobacco: −0.23 (inelastic) and Alcohol: −0.31 (also inelastic)
- Income elasticity: Tobacco: +0.695 (statistically significant) and Alcohol: +0.077 (not significant, but included for directionality)

Table 2. Scenarios and policy design

Scenario	Policy design	
	Tobacco Excise Increases	**Alcohol Excise Increases**
Scenario 1: Moderate progressive (Conservative Approach)	Year 1: 15% increase in excise tax rates Year 2: Additional 10% increase (26.5% cumulative) Year 3: Additional 8% increase (36.6% cumulative) *Index calculation*: (1,15*1,1*1,08 = 1,366)	Year 1: 12% increase in excise tax rates Year 2: Additional 8% increase (20.96% cumulative) Year 3: Additional 6% increase (28.2% cumulative) *Index calculation*: (1,12*1,08*1,06 = 1,282)
Scenario 2: Aggressive taxation strategy	Year 1: 25% increase in excise tax rates Year 2: Additional 20% increase (50% cumulative) Year 3: Additional 15% increase (72.5% cumulative) *Index calculation*: (1,25*1,2*1,15 = 1,725)	Year 1: 20% increase in excise tax rates Year 2: Additional 15% increase (38% cumulative) Year 3: Additional 12% increase (54.6% cumulative) *Index calculation*: (1,2*1,15*1,12 = 1,546)
Scenario 3: Adaptive dynamic taxation (Income-related framework)	Year 1–3 Implementation: Base taxation increase: **20%** (tobacco), **15%** (alcohol) Annual income-responsive adjustment: Additional increase equal to **1.5× GNDI growth rate** Automatic review mechanism: Elasticity re-estimation every 18–24 months	

Source: authors work

Table 3 Consumption impact by scenario

	Projected Consumption Impact	
	Tobacco:	**Alcohol:**
Scenario 1	Expected consumption reduction: 8.6% by Year 3 Calculation: –0.234 × 36.6% = –8.6% Income offset effect: +25.5% expenditure increase due to income growth	Expected consumption reduction: 8.6% by Year 3 Calculation: –0.306 × 28.2% = –8.6% Weaker income offset due to low-income elasticity
Scenario 2	Expected consumption reduction: 17.0% by Year 3 Strong preventive effect despite inelastic demand and substantial impact on initiation rates among price-sensitive demographics	Expected consumption reduction: 16.7% by Year 3 Substantial public health impact given alcohol's role in multiple cancer types
Scenario 3	Year 1: 4.7% consumption reduction Year 2: 7.2% cumulative reduction (accounting for income offset) Year 3: 9.8% cumulative reduction	Year 1: 4.6% consumption reduction Year 2: 6.9% cumulative reduction Year 3: 9.1% cumulative reduction
	Key advantage: Prevents erosion of taxation effectiveness due to income growth	

Source: authors calculation based on EViews panel data estimates

Critical success factors for effective fiscal health policy implementation

To ensure that taxation-based interventions on alcohol and tobacco effectively reduce consumption and contribute to cancer prevention, several critical success factors must be addressed. These elements are essential not only for the success of the policy itself but also for maintaining public trust, institutional accountability, and long-term health outcomes.

Evidence-based adjustment mechanisms

Continuous policy relevance and effectiveness depend on regular re-estimation of price and income elasticities. These econometric updates should be based on the latest consumption data, price dynamics, and socio-economic trends. The elasticity of demand is not static; it can evolve in response to behavioural adaptation or structural economic

changes. Hence, incorporating up-to-date empirical evidence into fiscal modelling is a cornerstone for targeted and proportionate taxation.

Stakeholder engagement and institutional dialogue

Broad and inclusive consultations with key stakeholders—including public health experts, representatives from the alcohol and tobacco industries, civil society organizations, and policymakers—are crucial. Such engagement helps anticipate potential resistance, ensures the legitimacy of interventions, and fosters consensus around public health objectives. Stakeholder collaboration also enhances the design and implementation of complementary policies, such as support for vulnerable groups.

Revenue transparency and earmarking

A transparent fiscal framework that visibly allocates additional tax revenues toward cancer prevention initiatives significantly enhances public and political support. This includes funding for national cancer plans, screening programs, primary care infrastructure, and health education campaigns. Clear communication about the public health use of revenues can increase policy acceptability and reduce perceptions of fiscal opportunism.

Complementary interventions and multi-sectoral integration

Excise taxes are most effective when embedded within a broader set of health promotion strategies. This includes the expansion of smoking cessation services, alcohol abuse treatment programs, restrictions on advertising, and mandatory health labelling. These complementary policies create synergies that amplify the behavioural impact of price signals and contribute to sustainable consumption patterns.

Regional coordination and policy harmonisation

In the context of the European Union, policy coherence across member states is vital to avoid tax evasion, cross-border shopping, and internal market distortions. Coordinated tax floors and convergence of excise structures across the EU enhance the effectiveness of national policies and strengthen the region's collective capacity to reduce cancer-related risk factors. Harmonised policies also facilitate comparative evaluation and collective learning.

Cancer control intervention scenarios: economic impact assessment framework and estimates

Building upon the comprehensive baseline analysis of cancer-related economic losses across European countries with available datasets, the proposed framework in the current section establishes methodological approaches for quantifying the economic benefits of three primary intervention categories: prevention, screening and early detection, and improved management and treatment. The analysis demonstrates that strategic investments in cancer control can generate substantial returns through reduced mortality and enhanced workforce productivity.

Baseline scenario construction

The intervention scenarios utilize the established baseline for crude mortality rates and economic losses as the reference point for measuring potential improvements. For each country, the baseline scenario assumes continuation of current mortality trends, productivity and demography enabling a solid quantification of intervention benefits through comparative analysis (**intervention scenarios** vs. **the baseline "No-measure" scenario**).

Key baseline parameters include:

- Current crude cancer mortality rates per 100,000 persons in active population
- Established fiscal loss patterns (social contributions, PIT, VAT)
- Average national productivity trajectories based on 2015-2023 CAGR values
- Demographic projections for the active population (20-64 years)
- Economic growth assumptions consistent with national forecasts and the CAGR of national GDP in current prices for 2015-2023

The model used to quantify Gross Value Added is the following:

$$\text{GVA loss } t = (1-\pi) * H_t * L_t * W_t,$$

where:

L_t = estimated number of patients in year t;

H_t = total number of working hours in year t;

W_t = estimated labour productivity (based on 2015-2023 CAGR values).

To estimate the evolution of patient's number according to the type of government intervention, the **π coefficient** was determined based on the cancer crude mortality rates among active patients at 100000 persons for three scenarios (see for details Scenario Analysis Framework section):

- *μ = –7.5%* for " **Comprehensive Cancer Control"** scenario
- *μ = –5%* for " **Screening and Treatment Focus**" scenario
- *μ = –2%* for "**Better treatment and management**" scenario

Depending on the decrease in cancer crude mortality rates and the active population 20–64 years evolution, the π coefficient for every country was determined presented in table below.

Table 4 Adjusted CAGR calculated for active patients by scenario

Countries	Adjusted CAGR values for active patients
Romania	Scenario 1: 7.26% Scenario 2: 5.18% Scenario 3: 2.69%
Moldova	Scenario 1: 7.96% Scenario 2: 5.9% Scenario 3: 3.43%
France	Scenario 1: 6.05% Scenario 2: 3.94% Scenario 3: 1.42%
Belgium	Scenario 1: 5.85% Scenario 2: 3.73% Scenario 3: 1.21%
Bulgaria	Scenario 1: 7.18% Scenario 2: 5.1% Scenario 3: 2.61%
Portugal	Scenario 1: 5.95% Scenario 2: 3.83% Scenario 3: 1.31%
North Macedonia	Scenario 1: 20.14% Scenario 2: 18.35% Scenario 3: 16.21%
Montenegro	Scenario 1: 6.2% Scenario 2: 4.1% Scenario 3: 1.58%

Source: authors' estimates; the values were computed based on the CAGR for T – T+5 period and represent the decline in the *average annual number of patients*; the latter was calculated based

on the evolution of adjusted cancer mortality rate of active patients for every scenario and the active persons dynamic during the same period.

Scenario Analysis Framework

Scenario 1: Comprehensive Cancer Control (π = 0.3228 for the entire period)

This scenario represents the most ambitious intervention approach, combining primary prevention, early screening, and enhanced treatment. The 32.28% reduction coefficient reflects a comprehensive structure:

Prevention Component	Screening Component	Treatment Component
Tobacco control programs reducing smoking prevalence Alcohol policy interventions Environmental carcinogen regulation Vaccination programs (HPV, Hepatitis B)	Organised breast, cervical, and colorectal screening programs Optimal population coverage (>75%) Advanced screening technologies	Multidisciplinary care implementation Access to novel therapies Reduced treatment delays Enhanced survivorship care

Scenario 2: Screening and Treatment Focus (π = 0.2262 for the entire period)

This scenario emphasizes healthcare system interventions without comprehensive prevention policies with a reduction of 22.6% for the entire T–T+5 period.

Screening Component	Treatment Component
Expanded screening program coverage Technology upgrades and protocol optimisation Improved follow-up and care coordination	Enhanced treatment protocols Improved access to specialised care Quality improvement initiatives

Scenario 3: Better treatment and management (π = 0.096 for the entire period)

This scenario focuses exclusively on improving outcomes among diagnosed patients, generating a decrease of the cancer crude mortality rate of 9.6% for the entire period, with accent on the treatment component:

- Advanced therapeutic protocols
- Multidisciplinary care teams
- Reduced diagnostic and treatment delays
- Enhanced supportive care

Box 2. Policy Implications

The mathematical framework provides a foundation for quantifying intervention benefits across diverse national contexts. The *π coefficient* structure effectively captures intervention while enabling the economic benefit calculations. The framework supports evidence-based policy development and resource allocation decisions across the cancer control continuum.

Investment Prioritisation

The mathematical framework demonstrates clear hierarchy:

- Comprehensive approaches offer greatest economic returns
- Prevention components provide highest cost-effectiveness
- Treatment-only strategies have lowest benefit-cost ratios

Country-Specific Strategies

High-Mortality Countries (Romania, Bulgaria):

- Prioritise comprehensive interventions
- High absolute and relative returns justify investment
- Focus on prevention for maximum impact

Well-Performing Countries (Belgium, France, Portugal):

- Emphasize screening and treatment optimization
- Leverage existing infrastructure for incremental improvements
- Focus on innovation and quality enhancement

Resource-Constrained Countries (Moldova, North Macedonia):

- Phased implementation starting with highest-impact interventions

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- International cooperation and technology transfer
- Focus on cost-effective prevention strategies

Scenario results

The intervention scenario results provide robust evidence for substantial economic returns from strategic cancer control investments. The potential 5-year gains across eight countries comparative with *No intervention* scenario demonstrates that cancer control represents not merely a health imperative but a critical economic development strategy.

However, the intervention scenario results reveal substantial heterogeneity in economic benefits across the eight study countries, reflecting the complex interplay between baseline cancer mortality rates, labour productivity levels, and demographic characteristics (active persons 20-64 years evolution). This variation provides important insights into optimal intervention strategies and resource allocation priorities across diverse European contexts.

In absolute values, France emerges as the most significant beneficiary of cancer control interventions across all three scenarios, generating annual average economic benefits of €309 million under the comprehensive intervention approach (Scenario 1). This substantial figure translates to cumulative five-year benefits of €1.54 billion, representing 36.5% of the total cross-country economic gains despite France having one of the lower baseline mortality rates among the study countries. The magnitude of France's potential benefits illustrates how large economies with high labour productivity can amplify intervention returns, as each prevented cancer death carries exceptionally high economic value due to elevated wage levels and output per worker.

Romania demonstrates the second-highest absolute intervention benefits, with comprehensive cancer control strategies yielding annual gains of €203 million and cumulative five-year benefits exceeding €1.02 billion. These substantial returns are particularly noteworthy given Romania's elevated baseline cancer mortality rate of 152 per 100,000 active persons—the highest among the study countries. Romania's position, capturing 24% of total cross-country benefits, illustrates the exceptional return potential in countries experiencing elevated cancer burden. The combination of high mortality rates and rising labour productivity creates conditions where intervention effectiveness is maximised, as comprehensive cancer control programs can simultaneously address significant disease burden while capturing the economic value of an increasingly productive workforce. This analysis suggests that Romania represents one of the most compelling investment opportunities for cancer control initiatives within the European context.

Belgium and Portugal occupy an intermediate position in the intervention benefit hierarchy, with both countries demonstrating substantial economic returns that justify comprehensive policy attention. Belgium would generate annual gains comparative with No measure scenario of €102 million under comprehensive intervention scenarios, translating to cumulative five-year gains of €512 million. Portugal follows closely with annual benefits of €84 million and cumulative returns of €420 million over the projection period. Both countries exhibit strong returns relative to their economic size and baseline cancer burden, suggesting that their established healthcare infrastructure and moderate mortality rates create favourable conditions for intervention effectiveness.

Bulgaria presents an interesting case study in intervention potential within the Eastern European context, generating annual economic benefits of €32 million and cumulative five-year returns of €161 million under comprehensive intervention scenarios. While these absolute figures appear modest compared to larger economies, they represent significant relative impact given Bulgaria's smaller economic base and the challenging fiscal environment characteristic of the region. The country's elevated baseline mortality rate of 138 per 100,000 active persons (average 2015-2023) suggests substantial room for improvement through systematic cancer control interventions, while the growing labour productivity documented in the baseline analysis indicates that the economic value of interventions will continue to amplify over time.

The three smallest economies in the analysis—Moldova, North Macedonia, and Montenegro—collectively generate annual benefits of €17.5 million under comprehensive intervention scenario comparative with No measure scenario (€5.5 million, €8 million, and €4 million respectively). While these absolute figures appear modest in comparison to larger economies, they represent proportionally significant impacts within their respective national contexts.

Table 5 Average and cumulative gains by scenario in selected European countries

	Scenarios – average gains (mil.EUR)							
	Romania	**Moldova**	**Belgium**	**Bulgaria**	**Portugal**	**North Macedonia**	**Montenegro**	**France**
Sc1	203	5.5	102	32	84	8	4	309
Sc2	146	4.0	65	23	61	6	3	216
Sc3	71	2.1	17	11	31	3	1	95

	Scenarios – cumulative gains (mil.EUR)							
	Romania	**Moldova**	**Belgium**	**Bulgaria**	**Portugal**	**North Macedonia**	**Montenegro**	**France**
Sc1	1017	27	512	161	420	39	19	1543
Sc2	728	20	327	115	305	29	13	1079

Sc3	353	11	87	54	156	17	6	476

Source: authors estimate

Table 6 Baseline parameters used for intervention gains

2015–2023	BASELINE PARAMETERS							
Parameter	Romania	Moldova	Belgium	Bulgaria	Portugal	North Macedonia	Montenegro	France
CAGR active persons	–1.2%	–2.1%	0.6%	–1.1%	0.5%	–0.1%	0.1%	0.3%
CAGR labor productivity	9.2%	8.1%	2.9%	8.2%	3.8%	4.6%	7.1%	1.8%
CAGR net wages	8.7%	12.7%	3.1%	8.9%	3.5%	5.9%	5.7%	1.7%
CAGR gross wages	10.5%	12.4%	2.5%	9.1%	3.5%	6.1%	3.5%	1.4%
CAGR diff. gross–net	14.2%	10.6%	2.0%	9.6%	3.6%	6.6%	–2.5%	1.0%
Nominal GDP	8.0%	9.2%	4.1%	8.4%	4.6%	5.4%	7.4%	2.8%
Crude mortality rate	0.6%	1.1%	–1.0%	0.5%	0.9%	1.6%	0.5%	0.2%

Source: authors estimate

Conclusions

1. Across the eight countries analysed (Romania, Moldova, France, Belgium, Bulgaria, Portugal, North Macedonia, and Montenegro), total annual economic losses due to cancer mortality in the active population (20–64 years) ranged from €16 million (Montenegro) to €3.52 billion (France).

2. France incurred the highest indirect economic losses due to cancer mortality among working-age individuals, with an annual GVA loss of €2.6 billion and fiscal losses of €904 million, despite having the lowest mortality rate (107 per 100,000) among the countries analysed.

3. High labour productivity amplifies the economic cost of each premature death.

4. Romania reported a high mortality rate (152/100,000) and sustained €564 million in total annual economic losses, including €466 million from lost productivity and €98 million from forgone tax revenues. The economic burden accelerated sharply after 2020, in parallel with worsening health outcomes.

5. Moldova experienced a 20% rise in cancer mortality rates from 2019 to 2023, but this translated into a 58% increase in total economic costs, driven by rising wages and productivity. By 2023, annual GVA losses reached €37.8 million, and fiscal losses climbed to €4.81 million, despite a shrinking active population.

6. In several countries, productivity losses grew faster than mortality rates, due to rising wages and shrinking labor forces. For instance, in Moldova between 2019 and 2023, the mortality rate increased by 20%, but productivity losses rose by 58%, due to rising wages and improved labour efficiency.

7. The fiscal losses component, consisting of personal income tax, social security contributions and value-added tax, accounted for 15–25% of total indirect costs across countries.

8. Both alcohol and tobacco show inelastic price responses (elasticities of −0.306 and −0.234 respectively), indicating that taxation alone can moderately reduce consumption but may not be sufficient.

9. Tobacco consumption is highly sensitive to income growth (income elasticity = +0.695), meaning that without strong fiscal measures, rising incomes will increase consumption and cancer risk as affordability rise.

10. The simulations highlight the need for income-indexed taxation strategies, especially for tobacco, to counteract the erosion of prevention effects caused by economic growth.

11. Given demographic pressures (e.g., high labour force decline in Moldova and Romania), each premature death among the active population carries increasing economic weight, emphasizing the urgency of preventive investment.

12. Taxation policies on alcohol and tobacco, if indexed to income and paired with reinvestment in prevention, can serve as a self-financing mechanism to reduce cancer incidence and associated economic burdens.

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ANNEX 1

Estimation Command:

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Alcohol:

LS(?,CX=F) LOG(Alcohol_EXPenditure) C LOG(GNDI) LOG(PRICE_change_Alcohol(–1))

Tobacco:

LS(?,CX=F) LOG(Tobacco_EXPenditures) C LOG(GNDI) LOG(PRICE_change_Tobacco(–1))

Estimation Equation:

=========================

LOG(A_EXPenditure) = C(1) + C(2)*LOG(GNDI) + C(3)* LOG(PRICE_change_Alcohol(–1)) + [CX=F]

LOG(Tobacco_EXPenditures) = C(1) + C(2)*LOG(GNDI) + C(3)* LOG(PRICE_change_Tobacco(-1)) + [CX=F]

Dependent Variable: LOG(A_EXP)
Method: Panel Least Squares
Date: 04/28/25   Time: 15:17
Sample (adjusted): 2012 2024
Periods included: 13
Cross-sections included: 5
Total panel (unbalanced) observations: 37

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.900239	0.505601	3.758373	0.0007
LOG(GNDI)	0.077181	0.276372	0.279264	0.7820
LOG(PRICEA(-1))	-0.306001	0.234852	-1.302955	0.2025

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.447309	Mean dependent var		1.799495
Adjusted R-squared	0.336771	S.D. dependent var		1.205030
S.E. of regression	0.981363	Akaike info criterion		2.968910
Sum squared resid	28.89222	Schwarz criterion		3.273678
Log likelihood	-47.92483	Hannan-Quinn criter.		3.076355
F-statistic	4.046646	Durbin-Watson stat		1.824104
Prob(F-statistic)	0.004351			

Source: Authors work in EViews 8 program

Dependent Variable: LOG(T_EXP)
Method: Panel Least Squares
Date: 04/28/25   Time: 15:13
Sample (adjusted): 2012 2024
Periods included: 13
Cross-sections included: 5
Total panel (unbalanced) observations: 39

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.715940	0.545308	1.312910	0.1986
LOG(GNDI)	0.695025	0.262821	2.644485	0.0126
LOG(PRICET(-1))	-0.233931	0.154448	-1.514623	0.1397

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.315783	Mean dependent var		1.572787
Adjusted R-squared	0.187492	S.D. dependent var		1.153328
S.E. of regression	1.039600	Akaike info criterion		3.076698
Sum squared resid	34.58460	Schwarz criterion		3.375286
Log likelihood	-52.99562	Hannan-Quinn criter.		3.183829
F-statistic	2.461466	Durbin-Watson stat		2.298808
Prob(F-statistic)	0.045256			

Source: Authors work in EViews 8 program