Health Forecasting Possibilities based on Open Data: Quantifying the Burden of Smoking in Spain

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Recommended citation:

Cabezas Ares, Alfredo; Delgado Rodriguez, María Jesús; Pinto Hernández, Fernando (2025). "Health Forecasting Possibilities based on Open Data: Quantifying the Burden of Smoking in Spain". *Profesional de la información*, v. 34, n. 2, e34206.

https://doi.org/10.3145/epi.2025.ene.34206

Received: 16-03-2025
Accepted: 15-04-2025

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Abstract

The utilization of open data presents significant opportunities for transformative analysis in the health sector, particularly in understanding consumer habits and their impact on health. This study offers a pioneering and comprehensive cohort analysis of the long-term effects of smoking within Spain's healthcare system, projecting trends through 2030. Despite a nationwide decline in smoking rates, critical challenges persist, notably among the aging "baby-boomer" generation, who are experiencing sharp increases in disease prevalence and related healthcare costs. This analysis highlights the substantial economic burdens, including direct healthcare expenses and broader impacts such as productivity losses and diminished quality of life. It demonstrates the power of open data in facilitating these insights. By leveraging openly accessible health data, this paper underscores the potential for in-depth analysis supporting informed public health policy decision-making. The findings emphasize the crucial role of open data in crafting effective health interventions and policies aimed at mitigating the ongoing impact of smoking, thereby contributing to a more sustainable and health-conscious society.

Keywords

Health Sector, Public Health, Smoking Habits, Healthcare Costs, Cohort Analysis, Open Data.

1. Introduction

Analyses on the effects of tobacco are very limited due to the lack of systematized and open data information on this topic. More common are reports that provide occasional data about smokers' situations and the smoking market. Given the lack of direct data available in this regard, we considered data reuse (**Abella *et al.***, 2020) as a form of research, and to do so we delved into the available open data, which will be used in this work. Smoking is a significant global public health challenge, causing over eight million deaths annually (**WHO**, 2023). Smoking primarily affects the respiratory and cardiovascular system, leading to diseases such as chronic obstructive pulmonary disease (COPD), lung cancer, ischemic heart disease (IHD), and stroke. The economic burden is substantial, with global healthcare expenditure due to smoking-

attributable diseases totaling approximately $467 billion in 2012, and total economic costs, including productivity losses, rising to $1,852 billion annually (**Goodchild *et al.***, 2018).

In the European Union (EU), smoking causes nearly 700,000 deaths each year, making it the leading avoidable health risk (**European Commission**, 2023). The EU's annual cost of smoking-related diseases is around €100 billion (**Decramer**, 2011). In Spain, smoking caused 56,124 deaths in 2016, predominantly due to lung cancer and COPD. Despite reductions in smoking rates from 1987 to 2020, prevalence remains high, especially among men and older women (**Martín-Sánchez *et al.***, 2017). Spain's aging population exacerbates the problem as the prevalence of non-communicable diseases increases with age, placing substantial pressure on the healthcare system.

The smoking-related burden comes against a backdrop of serious structural challenges. In terms of the economy, Spain has been struggling to catch up with its euro-area peers. While the gap between Spain and the rest of the euro area in terms of per capita income and employment rates had steadily decreased until the financial crisis in 2007, this convergence has stopped. As of 2023, Spain's employment rate, productivity, and per capita income are 10-15% lower than the rest of the Euro area. The country's aging population poses further challenges to the labor market, social security, and healthcare systems. Public finances are vulnerable, with a debt-to-GDP ratio of 108% and a budget deficit of 3.7% in 2023 – both significantly higher than the limits of 60% and 3% respectively set out in the EU's Maastricht Treaty (**Bank of Spain**, 2024). As the smoking-related burden is set to exacerbate all these issues, policymakers must address it. To carry out this analysis, it is necessary to have sufficient up-to-date data, which is not usually available. Publishing and using open data on health issues can offer significant benefits, but it also comes with several challenges. Privacy concerns and data security are among the major difficulties. Even anonymized data can sometimes be re-identified, leading to potential breaches of privacy. Additionally, ensuring the security of health data is crucial to prevent unauthorized access, which can compromise sensitive information. On the other hand, open data must be accurate and reliable. Inconsistent or poor-quality data can lead to incorrect conclusions and potentially harmful public health decisions.

The need for rigorous policy measures is underscored by the projection of escalating healthcare costs attributable to smoking. This study aims to review and provide open data to inform policy by highlighting the critical areas where intervention can significantly alter health spending and improve public health outcomes. By leveraging open data, the paper supports the drive for policy transparency and informed decision-making in public health, advocating for strategies that address the unique challenges posed by the smoking habits of Spain's aging population. This paper addresses a significant gap in the understanding of the long-term effects of smoking within Spain's healthcare system, particularly focusing on the aging "baby-boomer" generation. Despite the overall decline in smoking rates, this demographic is experiencing a sharp increase in disease prevalence and related healthcare costs. In essence, the paper fills the gap by providing a detailed cohort analysis that projects trends through 2030, offering valuable insights for public health policy and intervention strategies.

This analysis opens a line of research made possible by the availability of open data in the health sector with a long-term perspective. Emphasizing the principle of transparency and data accessibility, this study utilizes publicly available datasets to trace the trajectory of smoking-related diseases and healthcare costs. The synthesis of this open data provides a robust foundation for evaluating the impact of smoking across different birth cohorts and underpins the call for targeted public health interventions. In the following, this work is organized as follows. The literature review and methodology, including details of the sources used, and the approach and results obtained, are presented below. Finally, the limitations of the work and policy implications are presented, as well as a section of conclusions.

2. Background

2.1. Open Data in Health

This study underscores the importance of open data in enhancing the transparency and accessibility of research. By utilizing publicly accessible data sources, our research aligns with modern scholarly values that promote reproducibility and public engagement, ensuring that our findings are verifiable and useful for both academic and policy-making communities. Smoking is an epidemic in Spain, with current trends suggesting that it will not be eradicated soon. Due to historically high smoking prevalence among Spain's large birth cohorts, the situation may worsen, with effects becoming more apparent in the coming years. The WHO tobacco control rating placed Spain 11th out of 37 European countries in 2021, acknowledging its existing efforts. However, the smoking burden is expected to rise as society ages. Specifically, the costs were calculated at nearly €13 billion in 2020. Yet the peak of demographic change has not been reached. More precisely, 56% of smoking baby boomers are not even 55 years old. Once they surpass 60 years of age, the costs are expected to rise dramatically (**Forey *et al.***, 2011; **Venuta *et al.***, 2016). The Integrated Plan for the Prevention and Control of Tobacco Use, announced in April 2024, aims to strengthen Spain's efforts. Key measures include expanding smoke-free zones, significantly increasing tobacco taxes, preventing the onset of smoking, encouraging cessation, promoting research and monitoring, establishing anti-tobacco alliances, introducing neutral packaging, and banning flavor additives.

An area where Spain seems to lag is in the handling of non-combustible alternatives (NCAs). Spain plans to regulate NCAs the same way as conventional combustible cigarettes, despite these being considered less harmful (see **Forster *et al.***, 2018; **Mallock *et al.***, 2018; **Slob *et al.***, 2020) and a useful tool to help smokers quit and thereby mitigate smoking-related harms. Countries such as the UK, Japan, and Sweden have adopted a more progressive approach. For example, Japan was among the first markets in which NCAs were offered in the form of HTPs. Thanks to Japan's openness to new technologies, this led to a rapid decline in smoking prevalence. Sweden has reduced smoking rates by promoting smoke-free alternatives like snus. Equating NCAs with conventional tobacco products could hinder Spain's efforts to curb the smoking epidemic. Treating both product categories equally may stall the establishment of newer, less harmful products. Smokers who choose to consume harmful products should be informed about less harmful options. Regulatory measures for tobacco consumption are justified by the societal harm smoking causes. Equating less harmful products with conventional ones signals to consumers that there are no substantial differences, which creates misinformation.

In the next decade, smoking-related damages are expected to escalate due to rising healthcare costs and the aging population of heavy smokers, as can be seen by the birth cohort born 1956-1975, which already accounts for 63% of total costs in 2020. A differentiated regulation targeting older age groups who cannot quit could potentially mitigate these issues. Quitting smoking even at advanced ages can significantly improve health (**Mons *et al.***, 2015). The 45 to 64 cohort's smoking rates show that quitting smoking is not a priority for this cohort. Hence, switching to less harmful products may be a more realistic alternative. Current use rates of e-cigarettes in Spain are below average, with only 1% of the population using them – one-quarter of the European average (**European Commission**, 2021a). This indicates that not enough is being done to encourage smokers to switch, revealing significant potential to mitigate smoking damage. To enhance tobacco control effectiveness, Spain should consider implementing more proactive and targeted policies. By embracing a harm reduction approach and differentiating taxation based on product risk, Spain could better manage public health outcomes and healthcare costs, leading to a more effective tobacco control strategy.

Additionally, health cost data from literature may not reflect current costs accurately and focusing on individuals aged 34 and above excludes younger populations. It is also possible that the results are underestimated, as direct healthcare costs per person are held constant over time but have tended to rise historically in reality (**Rama**, 2024). Furthermore, cohort analysis is a theoretical exercise and not a randomized sample study that follows a selected group (representing a specific cohort) over time. Finally, the methodology may not fully capture variability across different socioeconomic and demographic groups. While this methodology accounts for differences across genders, socioeconomic factors such as income, area of residence, or ethnicity are not considered.

2.2. Theoretical Framework on Smoking

The availability of health data is essential for analyses of the socio-economic impact of tobacco use. Smoking is a leading cause of several major diseases, primarily affecting the respiratory and cardiovascular systems. The most significant smoking-related diseases include chronic obstructive pulmonary disease (COPD), lung cancer, ischemic heart disease (IHD), and stroke (**European Commission**, 2021b). These diseases appear more frequently after the age of 60 as the immune system and other repair mechanisms weaken with age, making older individuals more susceptible to the accumulated damage caused by smoking (**Venuta *et al.***, 2016). COPD, characterized by progressive airflow obstruction and disabling symptoms, requires frequent hospitalizations and long-term management (**European Medicines Agency**, 2012). Ischemic heart disease and stroke necessitate acute care during events such as heart attacks and strokes, along with ongoing chronic management. Lung cancer, due to its severe nature, involves extensive treatment, including surgery, chemotherapy, radiation therapy, and palliative care, leading to extremely high costs (**European Commission**, 2021b).

Globally, 15.5% of adults aged 15 and older were current cigarette smokers as of the latest WHO open data (**WHO**, 2021). Despite efforts to curb smoking rates, the number of smokers remains significant due to population growth and disparities in tobacco control measures across countries. Although the South-East Asia Region is anticipated to see the most significant reduction in smoking rates, the European Region is also experiencing a decline. However, the European Region still maintains the highest average smoking rate among all WHO regions throughout the years 2000 to 2020. In the EU, prevalence decreased from 30% in 2015 to 23% in 2020 (**WHO**, 2021). Recent estimates indicate that healthcare expenditure due to smoking-attributable diseases globally totaled approximately $467 billion in 2012, representing 5.7% of global health expenditure. When considering both healthcare expenditures and productivity losses, the total economic costs of smoking rise to $1,852 billion annually, equivalent to 1.8% of the world's annual gross domestic product (GDP) (**Goodchild *et al.***, 2018). The EU faces an annual cost of around €100 billion due to diseases such as lung cancer, COPD, cardiovascular diseases, and stroke (**Decramer**, 2011; **Gallus *et al.***, 2021).

In 2016, there were 56,124 deaths attributed to smoking in Spain, with lung cancer and COPD being the leading causes. Smoking-related mortality predominantly affects men, with 84% of the attributable deaths occurring in males, and 50% of the deaths in individuals over 74 (**Pérez-Ríos *et al.***, 2020). Even though the number of male and female smokers has decreased in Spain between 1987-2020 from 55% to 26% among men and 23% to 18% among women, overall prevalence is still high. Spain is in the average range in terms of prevalence and is consistent with the broader EU trend, showing

significant gender and age variations. Recent projections using the Spanish National Health Survey (**Ministry of Health Spain**, 2023b) indicate that the smoking rate among men is decreasing at a rate of 2.6% annually, while the rate among women shows a slight decline of 0.4% annually (**Martín-Sánchez *et al.***, 2017). By age groups, the results suggest smoking prevalence will decrease during 2012 – 2025 in all age groups for both sexes except for women aged 40 to 64.

A further study examined the prevalence of cigarette smoking among subsequent cohorts in Spain, adjusting for the higher mortality rates among smokers. Among men, smoking reached its peak in the "baby boomer" cohort born between 1950 and 1959, with a prevalence rate of 68% during their twenties. For women, smoking was uncommon until 1960. From then on, smoking rates among women progressively increased in subsequent cohorts until 1980. By 1990, the age distribution of smoking prevalence in women resembled that observed in men 40 years earlier (**Fernández *et al.***, 2003). Spain has implemented various measures to curb smoking. These include comprehensive smoking bans in public places, restrictions on tobacco advertising, and taxation policies aimed at reducing tobacco consumption. The history of smoking regulation in Spain dates to the early 2000s, with significant legislative efforts such as the 2005 law banning smoking in workplaces and public spaces. In 2024, Spain will continue to strengthen its tobacco control policies, focusing on public health campaigns and smoking cessation programs to reduce the prevalence of smoking, particularly among young people and vulnerable populations (**WHO**, 2023). This revised literature review section ensures better flow and coherence, linking the economic, demographic, and health-related aspects of smoking in Spain to the broader context of public health policy and cohort analysis. Each part builds upon the before creating a comprehensive understanding of the complex issue at hand.

3. Data and Methodology

3.1. Sources of Information

Data provided by public health institutions in Spain are the main open sources for health studies. Specifically, the following key open data sources can be highlighted for analysis of the socio-economic effects of smoking across different generational cohorts in Spain from 1990 to 2030:

1. **National Health Survey**: These surveys, provided by the Spanish Ministry of Health, offer essential data on smoking prevalence, consumption patterns, and demographic characteristics. This data is crucial for tracking and analyzing trends in smoking behavior across various age groups. The data from this survey are publicly available and can be accessed through the INE website: www.ine.es
2. **Disease Registries**: Disease registries, such as those provided by the Instituto de Salud Carlos III (ISCIII), include detailed data on the incidence, prevalence and mortality rates of smoking-related diseases. These registries are publicly available and can be accessed through the network of rare disease registries in Spain: https://www.health informationportal.eu/health-information-sources/spanish-rare-diseases-registries-research-network These registries include detailed records on the incidence, prevalence, and mortality rates of major smoking-related diseases, such as chronic obstructive pulmonary disease (COPD), ischemic heart disease (IHD), stroke, and lung cancer.
3. **Healthcare Cost Databases**: These databases, compiled by the Spanish Ministry of Health and the National Institute of Statistics, provide information on direct healthcare expenditures related to smoking-associated diseases, covering inpatient care, outpatient services, pharmaceuticals, and ancillary services. These data are publicly available through the Spanish government's open data platform: https://www.sanidad.gob.es/en/estadEstudios/home.htm
4. **Economic and Demographic Data**: Economic and demographic data include population projections, GDP figures, government spending and labour statistics, and can be accessed via the Spanish government`s open data platform: https://datos.gob.es/en

An overview of these open-source data is in Table 1.

Table 1: Overview of Open-Source Data used for the Analysis.

	Indicator	Source
[1]	Smoking prevalence data from 1987 to 2020	Ministry of Health (National Health Survey (SNHS) and the European Health Survey in Spain (EHSS)
[2]	Disease cases, YLLs and YLDs	Global Burden of Disease Study 2019 (GBD)
[3]	Population	United Nations, Department of Economic and Social Affairs, Population Division (2022)
[4]	Relative risks per disease	**Thun *et al.*** (2000)
[5]		**Gandini *et al.*** (2008)
[6]	Treatment cost per disease in USD	Lung Cancer: **Corral *et al.*** (2015)
[7]		Ischemic heart disease: **de Almeida Gouveia *et al.*** (2020)
[8]		Stroke: **Alvarez-Sabín *et al.*** (2017)
[9]		COPD: **Merino *et al.*** (2018)
[10]	Life expectancy at birth in Spain from 1960-2020	World Bank
[11]	Average retirement age in Spain in 2020	OECD
[12]	Unemployment rate in Spain from 1969-2020	International Labor Organization (ILO)
[13]	Annual average wage in Spain from 2004-2020	Statistical Institute of Catalonia
[14]	Consumer Price Index 1984-2020	International Monetary Fund (IMF)
Source: own elaboration.		

3.2. Sample

This study relies on open data sources in the health sector (Table 1) to calculate the economic costs of smoking-related diseases in Spain. We proceed in three steps. The databases used to carry out this study are highly relevant for carrying out analyses in the health sector. First, we calculate the smoking-attributable disease cases using population-attributable fractions by age group, gender, and disease. Second, we calculate direct healthcare costs based on disease-specific treatment costs. Third, we calculate indirect costs using the human capital approach (HCA). The data is segmented into 5-year age groups, focusing specifically on individuals aged 34 and above (**Global Burden of Disease**, 2023). Relative risks associated with smoking-related diseases are sourced from WHO models (**Scarborough *et al.***, 2014). Health cost data is collected from various literature sources, detailing treatment costs per person, age group, and gender for diseases such as lung cancer (**Corral *et al.***, 2015), ischemic heart disease (**de Almeida Gouveia *et al.***, 2020), stroke (**Alvarez-Sabín *et al.***, 2017), and COPD (**Merino *et al.***, 2018). Annual wage data, representing gross annual salaries in Spain from 2004 to 2000, is sourced from the Statistical Institute of Catalonia. Missing data for the years 1990-2003 is filled in using a compound annual growth rate (CAGR) from 2004-2020. For health cost calculations standardized to 2020 values, the annual wage of 2020 is used and kept constant over time (**Statistical Institute of Catalonia**, 2024). Life expectancy at birth is drawn from the World Bank, covering the years 1960 to 2020. For birth years before 1960, a constant life expectancy is assumed (**World Bank**, 2024). Unemployment rates in Spain are taken from the International Labor Organization, available for the years 1969 to 2020. This rate is used to adjust the productive life years remaining by the active labor force among smokers (**International Labour Organization**, 2024). The retirement age in Spain, set at 65 for individuals retiring after an uninterrupted career from age 22, is used to calculate expected productive life years remaining (**OECD**, 2021). Finally, the Consumer Price Index (CPI) from the International Monetary Fund is used to adjust treatment costs per person for inflation over time. Data from 1984 to 2020 is used (**International Monetary Fund**, 2024).

3.3. Statistical Techniques

Our analytical process employs standard statistical techniques suitable for large dataset analysis, ensuring the integrity and reliability of our results. These methods are crucial for uncovering the trends and implications of smoking-related health burdens in Spain. We calculate smoking-attributable diseases by first estimating Population-Attributable Fractions (PAF). This indicator measures the extent that population prevalence or incidence of a particular disease is affected by a known disease risk factor. In our analysis we apply it to the disease-specific incidence by age group and gender each year.

$$\mathrm{PAF}_{ij} = \frac{\mathrm{SP} * (\mathrm{RR}_{ij} - 1)}{1 + \mathrm{SP} * (\mathrm{RR}_{ij} - 1)}$$

where:

SP the smoking prevalence and

RR_{ij} is the relative risk of contracting the respective disease.

To calculate direct healthcare costs attributable to smoking we multiply inferred smoking-attributable disease cases per disease with their respective treatment costs. Treatment costs are annually price-adjusted using the CPI to estimate current price costs. For constant prices, we use 2020 prices. Indirect costs due to productivity losses are assessed first using current prices and second with constant prices from 2020 using the Human Capital Approach (HCA). We incorporate Years of Life Lost (YLLs) and Years Lived with Disability (YLDs), categorized by age group, gender, and disease. To account for the Years of Productive Life Lost (YPLL), we infer from age group-specific YLLs and YLDs the remaining productive years based on year-specific life expectancy and a constant retirement age (**Bencina *et al.***, 2023; **OECD**, 2021). The economic value of these lost years, known as the Present Value of Future Lost Productivity (PVFLP), is calculated by applying wage data to the calculated remaining productive years. This model includes adjustments for yearly unemployment rates, reflecting actual labor force characteristics. Annual earnings are discounted to their present value using the CPI index (**Kasman *et al.***, 2019).

4. Results

Emphasizing the principle of transparency and data accessibility, this study utilizes publicly available and open datasets to trace the trajectory of smoking-related diseases and healthcare costs. This method enables reproducibility of findings but also supports informed decision-making in public health policy. The dynamics of smoking prevalence in Spain reveal significant shifts that have complex implications for public health and healthcare systems. Despite a nationwide decrease in smoking rates, the persistent burden on the health system remains a critical concern. This section examines the nuances of these trends, underpinned by data-driven insights. Our results are presented in three sections. First, we examine smoking prevalence among different genders and birth cohorts until 2020. Second, we provide an overview of

smoking-attributable disease cases, building on our findings for smoking prevalence. Third, we project the direct and indirect costs attributable to smoking in relation to the disease cases.

The overall smoking prevalence has declined from 35% in 2000 to 22% in 2020. The prevalence among men is consistently higher than among women. In 2000 approximately 43% of men smoked, but only about 27% of women. As of 2020, prevalence rates had converged, with 26% of men smoking vs. 18% of women, as shown in further detail in the Appendix. Thus, smoking prevalence has declined more significantly for men than for women, although men still exhibit a much higher smoking prevalence. This observation leaves room for interpretation, though definitive conclusions cannot be drawn and will be left for further research. The stronger decline in male smoking rates could be attributed to the higher initial prevalence among men. Consequently, smoking rates appear to be decreasing marginally, which in turn implies that cessation rates are declining as the overall smoking prevalence decreases.

A further look into specific birth cohorts is noteworthy. The largest birth cohort, born between 1956 and 1975, had an extraordinarily high smoking prevalence in 2000, with approximately 54% of men and 44% of women smoking. These rates have since declined to 29% and 24%, respectively, in 2020. However, they remain high, above the national average at that time, indicating a twenty-year history of consistent and high smoking rates. This is undoubtedly a worrying trend. To draw a comparison to younger cohorts, a group born between 1976 and 1995 is further examined: In 2000, they had a smoking prevalence of 41% (male) vs. 42% (female). In 2020, the prevalence was 32% (male) vs. 24% (female).

In 2000, there were 1.71 million smoking-related disease cases in Spain. By 2020, this increased to 2.12 million smoking-related cases, as pictured in Figure 1. 1.43 million of the total smoking-attributable disease cases are male and 0.68 million females in 2020, compared to only 1.36 million males and 0.35 million females in 2000. The reason for this increase is a rather stagnating number of smokers among women overall. Although cases of the disease are more numerous among men in 2020, it is more likely that there will be a redistribution in the future, as smoking rates among men are falling more sharply than among women. Thus, the distribution of smoking-related diseases by gender is likely to become more equal, with 68% of smoking-related disease cases being male and 32% female in 2020, compared to 79% male vs. 21% female in 2000.

Again, examining the cohort born between 1956 and 1975 there were 0.20 million smoking-related cases in 2000. 54% of these cases affected men and 46% women. By 2020, when the cohort was aged 45-64, the number of smoking-related disease cases had increased to 0.80 million.

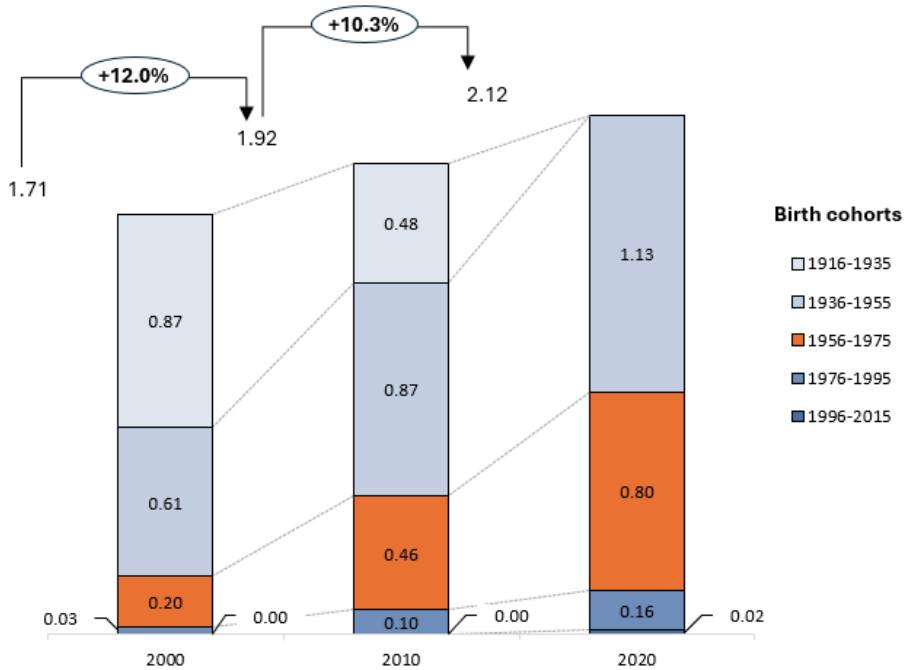

Figure 1: Smoking-Attributable Disease Cases 2000-2020 by Birth Cohort [in million disease cases].
Source: Authors own computation based on [1] - [5].

For comparison, we also examine the generation born between 1976 and 1995. In 2000, for example, only 0.03 million smoking-related disease cases affected this generation. By 2020, this number had increased to 0.16 million. This trend draws a similarly worrying picture as seen with the earlier generation. These results show that the number of disease cases will increase with age in all generations, not just among boomers. Demographic change will thus lead to greatly increased capacity use of the healthcare system. At current prices, total smoking-attributable costs have increased from €8.6 billion in 2000 to €12.7 billion in 2020, see Figure 2.

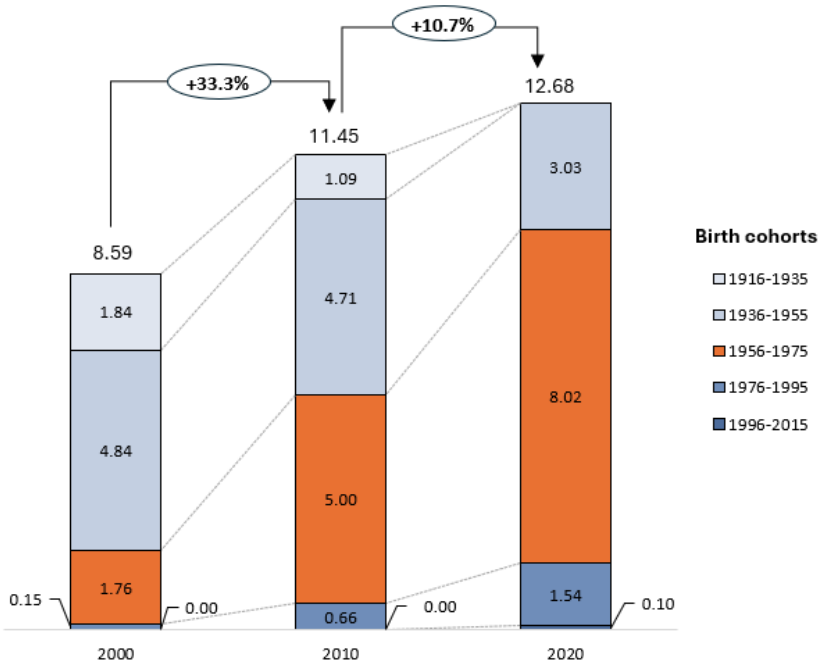

Figure 2: Smoking-Attributable Total Costs 2000-2020 by Birth Cohort in Current Prices [in bn EUR].
Source: Authors own computation based on [1] - [14].

For our analysis, we calculate direct and indirect smoking-attributable costs using two methods. First, we use current prices to provide an outlook on how cost changes will develop over time (see Appendix Table 2: Current prices direct, indirect and total costs over time from 2000 to 2020 (in bn €), based on 2020 values). Second, we use constant prices, based on 2020 prices, to account for changes due to demographic effects (see Appendix Table 3: Constant direct, indirect and total costs over time from 2000 to 2020 (in bn €), adjusted for inflation with CPI). In 2020, using the current price values, the birth cohort born between 1956 and 1975 accounted for an astonishing 63% of all smoking-attributable costs, while the subsequent generation born between 1976 and 1995 accounted for 12%. In the future, this younger cohort will probably have a higher proportion, as they will then reach the age at which people develop smoking-related diseases. This highlights the urgent need for targeted policy interventions, first aiming at older smokers to curb the drastic increase in healthcare costs, and second, focusing on younger generations to prevent sustained high smoking rates over the coming decades.

For comparability, we also use constant price results. We observe that while direct costs increase by 10% from 2000 to 2020, indirect costs decrease. This counterplay sums up a stagnation in total costs, leaving all other factors aside. This demonstrates demographic effects, as the population ages and the number of disease cases increases, while the working-age population is now peaking currently and is likely to shrink in the future due to fewer birth rates in the last decades. Public decision-makers, including government officials and policymakers, play a crucial role in shaping and implementing tobacco control policies. Enacting laws that increase tobacco taxes, restrict advertising and mandate smoke-free environments are actions that have significant implications for public health. Healthcare professionals, community organizations and non-governmental organizations play a vital role in supporting tobacco control efforts. By working together, these actors can create a comprehensive and effective approach to reducing rates and mitigating the associated health and economic burdens.

5. Discussion

Current and proposed measures to regulate tobacco consumption are insufficient to prevent the cost explosion that demographic forces will produce. The strategies in place are not effective enough to counteract the significant economic burden posed by long-term smokers who are now entering a high-risk age bracket for smoking-related illnesses. Smoking is an addiction and habit resistant to quick changes and requires the personal will to quit. Existing measures to help in the process of smoking cessation are redundant unless they effectively spark this will. Sadly, only 30% of current Spanish smokers consider quitting (**Trapero-Bertran *et al.***, 2018). Realistic alternatives should be taken in consideration, such as encouraging smokers to switch to less harmful alternatives.

To address the looming wave of dramatically increasing smoking-attributable healthcare costs, we propose a two-step approach (see Figure 3). First, measures to promote smoking cessation must be intensified, especially for long-term smokers who are entering the high-risk age bracket for smoking-related illnesses. This includes strengthening primary

care involvement, expanding access to cessation treatments, and enhancing public awareness campaigns. Second, those smokers who cannot quit should be encouraged to transition to less harmful products. This can be achieved through financial incentives utilizing tax differentials between combustible and non-combustible products. Public health campaigns explaining the products' differences would be beneficial for informed (healthier) consumption. This can mitigate, though not entirely prevent, the explosion of healthcare costs. An active policy against combustible cigarettes and in favor of less harmful alternatives can quickly and effectively bring about change, as demonstrated by the example of Sweden, Japan, and UK (**Clarke *et al.***, 2019; **ONS**, 2023; **Stoklosa *et al.***, 2020). This two-step approach would give Spain more time to stem the tidal wave of healthcare costs by actively promoting harm-reduction strategies.

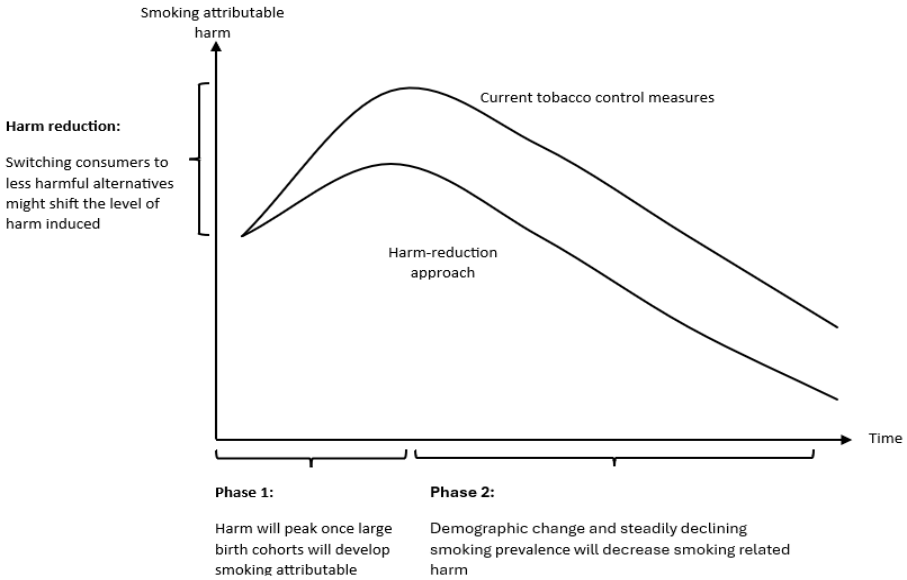

Figure 3: Potential outcomes of current tobacco control measures vs. harm-reduction approach on smoking-attributable harm over time.
Source: Own illustration.

Thus, we argue for a first things-first principle. Spain needs a solution that mitigates the expected cost explosion induced by the elderly smoking population. While cessation is the optimal outcome, steering long-term smokers who cannot quit towards less harmful alternatives via financial incentives and education appears to be a viable strategy and second-best option. To quantify the potential effects, we calculate the impact of 50% of smokers switching to non-combustible alternatives in 2020. Our results, though a snapshot, indicate that such a switch could reduce smoking-attributable direct and indirect costs by about €5.5 billion, equivalent to 57% of the total costs (see Figure 4).

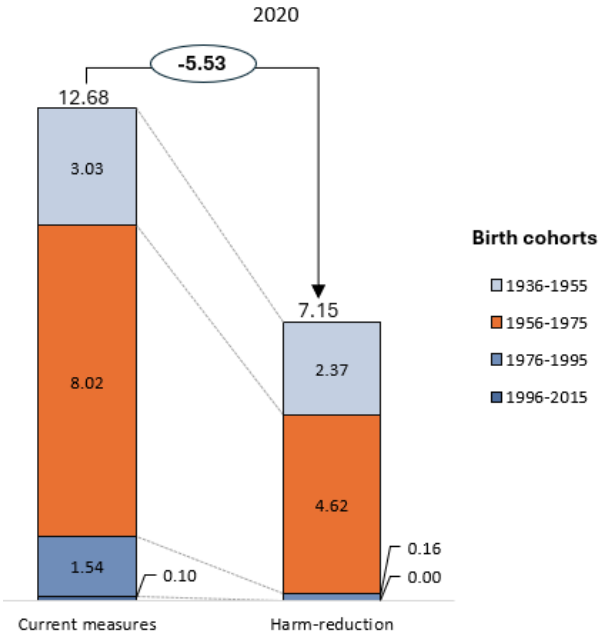

Figure 4: Total Smoking-Attributable Costs in 2020 in Current Prices Under Current Measures vs. Harm-reduction Scenario (50% of Smokers Switch & 80% less risk Assumed in NCAs) [in bn EUR].
Source: Authors own computation based on [1] - [14].

Of this, €3.3 billion could be saved through reduced hospital treatments alone. In a scenario where all smokers switch, this number spikes to €8.3 billion, marking a decline of two-thirds of costs (see Figure 5). For context, the introduction of health warnings on cigarette packages in 2011 resulted in a decline of 1.9% in smoking-related costs by 2012, equal to €0.2 billion. As smoking can cause long-term damage over many years, not all costs can be eliminated immediately. Some costs will remain, but they will shrink over time (see Figure 5).

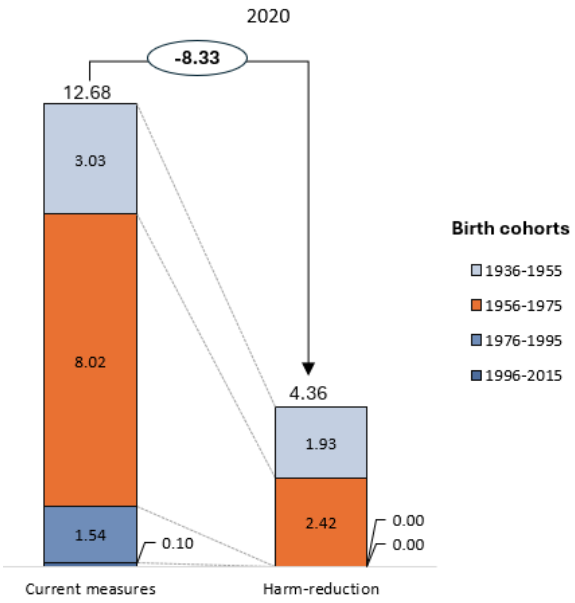

Figure 5: Total Smoking-Attributable Costs in 2020 in Current Prices Under Current Measures vs. Harm-reduction Scenario (100% of Smokers Switch & 80% Less Risk Assumed in NCAs) [in bn EUR].
Source: Authors own computation based on [1] - [14].

The calculated savings could be used to address the Spanish nurse shortage, which is estimated at €1.7 billion, with 41,000 nurses currently missing. Additionally, the remaining funds could be used to increase wages in the healthcare sector to prevent the further drain of skilled workers (**Economic Research Institute**, 2024; **Galbany-Estragués; Millán-Martínez**, 2024; **Ministry of Health Spain**, 2023a). There is no time for gradually weaning off combusted tobacco. Harm reduction can serve as a powerful tool to mitigate the immediate harm and economic impact of smoking. By adopting these strategies, Spain can better manage the current crisis and pave the way for a healthier future, minimizing the impending financial strain on its healthcare system.

6. Conclusions

This study emphasizes the principle of transparency and data accessibility by utilizing publicly available and open datasets to trace the trajectory of smoking-related diseases and healthcare costs. This approach not only ensures the reproducibility of findings but also supports informed decision-making in public health policy. The comprehensive analysis presented in this paper, utilizing a wide array of open data sources, offers a profound insight into the smoking-related health and economic burdens facing Spain from 1990 to 2030. The use of open data has not only ensured the transparency and reproducibility of our findings but has also highlighted significant trends that can inform public health policies and interventions aimed at mitigating the impacts of smoking. Here we encapsulate the major conclusions drawn from our analysis, emphasizing the vital role that open data plays in public health research.

This paper addresses a significant gap in the understanding of the long-term effects of smoking within Spain's healthcare system, particularly focusing on the aging "baby-boomer" generation. Despite the overall decline in smoking rates, this demographic is experiencing a sharp increase in disease prevalence and related healthcare costs. The study contributes to several key areas. It quantifies the substantial economic impact of smoking, including direct healthcare expenses and broader costs such as productivity losses and diminished quality of life. The paper demonstrates the power of open data in facilitating comprehensive health analyses, which can support informed public health policy decisions. Finally, by leveraging open data, the study underscores the potential for crafting effective health interventions and policies aimed at mitigating the ongoing impact of smoking. The dynamics of smoking prevalence in Spain reveal significant shifts with complex implications for public health and healthcare systems. Despite a nationwide decrease in smoking rates, the persistent burden on the health system remains a critical concern. For this reason, evaluating the impact of tobacco control policies is essential to ensure they are effective and identify areas for improvement.

Our findings underscore the critical role of open data in crafting effective health interventions and policies aimed at mitigating the ongoing impact of smoking. By leveraging open data, we support the drive for policy transparency and

informed decision-making in public health. This study opens new avenues for research and highlights the importance of continued efforts to reduce smoking prevalence and its associated health and economic burdens. In this paper, we offer open data in the health sector that can be of great use in researching smoking habits. Our research demonstrates that Spain is running out of time to curb the smoking epidemic. This urgency is primarily driven by large birth cohorts, who have smoked consistently and intensively over decades and are now reaching an age where smoking-attributable diseases typically manifest. This looming demographic shift is set to unleash a tidal wave of dramatically increasing healthcare costs, with data indicating that smoking-attributable expenses have approached €13 billion in 2020.

The methodology, while comprehensive, has several limitations. Using CAGR to fill data gaps assumes uniform changes in smoking prevalence, potentially missing short-term fluctuations. The PAF calculation assumes constant relative risks, which can vary due to genetic, environmental, and healthcare differences. With this work we have contributed to the dissemination and work with open data in the public sector, demonstrating that it is possible to advance in the analysis of health data on topics as relevant as tobacco consumption. Until now, its analysis has been limited by the existence of barriers to access, mainly due to data protection laws. With this work, they open new possibilities for their use with updated data that will be able to be used to create value in this sector. The work offers systematized data made available to researchers who will be able to make free use of the data used. Future lines of research for this type of work on smoking cessation and the use of open data in the public sector could include conducting long-term studies to track the health outcomes of individuals who quit smoking, using open data to monitor changes over decades and comparing different birth cohorts to understand how smoking behaviors and health outcomes evolve over time.

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Appendix

Table 2: List of Abbreviation.

Abbreviation	Definition
CAGR	Compound Annual Growth Rate
CISNS	Interterritorial Council of the National Health System
COPD	Chronic Obstructive Pulmonary Disease
ENSE	Spanish National Health Survey
EU	European Union
HCA	Human Capital Approach
HNCD	High-prevalence Non-Communicable Diseases
GDP	Gross Domestic Product
IHD	Ischemic Heart Disease
NHS	National Health System
NCA	Non-combustible alternative
PVFLP	Present Value of Future Lost Productivity
YLD	Years Lived Disabled
YLL	Years Lost Life
YPLL	Years of Productive Life Lost
WHO	World Health Organization

Table 3: Smoking Prevalence, Number of Smokers, Disease Cases Over Time from 2000 to 2020 by Gender

	Year	2000			2010			2020		
	Cohort	Smoking Prevalence (%)	Number of Smoker (mio)	Smoking Related Disease Cases (mio)	Smoking Prevalence (%)	Number of Smoker (mio)	Smoking Related Disease Cases (mio)	Smoking Prevalence (%)	Number of Smoker (mio)	Smoking Related Disease Cases (mio)
Male	1916-1935	20%	0.57	0.77	9%	0.15	0.40	-	0.00	0.00
	1936-1955	43%	1.91	0.46	25%	1.05	0.67	13%	0.51	0.81
	1956-1975	54%	3.54	0.11	38%	2.76	0.29	29%	2.02	0.53
	1976-1995	41%	1.24	0.02	37%	2.29	0.05	32%	2.03	0.09
	1996-2015	-	0.00	0.00	-	0.00	0.00	21%	0.53	0.01
Female	1916-1935	2%	0.07	0.10	1%	0.03	0.09	-	0.00	0.00
	1936-1955	16%	0.75	0.14	12%	0.54	0.20	6%	0.29	0.32
	1956-1975	44%	2.84	0.10	32%	2.29	0.18	24%	1.71	0.28
	1976-1995	42%	1.23	0.02	30%	1.77	0.05	24%	1.47	0.08
	1996-2015	-	0.00	0.00	-	0.00	0.00	16%	0.37	0.01
Source: Authors own computation based on [1] - [14]										

Table 4: Current Prices Direct, Indirect and Total Costs Over Time from 2000 to 2020 (in bn EUR), Adjusted for Inflation with CPI.

Year	2000			2010			2020		
Cohort	Direct Cost	Indirect Cost	Total Cost	Direct Cost	Indirect Cost	Total Cost	Direct Cost	Indirect Cost	Total Cost
1916-1935	1.84	0.00	1.84	1.09	0.00	1.09	0.00	0.00	0.00
1936-1955	1.97	2.87	4.84	2.88	1.82	4.71	3.03	0.00	3.03
1956-1975	0.93	0.83	1.76	2.21	2.79	5.00	3.74	4.28	8.02
1976-1995	0.15	0.00	0.15	0.56	0.10	0.66	0.98	0.56	1.54
1996-2015	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.10
Total	4.89	3.70	8.59	6.74	4.71	11.45	7.85	4.84	12.68
Source: Authors own computation based on [1] - [14]									

Table 5: Constant Direct, Indirect and Total Costs Over Time from 2000 to 2020 (in bn EUR), based on 2020 Values.

Year	2000			2010			2020		
Cohort	Direct Cost	Indirect cost	Total Cost	Direct Cost	Indirect Cost	Total Cost	Direct Cost	Indirect Cost	Total Cost
1916-1935	2.68	0.00	2.68	1.20	0.00	1.20	0.00	0.00	0.00
1936-1955	2.87	4.39	7.26	3.19	2.00	5.19	3.03	0.00	3.03
1956-1975	1.36	1.27	2.63	2.44	3.07	5.52	3.74	4.28	8.02
1976-1995	0.22	0.00	0.22	0.62	0.11	0.73	0.98	0.56	1.54
1996-2015	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.10
Total	7.13	5.65	12.78	7.46	5.19	12.64	7.85	4.84	12.68
Source: Authors own computation based on [1] - [14]									

Methodology for Estimating Potential Savings for Smokers Switching to Risk-Reduced Products

Assumptions

1. **Switching Factor:** We assume that 50% of current smokers will switch to less harmful alternatives.
2. **Risk Reduction Factor:** We assume an 80% reduction in risk when consuming less harmful alternatives compared to smoking (**Forster *et al.***, 2018; **Mallock *et al.***, 2018; **Slob *et al.***, 2020).

Estimating the New Number of Smoking-Attributable Disease Cases

1. Calculating Post-Switching Smoking Prevalence (SP)

$$SP_{post\_switching} = \frac{n_{smoker} \times switching\ factor}{n_{adult\_population}}$$

2. Estimating New Population Attributable Fraction (PAF) for Smokers

$$PAF_{smoker\_post\_switching} = \frac{SP_{smoker\_post\_switching} \times (RR\ -\ 1)}{1 + SP_{smoker\_post\_switching} \times (RR - 1)}$$

3. Calculating New Number of Smoking – Attributable Disease Cases for Smokers

$$N_{smoker\_disease\_cases\_post\_switching} = PAF_{smoker\_post\_switching} \times N_{disease\_cases}$$

Estimating Disease Cases from Switchers

1. Adjusting Relative Risks (RR) for Switchers

$$RR_{switcher} = 1 + ((1 - risk_{reduction}) * RR_{current_{smoker}})$$

Calculating Switcher Prevalence ($P_{switcher}$)

$$P_{switcher} = \frac{n_{switcher}}{n_{adult\_population}}$$

2. Calculating new Population Attributable Fraction (PAF) for Switchers

$$PAF_{switcher} = \frac{P_{switcher} \times (RR_{switcher} - 1)}{1 + P_{switcher} \times (RR_{switcher} - 1)}$$

3. Calculating Number of Disease Cases Attributable to Switchers

$$N_{disease\_cases\_switcher} = (N_{disease_{cases}} - N_{smoker\_disease\_cases\_post\_switching}) \times PAF_{switcher}$$

Total Number of Smoking-Attributable Disease Cases After Switching

$$N_{disease\_cases\_post\_switching} = N_{smoker\_disease\_cases\_post\_switching} + N_{disease\_cases\_switcher}$$

Savings in Disease Cases

$$Savings\ in\ disease\ cases = N_{disease\_cases\_pre\_switching} - N_{disease\_cases\_post\_switching}$$

Direct Healthcare Cost Savings

Direct healthcare cost savings are obtained by multiplying the number of disease cases with the corresponding treatment cost per disease.

Indirect Cost Savings

Indirect cost savings are inferred using the fraction of indirect to direct costs from the previous analysis. This fraction is then multiplied by the direct costs to obtain the total indirect cost savings.

By combining both direct and indirect cost savings, we can calculate the total cost savings associated with smokers switching to risk-reduced products.