Paid and unpaid productivity losses across 28 European countries due to excess deaths and COVID-19 deaths from 2020 to 2023

Paweł Niewiadomski[1], Marta Ortega-Ortega[2], Błażej Łyszczarz[3]

Abstract

Background: The COVID-19 pandemic has caused significant epidemiological and economic burdens. Although extensive epidemiological research exists, data on productivity losses resulting from COVID-19 remain limited. Therefore, this study aimed to estimate paid and unpaid productivity losses from excess deaths and COVID-19 deaths across 28 European countries from 2020 to 2023.

Methods: This study used retrospective, population-level Eurostat data and a societal perspective to estimate paid and unpaid productivity losses (indirect costs) related to mortality caused by the COVID-19 pandemic (excess deaths and COVID-19 attributable deaths) in 28 European countries (European Union and Norway) from 2020 to 2023. For paid (market) losses, we applied the alternatives of the human capital approach (HCA) and the friction cost approach (FCA); for unpaid (non-market) losses, we used the opportunity cost approach (OCA).

Results: Total paid productivity losses from excess deaths in 2020-2023 across all 28 countries combined were €82.9 billion in the Human Capital Approach and €3.9 billion in the Friction Cost Approach. Non-paid productivity losses amounted to €96.0 billion, of which €28.6 billion were attributable to the employed and €67.4 billion to the non-employed. For COVID-19 deaths, the productivity losses were lower: €35.0 billion for HCA, €2.1 billion for FCA, and 56.2 billion for unpaid losses (€12.4 billion for the employed, and €43.8 billion for the non-employed). The highest relative economic burden was experienced in the Central and Eastern European countries and three Baltic states (Latvia, Lithuania and Estonia). Losses were higher among men than women, particularly in paid productivity losses (>80% of total). Age-specific paid losses and unpaid losses among the employed were the greatest in the middle-aged (40-59), while for unpaid losses among non-employed, most of the burden was identified in the elderly (aged 60-74). Additionally, we identified heterogeneous time patterns across regions, with Central and Southern European countries experiencing the highest losses in 2021, Western countries in 2022 and Northern ones in 2023.

Conclusions: This study shows that the burden of productivity losses caused by pandemic mortality was substantial, highly variable across regions and over time, and sensitive to the baseline mortality and valuation method used.

Keywords: Productivity losses; COVID-19; excess deaths; mortality; human capital approach; friction cost approach; opportunity cost approach; indirect costs; Europe

[1] Nicolaus Copernicus University in Toruń, Doctoral School of Medical and Health Sciences, Bydgoszcz, Poland; ORCID: 0000-0003-4522-0595; corresponding author; e-mail: pawel.niewiadomski@doktorant.umk.pl.
[2] Department of Applied and Public Economics, and Political Economy, Complutense University of Madrid, Madrid, Spain; ORCID: 0000-0001-8164-9415.
[3] Nicolaus Copernicus University in Toruń, Department of Health Economics, Bydgoszcz, Poland; ORCID: 0000-0002-5825-5079.

This preprint has not undergone peer review (when applicable) or any post-submission improvements or corrections. The Version of Record of this article is published in European Journal of Health Economics, and is available online at [doi to be completed after publication].

Funding: This research was supported by the National Science Centre, Poland, under grant no. 2022/47/B/HS4/00081.

1. Background

Burden of disease studies on COVID-19 have provided a comprehensive picture of the pandemic's health toll in terms of both mortality and morbidity (1,2). Numerous analyses have documented declines in life expectancy (3,4), excess mortality (5,6), and reported on morbidity-related outcomes such as disability-adjusted life years (7). In contrast, comparative evidence on the broader socio-economic consequences of this health deterioration remains limited.

One under-researched area of the COVID-19 economic burden is the estimation of productivity losses resulting from the pandemic (8). The productivity losses, also referred to as indirect costs, represent the potential economic output foregone as a result of disease. As such, productivity losses estimates provide complementary information to burden of disease studies (9,10). While the burden of disease studies estimate health impacts, productivity losses analyses translate those impacts into economic terms, quantifying the economic output lost due to morbidity and premature mortality. Although the two approaches are conceptually distinct, together they provide a more comprehensive assessment of the societal burden of disease.

A recent worldwide systematic review of population-level studies on COVID-19 productivity losses identified major research gaps in the literature (11). First, methodological approaches used were limited; most studies employed exclusively the human capital approach (HCA), and none applied the friction cost approach (FCA) to identify losses (12). Second, only one study (13) provided estimates of unpaid productivity losses that arise in non-market settings, such as household or volunteer production lost due to the disease. Third, evidence often covered only the early phase of the pandemic and rarely captured long-term COVID-19 effects that persist also post-pandemic. Fourth, cross-country comparisons of productivity losses remain difficult due to differences in study design, calculation methods, and time horizons. This impedes direct comparison of losses in various time and geographical settings. Finally, few studies incorporated the notion of excess mortality (13,14), as most of the evidence focused strictly on COVID-19 mortality (11). This contrasts with epidemiological literature, which has highlighted excess deaths as a key indicator of the pandemic's health burden (15,16).

This study addresses these gaps by estimating productivity losses from both COVID-19 and excess mortality in 28 European countries in pandemic and post-pandemic years, 2020-2023. Using Eurostat data and a unified methodology, we provide highly comparable, cross-country evidence. Our analysis contributes to the literature in three key ways: it investigates both paid (market) and unpaid (non-market) productivity losses; it compares results based on the HCA and the FCA; and it extends beyond single-country assessments by covering a wide range of European states. Moreover, we report an additional economic burden category of public revenue losses. Together, these contributions enhance understanding of the COVID-19 economic toll and support evaluation of pandemic-related policy responses.

Therefore, this study aimed to estimate paid and unpaid productivity losses from excess deaths and COVID-19 deaths in 28 European countries in the 2020-2023 period, using a uniform methodology based on highly comparable Eurostat data. By providing estimates based on this approach, our study offers policymakers robust evidence on the economic burden of the pandemic across Europe. These findings may provide policy-makers with a better understanding of the recent pandemic economic costs and inform evidence-based decisions regarding future pandemic preparedness and mitigation of societal impacts of health crises (17).

2. Methods

2.1. General approach

This study used retrospective, population-level data and a societal perspective (18,19) to estimate productivity losses (indirect costs) associated with mortality attributable to the COVID-19 pandemic in 28 European countries (European Union and Norway) in 2020-2023. Productivity losses represent an economic output unproduced (9,12) due to mortality associated with the COVID-19 pandemic.

We use two alternative approaches to define mortality attributable to COVID-19: (a) deaths reported with the ICD-10 code U07 assigned as a cause of death; and (b) excess deaths. For both approaches, we estimate paid and unpaid productivity losses (20); the former represent formal losses from market activities undone, and the latter account for non-formal output lost. For paid losses, we rely on two alternative loss estimation methods, the human capital approach (HCA) and the friction cost approach (FCA). For unpaid losses, we use the opportunity cost approach (OCA). All these methods are explained in detail below.

Following a recent systematic review of COVID-19 productivity losses (11), we report results broken down by sex and three age-based groups: the young (0–39 years), middle-aged (40–59 years), and elderly (60+ years).

All analyses, data pre-processing and visualisations were carried out in R (v. 4.4.1) using RStudio (v. 2024.09), Microsoft Office Excel 2021 and Python (3.11.6) with libraries pandas (2.2.3), numpy (2.2.1) and statsmodels (0.14.4).

2.2. Mortality attributable to COVID-19

Country-specific Eurostat annual data on all-cause deaths and COVID-19 deaths (broken down by sex and 5-year age groups) (21), were used to determine excess deaths and deaths attributable directly to the virus, respectively.

For excess deaths, we used age-group- and sex-specific mortality rates from the 2002-2019 baseline period to build Ordinary Least Squares (OLS) regression models, allowing us to predict mortality rates during the pandemic and post-pandemic years, 2020-2023. To avoid the arbitrariness of choosing one reference baseline period, we analysed a complete set of potential baseline periods (2002-2019, 2003-2019,…,2018-19, 2019 observation only) and averaged the eighteen sex- and age-specific forecasts for each group and each year of the predicted period. Also, to avoid the impact of outlier estimates, we excluded from such calculated averages those models for which forecasts were >1.5 interquartile range from the median value for each year. Eventually, to determine the predicted death numbers for 2020-2023, the mean mortality rates were multiplied by the respective population counts and excess mortality for the period was calculated as the difference between observed and predicted mortality.

Because we used 5-year age groups, we assumed that each death occurs at the midpoint of a group, e.g. at the age of 27 for the 25-29 age group. Additionally, a half-cycle adjustment was applied, meaning that all deaths occurred in the middle of the year (22) (not in the FCA, where this adjustment was irrelevant).

2.3. Economic measures

A productivity measure applied was per worker gross domestic product (GDP) adjusted for purchasing power parity (23). Because the per worker GDP reflects average economic output and indirect cost estimation should rather rely on marginal, not average productivity (12,24), we adjusted per worker GDP by a 0.65 coefficient that approximates the output elasticity of labour as used in the European context (25) (for applications, see (26,27)).
To account for productivity variation across age- and sex-specific sub-populations, we used available Eurostat data on mean annual earnings (28). We assume that the variation of per worker GDP between particular age groups and sexes might be reflected by respective differences in earnings between sub-populations defined as such. In detail, we used three age groups as reported by Eurostat: <30, 30-49, and ≥50 years of age for each of the 28 states analysed. For example, in Belgium, earnings of men (women) aged <30 (50+) are 31.2% lower (15.7% higher) than on average for men (women), and we assume that the productivity measure (per worker GDP) varies accordingly.
In contrast to previous studies (20,26), we do not estimate losses in the strictly working-age population (using either factual or legal retirement age as a threshold for quitting the labour market). Instead, we include the population at each age for which employment rates are reported by Eurostat (29), meaning that the population aged 15-74 years is analysed here.

For the HCA and OCA estimates, we used a 5% discount rate to account for the diminishing future value of production lost. Additionally, to incorporate the impact of future economic growth across the EU, we used the EU average potential per worker GDP growth rates for the forthcoming decades (30). For FCA, neither discounting nor economic growth adjustment was applicable because, for this method, losses do not extend into the future to more than a year.

All the losses were expressed in real terms, using the harmonised index of consumer prices as a deflator (31) and 2020 as a base year.

2.4. Human capital approach

Using the HCA, productivity losses represent the potential discounted value of market output lost (paid losses) that would be produced if those who died were still alive and were working until the end of their projected labour market activity period. To adjust for variations in employment participation and productivity between sexes and populations across different age, we used sex- and age-specific input data for employment rates and per worker GDP, as explained above. Subsequently, productivity losses were estimated by incorporating the progressive variability of per worker GDP and employment rates, which change by sex and age group. Specifically, the calculations reflected the fact that productivity tends to increase with age, while labour market participation declines in the elderly.

Unlike most of the studies that deal with COVID-19-related deaths in the working age population (see e.g. (13,32,33)), we included deaths at pre-productive age (age groups 0-4, 5-9, 10-14). This is because those dying young would eventually enter the labour market, and the potential economic output lost due to these deaths should be accounted for (adjusting for expected employment rates and the discounted value of future productivity). For example, as we assume that labour market entry occurs at the age of 15, a 2020 death in the age group 0-4 would result in employment entry in 13 years (15 - 2 [middle of the age range] = 13), that is, in 2033.

2.5. Friction cost approach

The friction cost approach offers an alternative to the HCA for assessing productivity losses attributable to diseases. FCA assumes that the productive time lost due to illness is limited only to the period needed to replace a deceased worker, allowing for production restoration with this replacement (10,24).

For the calculation of the friction period, we relied on the study (34), which estimated the friction period in 30 European countries. Using their base-case method (1_{BC}) for each country and year, we obtained respective friction periods. Estimates of productivity losses based on the FCA were limited to the population aged 15-74, meaning that the pre-productive population was excluded. This is because the FCA, unlike the HCA, does not deal with losses of those anticipated to start work in future. We used sex- and age-specific input data, as we do in the HCA. Accordingly, productivity losses are calculated as the product of the number of deaths and per worker GDP corresponding to the country- and year-specific friction period.

2.6. Opportunity cost approach

The OCA is used to estimate losses from unpaid production. This indirect cost category represents the non-market production uncompleted by those (working in the labour market or not) who domestically undertake productive tasks that have societal value and could be monetised according to market rates (20). A single category of unpaid production was created by summing up the time spent (based on Eurostat's Time Use Survey 2010 (35); no more recent edition available) on several categories, including household and family care, laundry, among others[4].

Following (20) we divide unpaid production into categories based on sex, age-groups and employment status. For those in the working category, we average the time spent on the above activities by those working full-time and part-time. For the non-working population, we average the time of unpaid work done by the unemployed, students, homemakers and retired people.
To determine the annual time and economic value of non-market production lost, we refer to the time lost in the formal economy and its GDP valuation. In detail, we assume 250 working days (in the formal economy) and an average of 8 work hours a day, yielding 2,500 labour hours per year. Since we used per worker GDP in the non-market valuation, we aimed to express the value of the non-market losses by relating them to market losses. The following illustrative example explains our approach. Male paid workers in Belgium spent an average of 1,427 hours per year on unpaid work (Eurostat data (35)) and this represents 71.4% of time spent on paid work (1,427 of 2,500 hours). Therefore, the annual non-market output of an average worker is 71.4% of per worker GDP, additionally adjusted for lower productivity (using minimum earnings – 38.6% of an average earnings), as explained below. The respective estimates were broken down by sex, employment status, and age groups.

In practice, the use of OCA reflects the concepts of the HCA, with the following modifications. First, it accounts for losses among both the working and the non-working (unemployed and economically inactive persons). The non-working share of the population was obtained by subtracting (sex- and age-specific) employment rates from 100%. Second, we assumed that unpaid work is less productive than market activities on average. This is because most of the domestic activities are the ones that could be replaced by labour paid at rates closer to minimum earnings rather than average ones. Therefore, following (26), minimal productivity was obtained by dividing the minimum wage by the average wage in particular economies.

[4] The complete list of categories used to evaluate time spent on unpaid work includes: food management except dish washing; dish washing; household upkeep except cleaning dwelling; cleaning dwelling; laundry; ironing; construction and repairs; household management and help family member; childcare, except teaching, reading and talking; teaching, reading and talking with child; informal help to other households; organisational work; participatory activities.

Because there was no minimum wage legislation in six European countries in 2025 (Denmark, Italy, Austria, Finland, Sweden and Norway), the weighted (population size) mean value for the remaining countries was used for the states with no minimum wage; this mean was 43.47% of the average wage. Third, we assumed that young people aged 15-19 require care from their parents and do not perform household tasks, so we shifted the starting age of losses in the non-market economy to those aged 20-24.

2.7. Public finance burden

In addition to productivity losses analysis, we report how these losses potentially affect public finance revenues. The labour supply decay resulting from premature mortality leads to a reduction in the total output produced. A decrease in the potential GDP results in declined income and lower consumption, which subsequently diminishes public revenues by reducing potential revenues from income and consumption taxes. This simplified analysis illustrates potential losses of public finance revenues that are attributable to decreased GDP resulting from the pandemic. For this purpose, we used Eurostat data (36) on the GDP share of the revenues for the four most important taxes (personal income tax (PIT), corporate income tax (CIT), excise tax, value added tax (VAT)) and social contributions (37,38).

To illustrate our approach, for Belgium in 2020 (according to Eurostat data), VAT revenues constituted 6.4% of GDP and we assume that the same share of estimated productivity losses represents a rough estimate of potential VAT revenue lost. Importantly, the category of public finance burden does not represent an additional economic burden to estimated productivity losses. Rather, these potential revenues lost are a share of productivity lost within the public finance sector. The following categories of the Eurostat's main national accounts tax aggregates (36) database were used: D211 for VAT; D214A for excise tax; D51A for PIT; D51B for CIT; D61 for social contributions.

2.8. Sensitivity analysis

A one-way deterministic sensitivity analysis was performed. The following sensitivity scenarios were applied: gross value added (GVA) instead of GDP, a 3.5% and 0% discount rate instead of the base scenario of 5%; and 0% and 2% future economic growth for all the countries, instead of country-specific growth rates.

3. Results

3.1. Productivity losses from excess and COVID-19 deaths

Total paid productivity losses from excess deaths (ED) in 2020-2023 across all 28 countries combined were €82.9 billion in the Human Capital Approach (HCA) and €3.9 billion in the Friction Cost Approach (FCA) (Table 1). Non-paid productivity losses estimated using the Opportunity Cost Approach (OCA) amounted to €28.6 billion for the employed (OCAe) and €67.4 billion for the non-employed (OCAn) (Table 2), resulting in a total OCA (OCAe + OCAn) of €96.0 billion. For losses based on COVID-19 deaths (CD), the productivity losses were lower: €35.0 billion for HCA, €2.1 billion for FCA (Table S1), €12.4 billion for OCAe, and €43.8 billion for OCAn (Table S2), totalling €56.2 billion for OCA.

[Table 1 here] [Table 2 here]

In absolute terms (total losses for 2020-2023), differences across countries are apparent, and they reflect population size of the countries investigated. Under HCA, the highest losses were identified in Germany (€12.3 billion for ED (Table 1) and €5.4 billion for CD (total COVID-19 deaths) (Table S1)), followed by Poland (€11.2 billion) and Italy for ED (€8.9 billion), and again by Poland and Italy for CD (€5.0 billion and €4.6 billion). Under FCA, Germany also experienced the highest losses (€0.7 billion for ED (Table 1) and €0.4 billion for CD (Table S1)), followed by Poland (ED: €0.5 billion, CD: €0.3 billion) and Italy (ED: €0.4 billion, CD: €0.2 billion). On the other hand, for unpaid losses (total OCA = OCAe + OCAn), the highest absolute losses were estimated for Poland (ED: €13.6 billion; CD: €8.5 billion) and Italy (ED: €13.3 billion; CD: €8.1 billion), followed by France (ED: €11.4 billion; CD: €6.9 billion) (Table 2 and Table S2).

In the HCA model, the average paid productivity losses across all countries and years, expressed as a share of GDP lost, were 0.15% for ED (range: 0.04%–0.62%) (Fig. 1), and 0.06% (0.01%–0.28%) for CD (Fig. S1). The highest HCA-based shares of GDP lost were observed in Latvia, 0.62% for ED (Fig. 1), and in Bulgaria, 0.28% for CD (Fig. S1). The lowest shares for ED were identified in Sweden (0.04%), and for CD in Denmark, Finland, and Norway (0.01%). In the FCA model, the shares of GDP lost were lower, averaging 0.007% (range: 0.002%–0.032%) for ED (Fig. 1) and 0.004% (range: 0.001%–0.013%) for CD (Fig. S1). For FCA, Latvia (0.032%), and Bulgaria (0.013%) experienced the highest shares of GDP lost for ED and CD, respectively. In contrast, Sweden and Luxembourg (0.002%) had the lowest burden in terms of FCA based on ED; and Ireland, Finland, Norway, Denmark, Malta, and Luxembourg had the lowest shares in CD (0.001%). Under OCAn (for unpaid productivity loss) the average lost GDP share was 0.12% for ED (range: 0.03%–0.37%) (Fig. 2) and 0.08% for CD (range: 0.01%–0.25%) (Fig. S2). For OCAe losses, the share of GDP lost was 0.05% (range: 0.01%–0.18%) (Fig. 2) and 0.02% (0.001%–0.1%) (Fig. S2), respectively. The three Northern Europe (NE) countries (Lithuania, Latvia, and Estonia) had the highest OCAe losses of 0.15% to 0.18% GDP for ED, while for OCAn, these were the Central and Eastern Europe (CEE) countries (Bulgaria, Romania, and Slovakia), that experienced the greatest burden of 0.32%-0.37% of GDP lost (Fig. 2). For OCAe based on CD, Bulgaria, Slovakia, and Hungary had the highest losses of 0.06%-0.1% GDP. For OCAn, the most burdened countries in terms of CD were Bulgaria, Slovakia, and Romania (0.20%-0.25% GDP) (Fig. S2).

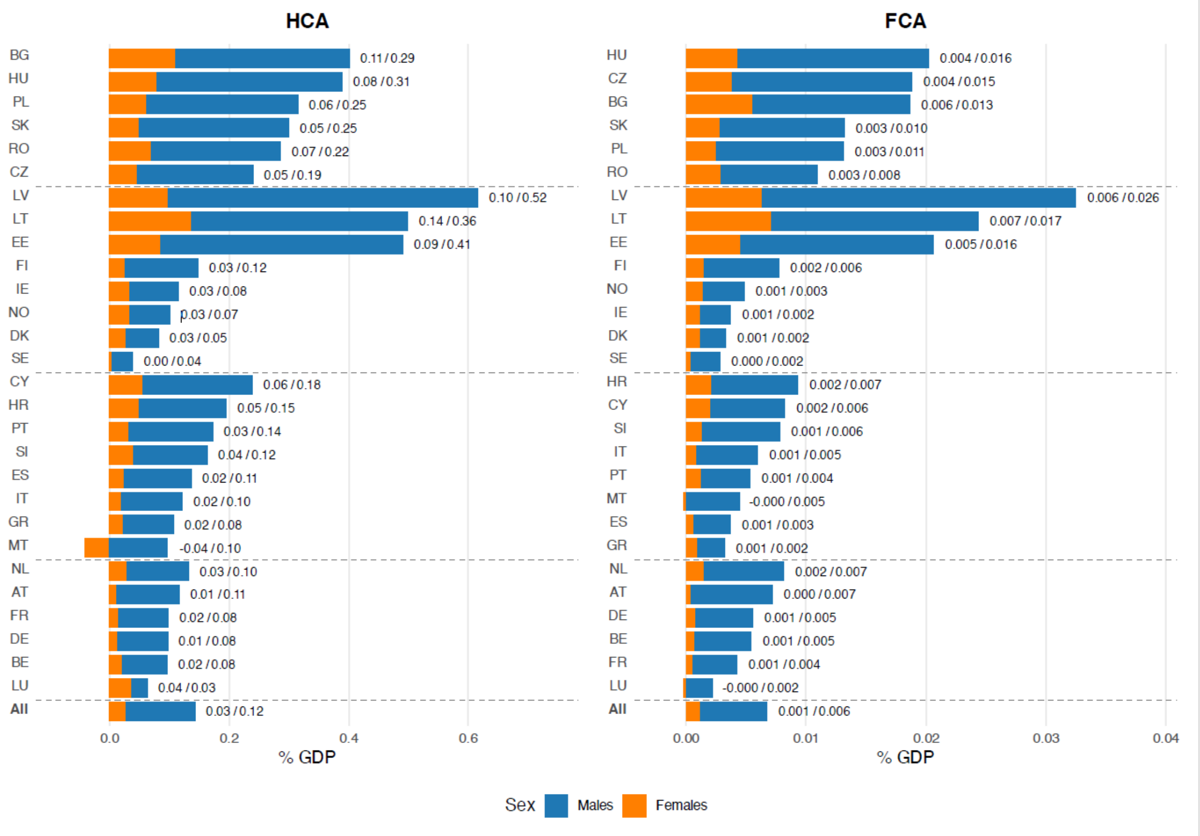

Figure 1. Paid productivity losses from excess deaths in 28 European countries, 2020-2023: share of gross domestic product (GDP) lost

Notes: HCA – human capital approach; FCA – friction cost approach.

3.2. Time distribution of productivity losses

Our results show marked variation in how productivity losses were distributed over time and regions. For ED, it was 2021 when losses were the highest in CEE and Southern Europe (SE) countries. On the other hand, Western Europe (WE) states experienced the highest ED losses in 2022, while NE in 2023. This time-region pattern was universal across methods used, but only for excess deaths. Countries such as Lithuania, Latvia, Poland and Romania had the highest losses in 2021 and the lowest in 2023, while Finland, Norway and Sweden experienced the greatest burden as late as 2023. For some other countries, e.g. Spain and Italy, the burden was distributed more equally across years (Table 1 and Table 2). In contrast, for COVID-19 deaths, the burden of productivity losses was the highest in 2021 for all regions (data for 2023 not available for most countries) (Table S1 and Table S2).

3.3. Sex- and age-specific productivity losses

Sex-specific figures reveal a notable disparity, with men experiencing most productivity losses across methods and mortality measures. Under HCA, male ED made up 81% of losses (Fig. 3) and 76% in CD (Fig. S3). Under FCA, male shares were 82% in ED (Fig. 3) and 76% in CD (Fig. S3). For unpaid losses, sex differences were slightly smaller but still notable: among the employed (OCAe), males contributed 73% of losses for ED (Fig. 3) and 66% for CD (Fig. S3); in non-employed (OCAn), male shares were 66% (Fig. 3) and 61% (Fig. S3), respectively. The sex differences are also evident when looking at results in relative terms. For HCA-based ED estimates, men accounted for 0.12% of GDP lost and women for 0.03% (all countries and years combined). For FCA, these figures were 0.006% and 0.001% (Fig. 1), for OCAe, 0.04% and 0.01% (Fig. 2), and for OCAn, 0.08% and 0.04% (Fig. 2), respectively.

For HCA, productivity losses were concentrated in the 40–59 age group: for ED, losses in this age group amount to 60% (Fig. 3), compared to 14% for 60–74 and 26% for 0–39, and for CD, 61% (Fig. S3), with 25% and 14% in the other groups, respectively. FCA showed a similar age profile, but the burden shifted to the 60–74 age group (Fig. 3 and Fig. S3): 57% in 40–59, 34% in 60–74, and 10% in 0-39 for ED; 50%, 45%, and 5% respectively for CD. In OCAe, age shares closely followed HCA, at 60% in 40–59 for ED (Fig. 3) and 61% for CD (Fig. S3). In OCAn, losses were mainly among the elderly, with the 60–74 age group comprising 60% for ED (Fig. 3) and 69% (Fig. S3) for CD.

3.4. Regional differences in productivity losses

From a regional and absolute value perspective, the countries at the top of the productivity losses ranking (across all years) for HCA and FCA for ED, and for FCA for CD, are WE countries (Table 1) with €28.3 billion for HCA for ED, €1.5 billion for FCA for ED, and €0.8 billion for FCA for CD (Table S1). They are followed by CEE countries (€25.8 billion, €1.2 billion, and €0.7 billion, respectively), SE countries (€20.2 billion, €0.8 billion, and €0.5 billion, respectively), and NE countries (€8.5 billion, €0.4 billion, and €0.1 billion, respectively) (Table 1). Under HCA for CD and under unpaid losses (both among working (OCAe) and non-working (OCAn)) and for ED and CD, the CEE countries were at the top of the regional ranking (Table 1, Table 2, Table S1, Table S2). Northern European countries (except Lithuania, Latvia, and Estonia) experience the lowest productivity losses, regardless of the estimation method and mortality measure used. From a relative perspective (as a percentage of GDP), the results differ significantly. CEE countries experience the highest losses relative to GDP (Fig. 1, Fig. 2, Fig. S1, Fig. S2), for all approaches used (HCA: 0.31% for ED, 0.14% for CD; FCA: 0.015%, 0.008%; OCAe: 0.11%, 0.05%; OCAn: 0.27%, 0.18%). Additionally, for the relative measure of GDP lost, WE countries were among those with comparatively lower burden, regardless of the method and mortality measure used.

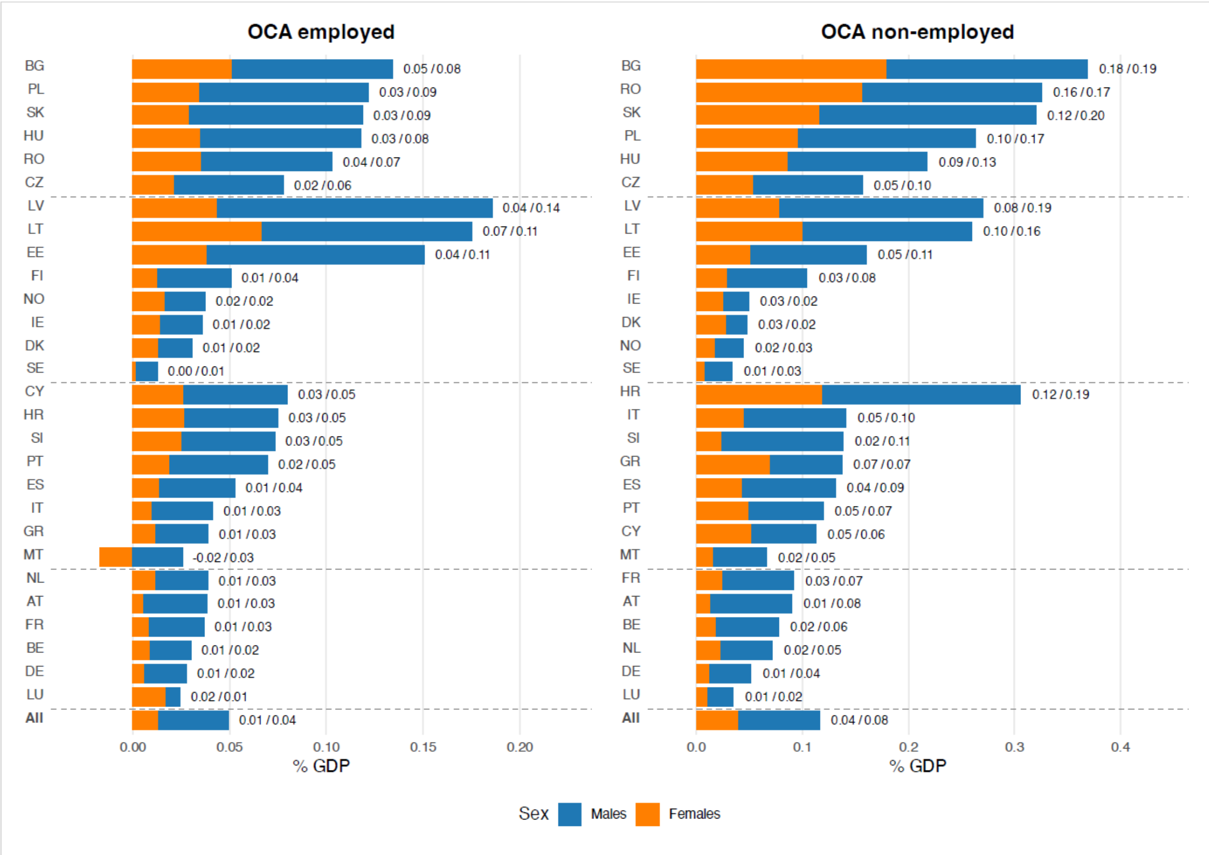

Figure 2. Unpaid productivity losses from excess mortality in 28 European countries, 2020-2023: share of gross domestic product (GDP) lost

Notes: OCA employed – opportunity cost approach for employed; OCA non-employed – opportunity cost approach for non-employed (unemployed persons, students, homemakers and retired).

3.5. Per capita productivity losses

For HCA, the most heavily burdened countries per capita were Latvia (€130.9), Lithuania (€130.6), and Estonia (€122.1) for ED (Table 1), and Bulgaria (€51.9), Hungary (€41.1), and Lithuania (€37.0) for CD (Table S1). For FCA, the most burdened countries were Latvia (€6.9), Lithuania (€6.4), and Czechia (€5.3) for ED (Table 1), and Czechia (€2.7), Hungary (€2.6), and Bulgaria (€2.4) for CD (Table S1). For non-paid losses among employed (OCAe), the countries most affected were Lithuania (€45.9), Latvia (€39.5), and Estonia (€37.5) for ED (Table 2), and Bulgaria (€17.5), Lithuania (€13.4), and Poland (€13.1) for CD (Table S2). For non-paid losses among non-working (OCAn), the most impacted countries were Romania (€73.6), Slovakia (€72.5), and Bulgaria (€69.0) for ED (Table 2), and Bulgaria (€46.8), Slovakia (€46.0), and Romania (€45.2) for CD (Table S2). In each method of productivity losses estimation, Norway, Finland, Sweden, Denmark, and Malta were among the countries experiencing the lowest losses per capita most frequently.

3.6. Public finance burden

The public finance burden attributable to ED (combining all countries and years) was €28.2 billion for HCA and €1.3 billion for FCA (Table 3). The region with the highest burden was WE (€10.7 billion for HCA and €0.6 billion for FCA), followed by CEE (€7.8 billion and €0.4 billion), SE (€7.0 billion and €0.3 billion), and NE (€2.8 billion and €0.1 billion). The public revenue burden for CD used as a mortality measure (all countries and years combined) was €11.9 billion for HCA and €0.7 billion for FCA (Table S3). The regional order of fiscal burden remains unchanged and is analogous to that for excess deaths.

[Table 3 here]

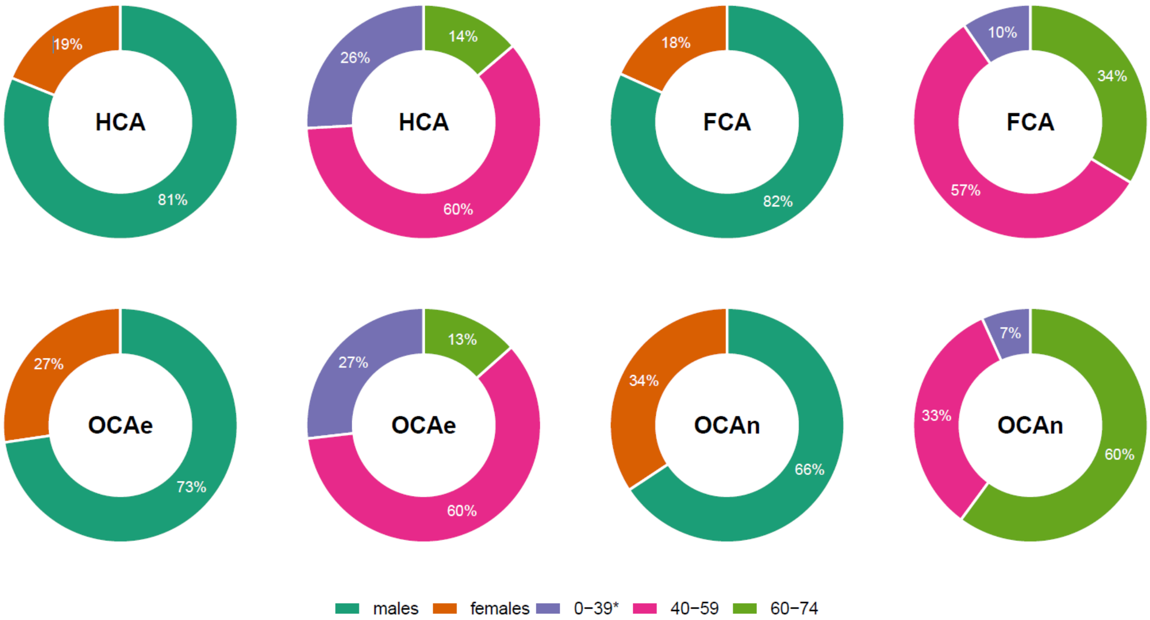

Figure 3. Sex- and age-specific breakdowns of productivity losses from excess mortality in 28 European countries

Notes: HCA – human capital approach; FCA – friction cost approach; OCAe – opportunity cost approach for the employed; OCAn – opportunity cost approach for the non-employed (unemployed persons, students, homemakers and retired).

3.7. Sensitivity analysis

The one-way deterministic sensitivity analysis shows that the cost estimates are subject to notable variation with changes in some of the model's parameters. Table 4 reports average changes for all scenarios in ED, while Table S4 reports analogous variations in CD, and Tables S5 and S6 provide detailed estimates for all individual countries using ED and CD.

For FCA in the only analysed category, gross value added (GVA), the change was -9.0% for ED (Table 4) and -9.7% for CD (Table S4). The largest variation in the results for HCA, at 64.1% for ED (Table 4) and 46.0% for CD (Table S4), was associated with no discounting (discount rate of 0%). For other parameter variations, results differ from the baseline scenario by up to 13.4% for ED and 10.3% for CD (discount rate = 3.5%), and by -8.1% for ED (future economic growth = 0%) and -7.0% for CD (GVA). For non-paid losses (OCAe and OCAn), the variations are similar to those seen in HCA (Tables 4 and S4). For some countries, particularly the low-populated ones as Malta, Luxembourg, the sensitivity analysis based on ED shows high variability, reaching as high as -547.7% (Malta) compared to the baseline (Tables S5). These results arise from the fact that negative and positive excess deaths cancel up, leading to low loss estimates that are prone to large relative variability. Therefore, such results should be treated with caution.

In countries with larger populations, ED results were more stable (Table S5). Results based on CD were also stable, even in countries with small populations (Table S6).

[Table 4 here]

4. Discussion

Our cross-country analysis of productivity losses attributable to the COVID-19-related mortality in 28 European countries provides new evidence on the economic burden of the recent health crisis. Applying a four-year period (2020-2023), our study is the first to analyse both the acute pandemic and the post-pandemic endemic phases. We also contribute to the literature by applying a range of loss estimation methods that account for both paid and unpaid productivity losses. For the paid losses, we used alternatives of the human capital approach and the friction cost approach, with the latter being used for the first time in the recent pandemic context. Additionally, we distinguished between losses from COVID-19 deaths and excess deaths. The latter approach is rare in productivity loss estimation (11); yet, it deserves more attention in assessing the true burden of the pandemic. Epidemiological literature has placed more emphasis on excess deaths rather than deaths attributable directly to COVID-19 (15,16,39), and economic studies would benefit from following this approach.

4.1. Productivity losses differences across methodological approaches

Our results reveal that the COVID-19 pandemic caused a notable economic burden in terms of productivity losses across Europe. Paid productivity losses from excess deaths in 2020-2023 were €82.9 billion under the HCA and €3.9 billion under the FCA. This disparity between the two methods is expected, given their theoretical differences. The FCA, which is based on a friction period (24), reflects labour substitution and market adjustments, while the HCA assigns the whole potential future income lost up to retirement, reflecting the maximum value of production uncompleted (9). Therefore, the HCA/FCA ratio of 21.2 for excess deaths (range across countries: 12.7-37.0) and 16.4 for COVID-19 deaths (range: 10.2-22.3) is not surprising; a review (12) identified a respective ratio of as much as 72 for a study on coronary heart disease, and another study identified a ratio of 34.4 in cancer (40).

Interestingly, unpaid losses, resulting from non-market activities, such as housekeeping and volunteering, generated a higher economic burden (€96.0 billion) than those from paid productivity losses (€82.9 billion under the HCA) across all the countries and years combined. There are no COVID-19-based studies to compare this proportion; however, estimates from cancer-related mortality also prove that unpaid losses are an important contributor to overall burden. European estimates from 2018 cancer mortality identified the share of unpaid losses as 49% of the total (20) while the respective proportion in our study was 53.7% of the sum of HCA and OCA for excess deaths and 61.6% for COVID-19 deaths. The higher proportion of unpaid losses in our study, compared to cancer, plausibly results from sex and age differences in mortality between these diseases and dissimilar methods. Yet, we shall note that for some countries, paid losses were larger than the unpaid ones, particularly in the excess mortality framework. This was true for most NE states, Germany and the Netherlands, all characterised by high employment rates and long economic activity. On the other hand, for countries such as Italy, Spain, Poland and Romania, the opposite was true, with unpaid losses disproportionately high.

Additionally, 70% of the unpaid losses in excess mortality (78% in COVID-19 mortality) resulted from deaths among those not active in the labour market. As this group consists largely of older adults, the figures highlight that the elderly, who often contribute more to unpaid production, were at high risk of mortality during the pandemic. Their unpaid but economically significant contribution, which was lost during the COVID-19 mortality surge, should therefore be emphasised in assessing the real economic burden of the virus. To date, productivity loss studies have mostly omitted the unpaid losses category, and our study proves that their magnitude is crucial, underlining the importance of considering both paid and unpaid labour in health economic assessments.

Finally, the proportion of COVID-19 mortality losses in excess mortality losses in all countries and years was 42% under HCA, 55% under FCA and 59% in unpaid losses. Again, these shares vary across countries; e.g. with HCA, from 11% in Estonia to 101% in Greece. These differences reflect several factors, including varying testing capacities across countries, but also the ability of health systems to tackle the health crisis and populations' vulnerability, among others (41,42). In general, higher excess mortality losses than COVID-19 mortality losses reflect what we know from the burden of disease studies during the pandemic. Excess mortality captures both direct COVID-19 deaths and indirect mortality attributable to the crisis – from delayed care, health system strains, and behavioural responses – offering a more comprehensive measure of the pandemic's mortality impact than cause-specific data alone (15,39), and this similarly applies to economic studies.

4.2. Comparison to previous studies

There is no direct way to compare previous estimates to our findings, since no study used a comparable range of methodological approaches. Our recent systematic review (11) analysed 38 studies on productivity losses, but this evidence is only partially comparable to our figures. Using HCA, time-normalised productivity losses from excess mortality in eight EU countries until May 2020 (original study (13); time-normalised data (11)) ranged from 0% of GDP in Germany to 0.53% in Spain. For other studies that used different methodological approaches and time frames, these time-normalised losses were 0.05% of GDP lost in Germany and 2.1% in Spain (11). Yet, these last results from Germany refer to a longer period (until 8 Nov 2020) than the ones from Spain (19 Apr 2020); illustrating that loss estimates depend not only on mortality burden but also on the period analysed. To compare these figures with our estimates, productivity losses in Germany across four years constituted 0.09% of GDP under HCA and 0.08% of GDP in non-paid losses, and respective figures for Spain were 0.13% and 0.18%. This relatively lower variability of our estimates suggests that long-term analysis is crucial because pandemic waves struck countries at different times, and using short time frames may obscure the overall picture. Our long-term approach reduces the effects of individual pandemic waves that could otherwise inflate or deflate estimates, depending on whether the period covered included them.

4.3. Cross-country and temporal variation in productivity losses

In absolute values, the highest productivity losses were identified in the most populous countries – Germany (€12.3 billion, HCA estimates across the whole period), Poland (€11.2 billion), Italy (€8.9 billion), France (€8.7 billion) and Spain (€7.2 billion). This hierarchy is consistent regardless of the method and mortality measure used. However, in relative terms, the burden shifts towards CEE countries and, even more, to the three Baltic states – Lithuania, Latvia and Estonia. The greatest paid productivity losses were identified in Latvia (0.62% of GDP in HCA and 0.032% in FCA), followed by Lithuania, Estonia and six CEE states (refers to both HCA and FCA). A similar pattern applies to unpaid losses. This clearly reflects the higher mortality rates during the pandemic in the CEE region and the three Baltic states. Epidemiological studies (39,43) consistently report that total excess mortality rates from 2020 to 2023 in CEE countries exceeded those of other European subregions. This higher vulnerability of Eastern European states might arise from lower health system resilience (44), lower vaccination uptake (45), socioeconomic factors (lower GDP, higher poverty rates and inequalities) (39), and a population health profile, such as a higher prevalence of chronic diseases (46).

The pattern of productivity losses across regions highlights how the pandemic's mortality evolved heterogeneously across Europe. Under the excess mortality approach, losses peaked earlier in CEE and SE (2021), later in WE (2022), and last in NE (2023), consistent across paid (both HCA and FCM), and unpaid losses. This staging likely reflects the interaction of different trajectories of the spread of COVID-19 (47), vaccination coverage (48), and strain on health systems (49–51). The sharp peak of losses in 2021 in Lithuania, Latvia, Poland, and Romania, followed by significant declines in 2023, contrasts with Finland, Norway, and Sweden, where the productivity losses were the highest in 2023 – consistent with a delayed excess mortality impact. In comparison, Spain and Italy show a more even, multi-year spread of losses, illustrating more dispersed waves. Importantly, when considering deaths directly attributed to COVID-19, losses peak in 2021 for all regions (with limited 2023 data), narrowing the apparent timing differences. This divergence shows that excess mortality, by capturing both direct and indirect effects, provides a more accurate measure of the pandemic's true burden in both epidemiological and economic terms.

4.4. Sex and age patterns in productivity losses

Across methods and both mortality measures, men account for the majority of losses. This is consistent with evidence showing that men are at greater risk of mortality, either from COVID-19 or most other conditions (52,53). The sex disproportion in excess mortality is therefore not surprising and is not exclusive to the COVID-19 pandemic, but is a general characteristic of any excess mortality (54). These epidemiological differences, combined with labour market characteristics (higher male employment and earnings in most EU countries (55)), results in larger paid productivity losses for men.

Age profiles in our results differ by method, reflecting what theory predicts. HCA and unpaid losses among the employed concentrate in prime working ages (40–59), where remaining work years, participation, and productivity are highest. FCM flattens the profile because replacement reduces long-term burden; therefore, losses among the elderly are substantial here (34% of the total, compared to 13-14% in HCA and OCAe). Unpaid losses in non-employed (OCAn) shifts focus to older working ages (60–74) and females, consistent with higher mortality among older adults (56) and the greater participation of women in unpaid work (57). Our results in terms of age and sex distribution are in line with the systematic review (11), claiming that losses concentrated among the middle-aged and that three-quarters of mortality losses were due to men's deaths.

4.5. Public finance burden – potential revenues lost

Estimates indicate a significant burden on public finance related to pandemic mortality, with its level depending on both the mortality measure and the valuation methodology. The sum of potential public revenues (taxes and social contributions) lost due to decreased GDP resulting from mortality was €28.2 billion under HCM and €1.3 billion under FCA. Again, the difference between HCA and FCA is evident; HCA considers lost future income, whereas FCA is limited to the short-term replacement period. The regional hierarchy remains consistent (WE > CEE > SE > NE), reflecting differences in tax rates and mortality rates. From a fiscal policy perspective, HCA results highlight the importance of a long-term view – preventing deaths among working-age populations preserves future tax revenues.

4.6. Stability of estimates

The stability of our estimates was tested using a one-way deterministic sensitivity analysis. The results were most prone to changes in the discount rate. The losses at a 0% discount rate were, on average, 64.1-71.9% higher than the baseline scenario for excess deaths and 46.0-49.1% for COVID-19 deaths. We identified high variability of the results for low-populated countries for the approach based on excess deaths. The results that deviate most from the base scenario were identified at a discount rate of 0% in countries such as Malta (-547.7% for OCAe), Denmark (-155.9% for HCA), Luxembourg (153.3% for OCAn), Estonia (131.4% for HCA), Ireland (133.3% for OCAe) and Cyprus (115.3% for HCA). As highlighted in the results, these massive variations arise from the fact that negative and positive excess deaths cancel up, leading to low loss estimates that are prone to large relative variability. Therefore, the results regarding losses from excess mortality for such countries should be treated with caution.

4.7. Policy implications

Our results have important policy implications for assessing the pandemic's economic burden. First, although COVID-19 most severely affected the elderly, mortality among the middle-aged generated the greatest productivity losses. This is not surprising because this group is the most productive and has the highest employment rates. As those in their 40s and 50s combine the highest economic contribution with increasing chronic-disease risk, disruptions to routine care during health crises translate directly to substantial productivity losses. Ensuring continuity of routine care (e.g. cardiovascular, oncology services) is therefore not only a clinical priority but also an economic one. Second, our approach that extends losses beyond retirement age (up to age 75) shows that economic studies should account for the retirement-aged population that is economically active, in terms of both paid and unpaid productivity. Substantial losses among those over 60, combined with rising employment rates in this group and population ageing in Europe, underscore the importance of investments in the elderly's health to secure future economic growth. Third, the magnitude of unpaid losses highlights the significant economic impacts of household production, caregiving, and volunteer activities. In our study, the unpaid losses exceeded those of paid work, despite using conservative assumptions (minimum productivity for calculating unpaid work instead of the average productivity applied to paid work). Eventually, the concentration of losses among men, particular countries, and in specific age groups interacts with regional socio-economic gradients. Where excess mortality and economic vulnerability converged (CEE and the three Baltic states), the proportional productivity burden was greatest. This calls for targeted investment in preventive services, occupational health, and surge capacity within the health systems of the most affected regions.

4.8. Limitations

The following caveats apply to our study. Our estimates only report productivity losses arising from deaths attributable to the pandemic, while losses from COVID-19 morbidity (absenteeism, presenteeism, caregiving) might be even higher than from mortality (4,58). Also, the methods used for productivity losses estimation are not perfect. Each method we employed, either the human capital or friction cost approaches for paid losses and the opportunity cost approach for unpaid losses, has its own drawbacks (9,12). We opted for analysing a wide range of estimation approaches and provided a comprehensive set of estimates, allowing readers to judge which method is most useful for their purpose. Moreover, there are concerns regarding the quality of mortality data, either excess mortality or COVID-19 mortality. For the former, there are numerous approaches used for identifying the number of excess deaths and no gold standard for this procedure has been established so far (15,59). For COVID-19 deaths, testing capacities across countries and time differ, making cross-country and temporal comparisons challenging (60). Moreover, the use of population-level data might introduce bias. Individuals dying prematurely might differ from the population average in their economic characteristics, such as employment rates or productivity. Given well-documented socio-economic health disparities, this could lead to upward bias in our estimates. Yet, in line with common practice in the literature, we opted for average population values for the economic measures used. Finally, our results for low-populated countries are sensitive to changes in the input data and estimates for these should be treated with caution.

5. Conclusions

This study of 28 European countries from 2020 to 2023 shows that the burden of productivity losses caused by pandemic mortality was large, highly variable across regions and over time, and sensitive to the baseline mortality and valuation method used. From a health and economic policy perspective, preventing deaths at both working and older ages would yield benefits to productivity and public revenues. At the same time, the unpaid losses experienced should be explicitly accounted for in economic burden of disease studies, as they are substantial. Further, high excess mortality in CEE and the three Baltic states resulted in the greatest economic burden on these societies; this calls for reforms of health and social policies to mitigate threats to economic growth in case of potential future health crises. Finally, better-informed decisions might be made with comprehensive estimates of productivity losses. Using multiple methods as we did provides a broader understanding of the pandemic's economic burden and supports better strategic decision-making.

List of abbreviations

CD - COVID-19 deaths

CEE – Central and Eastern Europe

CIT - corporate income tax

ED - excess deaths

EU - European Union

FCA - friction cost approach

GDP - gross domestic product

GVA - gross value added

HCA - human capital approach

NE – Northern Europe

OCA - opportunity cost approach

OCAe - opportunity cost approach for the employed

OCAn - opportunity cost approach for the non-employed

OLS - ordinary least squares

PIT - personal income tax

SE – Southern Europe

VAT - value added tax

WE - Western Europe

Declarations

Ethics approval and consent to participate: This study used publicly available data only, and no human participants were involved. Approval for the research was granted by the Ethics Committee of the Nicolaus Copernicus University in Toruń, Collegium Medicum in Bydgoszcz (24/10/2023; no. KB 425/2023). Because of the study design and data used, consent to participate does not apply.

Consent for publication: Not applicable.

Availability of data and materials: This study used publicly available data only. The dataset may be replicated with the sources reported in the manuscript and references.

Competing interests: The authors declare that they have no competing interests.

Funding: This research was supported by the National Science Centre, Poland under grant no. 2022/47/B/HS4/00081 (refers to authors PN and BŁ). The funding agency had no role in the design of the study; in the collection, analysis, or interpretation of data; in the writing of the manuscript; or in the decision to submit the article for publication.

Authors' contributions: PN collected and curated the data, co-designed and handled formal analyses and wrote the first draft of the manuscript. MOO critically assessed the formal analyses and edited the draft of the manuscript. BŁ conceptualised and supervised the formal analyses and edited the draft of the manuscript.

Acknowledgements: Not applicable.

References

1. Gebru AA, Birhanu T, Wendimu E, Ayalew AF, Mulat S, Abasimel HZ, et al. Global burden of COVID-19: Situational analyis and review. Hum Antibodies [Internet]. 2021 [cited 2025 Oct 4];29(2):139–48. Available from: https://pubmed.ncbi.nlm.nih.gov/32804122/
2. Choi K, Jang M, Kim S, Park SJ, Suh HS. Impact of COVID-19 on disease-specific mortality, healthcare resource utilization, and disease burden across a population over 1 billion in 31 countries: an interrupted time-series analysis. EClinicalMedicine [Internet]. 2025 Jul 1 [cited 2025 Oct 4];85:103315. Available from: https://www.thelancet.com/action/showFullText?pii=S2589537025002470
3. Schöley J, Aburto JM, Kashnitsky I, Kniffka MS, Zhang L, Jaadla H, et al. Life expectancy changes since COVID-19. Nat Hum Behav [Internet]. 2022 Dec 1 [cited 2025 Oct 4];6(12):1649–59. Available from: https://pubmed.ncbi.nlm.nih.gov/36253520/
4. Wang F, Lui J, Wang J Der. Losses of Life Expectancy and Productivity Associated with COVID-19 Pandemic in Canada: Policy Implication for Future Communicable Disease Control. Int J Environ Res Public Health [Internet]. 2023 Feb 1 [cited 2025 Sep 27];20(3):2419. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC9916087/
5. Pallari CT, Achilleos S, Quattrocchi A, Haghighi MRR, Phan MT, Artemiou A, et al. Sustained excess all-cause mortality post COVID-19 in 21 countries: an ecological investigation. Int J Epidemiol [Internet]. 2025 Jun 1 [cited 2025 Sep 27];54(3):dyaf075. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC12150023/
6. Pallari CT, Achilleos S, Quattrocchi A, Gabel J, Critselis E, Athanasiadou M, et al. Magnitude and determinants of excess total, age-specific and sex-specific all-cause mortality in 24 countries worldwide during 2020 and 2021: results on the impact of the COVID-19 pandemic from the C-MOR project. BMJ Glob Health [Internet]. 2024 Apr 18 [cited 2025 Oct 4];9(4). Available from: https://pubmed.ncbi.nlm.nih.gov/38637119/
7. Barfar E, Raei B, Daneshi S, Bagher Barahouei F, Hushmandi K. The burden of COVID-19 based on disability-adjusted life years: a systematic review of available evidence. Front Public Health [Internet]. 2025 Feb 24 [cited 2025 Oct 4];13:1401726. Available from: www.casp-uk.net
8. Yaghoubi M, Salimi M, Meskarpour-Amiri M. Systematic review of productivity loss among healthcare workers due to Covid-19. Int J Health Plann Manage [Internet]. 2022 Jan 1 [cited 2025 Oct 4];37(1):94–111. Available from: https://pubmed.ncbi.nlm.nih.gov/34655098/
9. Zhang W, Bansback N, Anis AH. Measuring and valuing productivity loss due to poor health: A critical review. Soc Sci Med [Internet]. 2011 Jan [cited 2025 Oct 4];72(2):185–92. Available from: https://pubmed.ncbi.nlm.nih.gov/21146909/
10. Setiawan E, Cassidy-Seyoum SA, Thriemer K, Carvalho N, Devine A. A Systematic Review of Methods for Estimating Productivity Losses due to Illness or Caregiving in Low- and Middle-Income Countries. Pharmacoeconomics [Internet]. 2024 Aug 1 [cited 2025 Oct 4];42(8):865–77. Available from: https://pubmed.ncbi.nlm.nih.gov/38874846/

11. Niewiadomski P, Ortega-Ortega M, Łyszczarz B. Productivity Losses due to Health Problems Arising from COVID-19 Pandemic: A Systematic Review of Population-Level Studies Worldwide. Appl Health Econ Health Policy [Internet]. 2025 Mar 1 [cited 2025 Apr 6];23(2):231–51. Available from: https://link.springer.com/article/10.1007/s40258-024-00935-8
12. Pike J, Grosse SD. Friction Cost Estimates of Productivity Costs in Cost-of-Illness Studies in Comparison with Human Capital Estimates: A Review. Appl Health Econ Health Policy [Internet]. 2018 Dec 1 [cited 2025 Apr 6];16(6):765–78. Available from: https://link.springer.com/article/10.1007/s40258-018-0416-4
13. Hanly P, Ahern M, Sharp L, Ursul D, Loughnane G. The cost of lost productivity due to premature mortality associated with COVID-19: a Pan-European study. Eur J Health Econ [Internet]. 2022 Mar 1 [cited 2025 Sep 27];23(2):249–59. Available from: https://pubmed.ncbi.nlm.nih.gov/34417904/
14. Bhattacharya P, John D, Mukherjee N, Ms N, Menon J, Banerjee A. Estimation of non-health gross domestic product (NHGDP) loss due to COVID-19 deaths in West Bengal, India. BMJ Open [Internet]. 2023 Oct 1 [cited 2025 Sep 27];13(10):e072559. Available from: https://bmjopen.bmj.com/content/13/10/e072559
15. Levitt M, Zonta F, Ioannidis JPA. Comparison of pandemic excess mortality in 2020–2021 across different empirical calculations. Environ Res. 2022 Oct 1;213:113754.
16. Levitt M, Zonta F, Ioannidis JPA. Excess death estimates from multiverse analysis in 2009–2021. Eur J Epidemiol [Internet]. 2023 Nov 1 [cited 2025 Sep 27];38(11):1129–39. Available from: https://link.springer.com/article/10.1007/s10654-023-00998-2
17. Vardavas C, Zisis K, Nikitara K, Lagou I, Marou V, Aslanoglou K, et al. Cost of the COVID-19 pandemic versus the cost-effectiveness of mitigation strategies in EU/UK/OECD: a systematic review. BMJ Open [Internet]. 2023 Oct 31 [cited 2025 Oct 4];13(10). Available from: https://pubmed.ncbi.nlm.nih.gov/37907290/
18. Jönsson B. Ten arguments for a societal perspective in the economic evaluation of medical innovations. Eur J Health Econ [Internet]. 2009 Oct [cited 2025 Oct 4];10(4):357–9. Available from: https://pubmed.ncbi.nlm.nih.gov/19618224/
19. Neumann PJ. Costing and perspective in published cost-effectiveness analysis. Med Care [Internet]. 2009 [cited 2025 Oct 4];47(7 Suppl 1). Available from: https://pubmed.ncbi.nlm.nih.gov/19536023/
20. Ortega-Ortega M, Hanly P, Pearce A, Soerjomataram I, Sharp L. Paid and unpaid productivity losses due to premature mortality from cancer in Europe in 2018. Int J Cancer [Internet]. 2022 Feb 15 [cited 2025 Apr 6];150(4):580–93. Available from: https://onlinelibrary.wiley.com/doi/full/10.1002/ijc.33826
21. Eurostat. Deaths by age and sex [Internet]. [cited 2024 Nov 30]. Available from: https://ec.europa.eu/eurostat/databrowser/view/demo_magec/default/table?lang=en
22. Díaz-Jiménez D, Castañeda-Orjuela C, Castillo-Rodríguez L, De la Hoz-Restrepo F. Economic Costs Analysis of the Avoidable Mortality in Colombia 1998-2011. Value Health Reg Issues [Internet]. 2015 Dec 1 [cited 2025 Apr 6];8:129–35. Available from: https://www.valuehealthregionalissues.com/action/showFullText?pii=S2212109915000680
23. Dieleman JL, Templin T, Sadat N, Reidy P, Chapin A, Foreman K, et al. National spending on health by source for 184 countries between 2013 and 2040. Lancet [Internet]. 2016 Jun 18 [cited 2025 Oct 4];387(10037):2521–35. Available from: https://pubmed.ncbi.nlm.nih.gov/27086174/
24. Koopmanschap MA, van Ineveld BM. Towards a new approach for estimating indirect costs of disease. Soc Sci Med. 1992 May 1;34(9):1005–10.
25. Havik K, Mc Morrow K, Orlandi F, Planas C, Raciborski R, Röger W, et al. The Production Function Methodology for Calculating Potential Growth Rates & Output Gaps. [cited 2025 Apr 28]; Available from: http://ec.europa.eu/economy_finance/publications/.
26. Łyszczarz B. Production losses associated with premature mortality in 28 European Union countries. J Glob Health [Internet]. 2019 [cited 2025 Apr 28];9(2). Available from: https://pubmed.ncbi.nlm.nih.gov/31656606/
27. Mela A, Rdzanek E, Poniatowski ŁA, Jaroszyński J, Furtak-Niczyporuk M, Gałązka-Sobotka M, et al. Economic Costs of Cardiovascular Diseases in Poland Estimates for 2015–2017 Years. Front Pharmacol [Internet]. 2020 Sep 8 [cited 2025 Apr 28];11:552773. Available from: www.frontiersin.org

28. Mean annual earnings by sex, age and economic activity (2022) [Internet]. [cited 2025 Apr 6]. Available from: https://ec.europa.eu/eurostat/databrowser/view/earn_ses22_27/default/table?lang=en
29. Employment rates by sex, age and citizenship (%) [Internet]. [cited 2025 Apr 6]. Available from: https://ec.europa.eu/eurostat/databrowser/view/lfsa_ergan/default/table?lang=en
30. European Commission. 2024 ageing report : economic and budgetary projections for the EU Member States (2022-2070). Institutional Paper 279 April 2024 Brussels.
31. HICP - annual data (average index and rate of change) [Internet]. [cited 2025 Apr 28]. Available from: https://ec.europa.eu/eurostat/databrowser/view/prc_hicp_aind__custom_16425858/default/table?lang=en
32. Gökler ME, Metintaş S. Years of potential life lost and productivity costs due to COVID-19 in Turkey: one yearly evaluation. Public Health. 2022 Feb 1;203:91–6.
33. Shindhe SD, Bhat S, Munoli SB. Burden of COVID-19: DALY and productivity loss for Karnataka, India. Indian J Public Health [Internet]. 2022 Jul 1 [cited 2025 Apr 28];66(3):239–44. Available from: https://journals.lww.com/ijph/fulltext/2022/66030/burden_of_covid_19__daly_and_productivity_loss_for.2.aspx
34. Hanly P, Ortega Ortega M, Pearce A, Soerjomataram I, Sharp L. Advances in the methodological approach to friction period estimation: A European perspective. Soc Sci Med. 2020 Nov 1;264:113289.
35. Time spent, participation time and participation rate in the main activity by sex and self-declared labour status [Internet]. [cited 2025 Apr 9]. Available from: https://ec.europa.eu/eurostat/databrowser/view/tus_00selfstat/default/table?lang=en
36. Main national accounts tax aggregates [Internet]. [cited 2025 May 10]. Available from: https://ec.europa.eu/eurostat/databrowser/view/gov_10a_taxag/default/table?lang=en
37. Łyszczarz B. Indirect costs and public finance consequences of heart failure in Poland, 2012-2015 14 Economics 1402 Applied Economics. BMC Public Health [Internet]. 2018 Sep 19 [cited 2025 May 18];18(1):1–9. Available from: https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-018-6034-0
38. Łyszczarz B, Nojszewska E. Productivity losses and public finance burden attributable to breast cancer in Poland, 2010-2014. BMC Cancer [Internet]. 2017 Oct 10 [cited 2025 May 18];17(1):1–13. Available from: https://bmccancer.biomedcentral.com/articles/10.1186/s12885-017-3669-7
39. Pizzato M, Gerli AG, La Vecchia C, Alicandro G. Impact of COVID-19 on total excess mortality and geographic disparities in Europe, 2020-2023: a spatio-temporal analysis. The Lancet regional health Europe [Internet]. 2024 Sep 1 [cited 2025 Sep 27];44. Available from: https://pubmed.ncbi.nlm.nih.gov/39410937/
40. Hanly P, Ortega-Ortega M, Soerjomataram I. Cancer Premature Mortality Costs in Europe in 2020: A Comparison of the Human Capital Approach and the Friction Cost Approach. Current Oncology. 2022 May 1;29(5):3552–64.
41. Karlinsky A, Kobak D. Tracking excess mortality across countries during the COVID-19 pandemic with the World Mortality Dataset. Elife [Internet]. 2021 Jun 1 [cited 2025 Oct 4];10. Available from: https://pubmed.ncbi.nlm.nih.gov/34190045/
42. Wang H, Paulson KR, Pease SA, Watson S, Comfort H, Zheng P, et al. Estimating excess mortality due to the COVID-19 pandemic: a systematic analysis of COVID-19-related mortality, 2020–21. The Lancet [Internet]. 2022 Apr 16 [cited 2025 Oct 4];399(10334):1513–36. Available from: https://www.thelancet.com/action/showFullText?pii=S0140673621027963
43. Bonnet F, Grigoriev P, Sauerberg M, Alliger I, Mühlichen M, Camarda CG. Spatial disparities in the mortality burden of the covid-19 pandemic across 569 European regions (2020-2021). Nature Communications 2024 15:1 [Internet]. 2024 May 18 [cited 2025 Sep 27];15(1):1–10. Available from: https://www.nature.com/articles/s41467-024-48689-0
44. Rahmanian Haghighi MR, Pallari CT, Achilleos S, Quattrocchi A, Gabel J, Artemiou A, et al. Excess Mortality and its Determinants During the COVID-19 Pandemic in 21 Countries: An Ecological Study from the C-MOR Project, 2020 and 2021. J Epidemiol Glob Health [Internet]. 2024 Dec 1 [cited 2025 Oct 4];14(4):1650–61. Available from: https://pubmed.ncbi.nlm.nih.gov/39527396/

45. Ylli A, Burazeri G, Wu YY, Sentell T. COVID-19 excess deaths in Eastern European countries associated with weaker regulation implementation and lower vaccination coverage. East Mediterr Health J [Internet]. 2022 Oct 1 [cited 2025 Oct 4];28(10):776–80. Available from: https://pubmed.ncbi.nlm.nih.gov/36382733/
46. Bogos K, Kiss Z, Kerpel Fronius A, Temesi G, Elek J, Madurka I, et al. Different Trends in Excess Mortality in a Central European Country Compared to Main European Regions in the Year of the COVID-19 Pandemic (2020): a Hungarian Analysis. Pathol Oncol Res [Internet]. 2021 Apr 13 [cited 2025 Oct 4];27. Available from: https://pubmed.ncbi.nlm.nih.gov/34257618/
47. Habershon S, Nenoff K, Kraemer G, Schüler L, Zozmann H, Calabrese JM, et al. The spatiotemporal dynamics of COVID-19 in Europe: time-series clustering maps 5 distinct trajectories to spatial patterns. Popul Health Metr [Internet]. 2025 Dec 1 [cited 2025 Sep 27];23(1):1–13. Available from: https://pophealthmetrics.biomedcentral.com/articles/10.1186/s12963-025-00405-w
48. Matveeva O, Shabalina SA. Comparison of vaccination and booster rates and their impact on excess mortality during the COVID-19 pandemic in European countries. Front Immunol [Internet]. 2023 [cited 2025 Sep 27];14:1151311. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC10357837/
49. Rennert-May E, Leal J, Thanh NX, Lang E, Dowling S, Manns B, et al. The impact of COVID-19 on hospital admissions and emergency department visits: A population-based study. PLoS One [Internet]. 2021 Jun 1 [cited 2025 Sep 27];16(6). Available from: https://pubmed.ncbi.nlm.nih.gov/34061888/
50. Gasch-Illescas A, Calle-Serrano M, Vallejo-Vaz AJ, Praena-Fernández JM, Guerrero JA, Calderón EJ, et al. Impact of the first wave of the COVID-19 pandemic on non-COVID inpatient care in southern Spain. Scientific Reports 2023 13:1 [Internet]. 2023 Jan 30 [cited 2025 Sep 27];13(1):1–10. Available from: https://www.nature.com/articles/s41598-023-28831-6
51. Mularczyk-Tomczewska P, Zarnowski A, Gujski M, Jankowski M, Bojar I, Wdowiak A, et al. Barriers to accessing health services during the COVID-19 pandemic in Poland: A nationwide cross-sectional survey among 109,928 adults in Poland. Front Public Health [Internet]. 2022 Sep 8 [cited 2025 Sep 27];10. Available from: https://pubmed.ncbi.nlm.nih.gov/36159267/
52. Takahashi T, Ellingson MK, Wong P, Israelow B, Lucas C, Klein J, et al. Sex differences in immune responses that underlie COVID-19 disease outcomes. Nature 2020 588:7837 [Internet]. 2020 Aug 26 [cited 2025 Sep 27];588(7837):315–20. Available from: https://www.nature.com/articles/s41586-020-2700-3
53. Mauvais-Jarvis F, Bairey Merz N, Barnes PJ, Brinton RD, Carrero JJ, DeMeo DL, et al. Sex and gender: modifiers of health, disease, and medicine. Lancet [Internet]. 2020 Aug 22 [cited 2025 Sep 27];396(10250):565–82. Available from: https://pubmed.ncbi.nlm.nih.gov/32828189/
54. Nielsen J, Nørgaard SK, Lanzieri G, Vestergaard LS, Moelbak K. Sex-differences in COVID-19 associated excess mortality is not exceptional for the COVID-19 pandemic. Scientific Reports 2021 11:1 [Internet]. 2021 Oct 21 [cited 2025 Sep 27];11(1):1–9. Available from: https://www.nature.com/articles/s41598-021-00213-w
55. Leythienne Denis, Pérez-Julián Marina. Gender pay gaps in the European Union : a statistical analysis : 2022 edition. 2022;
56. Team F. Variation in the COVID-19 infection–fatality ratio by age, time, and geography during the pre-vaccine era: a systematic analysis. The Lancet [Internet]. 2022 Apr 16 [cited 2025 Sep 27];399(10334):1469–88. Available from: https://www.thelancet.com/action/showFullText?pii=S0140673621028671
57. Fernandez Lopez L, Schonard M. An ambitious future for Europe's women after COVID-19: mental load, gender equality in teleworking and unpaid care work after the pandemic.
58. John D, Narassima MS, Menon J, Rajesh JG, Banerjee A. Estimation of the economic burden of COVID-19 using disability-adjusted life years (DALYs) and productivity losses in Kerala, India: a model-based analysis. BMJ Open [Internet]. 2021 Aug 18 [cited 2025 Sep 27];11(8). Available from: https://pubmed.ncbi.nlm.nih.gov/34408053/
59. Ioannidis JPA, Zonta F, Levitt M. Flaws and uncertainties in pandemic global excess death calculations. Eur J Clin Invest [Internet]. 2023 Aug 1 [cited 2025 Sep 27];53(8). Available from: https://pubmed.ncbi.nlm.nih.gov/37067255/

60. Corrao G, Rea F, Blangiardo GC. Lessons from COVID-19 mortality data across countries. J Hypertens [Internet]. 2021 May 1 [cited 2025 Oct 4];39(5):856. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC9584045/

Table 1. Paid productivity losses from excess mortality in 28 European countries, 2020-2023: total and per capita estimates

	2020		2021		2022		2023		2020-2023	
(2020 € PPS)	Million €	€	Million €	€	Million €	€	Million €	€	Million €	€
	HCA (FCA)	per capita HCA (FCA)	HCA (FCA)	per capita HCA (FCA)	HCA (FCA)	per capita HCA (FCA)	HCA (FCA)	per capita HCA (FCA)	Total HCA (FCA)	Average per capita HCA (FCA)
CEE	**5,436 (270)**	**60.6 (3.0)**	**12,807 (673)**	**144.9 (7.6)**	**5,345 (219)**	**60.8 (2.5)**	**2,194 (46)**	**24.9 (0.5)**	**25,782 (1,209)**	**72.8 (3.4)**
Bulgaria	518 (23)	78.8 (3.6)	1,259 (57)	192.8 (8.8)	248 (13)	38.3 (2.0)	-66 (-2.5)	-10.2 (-0.4)	1,960 (91)	74.9 (3.5)
Czechia	449 (44)	42.0 (4.1)	1,348 (121)	128.4 (11.5)	634 (39)	60.2 (3.7)	424 (20)	39.2 (1.9)	2,854 (224)	67.5 (5.3)
Hungary	526 (28)	54.3 (2.8)	1,664 (98)	172.4 (10.1)	702 (35)	73.0 (3.6)	464 (15)	48.3 (1.5)	3,356 (174)	87.0 (4.5)
Poland	2,546 (115)	67.1 (3.0)	4,971 (236)	134.1 (6.4)	2,612 (96)	70.8 (2.6)	1,026 (18)	27.9 (0.5)	11,156 (464)	75.0 (3.1)
Romania	1,254 (54)	64.9 (2.8)	2,748 (120)	143.1 (6.3)	824 (24)	43.3 (1.3)	151 (-9.0)	7.9 (-0.5)	4,976 (190)	64.8 (2.5)
Slovakia	144 (6.5)	26.4 (1.2)	817 (41)	149.6 (7.5)	325 (13)	59.8 (2.3)	195 (5.0)	35.9 (0.9)	1,481 (65)	67.9 (3.0)
NE	**1,219 (49)**	**32.0 (1.3)**	**2,253 (122)**	**58.9 (3.2)**	**2,511 (129)**	**65.3 (3.4)**	**2,609 (101)**	**67.1 (2.6)**	**8,593 (402)**	**55.8 (2.6)**
Denmark	88 (1.0)	15.1 (0.2)	139 (7.0)	23.9 (1.2)	290 (13)	49.4 (2.2)	300 (12)	50.5 (2.0)	817 (33)	34.7 (1.4)
Estonia	75 (3.6)	56.6 (2.7)	193 (10)	144.9 (7.6)	195 (7.9)	146.6 (5.9)	192 (5.9)	140.2 (4.3)	655 (28)	122.1 (5.1)
Finland	225 (8.6)	40.7 (1.6)	187 (13)	33.7 (2.3)	343 (20)	61.9 (3.7)	392 (18)	70.4 (3.3)	1,147 (60)	51.7 (2.7)
Ireland	249 (6.4)	49.6 (1.3)	509 (20)	100.5 (4.0)	465 (17)	90.3 (3.3)	455 (11)	86.2 (2.0)	1,678 (54)	81.7 (2.7)
Latvia	38 (2.4)	19.7 (1.3)	389 (24)	205.5 (12.6)	317 (15)	169.2 (8.1)	243 (11)	129.3 (5.6)	988 (52)	130.9 (6.9)
Lithuania	318 (16)	113.0 (5.5)	577 (31)	205.2 (11.1)	343 (16)	122.2 (5.8)	235 (8.7)	82.1 (3.1)	1,472 (72)	130.6 (6.4)
Norway	103 (1.5)	19.2 (0.3)	98 (4.9)	18.2 (0.9)	443 (29)	81.7 (5.4)	580 (23)	105.6 (4.2)	1,224 (59)	56.2 (2.7)
Sweden	123 (9.7)	12.0 (0.9)	162 (13)	15.6 (1.2)	114 (9.9)	10.9 (0.9)	214 (12)	20.4 (1.1)	613 (44)	14.7 (1.1)
SE	**4,388 (185)**	**32.4 (1.4)**	**6,151 (266)**	**45.5 (2.0)**	**5,266 (197)**	**39.1 (1.5)**	**4,438 (131)**	**32.8 (1.0)**	**20,244 (778)**	**37.4 (1.4)**
Croatia	92 (4.3)	23.4 (1.1)	315 (16)	80.8 (4.2)	159 (6.7)	41.2 (1.7)	118 (5.3)	30.5 (1.4)	684 (33)	44.0 (2.1)
Cyprus	41 (1.6)	45.3 (1.8)	98 (3.9)	107.5 (4.3)	57 (2.2)	61.3 (2.4)	69 (1.4)	72.8 (1.5)	265 (9.1)	71.7 (2.5)
Greece	106 (3.9)	9.8 (0.4)	654 (24)	61.3 (2.2)	203 (6.0)	19.4 (0.6)	0 (-4.8)	0.0 (-0.5)	963 (29)	22.6 (0.7)
Italy	1,849 (100)	31.0 (1.7)	2,659 (141)	44.9 (2.4)	2,201 (108)	37.3 (1.8)	2,174 (87)	36.9 (1.5)	8,884 (436)	37.5 (1.8)
Malta	13 (0.7)	24.8 (1.4)	10 (1.0)	20.1 (1.9)	19 (1.1)	36.3 (2.1)	-1 (0.3)	-2.3 (0.6)	41 (3.2)	19.7 (1.5)
Portugal	409 (12)	39.4 (1.2)	487 (18)	46.9 (1.7)	479 (15)	45.9 (1.4)	420 (10)	40.0 (1.0)	1,795 (55)	43.0 (1.3)
Slovenia	62 (2.8)	29.8 (1.4)	117 (6.6)	55.4 (3.1)	111 (4.9)	52.7 (2.3)	101 (4.3)	47.6 (2.0)	391 (19)	46.4 (2.2)
Spain	1,817 (59)	38.4 (1.3)	1,810 (56)	38.2 (1.2)	2,037 (53)	42.9 (1.1)	1,557 (27)	32.4 (0.6)	7,221 (195)	38.0 (1.0)

WE	**3,460 (189)**	**18.3 (1.0)**	**8,349 (495)**	**44.1 (2.6)**	**9,356 (513)**	**49.2 (2.7)**	**7,146 (319)**	**37.5 (1.7)**	**28,311 (1,515)**	**37.3 (2.0)**
Austria	175 (12)	19.6 (1.3)	518 (33)	58.0 (3.7)	469 (32)	52.2 (3.6)	460 (24)	50.5 (2.6)	1,621 (100)	45.1 (2.8)
Belgium	364 (24)	31.5 (2.1)	472 (26)	40.9 (2.3)	488 (28)	42.0 (2.4)	349 (16)	29.8 (1.4)	1,673 (95)	36.0 (2.0)
France	1,223 (65)	18.1 (1.0)	2,204 (111)	32.5 (1.6)	2,994 (125)	44.0 (1.8)	2,282 (73)	33.4 (1.1)	8,704 (374)	32.0 (1.4)
Germany	1,035 (55)	12.4 (0.7)	3,994 (247)	48.0 (3.0)	4,246 (256)	51.0 (3.1)	3,002 (144)	36.1 (1.7)	12,278 (702)	36.9 (2.1)
Luxembourg	27 (0.9)	43.9 (1.5)	37 (1.8)	58.1 (2.8)	34 (0.9)	52.3 (1.4)	33 (0.7)	49.2 (1.0)	131 (4.3)	50.8 (1.7)
Netherlands	635 (32)	36.5 (1.9)	1,123 (76)	64.3 (4.4)	1,126 (70)	64.0 (4.0)	1,020 (61)	57.3 (3.4)	3,904 (240)	55.5 (3.4)
Total	**14,503 (693)**	**35.8 (1.7)**	**29,561 (1,557)**	**73.3 (3.8)**	**22,478 (1,057)**	**53.6 (2.5)**	**16,387 (597)**	**40.6 (1.4)**	**82,929 (3,904)**	**50.8 (2.4)**

Notes: HCA – human capital approach; FCA – friction cost approach; CEE – Central and Eastern Europe; NE – Northern Europe; SE – Southern Europe; WE - Western Europe; PPS – purchasing power standard. For COVID-19 results, see Table S1 in the supplementary file.

Table 2. Unpaid productivity losses from excess mortality in 28 European countries, 2020-2023: total and per capita estimates

	2020		2021		2022		2023		2020-2023	
(2020 € PPS)	Million €	€	Million €	€	Million €	€	Million €	€	Million €	€
	OCAe (OCAn)	per capita OCAe (OCAn)	OCAe (OCAn)	per capita OCAe (OCAn)	OCAe (OCAn)	per capita OCAe (OCAn)	OCAe (OCAn)	per capita OCAe (OCAn)	OCAe (OCAn)	average per capita OCAe (OCAn)
CEE	**1,954 (5,748)**	**21.8 (64.1)**	**4,654 (13,091)**	**52.6 (148.1)**	**1,924 (3,380)**	**21.9 (38.4)**	**772 (-106)**	**8.8 (-1.2)**	**9,304 (22,113)**	**26.3 (62.3)**
Bulgaria	170 (465)	25.9 (70.8)	427 (1,090)	65.4 (166.9)	85 (275)	13.0 (42.4)	-25 (-27)	-3.9 (-4.2)	657 (1,803)	25.1 (69.0)
Czechia	148 (391)	13.9 (36.6)	446 (1,086)	42.5 (103.4)	205 (290)	19.5 (27.5)	128 (98)	11.8 (9.0)	927 (1,864)	21.9 (44.1)
Hungary	158 (350)	16.3 (36.1)	511 (1,088)	53.0 (112.7)	209 (321)	21.8 (33.4)	139 (122)	14.5 (12.7)	1,018 (1,880)	26.4 (48.7)
Poland	967 (2,592)	25.5 (68.3)	1,930 (5,051)	52.1 (136.3)	1,015 (1,655)	27.5 (44.9)	407 (23)	11.1 (0.6)	4,320 (9,320)	29.0 (62.5)
Romania	453 (1,752)	23.4 (90.6)	1,006 (3,736)	52.4 (194.6)	286 (568)	15.0 (29.9)	50 (-393)	2.6 (-20.6)	1,794 (5,663)	23.4 (73.6)
Slovakia	57 (199)	10.5 (36.4)	333 (1,041)	61.0 (190.6)	124 (272)	22.9 (50.0)	73 (71)	13.5 (13.1)	588 (1,582)	27.0 (72.5)
NE	**401 (607)**	**10.5 (15.9)**	**755 (1,295)**	**19.7 (33.9)**	**849 (1,421)**	**22.1 (36.9)**	**885 (1,164)**	**22.8 (29.9)**	**2,890 (4,487)**	**18.8 (29.2)**
Denmark	33 (34)	5.7 (5.8)	57 (110)	9.8 (18.8)	105 (187)	18.0 (31.8)	108 (143)	18.3 (24.1)	304 (474)	12.9 (20.1)
Estonia	23 (28)	17.2 (20.9)	60 (80)	45.3 (60.2)	60 (60)	44.7 (44.7)	59 (46)	43.0 (34.0)	201 (214)	37.5 (39.9)
Finland	71 (97)	12.9 (17.5)	64 (156)	11.5 (28.2)	123 (295)	22.1 (53.2)	135 (262)	24.3 (47.1)	393 (810)	17.7 (36.5)
Ireland	79 (95)	15.8 (18.9)	157 (241)	30.9 (47.6)	148 (211)	28.6 (41.0)	139 (170)	26.3 (32.3)	522 (718)	25.4 (35.0)
Latvia	11 (25)	5.8 (12.9)	121 (197)	64.0 (104.3)	95 (125)	50.8 (66.4)	70 (86)	37.2 (45.6)	298 (432)	39.5 (57.3)
Lithuania	108 (181)	38.5 (64.5)	204 (320)	72.4 (114.0)	124 (183)	44.1 (65.2)	82 (81)	28.7 (28.5)	517 (766)	45.9 (68.0)
Norway	39 (18)	7.3 (3.4)	40 (54)	7.5 (10.1)	161 (239)	29.8 (44.1)	214 (229)	39.0 (41.7)	455 (541)	20.9 (24.8)
Sweden	36 (130)	3.5 (12.6)	52 (136)	5.0 (13.1)	33 (121)	3.1 (11.6)	78 (146)	7.4 (13.9)	199 (532)	4.8 (12.8)
SE	**1,616 (6,021)**	**11.9 (44.4)**	**2,252 (7,066)**	**16.7 (52.3)**	**1,943 (5,111)**	**14.4 (37.9)**	**1,613 (3,107)**	**11.9 (22.9)**	**7,424 (21,305)**	**13.7 (39.4)**
Croatia	36 (196)	9.1 (49.9)	123 (520)	31.7 (133.6)	59 (216)	15.2 (56.0)	44 (137)	11.6 (35.7)	262 (1,070)	16.9 (68.8)
Cyprus	14 (21)	15.5 (23.6)	33 (55)	36.2 (60.0)	19 (33)	20.8 (35.7)	22 (16)	23.5 (16.6)	89 (125)	24.0 (34.0)
Greece	41 (198)	3.8 (18.5)	233 (783)	21.8 (73.3)	73 (272)	7.0 (26.0)	3 (-17)	0.3 (-1.6)	351 (1,236)	8.2 (29.0)
Italy	621 (2,945)	10.4 (49.4)	912 (3,202)	15.4 (54.1)	750 (2,352)	12.7 (39.8)	741 (1,819)	12.6 (30.8)	3,024 (10,318)	12.8 (43.5)
Malta	3 (11)	5.2 (20.4)	2 (17)	3.5 (32.4)	4 (17)	7.4 (33.4)	-2 (4.4)	-3.7 (8.1)	6 (49)	3.1 (23.6)
Portugal	164 (296)	15.8 (28.5)	200 (414)	19.2 (39.8)	195 (319)	18.7 (30.6)	167 (216)	15.9 (20.5)	725 (1,244)	17.4 (29.9)
Slovenia	28 (61)	13.4 (29.2)	51 (142)	24.2 (67.4)	52 (84)	24.5 (40.1)	45 (44)	21.2 (20.9)	176 (332)	20.8 (39.4)
Spain	710 (2,293)	15.0 (48.5)	698 (1,933)	14.7 (40.8)	791 (1,816)	16.7 (38.2)	591 (888)	12.3 (18.5)	2,791 (6,931)	14.7 (36.5)
WE	**1,075 (3,298)**	**5.7 (17.4)**	**2,615 (6,422)**	**13.8 (33.9)**	**3,038 (6,257)**	**16.0 (32.9)**	**2,278 (3,489)**	**11.9 (18.3)**	**9,006 (19,465)**	**11.9 (25.6)**

Austria	56 (193)	6.3 (21.7)	169 (463)	18.9 (51.9)	155 (379)	17.3 (42.2)	152 (217)	16.7 (23.9)	532 (1,253)	14.8 (34.9)
Belgium	110 (475)	9.5 (41.2)	147 (364)	12.8 (31.5)	153 (375)	13.2 (32.3)	111 (135)	9.5 (11.5)	521 (1,349)	11.2 (29.1)
France	453 (1,728)	6.7 (25.6)	805 (2,559)	11.9 (37.8)	1,133 (2,561)	16.6 (37.6)	851 (1,278)	12.5 (18.7)	3,242 (8,126)	11.9 (29.9)
Germany	268 (538)	3.2 (6.5)	1,142 (2,310)	13.7 (27.8)	1,247 (2,354)	15.0 (28.3)	856 (1,341)	10.3 (16.1)	3,514 (6,542)	10.6 (19.7)
Luxembourg	10 (19)	16.2 (30.4)	15 (31)	24.2 (48.4)	11 (27)	17.8 (41.4)	14 (-3.7)	21.0 (-5.5)	51 (73)	19.8 (28.6)
Netherlands	178 (345)	10.2 (19.8)	337 (695)	19.3 (39.8)	338 (561)	19.2 (31.9)	294 (521)	16.5 (29.3)	1,147 (2,121)	16.3 (30.2)
Total	**5,047 (15,673)**	**12.5 (35.5)**	**10,275 (27,874)**	**25.7 (67.0)**	**7,754 (16,168)**	**18.6 (36.5)**	**5,548 (7,654)**	**13.8 (17.5)**	**28,624 (67,370)**	**17.7 (39.1)**

Notes: OCAe – opportunity cost approach for the employed; OCAn – opportunity cost approach for the non-employed (unemployed, students, homemakers and retired persons); CEE – Central and Eastern Europe; NE – Northern Europe; SE – Southern Europe; WE - Western Europe; PPS – purchasing power standard. For COVID-19 results, see Table S2 in the supplementary file.

Table 3. Public finance burden from excess mortality in 28 European countries, 2020-2023

	Share of revenues from taxes and social insurance contributions as a proportion of GDP* (2020-2023 average)	Public finance revenue losses due to excess mortality (2020-2023, total in million €)	
		HCM	FCM
CEE	**-**	**7,795**	**368**
Bulgaria	27.2	545	25
Czechia	32.0	912	72
Hungary	28.7	955	50
Poland	32.3	3,649	153
Romania	25.0	1,246	47
Slovakia	32.9	488	21
NE	**-**	**2,706**	**130**
Denmark	41.0	328	13
Estonia	28.0	184	8
Finland	39.4	452	24
Ireland	17.9	303	10
Latvia	30.6	303	16
Lithuania	30.9	455	22
Norway	39.1	488	24
Sweden	31.7	194	14
SE	**-**	**6,991**	**271**
Croatia	34.1	233	11
Cyprus	32.5	86	3
Greece	34.4	333	10
Italy	35.9	3,183	156
Malta	23.8	10	1
Portugal	33.0	592	18
Slovenia	35.0	137	7
Spain	33.5	2,416	65
WE	**-**	**10,688**	**571**
Austria	38.0	617	38
Belgium	39.3	657	37
France	38.9	3,385	146
Germany	37.7	4,640	266
Luxembourg	33.9	44	1
Netherlands	34.5	1,345	83
Total	**-**	**28,181**	**1,340**

Notes: * – sum of Value added type taxes (VAT), Excise duties and consumption taxes, Taxes on individual or household income, Taxes on the income or profits of corporations, Net social contributions. HCA – human capital approach; FCA – friction cost approach; CEE – Central and Eastern Europe; NE – Northern Europe; SE – Southern Europe; WE - Western Europe. For COVID-19 results, see Table S3 in the supplementary file.

Table 4. Summary of sensitivity analysis of productivity losses from excess mortality in 28 European countries, 2020-2023

	Average* change from BS [%]			
	HCA	FCA	OCA employed	OCA non-employed
Discount rate (BS=5%):				
3.5%	13.4	n.a.	14.1	14.2
0%	64.1	n.a.	67.9	71.9
Productivity measure (BS=gross domestic product):				
Gross value added	-6.9	-9.0	-6.8	-6.9
Future economic growth (BS=average for EU countries):				
0% for all the countries	-8.1	n.a.	-8.5	-8.3
2% for all the countries	5.1	n.a.	5.3	5.1

Notes: * – population-weighted average. BS – base scenario; HCA – human capital approach; FCA – friction cost approach; OCA employed – opportunity cost approach for the employed; OCA non-employed – opportunity cost approach for the non-employed (unemployed persons, students, homemakers and retired); n.a. – not applicable. For COVID-19 results, see Table S4 in the supplementary file. Detailed results for individual countries are shown in Table S5 in the supplementary file.