Productivity losses due to health problems arising from COVID-19 pandemic: a systematic review of population-level studies worldwide

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

Abstract

Aim: To systematically review the evidence on productivity losses due to health problems arising from the COVID-19 pandemic based on evidence from population-level studies.

Methods: Following PRISMA statement, we conducted a systematic review using Medline, Embase, Scopus, Web of Science, EconLit, WHO COVID-19 Research and EuropePMC databases and a grey literature search. We included population-level studies using secondary data and qualitatively assessed eligible studies. For a quantitative cross-study comparison, we calculated losses in 2020 international dollars and as a share of gross domestic product. PROSPERO registration number: CRD42023478059.

Results: 38 studies were eligible for review and 33 studies met the qualitative threshold for inclusion in a quantitative comparison. Most of the studies reported losses in high-income countries and the European region. COVID-19 was a focus of 33 studies while 3 studies investigated losses from both long COVID and excess mortality. The Human Capital Approach dominated (30 studies) and no study used the Friction Cost Method. Most of the studies (84%) reported on premature mortality losses and a quarter provided estimates of absenteeism losses. We found that the productivity losses ranged from 0% to >10% of gross domestic product; the greatest losses were in the high-income countries and for those aged 40-59 years; and losses among men contributed to around 3/4 of the total burden.

Conclusion: The available evidence on the topic is limited, particularly considering the methodological approaches used. Thus, more research is needed to reach a more comprehensive picture of economy-level productivity losses resulting from the recent pandemic.

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 Applied Health Economics and Health Policy, and is available online at https://doi.org/10.1007/s40258-024-00935-8.

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

[1] Nicolaus Copernicus University in Toruń, Doctoral School of Medical and Health Sciences, Bydgoszcz, Poland; ORCID: 0000-0003-4522-0595.

[2] Complutense University of Madrid, Department of Applied Economics, Public Economics and Political Economy, Madrid, Spain; ORCID: 0000-0001-8164-9415.

[3] Nicolaus Copernicus University in Toruń, Department of Health Economics, Bydgoszcz, Poland; ORCID: 0000-0002-5825-5079; corresponding author; e-mail: blazej@cm.umk.pl

Key points for decision makers

- evidence on pandemic-related productivity losses from lockdowns, morbidity and excess mortality is scarce and require further investigation
- productivity losses from COVID-19 are concentrated among those at middle age (40-59 years) and men, pointing to population groups that require policy attention in potential future pandemics
- short-term evidence prevails and little is known about the long-lasting economic burden of the pandemic

1. Introduction

Apart from the enormous health burden of COVID-19 [1], [2], the pandemic has had significant economic consequences worldwide, with gross domestic product (GDP) decline, increased unemployment rates, public finance deficits, and loss of production capacity [3], [4]. Yet, the pandemic's economic burden extends beyond the general macroeconomic downturn. Health economics research on the impact of COVID-19 focused on healthcare resource utilization, patient outcomes, the economic burden of inpatients, the impact of nonpharmaceutical interventions on infection rates and population immunity, and productivity losses attributable to the disease (for systematic reviews on the economic aspects of the pandemic, see [5], [6], [7], [8]).

Estimation of productivity losses (indirect costs), which represent the potential economic output unproduced due to health problems, is a key tool for assessing the economic burden of diseases. These losses encompass costs from both mortality and morbidity, and they are identified as uncompleted production in formal market activities and informal economic production (e.g. housekeeping, volunteering) [9], [10]. Due to its enormous death toll and non-pharmaceutical interventions aimed at limiting the virus spread, COVID-19 plausibly resulted in substantial productivity losses. Only in an initial 10-week period of the pandemic, nine European states experienced 0.02% (Switzerland) to 0.11% (Spain) GDP loss due to market activities uncompleted as a result of excess mortality [11]. In an Italian study, temporary productivity losses from the pandemic until 28 Apr 2020 were €103 million and the respective losses from COVID-19 mortality were three times higher, reaching 0.17% of the country's GDP [12]. In a longer period, productivity losses due to COVID-19 in Canada between February 2020 and April 2022 were US$8.3 billion (0.48% of 2019 GDP) [13]. The above figures show a large diversity of loss estimates and are hardly comparable for several reasons. Firstly, as shown above, the period of analysis is diverse across studies and this makes a straightforward comparison of findings difficult. Secondly, the methods for productivity losses estimation differ and there is no agreement on which of the two commonly used approaches (human capital approach [HCA] or friction cost approach [FCA]) is superior [9]. Eventually, studies using population-level data (like the ones reported above) provide estimates of losses expressed in macro-measures, e.g. share of GDP lost, while the results from sample-based studies are more contextual and tougher to generalize for whole economies [14].

Previous systematic reviews on the cost of COVID-19 have analyzed productivity losses of the pandemic; yet, they were either limited to specific sub-groups (e.g. healthcare workers [5] or inpatients [15]) or aggregated different categories of costs (e.g. direct costs, indirect costs, out-of-pocket payments [15], [16]). Therefore, earlier reviews have provided a rather broad picture of COVID-19-related cost studies. We intend to take a narrower perspective and analyze a specific topic of productivity losses related to the pandemic and focus solely on population-based studies. The reasoning for this choice is the following. Using a relatively homogenous approach (only population-based settings), we intend to compare estimates from all included studies quantitatively. Also, we aim to compare methodological approaches used for indirect cost estimation and this could be done more thoroughly with a set of studies sharing common characteristics. Moreover, after more than four years since the inception of the pandemic, it seems that sufficient evidence arose that allows for synthesising quantitative evidence on the burden of COVID-19 in terms of whole-economy productivity losses. Eventually, reviewing the current state of knowledge on the topic aims to assess whether the evidence at hand enables policy-makers with valuable insights to inform evidence-based decisions regarding future pandemic preparedness and the magnitude of productivity losses as a part of the overall economic burden of COVID-19 [17], [18].

Hence, this is the first study that aimed to systematically review the evidence on productivity losses due to health problems arising from the COVID-19 pandemic based on results from population-level studies.

2. Methods

This systematic review follows the PRISMA (Preferred Reporting for Systematic Reviews and Meta-Analyses) guidelines for conducting and reporting a systematic review [19]. The protocol for this review was prospectively registered in PROSPERO (registration number CRD42023478059).

2.1. Search strategy and selection of studies

A systematic literature search was conducted in Medline (via PubMed), Embase, Scopus, Web of Science, EconLit, WHO COVID-19 Research Database and EuropePMC. The following websites were searched for grey literature: Google, Google Scholar, EconPapers, the National Bureau of Economic Research, the Organization for Economic Co-operation and Development, and the World Bank. The primary search query was developed for the PubMed search engine by BŁ and PN and subsequently assessed by a librarian expert for accuracy and quality. The Systematic Review Accelerator (Polyglot tool; sr-accelerator.com/#/polyglot), maintained by the Institute for Evidence-Based Healthcare at Bond University, was used to translate a query from PubMed to other databases used in literature search, except for EconLit. MOO developed a search syntax for the EconLit database. Keywords used for identifying concepts of COVID-19 and productivity losses are exhibited in table 1 while detailed queries are shown in Online Resource 1.

[Table 1 here]

The Rayyan online application (rayyan.ai) was used for the deduplication process. In the first stage of duplicates removal, we used a 95% similarity criterion, then deduplication was based on titles, DOI numbers and pages in the outlet (in the above order and each stage separately). The deduplication of the remaining part of the articles was resolved manually. The screening was performed manually using the Rayyan application. PN and BŁ independently (blind mode on) examined the titles and abstracts of potentially relevant articles. Disagreements were resolved by discussion between the two reviewers.

Subsequently, BŁ and PN reviewed full texts of the relevant studies based on the eligibility criteria and the systematic review objectives. We used backward and forward citation tracking to identify other studies that met the eligibility criteria. The citation tracking applied to (1) studies initially included based on database searches and initial screening of titles and abstracts; (2) studies initially included based on citation tracking of included studies (3) studies initially included based on citation tracking of systematic reviews on economic aspects of COVID-19 identified through database and hand searching; and (4) studies initially included based on hand searching of Google, Google Scholar, technical reports and organizations' websites. Online Resource 1 contains search queries, a strategy for searching grey literature, the number of hits per line in the Embase search, a list of studies included in the final analysis and a list of excluded studies after full-text analysis, together with the reasons for their exclusion.

2.2. Inclusion and exclusion criteria

The review included published studies meeting the following criteria: secondary, population-level quantitative studies using all methods that estimate productivity losses resulting from the COVID-19 pandemic. The following studies were excluded: studies limited to particular sub-populations (e.g. inpatients, outpatients, and workers) or economic sectors/industries, qualitative studies, editorials, commentaries, views, opinions, letters, and dissertations. Yet, to account for potential publication bias [20], we include preprints and unreviewed publications in our review. We searched publications from 1 Nov 2019 to 19 Dec 2023.

Studies using the value of statistical life (VSL) concept to determine the monetary value of lives lost due to the pandemic [21], [22] are not eligible for this review. This is because the VSL is conceptually different from the productivity losses methodology and estimates from these two approaches are incomparable.

2.3. Data extraction

PN designed forms for qualitative and quantitative data extraction. The forms were pilot-tested by extracting data from eight randomly selected studies (BŁ, PN). Subsequently, several corrections were made to the forms based on the extraction process tests.

Eventually, we extracted the following qualitative information from eligible studies: first author and publication year; title; study design; period of analysis; reference year; geographical settings; country classifications by income (World Bank) and by region (World Health Organization regional offices); currency; main data sources; study population; diagnosis; losses estimation approach; losses categories; discounting; perspective; productivity measure used; results reported; sensitivity analysis; study limitations; and authors' conflict of interest (more details explaining contents of the categories in Online Resource 2). For the quantitative data, we extracted raw estimates on the productivity losses for each study meeting inclusion criteria and reaching the minimum quality assessment score of 60% (see 'Quality assessment' sub-section below).

BŁ and PN extracted qualitative data from half of the included studies each and cross-checked the accuracy of the data extraction made by the other reviewer. PN performed quantitative data extraction, estimated quantitative figures reported, and BŁ cross-checked the data and results obtained. Completed quality and quantity forms are available in the Online Resources. The resultant quantitative form was used for a cross-study comparison of losses using common currency (International dollar – Int$) and common year (2020); these estimates are presented in detail in Online Resource 3.

2.4. Quality assessment

The tool designed by Stunhldreher et al. [23] which has been recently used in a systematic review focusing specifically on productivity losses [24] was used to assess the quality of the eligible studies. Two reviewers (PN and BŁ) carried out the qualitative assessment independently and any disagreements were resolved by the third reviewer (MOO). The checklist was adapted to our study design of interest (population-level settings) and we used the following categories: (1) Study objective; (2) Disease and diagnostic criteria; (3) Cost-description; (4) Currency; (5) Reference year; (6) Perspective; (7) Cost incorporated from more than one category; (8) Data source; (9) Valuation of costs; (10) Discounting; (11) Sensitivity analyses; (12) Results discussed with respect to other studies; (13) Limitations discussed; (14) Conclusion appropriate regarding uncertainty in results. For each of the above criteria, the exclusive assessment choices were (a) yes or (b) no/not clear. The resulting percentage of positive answers yielded a quality assessment score for the studies included. A minimum score of 60% was used to include a study in the cross-study quantitative comparison.

2.5. Approach to cross-study comparison of quantitative results

For the cross-study comparison of productivity losses, we used the following approach. First, studies assessed as not reaching a 60-percent threshold of quality assessment score were excluded as explained above. Second, to compare losses across time and different currencies used, and to express losses as a share of gross domestic product (GDP), we used the International Monetary Fund's (IMF) data on inflation rates, purchasing power parities and GDP [25]. For some studies, the currency used originally was Int$ and in these cases, we only adjusted for inflation using 2020 as a base year. For those studies that reported findings in local currencies, we used IMF's conversion rates to express losses in Int$ and adjusted for inflation as explained above. For some studies that deal with provincial loss estimation, regional input data on GDP were obtained from other sources, as shown in Online Resource 3. Third, to account for the fact that several studies reported loss estimates for periods different than full years, in calculating shares of GDP lost, we used a respective GDP proportion; e.g. an Italian study [12] analyzed the period 21/02/2020 to 28/04/2020 (68 days), therefore, we used 68/366 share of the country's GDP. Additionally, several studies did not report a starting period of analysis and, in such cases, we assumed the day of the first COVID-19 case in the country to be the starting date of the analysis. Fourth, to allow for more accurate cross-study comparison, we adjusted age categories as reported in the source studies to three bands, 0-39 years; 40-59 years and 60+ years. This was done by assuming an equal distribution of losses across all single ages in particular intervals in source studies, e.g. for an age band 31-45 years reported originally in the study analysed, we assigned 9/15 part of the losses to interval 0-39 years and 6/15 part to interval 40-59 years. All the detailed adjustments used for the cross-study comparison of losses are shown in Online Resource 3, separately for each study included.

3. Results

3.1. Study selection process

As a result of the database search, we identified 15,588 records. A total of 9,621 records were removed within the deduplication process. We selected 52 studies for a full-text assessment. Finally, 22 of these met the eligibility criteria. Identification of studies through alternative methods, such as searching grey literature and citation tracking, resulted in 4,188 identified records and, after the initial screening process, 87 items were selected for full-text analysis. Based on this stage, 16 articles were eligible for inclusion in the review. Eventually, 38 studies met the inclusion criteria; among the studies identified, we included two preprints [26], [27] and one unreviewed publication [28]. Detailed information on the study selection process is depicted in Fig 1 using a PRISMA diagram.

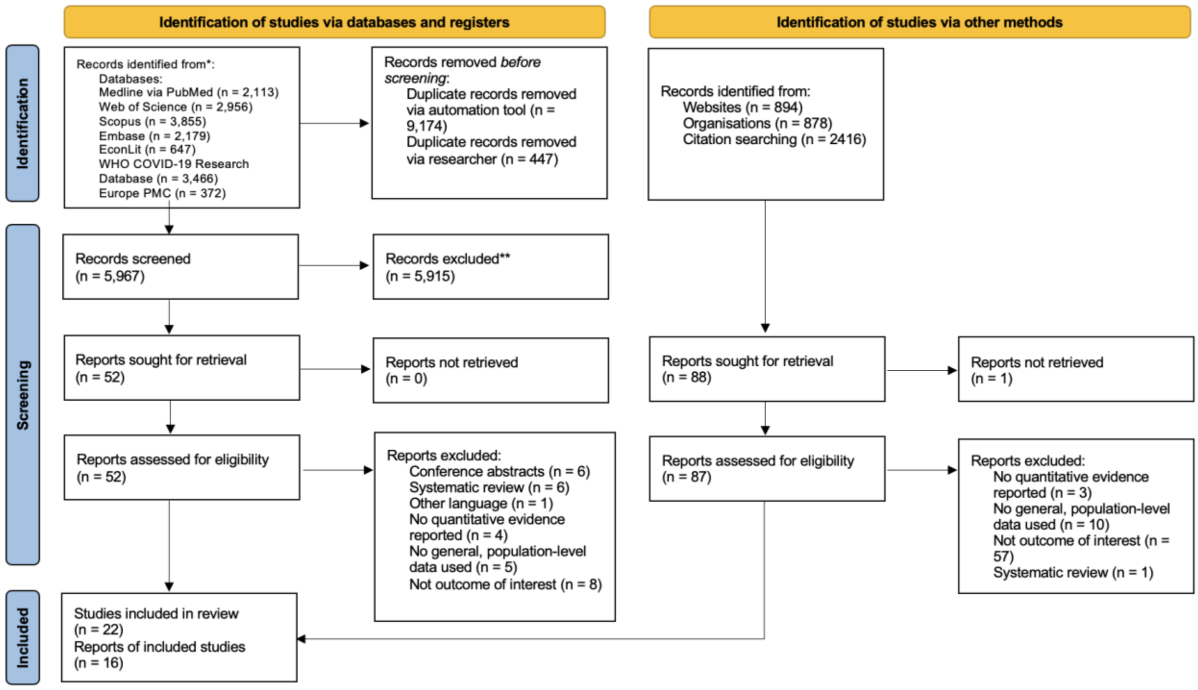

Fig 1 PRISMA (Preferred Reporting Items for Systematic review and Meta-Analysis) flow diagram for the study selection process

3.2. Characteristics of eligible studies

Table 2 summarises the qualitative characteristics of the studies included in the analysis. Half of the studies (n=19) focus on high-income countries while only two provide estimates from low-income countries. However, some studies report results for multiple countries [11], [29], [30], [31] and, once this is accounted for, around 1/3 of unique country-specific estimates come from high-income and lower-middle-income states each. Considering the World Health Organization's regions, 34 percent (n=13) of the articles report findings from Europe and 21 percent (n=8) from both the Americas and South-East Asia. Yet, because one study estimated losses for 54 African countries [29], more than half of single estimates are from Africa. The countries analysed in the highest number of articles were India (n=8); the United States (n=5); Canada, Germany and Italy (n=3 each). Interestingly, for India, half of the articles focused on single regions, not the whole country. COVID-19 itself was a focus in 33 articles included, while three studies dealt with either long COVID or excess all-cause deaths. For 30 studies, the human capital approach was used to estimate losses, in eight papers the method was not explicitly mentioned and one study used the proxy good approach to estimate losses from non-market activities [11]. Considering the productivity measures used, 61% of articles (n=23) relied on a GDP-based approach, 39% (n=15) used income- or earning-based measures and two articles did not provide details in this respect [28], [32]. The vast majority of studies included in the review estimated losses resulting from premature mortality (84%; n=32) and about a quarter of them reported on absenteeism costs. Eventually, more than half of the studies (n=22) applied sensitivity analysis to analyse how the results change with model assumptions/input data variations (table 2).

[Table 2 here]

3.3. Quality assessment of included studies

None of the 38 studies included in the review met all the 14 quality criteria. Two of the studies were assessed as of the highest quality meeting >90% of the criteria [27], [33]. For six studies [11], [29], [34], [35], [36], [37] the quality score was high and ranged from 80% to 89%. A majority of studies (22 of 38) included [12], [13], [26], [31], [38], [39], [40], [41], [42], [43], [44], [45], [46], [47], [48], [49], [50], [51], [52], [53], [54], [55], [56] met 70%-79% of the quality criteria. In three studies [32], [45], [55], [56], [57], we identified a low-quality score of 60%-69% and another five studies [28], [30], [58], [59], [60] were judged as the lowest-quality analyses with a score of <60%. The last category of lowest-quality studies was excluded from the quantitative analysis since we could not extract details relevant to cross-study loss comparison. The quality assessment broken down into five sub-categories evaluated is depicted in Fig 2 while the detailed results for each criterion are shown in Online Resource 4.

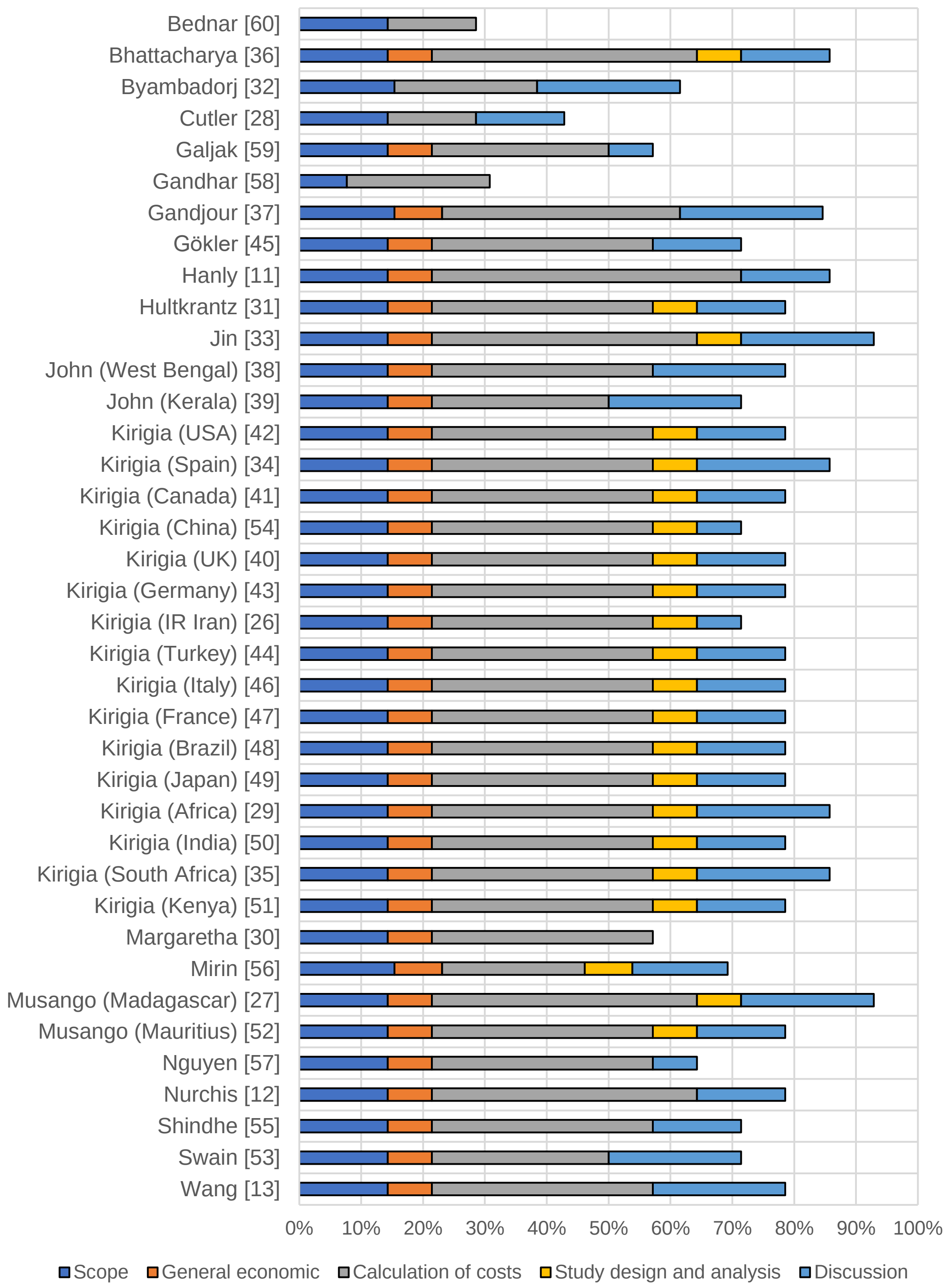

Fig 2 Results of quality assessment of studies included in the review

Notes: Labels for particular studies contain first author's name and reference to bibliography. In quality assessment, a tool developed by Stuhldreher et al. [23] was used. The tool consists of 22 items organised into 5 groups (scope; general economic; calculation of costs; study design and analysis; and discussion) but we used only some of them. Specifically, because this review focuses on population-level studies solely, we excluded assessment items that are specific to sample-based settings, i.e. inclusion and exclusion criteria; non-diseased comparison group or disease-specific costs; missing data and imputation method; statistics appropriate; sample size (subgroup); demographics (minimum age and sex); arithmetic mean cost; standard deviations (errors). In total, 14 out of 22 items were used for assessment. For four papers [32], [37], [56], [58], the number of items assessed was 13 because discounting was not applicable for these studies (one-year or shorter time horizon). The detailed results of the quality assessment are reported in Online Resource 4. Referencing details for labels used in the figure are shown in Table 3.

3.4. Cross-study comparison of productivity losses

We compared eligible studies' findings regarding productivity losses resulting from the pandemic. Table 3 presents comparative results for eligible studies and the magnitude of losses for each cost category, expressed in international dollars and deflated to a common year (2020Int$). In 33 studies included, we identified 96 separate estimates for a single country/region.

The highest productivity losses of Int$623 billion (10.36% of GDP) were identified in a Chinese study analysing COVID-19 losses from partial lockdown, premature mortality and cases in the first quarter of 2020 [33]. 99.9% of the losses estimated in this study were due to partial lockdown. No other research identified comparable indirect costs to that in China in the initial phase of the pandemic. The other studies that reported losses of >0.5% of GDP were those from India, 0.58% [36]; Spain, 0.53% [11] (both using the excess mortality approach); four papers by Kirigia et al. that used life expectancy as an upper bound of age in loss estimation in COVID-19 mortality (Spain, 2.12% [34]; the United Kingdom, 0.80% [40]; Italy, 0.96% [46]; and France, 0.54% [47]); and a study of long COVID cost related to absenteeism in the United States (an upper range of estimate identified was 0.72% of GDP) [56]. On the other hand, in three cases no losses were identified and this applies to the excess mortality analysis of Germany until 15 May 2020 [11] and to Eritrea and Seychelles until 1 Aug 2020 in terms of COVID-19 premature mortality [29]. In general, 2/3 of 96 single estimates of the share of GDP lost were below 0.1% of GDP, seventeen estimates were within a range of [0.1-0.2), four estimates were between 0.2% and 0.3% of GDP and three estimates were between 0.3% and 0.4% of GDP. More than 0.5% of lost GDP was identified for six studies and two of these estimates were >1% of GDP (these figures refer to total losses, not single cost categories from studies where more than one category was estimated; for details see table 3).

[Table 3 here]

More than half of single country/region estimates are from a study of productivity losses resulting from premature mortality in 54 African countries [29]. Generally, the indirect costs reported therein are relatively low; for most countries, they are below 0.01% of GDP and reach a maximum of 0.19% in South Africa. Using a similar methodological approach, the same author reported losses of >2% of GDP in Spain [34] and almost 1% in Italy [46] and the UK [40].

For further insight into patterns of productivity losses, we examined average values of losses in groups of countries and broken down by loss category (table 4) as well as age- and sex-specific costs (table 5 and table 6). We grouped the estimates based on two main loss categories (premature mortality and absenteeism) and whether the countries/regions of interest are high-income (HICs) or middle- and lower-income (LMICs).

Regarding average productivity losses by countries/regions, a clear relationship exists between income level (proxied by World Bank classification) and productivity losses experienced from COVID-19 in countries/regions; high-income countries lost 0.656% of GDP on average and this share declines with each income group to 0.007% lost in low-income countries (table 4). The same pattern is evident for losses expressed in Int$ per 1,000 population. The highest average losses for WHO regions were identified in the Western Pacific (2.628% of GDP and Int$113,674 per 1,000 population); however, these high losses were due to an outlier effect of a Chinese study accounting for enormous lockdown costs [33]. Substantial average losses of >0.3% of GDP were identified for studies analyzing data from the Americas and Europe, while for Africa losses were the lowest. Considering loss categories, lockdown/quarantine/cases translated to as much as 5.237% of GDP but, again, this results from high losses identified in a study from China in which this category yielded 99.9% of total losses [33]. Interestingly, losses from absenteeism proved to be higher than the cost of premature mortality. Generally, variation in all categories analyzed here was substantial with standard deviation values greater than average values in almost all cases.

[Table 4 here]

Based on results from 24 studies, we see that the highest losses were identified in the middle-aged (40-59 years) category for all countries combined, both in the premature mortality and absenteeism (42% and 50%, respectively) (table 5). The picture is more nuanced though, once we look separately at the two cost categories distinctly. For mortality in HICs, it was the elderly category that was much more important in terms of overall losses; its share was as much as 65% of total losses. On the other hand, for LMICs countries, the share of losses among the young (0-39 years) was relatively high (25% of the total and 5 times higher share than in HICs) and comparable to the elderly group. For absenteeism loss distribution across age groups, we see that the share of costs attributable to work absence of the young is higher than in mortality; in non-HICs, it is even higher than for the middle-aged.

[Table 5 here]

Considering sex-specific losses, we observe more homogenous shares of costs attributable to males and females across income groups and cost categories (table 6). Yet, the sex-specific figures are based on results from 7 studies (14 single estimates) only; thus, caution is required here while making across-group comparisons. More than 3/4 of mortality losses resulted from men's deaths and this was homogenous across country groups with a slightly higher share in HICs (77%) than in the remaining ones (75%). The distribution of losses between sexes for absenteeism was quite similar; however, costs due to men’s absence were 54% of total losses. This last share was only available for a single study [13]; therefore, it needs to be treated with caution.

[Table 6 here]

4. Discussion

This study aimed to systematically review the evidence on productivity losses due to health burden from the COVID-19 pandemic based on findings from population-level studies. We identified 38 studies meeting inclusion criteria and based on the quality assessment score (>60% using the tool [23]), 33 of the studies were included in the cross-study quantitative comparison using universal currency and times settings (2020 International dollars).

4.1. Interpretation of main review findings

Of the 96 unique estimates, a majority identified economy-level losses of <0.1% of GDP and used the human capital approach to estimate losses resulting mostly from COVID-19 mortality. The highest identified productivity losses of >10% of GDP were reported in the Chinese study [33] concerned with the cost of mortality, cases and lockdowns in the 1st quarter of 2020. Interestingly, 99.9% of the cost in this study resulted from lockdowns; the remarkable share of this loss category originates from restrictive non-pharmaceutical interventions (NPIs) in China in the initial phase of the pandemic [61], [62]. This strategy allowed for slower spread of infection there and low COVID-19 mortality [63], [64]. Only one more study reported losses from lockdown [32]; in Mongolia, the share of losses from this cost category was also remarkably high (98%). Yet, in this country, no COVID-19 deaths were reported in the period analyzed. Thus, although evidence is scarce, NPIs like lockdowns and social distancing measures might lead to a substantial economic burden of productivity losses. Nonetheless, more research is needed to verify whether in other settings, particularly when less restrictive NPIs are in place, lockdowns led to comparable losses. Ultimately, less stringent policies aimed at mitigating the virus spread would translate to higher morality and absenteeism losses due to greater death/work absence rates [65], [66]. Such a mechanism might be inferred from a study of absenteeism losses in three Nordic countries [31]; the burden of losses in Sweden, where less restrictive NPIs (e.g. no national lockdowns) were introduced in the first months of the pandemic [67], [68], proved to be 3-4 times higher (in terms of GDP share lost) than the respective losses in Iceland and Norway.

Our cross-country comparison of losses identified a clear income gradient of productivity losses within groups of countries categorized according to the World Bank's classification. High-income countries lost 0.656% of their GDP on average and this share declined with each consecutive group towards 0.007% GDP lost in low-income countries. The explanation behind this pattern appears to result from different demographic structures and socio-economic characteristics of particular country groups. Generally, high-income countries have older populations than other countries. Since COVID-19 affects the elderly's health more heavily than the young [69], [70], a greater share of the population in rich countries suffers from health deterioration that leads to productivity losses. This effect is strengthened by the higher age of exiting the labour market in high-income countries. Additionally, relatively low losses in less economically developed countries might result from their large informal economies [71]. This is because losses from the informal economy are not identifiable in the productivity losses framework that uses GDP- or income-based approach. Yet, the above reasoning explains the income gradient only partially and it should be kept in mind that some lower-income countries (e.g. India) also experienced a large COVID-19 health burden. Additionally, a systematic review [72] claims that infection fatality rates from COVID-19 were roughly 2 times higher in developing countries than in high-income ones.

For age-specific losses, we identified some interesting patterns that reflect differences across groups of countries and loss categories. In all countries combined, mortality losses were similar in the middle-aged group (40-59 years: 42% of total losses) and elderly (60+ years: 40%) categories. However, in high-income countries, the losses from the elderly's mortality accounted for 65% of total losses. This plausibly results from the higher economic activity of those 60+ years in developed countries than in the developing ones, as discussed above. Interestingly, the share of mortality losses among the young (0-39 years) in developing countries is five times higher than in high-income countries (25% and 5%) and this perhaps indicates the difference in health systems capabilities across the countries [73]. Considering absenteeism losses, these are much more pronounced in the younger population with 42% of total losses in all the countries. This large share is not surprising as the employment rates are high in this group; additionally, the young bore a large burden of childcare absenteeism during school closures in the initial period of the pandemic [74]. Considering sex-specific productivity losses, we note that the cost of COVID-19 in men accounted for around 3/4 of total losses and this might be explained by males' greater vulnerability to the virus [75] as well as their higher employment rates, greater income levels, and longer periods of economic activity before retirement.

4.2. Methodological approaches identified

One of our aims in this review was to overview the methodological approaches used to estimate productivity losses from the recent coronavirus pandemic. We focused particularly on estimation methods, loss categories, and specific diagnoses analyzed.

All studies included in the review that explicitly stated an approach to cost estimation, used HCA, the most commonly used method of indirect cost estimation [76]; Consequently, no study used the FCA, neither in a base scenario nor in a sensitivity analysis. Therefore, caution is needed when analyzing the results of our review as population-level research utilizing the friction cost method is missing. This shortcoming should be kept in mind as the review of two methods shows that results based on FCA were even 72 times lower than those resulting from the use of HCA [9]. Only one study used the proxy good approach to analyze losses from non-market activities unproduced due to premature mortality [11]. Therefore, the scope of estimation methods used in the studies included is limited and does not allow for a comprehensive assessment of the phenomenon of interest.

Even though all the eligible studies used HCA, it was still infeasible to make truthful comparisons between the estimates. This is because included studies made substantially different assumptions in estimation procedures. For example, in some studies using GDP as a productivity measure, e.g. [34], [35], [36], [38], [40], [41], [42], [52], life expectancy was used as an upper bound for identifying a population of interest, while retirement age (legal or factual) seems to be more appropriate here as those at ages between exiting labour market and reaching life expectancy are not likely to contribute to GDP. An approach based on life expectancy may lead to cost overestimation when using HCA, which traditionally uses retirement age as the cut-off point for loss identification.

Overall, losses from premature mortality were the most investigated cost category in the studies included in the review. This plausibly results from the fact that COVID-19 was a highly lethal disease from the onset of the pandemic [77], [78] and mortality data was relatively easily available. Unsurprisingly, the cross-study comparison revealed quite substantial differences between the estimates of mortality costs. Spain experienced a loss of 2.1% of GDP due to premature COVID-19 mortality [34] while the same methodological approach shows no losses in some African countries [29] or minor indirect costs in Japan (0.01%) [49] or Germany (0.05%) [43]. The explanation behind these differences results from different death burden across the countries. Japan experienced much lower COVID-19 mortality than most Western European countries or the United States [79], [80]. However, this varying magnitude of losses might result from differences in reporting COVID-19 deaths in particular settings, e.g. divergence in the way deaths are recorded, particularly in cases where COVID-19 is not the direct cause of death, but rather a contributing cause of complications in other diseases [81],

[82]. It was also recognized that in some settings governments were unable to sustain standards of COVID-19 death reporting (e.g. in some African countries [83], [84]) and this might bias results downward. In fact, estimates of premature mortality losses from 54 African countries [29] are relatively low as compared to those studies that report losses from countries characterized by higher standards of death causes reporting. Moreover, the studies analysed differ in terms of the periods covered. Most of the eligible studies (20 out of 33 in the quantitative analysis) refer to 2020, often accounting for only a few months of this year, see e.g. [12], [52], [55]. Such short periods do not identify losses that were yet to come with more dynamic virus spread. An example of this is a zero losses estimate for Germany in the study of excess mortality losses covering the period of 02/03 - 15.05.2020 [11]. With all these limitations, the potential of comparing mortality losses between studies, as we did above, is limited. Therefore, studies using longer time horizons are needed to draw more accurate conclusions on cross-country comparisons of productivity losses.

Absenteeism was another loss category investigated in some studies and resulting losses were substantial in some settings, ranging from 25% of total losses in an Italian study [12] to as much as 88% of the burden in the Indian state of Kerala [39]. Again, these differences might be contextual in terms of the period covered, territory, cost category definition, and between-countries reporting differences, similar to problems explained above in mortality comparisons. Concluding this part of the discussion, it is worth noting that no study provided evidence on presenteeism losses and only limited evidence is available on indirect costs resulting from lockdown and quarantine, possibly due to data constraints.

Considering the definition of health problem (diagnosis), it is clear that studies analyzing COVID-19 dominate the picture (33 of 38 eligible studies). Yet, we shall discuss the use of ‘excess’ burden measures in the context of the recent pandemic. Excess mortality used in three reviewed studies [11], [36], [60] is an epidemiological measure often considered a more reliable indicator of the real death burden of a pandemic. Excess mortality approximates the additional number of deaths in a period of interest, compared to the expected number which is usually based on mortality trends or average values observed in near past periods [82], [85]. The main benefit of excess mortality lies in the fact that it not only accounts for fatalities caused directly by SARS-CoV-2 but also for the deaths arising from the pandemic's indirect effects on health systems operation and societies in general [2], [86]. One of the studies analyzed here [36], apart from estimating productivity losses from COVID-19 mortality, calculated the losses from overall (all-cause) excess deaths. According to these findings from India, the economic burden from excess mortality was more than ten times greater than losses attributable to COVID-19 deaths. Unfortunately, the excess mortality measure has its drawbacks and there is no established gold standard for estimating it [85], [86]. For example, an important confounding factor that has a notable impact on the outcome is an adjustment for changing population age structure or the length of the pre-pandemic period used for forecasting an expected number of deaths [85], [87]. Yet, it seems that excess mortality might serve as a more trustworthy measure than the number of deaths caused by COVID-19 when evaluating the effects of the pandemic. Epidemiological literature has already recognized this fact [2], [81], [87] and we think that applied research on productivity losses resulting from the pandemic would also benefit from this approach.

4.3. Limitations of the study

Before concluding, we shall acknowledge the limitations of this study. To begin with, there was a large diversity of methodological approaches identified and this calls for caution in comparing the findings across studies. Next, for most of the studies analyzed, the period covered in the estimation is limited to the year 2020 and this precludes us from drawing long- or even medium-term conclusions on the pandemic's economic burden. Also, most studies dealt with COVID-19 mortality, and they rarely accounted for excess mortality – a more reliable measure of the true pandemic death toll. Importantly, we were not able to analyze losses broken down by the wave of the pandemic; such an approach was not feasible as there is no comparable data on the duration of particular waves in a large number of countries covered here. Another limitation is that we could compare quantitative results across studies to only a limited extent. Because estimates from eligible studies are based on population-level data, no mean values, variances or sample sizes are obtainable here; therefore, we could not consider meta-analysis in our review. Finally, the review was limited to studies published in either English, Spanish, or Polish language.

5. Conclusions

This study aimed to summarize evidence on productivity losses from the COVID-19 pandemic using relatively homogenous settings of population-level studies. We intended to compare estimates across studies from different regions in the hope of providing useful and policy-relevant evidence. We found that losses ranged from 0% to over 10% percent of GDP, but these estimates heavily depended on the loss categories included and the periods analyzed. We found the highest losses in high-income countries, for those aged 40-59 years, and that losses among men contributed to around 3/4 of the total indirect cost. Concluding with these findings, we note that the available evidence on the topic is rather limited. This is because eligible studies (1) are concentrated in limited time settings (mostly 2020); (2) in most cases, they do not account for excess burden; (3) use the human capital approach solely; and (4) hardly account for non-market losses. Therefore, more research is needed to provide a more detailed picture of productivity losses across countries. Such evidence is important from a public policy standpoint to identify how important health-related productivity losses are as a part of the overall economic burden of COVID-19. Such evidence might also be important for future pandemic preparedness, particularly for the evaluation of non-pharmaceutical interventions aimed at limiting virus spread, which work effectively but at the expense of severe economic losses as (limited) evidence from this review suggests.

Declarations

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

Conflict of interests: The authors have no relevant financial or non-financial interests to disclose.

Availability of data and material: The authors confirm that all data generated or analysed during this study are included in this published article or can be replicated with publicly available sources.

Ethics approval: This study only used publicly available data and no human participants were involved in the study; therefore, ethics approval was not sought.

Consent to participate: Not applicable.

Consent to publication: Not applicable.

Code availability: Not applicable.

Authors' contribution statements: PN & BŁ conceptualised and designed the research, collected the data, performed the analyses, interpreted results and wrote the manuscript. MOO participated in designing the study and in the interpretation of the results, collected the data, and critically revised the manuscript. All authors read and approved the final manuscript.

References

[1] D. Chang, X. Chang, Y. He, and K. J. K. Tan, "The determinants of COVID-19 morbidity and mortality across countries," *Sci Rep*, vol. 12, no. 1, Dec. 2022, doi: 10.1038/s41598-022-09783-9.

[2] C. T. Pallari *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 CMOR project," *BMJ Glob Health*, vol. 9, no. 4, Apr. 2024, doi: 10.1136/bmjgh-2023-013018.

[3] I. W. Rathnayaka, R. Khanam, and M. M. Rahman, "The economics of COVID-19: a systematic literature review," *Journal of Economic Studies*, vol. 50, no. 1, pp. 49–72, Jan. 2023, doi: 10.1108/JES-05-2022-0257.

[4] W. McKibbin and R. Fernando, "The global economic impacts of the COVID-19 pandemic," *Econ Model*, vol. 129, Dec. 2023, doi: 10.1016/j.econmod.2023.106551.

[5] M. Yaghoubi, M. Salimi, and M. Meskarpour-Amiri, "Systematic review of productivity loss among healthcare workers due to Covid-19," Jan. 01, 2022, *John Wiley and Sons Ltd*. doi: 10.1002/hpm.3351.

[6] C. Blázquez-Fernández, P. Lanza-León, L. Sanchez-Ruiz, and D. Cantarero-Prieto, "Economic costs related to coronavirus disease 2019 pandemic: A systematic literature review," Oct. 01, 2023, *SAGE Publications Ltd*. doi: 10.1177/00368504231201548.

[7] R. Izadi, N. Hatam, F. Baberi, S. Yousefzadeh, and A. Jafari, "Economic evaluation of strategies against coronavirus: a systematic review," Dec. 01, 2023, *BioMed Central Ltd*. doi: 10.1186/s13561-023-00430-1.

[8] F. Richards *et al.*, "Economic Burden of COVID-19: A Systematic Review," 2022, *Dove Medical Press Ltd*. doi: 10.2147/CEOR.S338225.

[9] J. Pike and S. D. Grosse, "Friction Cost Estimates of Productivity Costs in Cost-of-Illness Studies in Comparison with Human Capital Estimates: A Review," Dec. 01, 2018, *Springer International Publishing*. doi: 10.1007/s40258-018-0416-4.

[10] W. Zhang, N. Bansback, and A. H. Anis, "Measuring and valuing productivity loss due to poor health: A critical review," *Soc Sci Med*, vol. 72, no. 2, pp. 185–192, Jan. 2011, doi: 10.1016/j.socscimed.2010.10.026.

[11] P. Hanly, M. Ahern, L. Sharp, D. Ursul, and G. Loughnane, "The cost of lost productivity due to premature mortality associated with COVID-19: a Pan-European study," *European Journal of Health Economics*, vol. 23, no. 2, pp. 249–259, Mar. 2022, doi: 10.1007/s10198-021-01351-8.

[12] M. C. Nurchis *et al.*, "Impact of the burden of COVID-19 in Italy: Results of disability-adjusted life years (DALYs) and productivity loss," *Int J Environ Res Public Health*, vol. 17, no. 12, pp. 1–12, Jun. 2020, doi: 10.3390/ijerph17124233.

[13] F. Wang, J. Lui, and J. Der Wang, "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*, vol. 20, no. 3, Feb. 2023, doi: 10.3390/ijerph20032419.

[14] M. Ghaffari Darab, K. Keshavarz, E. Sadeghi, J. Shahmohamadi, and Z. Kavosi, "The economic burden of coronavirus disease 2019 (COVID-19): evidence from Iran," *BMC Health Serv Res*, vol. 21, no. 1, Dec. 2021, doi: 10.1186/s12913-021-06126-8.

[15] K. Gholipour, S. Behpaie, S. Iezadi, A. Ghiasi, and J. S. Tabrizi, "Costs of inpatient care and out-of-pocket payments for COVID-19 patients: A systematic review," *PLoS One*, vol. 18, no. 9 September, Sep. 2023, doi: 10.1371/journal.pone.0283651.

[16] C. Vardavas *et al.*, "Cost of the COVID-19 pandemic versus the cost-effectiveness of mitigation strategies in EU/UK/OECD: A systematic review," *BMJ Open*, vol. 13, no. 10, Oct. 2023, doi: 10.1136/bmjopen-2023-077602.

[17] J. T. Rothwell, A. Cojocaru, R. Srinivasan, and Y. S. Kim, "Global evidence on the economic effects of disease suppression during COVID-19," *Humanit Soc Sci Commun*, vol. 11, no. 1, Dec. 2024, doi: 10.1057/s41599-023-02571-4.

[18] K. W. Lauterbach, "Evidence-based policy-making - epidemiology as a key science for quality of life in society," *Eur J Epidemiol*, vol. 38, no. 12, pp. 1205–1212, Dec. 2023, doi: 10.1007/s10654-023-01056-7.

[19] M. J. Page *et al.*, "The PRISMA 2020 statement: An updated guideline for reporting systematic reviews," Mar. 29, 2021, *BMJ Publishing Group*. doi: 10.1136/bmj.n71.

[20] N. J. Devito and B. Goldacre, "Catalogue of bias: Publication bias," Apr. 01, 2019, *BMJ Publishing Group*. doi: 10.1136/bmjebm-2018-111107.

[21] W. K. Viscusi, "Pricing the global health risks of the COVID-19 pandemic," *J Risk Uncertain*, vol. 61, no. 2, pp. 101–128, Oct. 2020, doi: 10.1007/s11166-020-09337-2.

[22] J. K. Hammitt, "Valuing mortality risk in the time of COVID-19," *J Risk Uncertain*, vol. 61, no. 2, pp. 129–154, Oct. 2020, doi: 10.1007/s11166-020-09338-1.

[23] N. Stuhldreher *et al.*, "Cost-of-illness studies and cost-effectiveness analyses in eating disorders: A systematic review," May 2012. doi: 10.1002/eat.20977.

[24] S. Mohammadpour *et al.*, "A systemmatic literature review on indirect costs of women with breast cancer," 2022. doi: 10.1186/s12962-022-00408-6.

[25] International Monetary Fund, "World Economic Outlook Database."

[26] J. M. Kirigia, R. N. D. K. Muthuri, and N. G. Muthuri, "The net present value of human lives lost due to coronavirus disease (COVID-19) in the Islamic Republic of Iran," 2020, doi: 10.21203/rs.3.rs-24711/v1.

[27] L. Musango, Mandrosovololona V, Randriatsarafara MF, Ranarison VM, Kirigia MJ, and Ratsimbasoa CA, "The present value of human life losses associated with COVID-19 and likely

productivity losses averted through COVID-19 vaccination in Madagascar," 2023, doi: 10.21203/rs.3.rs-2996128/v1.

[28] D. M. Cutler, "The Economic Cost of Long COVID: An Update." Accessed: Jun. 09, 2024. [Online]. Available: https://scholar.harvard.edu/files/cutler/files/long_covid_update_7-22.pdf

[29] J. M. Kirigia, R. N. D. K. Muthuri, L. H. K. Nkanata, and N. G. Muthuri, "The Present Value of Human Life Losses Associated with Coronavirus Disease in Africa," *Open Journal of Business and Management*, vol. 08, no. 06, pp. 2371–2395, 2020, doi: 10.4236/ojbm.2020.86146.

[30] H. Margaretha, D. I. Hadianto, D. Krisnadi, and D. Dikson, "An actuarial model of the economic cost of the first year of a pandemic and the community mobility index," *ICIC Express Letters, Part B: Applications*, vol. 14, no. 7, pp. 719–726, Jul. 2023, doi: 10.24507/icicelb.14.07.719.

[31] L. Hultkrantz and M. Svensson, "The economic cost of COVID-19 – Iceland, Norway, and Sweden," *Nordic Economic Policy Review*, pp. 114–141, 2022.

[32] A. Byambadorj *et al.*, "Spending Assessment and Economic Burden of COVID-19 in Mongolia, January- September, 2020," *Asia Pac J Public Health*, vol. 34, no. 4, pp. 456–458, May 2022, doi: 10.1177/10105395221074551.

[33] H. Jin *et al.*, "Economic burden of covid-19, china, january–march, 2020: A cost-of-illness study," *Bull World Health Organ*, vol. 99, no. 2, pp. 112–124, Feb. 2021, doi: 10.2471/BLT.20.267112.

[34] J. M. Kirigia and R. N. D. K. Muthuri, "The discounted money value of human lives lost due to COVID-19 in Spain," *J Health Res*, vol. 34, no. 5, pp. 455–460, Sep. 2020, doi: 10.1108/JHR-04-2020-0116.

[35] J. M. Kirigia, G. Mwabu, and F. Masiye, "The present value of human life losses associated with COVID-19 in South Africa," *Journal of Global Health Economics and Policy*, Nov. 2022, doi: 10.52872/001c.39792.

[36] P. Bhattacharya, D. John, N. Mukherjee, N. Ms, J. Menon, and A. Banerjee, "Estimation of non-health gross domestic product (NHGDP) loss due to COVID-19 deaths in West Bengal, India," *BMJ Open*, vol. 13, no. 10, Oct. 2023, doi: 10.1136/bmjopen-2023-072559.

[37] A. Gandjour, "Long COVID: Costs for the German economy and health care and pension system," *BMC Health Serv Res*, vol. 23, no. 1, Dec. 2023, doi: 10.1186/s12913-023-09601-6.

[38] D. John, M. S. Narassima, P. Bhattacharya, N. Mukherjee, A. Banerjee, and J. Menon, "Model-based estimation of burden of COVID-19 with disability-adjusted life years and value of statistical life in West Bengal, India," *BMJ Open*, vol. 13, no. 1, Jan. 2023, doi: 10.1136/bmjopen-2022-065729.

[39] D. John, M. S. Narassima, J. Menon, J. G. Rajesh, and A. Banerjee, "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*, vol. 11, no. 8, Aug. 2021, doi: 10.1136/bmjopen-2021-049619.

[40] J. M. Kirigia and R. N. Deborah Karimi Muthuri, "The Present Value of Human Lives Lost Due to COVID-19 in the United Kingdom," *Pharmaceutical and Biomedical Research*, Nov. 2020, doi: 10.18502/pbr.v6i3.4650.

[41] J. M. Kirigia and R. Nabi Deborah Karimi Muthuri, "The Dollar Value of Human Life Losses Associated With COVID-19 in Canada," *Pharmaceutical and Biomedical Research*, Mar. 2021, doi: 10.18502/pbr.v6i(s2).5660.

[42] J. M. Kirigia and R. N. D. K. Muthuri, “Discounted monetary value of human lives lost due to COVID-19 in the USA as of 3 May 2020,” *IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)*, vol. 19, no. 5, pp. 51–54, 2020.

[43] J. M. Kirigia and R. Nabi Deborah Karimi, “Valuation of human life losses associated with COVID-19 in Germany: A human capital approach,” *IOSR Journal of Dental and Medical Sciences (IOSR-JDMS) e-ISSN*, vol. 19, pp. 56–65, 2020, doi: 10.9790/0853-1911085665.

[44] J. M. Kirigia, R. N. D. K. Muthuri, and L. H. K. Nkanata, “The monetary value of human life losses associated with COVID-19 in Turkey,” *Emerald Open Research*, vol. 2, p. 44, Jul. 2020, doi: 10.35241/emeraldopenres.13822.1.

[45] M. E. Gökler and S. Metintaş, “Years of potential life lost and productivity costs due to COVID-19 in Turkey: one yearly evaluation,” *Public Health*, vol. 203, pp. 91–96, Feb. 2022, doi: 10.1016/j.puhe.2021.12.009.

[46] J. M. Kirigia, R. Nabi, D. K. Muthuri, L. Honesty, K. Nkanata, and N. G. Muthuri, “The discounted financial worth of human lives lost from COVID-19 in Italy,” *IOSR Journal of Economics and Finance*, vol. 11, no. 5, pp. 15–24, 2020, doi: 10.9790/5933-1105051524.

[47] J. M. Kirigia, R. N. D. K. Muthuri, L. H. K. Nkanata, and N. G. Muthuri, “The discounted value of human lives lost due to COVID-19 in France,” *F1000Res*, vol. 9, 2020, doi: 10.12688/f1000research.26975.1.

[48] J. M. Kirigia, R. Nabi, D. K. Muthuri, L. Honesty, K. Nkanata, and N. G. Muthuri, “The pecuniary value of human life losses associated with COVID-19 in Brazil,” 2020. [Online]. Available: www.iosrphr.org

[49] J. M. Kirigia, R. Nabi, D. K. Muthuri, L. Honesty, K. Nkanata, and N. G. Muthuri, “The present value of human life losses associated with Covid-19 in Japan,” *IOSR Journal of Economics and Finance*, vol. 11, no. 6, pp. 7–16, 2020, doi: 10.9790/5933-1106020716.

[50] J. M. Kirigia, R. Nabi, D. K. Muthuri, L. Honesty, K. Nkanata, and N. G. Muthuri, “The present value of human life losses from Coronavirus Disease (COVID-19) in India,” *IOSR Journal of Dental and Medical Sciences (IOSR-JDMS) e-ISSN*, vol. 19, pp. 54–64, 2020, doi: 10.9790/0853-1911045464.

[51] J. M. Kirigia, G. Mwabu, and R. N. D. K. Muthuri, “The present value of human life losses associated with COVID-19 and likely cost savings from vaccination in Kenya,” *F1000Res*, vol. 12, p. 232, Mar. 2023, doi: 10.12688/f1000research.129866.1.

[52] L. Musango, A. Nundoochan, and J. M. Kirigia, “The Discounted Money Value of Human Life Losses Associated With COVID-19 in Mauritius,” *Front Public Health*, vol. 8, Nov. 2020, doi: 10.3389/fpubh.2020.604394.

[53] C. K. Swain and H. S. Rout, “Gender and age group-wise inequality in health burden and value of premature death from COVID-19 in India,” *Aging Health Res*, vol. 3, no. 3, Sep. 2023, doi: 10.1016/j.ahr.2023.100151.

[54] J. M. Kirigia and R. N. D. K. Muthuri, “The fiscal value of human lives lost from coronavirus disease (COVID-19) in China,” *BMC Res Notes*, vol. 13, no. 1, Apr. 2020, doi: 10.1186/s13104-020-05044-y.

[55] S. D. Shindhe, S. Bhat, and S. B. Munoli, “Burden of COVID-19: DALY and productivity loss for Karnataka, India,” *Indian J Public Health*, vol. 66, no. 3, pp. 239–244, Jul. 2022, doi: 10.4103/ijph.ijph_959_21.

[56] A. A. Mirin, “A preliminary estimate of the economic impact of long COVID in the United States,” *Fatigue*, vol. 10, no. 4, pp. 190–199, 2022, doi: 10.1080/21641846.2022.2124064.

[57] E. Nguyen, I. Buder, K. Geisler, and E. Fore, “The economic costs of COVID-19 in a rural Western US state,” *World Med Health Policy*, 2023, doi: 10.1002/wmh3.591.

[58] H. Gandhar and S. Kumar, “Pandemic and health sector of India: An economic analysis,” in *The Impact of the Covid-19 Pandemic on People and their Lives: Socio-Political and Economic Aspects*, Taylor and Francis, 2023, pp. 244–262. doi: 10.4324/9781003333364-22.

[59] M. Galjak, “The effects of covid-19 pandemic on the premature mortality in Serbia in 2020,” *Demografija*, vol. 18, pp. 57–70, 2021, [Online]. Available: http://demografija.gef.bg.ac.rs/

[60] O. Bednar and B. Kaderabkova, “The Covid-19 pandemic economic costs in terms of labour force loss,” *International Journal of Economic Sciences*, vol. 11, no. 2, pp. 1–12, Nov. 2022, doi: 10.52950/es.2022.11.2.001.

[61] X. Yu and N. Li, “Understanding the beginning of a pandemic: China’s response to the emergence of COVID-19,” Mar. 01, 2021, *Elsevier Ltd*. doi: 10.1016/j.jiph.2020.12.024.

[62] Y. Liu and R. B. Saltman, “Policy lessons from early reactions to the COVID-19 virus in china,” Aug. 01, 2020, *American Public Health Association Inc.* doi: 10.2105/AJPH.2020.305732.

[63] S. Lai *et al.*, “Effect of non-pharmaceutical interventions to contain COVID-19 in China,” *Nature*, vol. 585, no. 7825, pp. 410–413, Sep. 2020, doi: 10.1038/s41586-020-2293-x.

[64] Y. Bo *et al.*, “Effectiveness of non-pharmaceutical interventions on COVID-19 transmission in 190 countries from 23 January to 13 April 2020,” *International Journal of Infectious Diseases*, vol. 102, pp. 247–253, Jan. 2021, doi: 10.1016/j.ijid.2020.10.066.

[65] S. Iezadi *et al.*, “Effectiveness of non-pharmaceutical public health interventions against COVID-19: A systematic review and meta-analysis,” Nov. 01, 2021, *Public Library of Science*. doi: 10.1371/journal.pone.0260371.

[66] I. Ayouni *et al.*, “Effective public health measures to mitigate the spread of COVID-19: a systematic review,” *BMC Public Health*, vol. 21, no. 1, Dec. 2021, doi: 10.1186/s12889-021-11111-1.

[67] B. Born, A. M. Dietrich, and G. J. Müller, “The lockdown effect: A counterfactual for Sweden,” *PLoS One*, vol. 16, no. 4 April 2021, Apr. 2021, doi: 10.1371/journal.pone.0249732.

[68] A. Kavaliunas, P. Ocaya, J. Mumper, I. Lindfeldt, and M. Kyhlstedt, “Swedish policy analysis for Covid-19,” *Health Policy Technol*, vol. 9, no. 4, pp. 598–612, Dec. 2020, doi: 10.1016/j.hlpt.2020.08.009.

[69] K. R. Starke, D. Reissig, G. Petereit-Haack, S. Schmauder, A. Nienhaus, and A. Seidler, “The isolated effect of age on the risk of COVID-19 severe outcomes: A systematic review with meta-analysis,” *BMJ Glob Health*, vol. 6, no. 12, Dec. 2021, doi: 10.1136/bmjgh-2021-006434.

[70] A. B. Gómez-Belda *et al.*, “COVID-19 in older adults: What are the differences with younger patients?,” *Geriatr Gerontol Int*, vol. 21, no. 1, pp. 60–65, Jan. 2021, doi: 10.1111/ggi.14102.

[71] A. Webb, R. McQuaid, and S. Rand, “Employment in the informal economy: implications of the COVID-19 pandemic,” *International Journal of Sociology and Social Policy*, vol. 40, no. 9–10, pp. 1005–1019, Dec. 2020, doi: 10.1108/IJSSP-08-2020-0371.

[72] A. T. Levin *et al.*, “Assessing the burden of COVID-19 in developing countries: Systematic review, meta-Analysis and public policy implications,” May 26, 2022, *BMJ Publishing Group*. doi: 10.1136/bmjgh-2022-008477.

[73] D. N. Brosi and G. P. Mays, “Local Public Health System Capabilities and COVID-19 Death Rates,” *Public Health Reports*, vol. 137, no. 5, pp. 980–987, Sep. 2022, doi: 10.1177/00333549221097660.

[74] J. Bayham and E. P. Fenichel, “Impact of school closures for COVID-19 on the US health-care workforce and net mortality: a modelling study,” *Lancet Public Health*, vol. 5, no. 5, pp. e271–e278, May 2020, doi: 10.1016/S2468-2667(20)30082-7.

[75] N. T. Nguyen, J. Chinn, M. de Ferrante, K. A. Kirby, S. F. Hohmann, and A. Amin, “Male gender is a predictor of higher mortality in hospitalized adults with COVID-19,” *PLoS One*, vol. 16, no. 7 July, Jul. 2021, doi: 10.1371/journal.pone.0254066.

[76] F. S. Mennini and L. Gitto, “Approaches to Estimating Indirect Costs in Healthcare: Motivations for Choice,” MPRA Paper No. 112129, 2022.

[77] N. D. Yanez, N. S. Weiss, J. A. Romand, and M. M. Treggiari, “COVID-19 mortality risk for older men and women,” *BMC Public Health*, vol. 20, no. 1, Dec. 2020, doi: 10.1186/s12889-020-09826-8.

[78] M. J. Hashim, A. R. Alsuwaidi, and G. Khan, “Population risk factors for COVID-19 mortality in 93 countries,” *J Epidemiol Glob Health*, vol. 10, no. 3, pp. 204–208, Sep. 2020, doi: 10.2991/jegh.k.200721.001.

[79] A. Iwasaki and N. D. Grubaugh, “Why does Japan have so few cases of COVID-19?,” *EMBO Mol Med*, vol. 12, no. 5, May 2020, doi: 10.15252/emmm.202012481.

[80] O. Amengual and T. Atsumi, “COVID-19 pandemic in Japan,” *Rheumatol Int*, vol. 41, no. 1, pp. 1–5, Jan. 2021, doi: 10.1007/s00296-020-04744-9.

[81] L. Böttcher, M. R. D’Orsogna, and T. Chou, “Using excess deaths and testing statistics to determine COVID-19 mortalities,” *Eur J Epidemiol*, vol. 36, no. 5, pp. 545–558, May 2021, doi: 10.1007/s10654-021-00748-2.

[82] T. Beaney *et al.*, “Excess mortality: the gold standard in measuring the impact of COVID-19 worldwide?,” Sep. 01, 2020, *SAGE Publications Ltd*. doi: 10.1177/0141076820956802.

[83] S. D. Judson *et al.*, “COVID-19 data reporting systems in Africa reveal insights for future pandemics,” *Epidemiol Infect*, vol. 150, Jun. 2022, doi: 10.1017/S0950268822001054.

[84] T. McKay, R. S. Robinson, S. Musungu, N. A. Padi-Adjirackor, and N. Angotti, “The Missing Millions: Uncovering the Burden of Covid-19 Cases and Deaths in the African Region,” *Popul Dev Rev*, vol. 50, no. 1, pp. 7–58, Mar. 2024, doi: 10.1111/padr.12608.

[85] J. P. A. Ioannidis, F. Zonta, and M. Levitt, “Flaws and uncertainties in pandemic global excess death calculations,” Aug. 01, 2023, *John Wiley and Sons Inc*. doi: 10.1111/eci.14008.

[86] I. Locatelli and V. Rousson, “Two complementary approaches to estimate an excess of mortality: The case of Switzerland 2022,” *PLoS One*, vol. 18, no. 8 August, Aug. 2023, doi: 10.1371/journal.pone.0290160.

[87] M. Levitt, F. Zonta, and J. P. A. Ioannidis, “Excess death estimates from multiverse analysis in 2009–2021,” *Eur J Epidemiol*, vol. 38, no. 11, pp. 1129–1139, Nov. 2023, doi: 10.1007/s10654-023-00998-2.

Table 1. Keywords used for search queries

Keywords for 'COVID-19':
covid-19, covid19, covid-2019, covid2019, coronavirus disease 2019, coronavirus disease 19, sars-cov-2, sars-cov-2, cov 2, cov2, severe acute respiratory syndrome coronavirus 2, SARS coronavirus 2, 2019-nCoV, 2019nCoV, 2019 novel coronavirus, ncov, novel cov, hCoV-19, pandemic, postcovid, longcovid, postcoronavirus, postsars
Keywords for 'productivity losses':
productivity loss*, productivity lost, productivity cost*, production loss*, production lost, lost productivity, lost production, labour productivity, labor productivity, indirect cost*, economic cost*, economic burden, economic loss*, financial loss*, cost of illness, burden of illness, illness cost*, illness burden, sickness cost*, cost* of sickness, disease cost*, cost* of disease, absenteeism, presenteeism, mortality burden, morbidity burden, burden of mortality, burden of morbidity, human capital, friction, intangible cost*, caregiv* burden, burden of caregiv*

Table 2. Summary characteristics of studies included in the systematic review (N = 38)

Study characteristic	Articles
World Bank classification	**N = 38**
• high-income	19 (50%)
• upper-middle income	10 (26%)
• lower-middle income	12 (32%)
• low-income	2 (5%)
World Health Organization region	**N = 38**
• Africa	5 (13%)
• Americas	8 (21%)
• Eastern Mediterranean	1 (3%)
• Europe	13 (34%)
• South-East Asia	8 (21%)
• Western Pacific	5 (13%)
Countries/regions	**N = 38**
• India	8 (21%)
• USA	5 (13%)
• Canada, Germany, Italy	3 (8%)
• China, France, Kenya, Madagascar, Mauritius, South Africa, Spain, Sweden, Turkey	2 (5%)
• 66 countries/regions (not listed separately here)	1 (3%)
Diagnosis	**N = 38**
• COVID-19	33 (87%)
• long COVID	3 (8%)
• all-cause excess mortality	3 (8%)
Losses estimation approach	**N = 38**
• human capital approach	30 (79%)
• proxy good approach	1 (3%)
• not specified/unclear	8 (21%)
Productivity measure used	**N = 38**
• average income- or earnings-based	15 (39%)
• average GDP-based	23 (61%)
• not reported	2 (5%)
Losses categories	**N = 38**
• premature mortality	32 (84%)
• absenteeism	11 (26%)
• quarantine/lockdown/cases	2 (5%)
Sensitivity analysis for losses estimates	**N = 38**
• yes	22 (58%)
• no	16 (42%)

Notes: For the column 'Articles' the percentages in some categories do not add up to 100 percent because some studies are counted more than once as they report estimates from more than one category.

Table 3. Overview of the studies' main characteristics and results

First author [reference]	Location (period of analysis[a]; dd/mm/yy)	Disease definition	Loss category	Productivity losses (2020 Int$[b])	Total productivity losses as % GDP	Share of total losses (%)	
						Age-specific losses	Sex-specific losses
Bhattacharya [36]	West Bengal (India) (17/03/2020 - 31/12/2022)	COVID-19	premature mortality	899,065,811	0.583	0-39 years: 21% 40-59 years: 56% 60+ years: 23%	Males: 60% Females: 40%
		excess all-cause mortality		9,224,432,810		0-39 years: 21% 40-59 years: 56% 60+ years: 23%	Males: 60% Females: 40%
Byambadorj [32]	Mongolia (22/01 - 3/09/2020)	COVID-19	total	26,996,257	0.108	n.a.	n.a.
			partial lockdown	26,572,538			
			cases	423,719			
Gandjour [37]	Germany (2021)	long COVID	absenteeism	4,458,503,094	0.093	n.a.	n.a.
Gökler [45]	Turkey (11/03 - 31/12/2020)	COVID-19	premature mortality	846,076,489	0.041	n.a.	Males: 79% Females: 21%
Hanly [11]	Belgium (9/03- 15/05/2020)	excess all-cause mortality	premature mortality	262,023,884	0.235	n.a.	Males: 79% Females: 21%
	France (2/03 - 1/05/2020)			826,215,468	0.164		Males: 66% Females: 34%
	Germany (2/03 - 15/05/2020)			0	0.000		Males: 0% Females: 0%
	Italy (9/03 - 1/05/2020)			588,356,772	0.162		Males: 92% Females: 8%
	Netherlands (9/03- 15/05/2020)			450,907,823	0.242		Males: 92% Females: 8%
	Portugal (9/03 - 1/05/2020)			40,070,104	0.078		Males: 59% Females: 41%
	Spain (9/03- 15/05/2020)			1,792,698,856	0.534		Males: 72% Females: 28%
	Sweden (9/03- 15/05/2020)			126,645,228	0.120		Males: 99% Females: 1%
	Switzerland (9/03- 15/05/2020)			51,382,389	0.044		Males: 65% Females: 35%
Jin [33]	China	COVID-19	total	623,585,647,558	10.365	n.a.	n.a.

	(01/01 - 31/03/2020)		premature mortality	424,833,687			
			cases	92,979,476			
			partial lockdown	623,067,834,395			
John [38]	West Bengal (India) (until 07/01/2022)	COVID-19	total	277,585,686	0.026	0-39 years: 36% 40-59 years: 64%	Males: 81% Females: 19%
			premature mortality	147,533,701		0-39 years: 25% 40-59 years: 75%	Males: 85% Females: 15%
			absenteeism	130,051,985		0-39 years: 48% 40-59 years: 52%	Males: 77% Females: 23%
John [39]	Kerala (India) (30/01/2020 - 10/06/2021)	COVID-19	total	630,564,364	0.125	0-39 years: 51% 40-59 years: 49%	Males: 86% Females: 14%
			premature mortality	73,857,811		0-39 years: 29% 40-59 years: 71%	Males: 84% Females: 16%
			absenteeism	556,706,553		0-39 years: 54% 40-59 years: 46%	Males: 86% Females: 14%
Kirigia [42]	United States of America (until 03/05/2020)	COVID-19	premature mortality	19,780,290,990	0.347	0-39 years: 9% 40-59 years: 41% 60+ years: 50%	n.a.
Kirigia [34]	Spain (until 19/04/2020)	COVID-19	premature mortality	9,629,234,112	2.122	0-39 years: 14% 40-59 years: 45% 60+ years: 41%	n.a.
Kirigia [41]	Canada (until 16/07/2020)	COVID-19	premature mortality	2,037,021,173	0.231	0-39 years: 2% 40-59 years: 11% 60+ years: 87%	n.a.
Kirigia [54]	China (until 24/02/2020)	COVID-19	premature mortality	924,346,794	0.025	0-39 years: 38% 40-59 years: 44% 60+ years: 18%	n.a.
Kirigia [40]	United Kingdom (until 2/07/2020)	COVID-19	premature mortality	9,883,426,226	0.802	0-39 years: 3% 40-59 years: 22% 60+ years: 75%	n.a.
Kirigia [43]	Germany (27/01 - 8/11/2020)	COVID-19	premature mortality	1,916,725,559	0.053	0-39 years: 3% 40-59 years: 24% 60+ years: 73%	n.a.
Kirigia [26]	Islamic Republic of Iran (until 11/04/2020)	COVID-19	premature mortality	436,275,007	0.245	0-39 years: 10% 40-59 years: 42% 60+ years: 48%	n.a.
Kirigia [44]	Turkey (until 15/06/2020)	COVID-19	premature mortality	1,098,469,122	0.170	0-39 years: 8% 40-59 years: 36% 60+ years: 56%	n.a.

Kirigia [46]	Italy (31/01 - 20/08/2020)	COVID-19	premature mortality	13,070,141,189	0.956	0-39 years: 1% 40-59 years: 9% 60+ years: 90%	n.a.
Kirigia [47]	France (until 14/09/2020)	COVID-19	premature mortality	10,492,290,194	0.544	0-39 years: 3% 40-59 years: 17% 60+ years: 81%	n.a.
Kirigia [48]	Brazil (25/02- 07/06/2020)	COVID-19	premature mortality	3,591,028,163	0.363	0-39 years: 10% 40-59 years: 42% 60+ years: 48%	n.a.
Kirigia [49]	Japan (16/01 - 29/10/2020)	COVID-19	premature mortality	496,463,298	0.012	0-39 years: 2% 40-59 years: 12% 60+ years: 86%	n.a.
Kirigia [29]	Algeria (until 01/08/2020)	COVID-19	premature mortality	245,299,956	0.119	n.a.	n.a.
	Angola (until 01/08/2020)			2,020,078	0.003		
	Benin (until 01/08/2020)			643,835	0.004		
	Botswana (until 01/08/2020)			297,052	0.003		
	Burkina Faso (until 01/08/2020)			545,968	0.003		
	Burundi (until 01/08/2020)			3,335	<0.001		
	Cameroon (until 01/08/2020)			6,768,581	0.016		
	Cape Verde (until 01/08/2020)			1,962,141	0.142		
	Central African Republic (until 01/08/2020)			113,916	0.006		
	Chad (until 01/08/2020)			512,961	0.005		
	Comoros (until 01/08/2020)			118,955	0.017		
	Cote d'Ivoire (until 01/08/2020)			1,757,306	0.003		
	Democratic Republic of Congo (until 01/08/2020)			848,346	0.002		
	Djibouti (until 01/08/2020)			2,375,995	0.119		
	Egypt			697,921,220	0.112		

	(until 01/08/2020)						
	Equatorial Guinea (until 01/08/2020)			6,520,729	0.067		
	Eritrea (until 01/08/2020)			0	0.000		
	Ethiopia (until 01/08/2020)			5,155,489	0.005		
	Gabon (until 01/08/2020)			6,766,041	0.053		
	Gambia (until 01/08/2020)			135,573	0.007		
	Ghana (until 01/08/2020)			7,661,250	0.011		
	Guinea (until 01/08/2020)			573,643	0.004		
	Guinea-Bissau (until 01/08/2020)			211,655	0.014		
	Kenya (until 01/08/2020)			9,543,972	0.010		
	Lesotho (until 01/08/2020)			119,827	0.010		
	Liberia (until 01/08/2020)			607,756	0.023		
	Libya (until 01/08/2020)			7,111,555	0.019		
	Madagascar (until 01/08/2020)			1,366,586	0.009		
	Malawi (until 01/08/2020)			795,628	0.008		
	Mali (until 01/08/2020)			1,358,740	0.008		
	Mauritania (until 01/08/2020)			4,776,900	0.049		
	Mauritus (until 01/08/2020)			3,071,846	0.031		
	Morocco (until 01/08/2020)			42,956,126	0.036		
	Mozambique (until 01/08/2020)			72,363	0.001		
	Namibia (until 01/08/2020)			617,442	0.007		
	Niger			393,189	0.003		

	(until 01/08/2020)						
	Nigeria (until 01/08/2020)			14,222,523	0.003		
	Republic of Congo (until 01/08/2020)			2,371,749	0.027		
	Rwanda (until 01/08/2020)			107,243	0.001		
	Sao Tome and Principe (until 01/08/2020)			454,147	0.183		
	Senegal (until 01/08/2020)			6,151,990	0.026		
	Seychelles (until 01/08/2020)			0	0.000		
	Sierra Leone (until 01/08/2020)			282,867	0.006		
	Somalia (until 01/08/2020)			220,060	0.002		
	South Africa (until 01/08/2020)			602,528,301	0.188		
	South Sudan (until 01/08/2020)			266,490	0.015		
	Sudan (until 01/08/2020)			18,189,513	0.026		
	Eswatini (until 01/08/2020)			2,073,934	0.052		
	Tanzania (until 01/08/2020)			482,046	0.001		
	Togo (until 01/08/2020)			172,506	0.002		
	Tunisia (until 01/08/2020)			8,062,957	0.016		
	Uganda (until 01/08/2020)			44,136	<0.001		
	Zambia (until 01/08/2020)			3,527,856	0.015		
	Zimbabwe (until 01/08/2020)			8,666,496	0.075		
Kirigia [50]	India (30/01 - 3/10/2020)	COVID-19	premature mortality	8,163,602,456	0.132	0-39 years: 28% 40-59 years: 56% 60+ years: 16%	n.a.
Kirigia [35]	South Africa (05/03/2020 - 30/05/2022)	COVID-19	premature mortality	6,693,609,607	0.364	0-39 years: 30% 40-59 years: 63%	n.a.

						60+ years: 7%	
Kirigia [51]	Kenya (12/03/2020 - 25/07/2022)	COVID-19	premature mortality	234,984,047	0.038	0-39 years: 31% 40-59 years: 44% 60+ years: 25%	n.a.
Mirin [56]	United States of America (until 25/06/2022)	long COVID	absenteeism	89,346,544,196 – 380,386,277,272	0.169-0.721	n.a.	n.a.
Musango [27]	Madagascar (20/03/2020 - 03/03/2023)	COVID-19	premature mortality	36,756,807	0.028	0-39 years: 71% 40-59 years: 26% 60+ years: 3%	n.a.
Musango [52]	Mauritius (18/03 - 16/10/2020)	COVID-19	premature mortality	3,120,689	0.007	0-39 years: 22% 40-59 years: 52% 60+ years: 26%	n.a.
Nguyen [57]	Idaho (USA) (2020-2021)	COVID-19	total	200,197,192	0.114	n.a.	n.a.
			premature mortality	114,211,828			
			absenteeism	85,985,365			
Nurchis [12]	Italy (21/02 - 28/04/2020)	COVID-19	total	600,570,967	0.131	0-39 years: 8% 40-59 years: 51% 60+ years: 41%	n.a.
			premature mortality	447,306,407		0-39 years: 4% 40-59 years: 49% 60+ years: 47%	
			absenteeism	153,264,560		0-39 years: 21% 40-59 years: 55% 60+ years: 23%	
Shindhe [55]	Karnataka (India) (08/03 - 21/07/2020)	COVID-19	premature mortality	27,108,524	0.010	0-39 years: 28% 40-59 years: 70% 60+ years: 2%	n.a.
Swain [53]	India (2020-2022)	COVID-19	premature mortality	6,958,199,370	0.024	0-39 years: 28% 40-59 years: 43% 60+ years: 29%	Males: 65% Females: 35%
Wang [13]	Canada (01/02/2020 - 30/04/2022)	COVID-19	total	7,229,422,113	0.161	0-39 years: 33% 40-59 years: 52% 60+ years: 16%	Males: 61% Females: 39%
			premature mortality	2,636,723,763		0-39 years: 15% 40-59 years: 62% 60+ years: 23%	Males: 73% Females: 27%
			absenteeism	4,592,698,350		0-39 years: 43% 40-59 years: 45% 60+ years: 12%	Males: 54% Females: 46%
	Iceland	COVID-19	absenteeism	18,941,807	0.060	n.a.	n.a.

Hultkrantz [31]	(until 15/08/2021)						
	Norway (until 15/08/2021)			233,057,955	0.043		
	Sweden (until 15/08/2021)			1,628,424,607	0.181		
Bednar [60]	Czechia (01/2020 - 10/2022)	excess all-cause mortality	premature mortality	The estimates of losses from these studies could not be included in the cross-study comparison shown in this table. The quality assessment score for the studies was low (<60%) and several parameters required in cross-study comparison were not retrievable from the articles.			
Cutler [28]	United States of America (until 05/05/2022)	long COVID	absenteeism				
Galjak [59]	Serbia (2020)	COVID-19	premature mortality				
Margaretha [30]	United States of America, Australia, India, Indonesia, Canada (22/01 - 21/01/2021); Taiwan (22/01 - 18/01/2021)	COVID-19	absenteeism				
Gandhar [58]	India (n.a.)	COVID-19	premature mortality				
			absenteeism				

Notes: n.a. – not available; a - The starting date for the period of analysis is not reported in some studies. In such cases, the table reports only end date of the period, e.g. “until 15/08/2021”. These cases refer to studies which estimate losses in periods starting at the inception of pandemic; therefore, for the purpose of cross-study estimates made here, we assume the day of the first COVID-19 case in the country to be a starting date of the analysis; b - International dollars (for details on the estimation procedure and cross-study comparison see sub-section “Approach to cross-study comparison of quantitative results” in the Methods section).

Table 4. Average productivity losses broken down by countries and loss categories

	Number of single country/region estimates	Productivity losses as % of GDP (SD)	Productivity losses in Int$ per 1,000 population (SD)
World Bank classification			
• high-income	28	0.656 (1.953)	69,454 (79,914)
• upper-middle income	15	0.119 (0.123)	13,663 (28,972)
• lower-middle income	30	0.063 (0.111)	4,993 (16,890)
• low-income	23	0.007 (0.008)	101 (271)
World Health Organization region			
• Africa	51	0.033 (0.064)	3,150 (15,474)
• Americas	6	0.301 (0.208)	115,513 (95,227)
• Eastern Mediterranean	8	0.072 (0.083)	22,806 (62,082)
• Europe	21	0.323 (0.487)	57,988 (70,998)
• South-East Asia	6	0.150 (0.219)	20,646 (35,705)
• Western Pacific	4	2.628 (5.159)	113,674 (218,849)
Losses categories			
• premature mortality	91	0.118 (0.275)	21,099 (61,024)
• absenteeism	10	0.143 (0.199)	92,618 (85,866)
• quarantine/lockdown/cases	2	5.237 (7.253)	225,055 (306,686)

Notes: GDP – gross domestic product; SD – standard deviation.

Table 5. Age-specific productivity losses for the studies included in the systematic review

	Average share of losses in age-group in total losses								
	all countries			high-income countries			middle- and lower-income countries		
	0-39 years	40-59 years	60+ years	0-39 years	40-59 years	60+ years	0-39 years	40-59 years	60+ years
Premature mortality losses	18%	42%	40%	5%	29%	65%	25%	49%	26%
Absenteeism losses	42%	50%	9%	32%	50%	18%	51%	49%	0%[a]

Notes: 24 studies reported age-specific losses [12], [13], [26], [27], [34], [35], [36], [38], [39], [40], [41], [42], [43], [44], [46], [47], [48], [49], [50], [51], [52], [53], [54], [55]. a - only two studies reported age-specific absenteeism losses in 'other countries' but did not analyse the older age category. To normalise age intervals across studies, we assumed an equal distribution of losses across all single ages as defined in particular intervals in source studies (e.g. for an age band 31-45 years reported originally in the study analysed, we assigned 9/15 part of the losses to interval 0-39 years and 6/15 part to interval 40-59 years). The averages shown are not weighted. Detailed calculations for each study included are shown in Online Resource 3.

Table 6. Sex-specific productivity losses for the studies included in the systematic review

	Average share of losses in age-group in total losses					
	all countries		high-income countries		middle- and lower-income countries	
	men	women	men	women	men	women
Premature mortality losses	77%	23%	77%	23%	75%	25%
Absenteeism losses	72%	28%	54%	46%	81%	19%

Notes: 7 studies reported sex-specific losses [11], [13], [36], [38], [39], [45], [53]. The averages shown are not weighted. Detailed calculations for each study included are shown in Online Resource 3.