Excess deaths by cause and place of death in England and Wales during the first year of COVID-19

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Abstract

Using officially registered weekly mortality data, we estimate a counterfactual death count in the absence of the pandemic and we calculate the number of excess deaths in England and Wales during 2020 after the pandemic onset. We also break down those figures by region, age, gender, place of death, and cause of death. Our results suggest that there were 82,428 (95% CI: 78,402 to 86,415) excess deaths, and 88.9% (95% CI: 84.8% to 93.5%) of them was due to COVID-19, suggesting that non-COVID-19 excess mortality may have been slightly higher that what has been previously estimated. Regarding deaths not due to COVID-19, persons older than 45 years old who died at their homes, mainly from heart diseases and cancer, were the most affected group. Across all causes of death, there was increased excess mortality from dementia and Alzheimer's disease, diabetes, Parkinson's disease and heart-related disease, while at the same period there was a reduction in deaths from pneumonia and influenza, stroke as well as infectious diseases and accidents. Supported by regional panel event estimates, our results highlight how measures to mitigate the pandemic spread and ease the pressure on healthcare service systems may adversely affect out-of-hospital mortality from other causes.

Keywords: COVID-19; Excess mortality; Lockdown; England and Wales

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Highlights

- We use regional weekly death data by gender, age, place of death, and cause of death.
- We use an alternative methodology to estimate baseline deaths in a no-pandemic scenario.
- During 2020, 90% of the excess deaths registered in England and Wales were due to COVID-19.
- Non-COVID-19 excess deaths are observed predominately among individuals over 45 years old.
- Cancer and heart diseases were the most contributing causes for deaths registered at private homes.

Data Availability Statement

The data that support the findings of this study are available from the Office for National Statistics (ONS).

Funding Statement

The authors declare that there are no financial or other relationships that could potentially influence the output of their research.

Ethics Statement

The authors declare that ethics approval was not required for this study.

1. Introduction

From the early days of the pandemic, governments and public health authorities started regularly releasing reports on the number of deaths related to COVID-19. However, it soon became apparent that the impact of such a major event on overall mortality is not only due to the pressure on health systems, but also due to the changes that significant policy responses, including local or national lockdowns, had on people's lives. These policy changes have averted some deaths, but at the same time they may have contributed to others. For example, Cicala et al. (2020) showed that reductions in emissions from less travel and lower electricity usage led to 360 fewer deaths per month in the US. Social distancing measures were also associated with fewer deaths from influenza and pneumonia as well as from vehicle crashes (Brodeur et al., 2021; Jones, 2020). On the other hand, more deaths were not only directly attributed to COVID-19 infections, but they also occurred indirectly, e.g. due to fewer hospital visits or delayed care of patients with cancer symptoms (Jeffery et al., 2020; Ward et al., 2021). As a result, excess mortality, defined as the number of deaths above an expected figure during the same period in previous years, became a key metric of the pandemic's impact (Islam, 2022).

There have been several attempts to estimate excess mortality during the pandemic, which have been proven challenging due to data issues and the fact that COVID-19 has not been always accurately diagnosed, especially in the beginning of the pandemic (Karlinsky and Kobak, 2021; WHO, 2022). The most systematic of those attempts was based on data from 74 countries and estimated there were approximately 18.2 million excess deaths across the world because of COVID-19 between January 2020 and December 2021 (COVID-19 Excess Mortality Collaborators, 2022). Although excess mortality differed across countries, the overall estimate was three times higher than the 5.94 million global reported deaths due to COVID-19 in the same period.

For these estimates to be more meaningful for policy purposes, it is crucial to analyse the causes of death that contribute to the overall excess mortality, and the groups of individuals who have been affected the most. To date, only a few countries around the world have released such data, and studies that analysed them look at specific causes, such as suicides (John et al., 2020), cancer (Lai et al., 2022) or dementia (Gilstrap et al., 2022). Understanding the causes of deaths and identifying the groups that have been mostly affected will support governments and public health authorities to better plan their responses to pandemic outbreaks and their consequences.

Moreover, it is important to compare observed total or group-specific mortality with accurate counterfactual numbers expected in a no pandemic scenario. Here we focus on England and Wales that had one of the highest rates of all-cause mortality per 100,000 people during the first wave of COVID-19 in 2020 (Kontis et al., 2020). Although the overall picture changed in the second wave of 2020, the UK had still among the highest excess mortality rates for people aged under 65 years in Europe (ONS, 2021a). The Office for National Statistics (ONS) investigated in depth excess mortality during the first year of the pandemic and showed that COVID-19 was the main reason for the increase in overall mortality in 2020, with many deaths not due to COVID-19, that would normally had happened in hospitals, happened in private homes instead (ONS, 2021b). Typically, death counts during the pandemic have been benchmarked against past 5-year averages (ONS, 2021a; 2021b; Vandoros, 2020). Due to seasonality, death counts vary within a calendar year. However, death counts appear to be highly volatile during the same period across years, i.e. during the first weeks each year, therefore 5-year averages for specific months or weeks could be problematic. Here we use a variation of a method proposed by Ruhm (2021; 2022) to estimate counterfactual death counts by region, week, demographics, place of death and cause of death.

Previous attempts in the literature focused on the early phase of the pandemic and considered only total mortality due to data limitations (Vandoros, 2020). Our paper provides a more detailed picture of the death causes that contributed to the overall excess mortality in England and Wales, and builds the profile of the groups that were mostly affected. Compared to our panel regression-based number of excess deaths, using 5-year averages at the national level overestimates the share of total excess deaths due to COVID-19 in 2020. Adjusting for excess volatility in death counts, resulted in narrower confidence intervals of our excess mortality estimates. Moreover, while the number of excess deaths decreased or stabilized after the first pandemic weeks in hospitals and care homes, it kept rising throughout 2020 in private homes. This was mainly due to excess mortality for those over 45 years old, and the most contributing factors were heart-related diseases and cancer. At the same time, in-hospital mortality from those two causes decreased significantly for this age group. Supported by a panel event analysis, our results are indicative on how responses to mitigate the spread of the pandemic and ease the pressure on healthcare services may substitute in-hospital for mortality in other places and by causes not directly related to the pandemic itself; and it may result in increased deaths later. For example, there is evidence that the virus outbreak and the subsequent lockdown measures let to significantly fewer attendances at emergency departments in England (Wyatt et al., 2021). Analysing 2019-2020 data, Mafham et al. (2020) showed that admissions for all types of acute coronary syndrome decreased substantially in English hospitals, i.e. by 40% (16%) relative to the baseline, by the end of March (May) 2020. Patients with heart diseases and their families felt unsupported, without the appropriate focused information and guidance (Marino et al., 2021).

The remainder of this paper is structured as follows. Section 2 describes the data we used and Section 3 our empirical methodology. Section 4 presents and discusses the results. Section 5 concludes.

2. Data

Daily data on all registered deaths in England and Wales were provided by the ONS. They cover the period between the first week of 2015 and the last week of 2020. Weeks refer to the weekly rather to the annual year. This means that, occasionally, there are some deaths from the previous annual year where the week start (end) dates fall into the previous (following) calendar year. We made the necessary adjustments so that years and months refer to their weekly year values, rather than the calendar ones. The data contained information on gender, region, and age per death registration. Region is classified into nine Government Office Regions for England, plus Wales. Age is grouped as follows: <1, 1-14, 15-44, 45-64, 65-74, and >85 years old. There is also information about the place of death, i.e. usual place of residence, care home, hospital, or elsewhere. Hospitals are inclusive of NHS and non-NHS institutions but exclude psychiatric hospitals. The “elsewhere” category includes all places not covered by what was available in the data. It is also inclusive of people who were pronounced dead on arrival at hospital or deaths in other persons’ residencies. Moreover, the underlying cause of death is provided, under the ICD-10 code classification at the 4-digit level. Deaths involving COVID-19 were also flagged up, whereas COVID-19 was mentioned anywhere on the death certificate, alongside the underlying death cause. We used the information in the data to compute total death counts by gender, age group, region, place of death, and cause of death. Regarding the latter, we considered: total deaths, deaths involving and not involving COVID-19, as well as deaths from: heart diseases, cancer (malignant neoplasms), stroke (cerebrovascular disease), influenza or pneumonia, diseases of the lower respiratory system, kidney disease, diabetes, Alzheimer’s and dementia, Parkinson disease, nervous system diseases, mental and behavioural disorders, infectious diseases, transport accidents, other accidents, suicides, homicides, and complications of medical care.

3. Empirical methodology

3.1 Counterfactual mortality

Figure 1 plots the weekly death count for each year, the number of deaths registered as due to COVID-19, as well as the 5-year (2015-2019) pre-pandemic national average of total weekly deaths. The latter is a popular benchmark against the actual death count observed during the pandemic, e.g. Vandoros (2020). The main advantages of this metric is that it is easily understood, straightforward to calculate, and accessible for wider audiences.

[Figure 1 here]

However, an issue with this approach is that mortality is substantially volatile during specific periods each year. In particular, the starting observation is that total death counts exhibit substantial volatility during the first 5 weeks of each year (Figure 1). Therefore, in order to construct a counterfactual death count that has been adjusted for this excess volatility, we follow Ruhm (2020;2021) but under the necessary modifications given the weekly frequency of our data. This allow us to estimate (a) an adjusted counterfactual death count, and (b) excess deaths registered between the pandemic onset and the last week of 2020. In the US study (Ruhm, 2020;2021), total registered deaths were highly volatile during each January. A similar pattern is observed during the first 5 weeks of each year in our weekly data, i.e. it spans into February as well, especially during years 2016-2019. To provide evidence for this pattern, we calculate year-over-year changes of weekly death counts (DW), covering the period 2015-2019:

$$\Delta DW_{wit} = \frac{DW_{wit} - DW_{wit-1}}{DW_{wit-1}} \times 100\% \tag{1}$$

where w indicates the w-th week of year t, i denotes the specified group or cause of death, and $t = 2015, \ldots, 2019$. As seen in the Appendix (Table A.1, Figure A.1, and Figure A.3) mean annual changes are higher and more volatile during the first 5-week period of each year. The average standard deviation in the annual weekly change (2015-2019) was 2,201 deaths for the first five weeks, and 675 for the remaining year (Table A.1 and Figure A.1). For the first 5 weeks, this excess volatility is particularly high for deaths from pneumonia & influenza, dementia and Alzheimer's disease, heart diseases, lower respiratory system diseases, and strokes (Table A.2).

Although the virus might have been in England and Wales from as early as the beginning of 2020, the first death due to COVID-19 was officially registered in week 11 of 2020. Therefore, for the remainder of our analysis, we are denoting as year the period covered between the 11th week of each year through the 10th week of the following year. For instance, 2019 refers to the period between week 11 of 2019 and week 10 of 2020. We are using the term "calendar year" when referring to years starting in the first week of January and ending in the last week of December.

In order to estimate a counterfactual (or baseline) count of deaths that would have been occurred in the absence of the pandemic, adjusted for the excess volatility observed during the first weeks of each year, we follow a procedure similar to Ruhm (2021; 2022). The difference in our case is that we use panel data at the regional level (England and Wales), instead of (US) national-level time series. First, from the total count of deaths registered from week 11 of each year to week 10 of the following year we subtract those deaths registered in the first 5 weeks of each year.[1] In other words, we calculate the total annual death count minus the number of deaths registered during weeks with high year-to-year volatility. We define this reduced annual death count by D'_{irt}, where i denotes the group (total deaths, gender, cause, etc.), r denotes the region, and $t = 2015, \dots, 2019$. Similarly, the total number of deaths registered during all weeks of each pre-pandemic year, i.e. including the 5 idiosyncratic weeks, is defined as D_{irt}. For each region, we calculate the ratio of the total annual death count, D_{irt}, over the reduced annual death count, D'_{irt}, i.e. without including the idiosyncratic weeks. Then we average this ratio for the total pre-pandemic 5-year period:

[1] For example, $t = 2016$ runs from week 11 of 2016 to week 10 of 2017.

$$Ratio_{ir} = \left(\frac{\sum_{t=2015}^{2019} D_{irt}}{\sum_{t=2015}^{2019} D'_{irt}}\right)/5 \quad (2)$$

Also, for each region, we calculate the share of deaths registered each week of the year by dividing each week's actual death count with the total death count of the respective year. Next, we calculate the mean weekly share of deaths, $\overline{w}_{iwr}$, for the total pre-pandemic period

$$D_{wirt}^{adj} = (D'_{irt} \times \overline{w}_{iwr}) \times Ratio_{ir} \quad (3)$$

In other words, the adjusted weekly death count for each region is the product of the reduced annual death count (distributed across all weeks of each respective pre-pandemic year) and the average ratio of the actual to the reduced death count in the pre-pandemic period. In this way, we maintain the total count of deaths before the pandemic, but having removed the excess volatility observed during the first weeks of each year (Ruhm, 2021; 2022). Indeed, the standard deviation of mean annual changes in weekly total deaths is much lower when using the adjusted versus the actual counts (Figure A.1). We also apply this method after weekly regional data were collapsed at the national level (England plus Wales) and the results are in line.

Having removed the excess volatility from the data, we estimate the number of baseline deaths that would have been registered had the pandemic not occurred, i.e. our counterfactual. This is obtained from OLS regressions of the following form:

$$D_{wirt}^{adj} = a_{ir}T_w + b_{ir}T_w^2 + \gamma_r + \lambda_t + u_{wirt} \quad (4)$$

where the outcome variable is in logs, and γ and λ are regional and year fixed effects, respectively. All models include a quadratic time trend as the root mean squared error ($RMSE$) is lower (and the squared time trend was significant) suggesting a better fit; hence we rely on such models for our predictions. The estimation sample covers the pre-pandemic period (2015-2019). By setting the quadratic trend to its 2020 values, and with year and region indicators being fixed, we obtain the counterfactual weekly number of deaths from week 11 to week 53 of 2020. The standard errors of those regressions are used to compute 95% confidence intervals. Weekly excess deaths are calculated as the difference between the observed 2020 death counts and our estimated counterfactual mortality measure. Adjusting for excess volatility in death counts, result in narrower confidence intervals of our excess mortality estimates, compared to those obtained when using pre-pandemic averages or when using the unadjusted death counts regardless of including or not the first weeks of each year.

3.2 Difference-in-differences framework

Moreover, the construction of counterfactual death counts, allows us to study excess mortality during 2020 under a difference-in-differences (DiD) framework. A control mortality measure to benchmark against actual mortality before and after the pandemic onset provides some reassurance about the observed change not being due to unobserved factors. Hence, actual weekly death counts in 2020 are considered as being exposed to the treatment, i.e. the pandemic. Counterfactual weekly death counts in 2020 are calculated as in sub-section 3.1, after collapsing the data by year, week, region, place of death, and gender. In this exercise, “year” refers to the period between the first and the last week of each year. This is necessary for the construction of a post-intervention indicator for our DiD regressions. Our models are specified as follows:

$$d_{wrt} = a_0 + a_1 Treat_t + a_2 Post_{rw} + a_3 Treat_t \times Post_{rw} + \delta_r + \varphi_w + u_{wrt} \qquad (5)$$

where d is the number of deaths by week w, region r, and year t, where $t = 0{,}1$. $Treat$ is equal to 1 if weekly deaths refer to the actual counts observed in 2020, and equal to 0 if they refer to the counterfactual, no-pandemic scenario. $Post$ is equal to 1 after the first week with a death registered as due to COVID-19 in the r-th region. In most of the English regions (plus Wales), the first death due to COVID-19 was officially registered in week 12. In North West, West Midlands, and South East the first pandemic-related death was registered at week 11. The coefficient of the interaction term, a_3, is the DiD parameter of interest. It measures how weekly regional mortality changed after the first death registered as due to COVID-19, relative to a counterfactual no-pandemic scenario. Models also control for regional fixed effects, a quadratic weekly time trend, gender, and place of death, i.e. home, hospital, care home, and elsewhere. The DiD estimates are valid under the assumption that actual and counterfactual death counts trended similarly before the pandemic onset, i.e. when $Post = 0$. Given that the onset of the pandemic, in terms of registered deaths explicitly attributed to it, did not occur simultaneously across all regions, we show that this assumption is met using a panel event study specification. There is an exploding DiD literature that exploits variation across units being treated in a staggered fashion and remain treated for the remaining period afterwards (Athey and Imbens, 2022; Goodman-Bacon, 2021; Callaway and Sant'Anna, 2021). In such settings, standard two-way fixed effects DiD specifications, as in Eq. 5, do not provide valid estimates of the parameters of interest. In fact, those estimates are weighted averages of all possible 2×2 DiDs that compare treated and control units before and after treatment and, depending on the treatment timing for each unit, the comparison might be problematic in the sense that some already treated units may serve as control ones (Baker et al., 2022). Therefore, we estimate a generalised variant of Eq. 5. Denote as $Onset_r$ a variable indicating the week w in which the first death due to COVID-19 was registered in region r. If deaths per week in each region are denoted as d_{rw}, then the panel event specification is the following:

$$d_{rw} = \alpha + \sum_{j=2}^{J} \beta_j (Lag\ j)_{rw} + \sum_{k=1}^{K} \gamma_j (Lead\ k)_{rw} + \delta_r + \varphi_w + \epsilon_{rw} \quad (6)$$

where δ_r and φ_w are region and week fixed effects, ϵ_{rw} is an unobserved error component, and lags and leads to the onset of COVID-19 deaths are defined as below:

$$(Lag\ j)_{rw} = \mathbb{I}[t = Onset_r - j] \text{ for } j \in \{1, \dots, J-1\} \quad (7)$$

$$(Lead\ k)_{rw} = \mathbb{I}[t = Onset_r + k] \text{ for } k \in \{1, \dots, K-1\} \quad (8)$$

Therefore, lags and leads are binary indicators on the number of weeks a specific region is away from the onset of deaths due to COVID-19. In Eq. 6 the reference period is the week right before the first death registered as due to COVID-19 in each region.

4. Results

4.1 Excess number of deaths

Table 1 presents the results for total excess mortality, as well as by gender, age group, and region, estimated according to subsection 3.1. Overall, there are 496,239 deaths during weeks 11-53 of 2020. In the absence of the pandemic, the counterfactual death count that would have been observed is 413,811 (95% CI: 409,824 to 417,837) deaths, as seen in Appendix Table A.3. Therefore, there are 82,428 (95% CI: 78,402 to 86,415) excess deaths during the first year of COVID-19 in England and Wales. The ratio of observed to counterfactual deaths is 1.20 (95% CI: 1.19 to 1.21). Given that there are 73,307 deaths registered as due to COVID-19, the share of excess deaths due to COVID-19 in 2020 is 88.9% (95% CI: 84.8% to 93.5%). Calculating the observed to counterfactual death ratio separately for various demographic groups indicates that excess mortality is particularly increased for males (1.24, 95% CI: 1.23

to 1.26), persons older than 65 years (1.21, 95% CI: 1.20 to 1.22), and residents of London (1.28, 95% CI: 1.27 to 1.30) and West Midlands (1.24, 95% CI: 1.23 to 1.25).

Figure 2 displays how cumulative excess deaths and their 95% CIs, based on regression-adjusted estimates of counterfactual mortality from a regional panel (subsection 3.1), evolve after the pandemic onset in week 11 of 2020. The extreme right values in the figure (black lines) correspond to what was reported in Table 1 (first row, column 2). Moreover, Figure 2 compares those estimates to excess deaths calculated using a counterfactual scenario based on pre-pandemic 5-year averages (red lines). Trends are similar, however, using 5-year averages as a counterfactual scenario underestimates cumulative excess mortality (77,968 deaths) and leads to considerably wider 95% confidence intervals (66,937 to 88,694).[2] Figure 3 shows how the share of cumulative excess deaths due to COVID-19 evolves over the year. It sharply increases during the very first weeks following the pandemic onset, and it remains on a steadily upward trend until the end of the 2020. Moreover, Figure 3 indicates that using a 5-year average measure of counterfactual mortality overestimates the share of excess deaths due to COVID-19 and leads to wider confidence intervals.

[Table 1 here]

[Figure 2 here]

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[2] Instead of adjusting for high year-to-year volatility in weekly death counts during the first 5 weeks of each pre-pandemic year, an alternative would be to simply exclude those weeks and obtain our counterfactual mortality measure using the remaining unadjusted death counts as the dependent variable in Eq. 4. Figure A.4 in the Appendix displays the results from this exercise. Using the unadjusted death count but excluding the first 5 weeks of each year leads to lower counterfactual mortality (408,158 deaths) and a wider 95% confidence interval (402,576 to 413,818). Hence cumulative excess mortality estimates (black solid line) are higher (88,081 deaths) and noisier (95% CI: 82,421 to 93,663) relative to our preferred adjusted estimates reproduced as in Figure 2 (grey area). Results are nearly identical if we use the unadjusted death counts but this time including the first 5 weeks of each year. Baseline mortality is lower (406,519 deaths) and with a wider confidence interval (401,242 to 411,866), and cumulative excess mortality (black dashed line) is slightly higher (89,720 deaths) and similarly less precise (95% CI: 84,373 to 94,997).

[Figure 3 here]

We also calculate the ratio of observed to counterfactual death count with respect to the place of death. Table 2 reveals some substantial differences. There is a relatively small increase for deaths in hospitals following the pandemic onset; the ratio is 1.06 (95% CI: 1.05 to 1.07). However, excess deaths in care homes increase substantially, by 27,435 (95% CI: 26,435 to 28,423), and this increase is even more pronounced in private residences (homes) by 43,127 (95% CI: 41,987 to 44,253), where the observed to counterfactual deaths ratio is 1.31 (95% CI: 1.29 to 1.32) and 1.45 (95% CI: 1.43 to 1.46), respectively. Stated otherwise, 52.3% of the total excess deaths in 2020 take place at homes, and 85.6% took place at homes and care homes combined. As highlighted by earlier reports, possible factors explaining this trend could be people choosing (or being instructed) to stay away from health care settings or choosing to stay at home if terminally ill (ONS, 2021c).

[Table 2 here]

When excluding deaths due to COVID-19, overall observed mortality is higher from our counterfactual no-pandemic scenario (Table 3). The observed to counterfactual death ratio is 1.02 (95% CI: 1.01 to 1.03), with 9,121 (95% CI: 5,095 to 13,108) excess deaths registered between weeks 11 and 53 of 2020. Cumulative excess mortality not due to COVID-19 sharply increases right after the pandemic onset. From 279 deaths (95% CI: 177 to 381) in week 11, it peaks to 17,359 deaths (16,309 to 18,399) in week 21. Since then however, it keeps decreasing until the last week of 2020 to 9,121 deaths (Figure 4). Similar patterns are observed for all English regions and for Wales (Figure A.2). Repeating the analysis by gender shows that excess mortality not linked to COVID-19 is mostly relevant for males with 8,836 excess deaths in total (95% CI: 6,746 to 10,904) and an observed-to-counterfactual deaths ratio of 1.04 (95% CI: 1.03 to 1.05). Deaths from other causes does not substantially affect females. This follows what is reported in Table 1, where 98.9% of cumulative excess female deaths are registered as due to COVID-19. Hence, the ratio of observed to counterfactual deaths for females in Table 3 is equal to 1.00 (95% CI: 0.99 to 1.01), i.e. nearly all excess female deaths after the pandemic onset are due to COVID-19.

There are also some substantial differences across the age distribution. Persons 45-64 years old are those mostly affected from causes of death other than COVID-19, relative to the no-pandemic counterfactual scenario. In total, 52,967 persons from that age group died from other causes, relative to the counterfactual scenario of 49,849 (95% CI: 49,241 to 50,463) deaths (Appendix Table A.3). Their ratio of observed to counterfactual death count is 1.06 (95% CI: 1.05 to 1.08). As seen in column 2 (Table 3), 3,119 (95% CI: 2,503 to 3,726) more persons died following the pandemic onset during that year from causes other than COVID-19, accounting for 34% of the respective total death count. In terms of absolute numbers, persons older than 65 years old pay the heaviest death toll. In total, 355,511 persons from that group died from other causes, relative to a counterfactual estimate of 348,862 (95% CI: 345,545 to 352,212) deaths (Table A.3). Hence, their ratio of observed to counterfactual mortality is 1.02 (95%CI: 1.01 to 1.03). The total number of excess deaths from causes other than COVID-19 is 6,649 (95% CI: 3,299 to 9,966).

[Table 3 here]

[Figure 4 here]

Moreover, there are some striking findings regarding excess deaths (not registered as due to COVID-19) by place of death. There are 156,448 in-hospital deaths after the pandemic onset in 2020, however, in a no-pandemic scenario 194,639 (95% CI: 192,651 to 196,648) deaths should have been expected. As seen in Figure 5, in-hospital excess mortality from other causes keeps decreasing during 2020. By the end of the year, there are 38,191 (95% CI: 36,203 to 40,200) fewer in-hospital deaths and the ratio of observed to counterfactual deaths is 0.80 (95% CI: 0.79 to 0.81). A reversed picture is revealed when considering excess deaths not from COVID-19 that occurred at home. In total, 136,521 persons died in their private residence, i.e. there were 39,945 (95% CI: 38,805 to 41,071) excess deaths relative to the counterfactual scenario of 96,576 (95% CI: 95,450 to 97,716) deaths; the observed to counterfactual deaths ratio is 1.41 (95% CI: 1.40 to 1.43). Cumulative excess mortality at home from other causes keep increasing until the end of 2020 (Figure 5). Moreover, deaths from other causes account for nearly 93% of all deaths occurred at home. Hence, few people died at home from COVID-19, however, the cost of treating COVID-19 cases in hospitals leads to a substitution of in-hospital mortality from other causes with deaths from those causes taking place at home and care homes. Regarding the latter, there are 8,542 (95% CI: 7,542 to 9,530) cumulative excess deaths, which, similarly to deaths from COVID-19 peak during the first weeks after the pandemic onset. In total, 48,487 (95% CI: 46,347 to 50,601) persons died from causes other than COVID-19 at homes and care homes combined, fully offsetting the reduced in-hospital mortality from those causes. Finally, cumulative excess mortality in places classified as “elsewhere” is lower relative to the counterfactual figure, i.e. there are 803 (95% CI: 416 to 1,195) less deaths by the end of 2020; the observed to counterfactual deaths ratio is 0.98 (95% CI: 0.96 to 0.99).

[Figure 5 here]

Table 4 reports the estimates for excess deaths from a series of causes, when considering the total age distribution. There are 54,943 deaths from dementia and Alzheimer’s disease in total, 8,681 (95% CI: 8,083 to 9,272) more relative to what was expected (46,262 deaths, 95% CI: 45,671 to 46,860) in the absence of the pandemic (Table A.3). Hence, the ratio of observed to counterfactual deaths from dementia and Alzheimer’s disease is 1.19 (95% CI: 1.17 to 1.20). Cumulative excess mortality is higher in the cases of diabetes and Parkinson’s disease, with 1,529 (95% CI: 1,425 to 1,630) and 1,596 (95% CI: 1,490 to 1,699) more deaths, respectively. For both those causes, the observed to counterfactual death ratio is 1.37 (95% CI: 1.34 to 1.41) Also, there are 73,351 deaths from heart diseases after the pandemic onset in 2020, i.e. 1,072 (95% CI: 163 to 1,969) more compared to the counterfactual estimate of 72,279 (95% CI: 71,382 to 73,188) deaths. There are also more deaths from malignant neoplasms, nervous system diseases (excluding Parkinson's disease) and from mental and behavioural disorders (excluding dementia and Alzheimer's disease).

On the other hand, there are considerably fewer deaths from pneumonia and influenza. In a no-pandemic scenario, 20,054 (95% CI: 19,706 to 20,497) deaths were expected, however, 6,179 (95% CI: 5,831 to 6,532) less people died from that cause, and the associated observed to counterfactual deaths ratio is 0.69 (95% CI: 0.68 to 0.70). There are also fewer deaths from lower respiratory system diseases, and infectious and parasitic diseases. Our counterfactual estimates of Table A.3 suggest that in the absence of the pandemic, there would have been 26,891 (95% CI: 26,535 to 27,252) deaths from strokes. After the pandemic onset and by the end of 2020, however, there are 3,463 (95% CI: 3,080 to 3,797) fewer deaths from that cause. Also, mortality from external causes, i.e. transport accidents, other accidents suicides, homicides and complications from medical and surgical care, are also lower relative to our counterfactual estimates.

[Table 4 here]

The results so far indicate that the burden of overall excess mortality and excess mortality not due to COVID-19 during the first pandemic year is mainly carried by persons aged 45-64 and ≥65 years old. Focusing on deaths not registered as due to COVID-19, Figure 6 displays how cumulative excess deaths evolves following the pandemic onset and over the year for those two age groups. Regarding persons aged 45-64 years old (panel A), excess mortality due to other causes is solely driven by deaths at home. By the end of 2020, nearly 6,000 persons of that age group are registered as dying at their usual place of residence, namely the usual residence of the deceased, where this is not a communal establishment. There are fewer deaths at hospital, around 2,000, and very few deaths elsewhere. As expected for this age group, there are very few excess deaths at care home. By the last week of 2020, the net sum of excess deaths across all places of death for this is 3,119 (95% CI: 2,503 to 3,726), as shown in Table 3.

Regarding persons older than 65 years, there are nearly 34,000 excess deaths at home not related to COVID-19 (Figure 6, panel B). At the same time, there are 35,000 fewer deaths from other causes at hospitals, and nearly 8,500 deaths at care homes, mainly due to their sharp increase right after the pandemic onset. Together with the low number of excess deaths registered as elsewhere, the cumulative count of excess deaths from all other causes for this age group is 6,649 (95% CI: 3,299 to 9,966) by the end of the year.

[Figure 6 here]

Next, we look what the main causes of death were for those two age groups in each place of death with a substantially increased excess death count from causes other than COVID-19 in 2020. Figure 7 graphs the results. The excess count of deaths for persons 45-64 years old who died at their usual place of residence, cancer, heart-related diseases, and lower respiratory system diseases are the causes that contributed the most (panel A). For persons older than 65 years who died at their home, the most common causes of death are cancer, heart-related diseases, and dementia (panel B). For the same age group, but for those who died at care homes, dementia is by far the most contributory cause of death, mainly due to the sharp increase right after the first death due to COVID-19 is officially registered in England and Wales (panel C).

[Figure 7 here]

4.2. Difference-in-differences results

Based on our counterfactual death count, there are 82,428 (95% CI: 78,402 to 86,415) excess deaths in England and Wales in 2020, from week 11 onwards. Nearly all of them, i.e. 82,355 (95% CI: 78,390 to 86,279) are for persons aged 45 years old and over. Most of the excess mortality is directly linked to COVID-19 in the official registries, specifically 88.9% (95% CI: 84.8% to 93.5%) of all excess deaths when considering the total age distribution, and 88.1% (95% CI: 84.1% to 92.6%) when restricting the sample to persons older than 45 years.

To ensure that those results are not driven by unobserved factors, we apply a DiD-style analysis restricting the sample to those age groups mostly responsible for the observed excess mortality, i.e. persons 45-64 years old and those over 65 years old. We consider observed weekly death counts in 2020 as those exposed to the “treatment”, i.e. the pandemic year. Counterfactual weekly death counts, that would have been observed in the absence of the pandemic in 2020, are the control group. For each region, the intervention period begins after the pandemic onset, i.e. the week following first death registered as due to COVID-19 in that region. For three regions the post-intervention period starts at week 12, for the rest of them is set from week 11 onwards. Table 5 shows the results. Panel A focuses on persons 45-64 years old. Restricting the sample by place of death, there are considerably fewer deaths in hospitals and elsewhere, however, mortality at private homes is significantly higher (columns 1-4). Using deaths registered elsewhere as our base group, and interacting our post with the place of death indicators (column 5) indicates highlights the significantly increased mortality at home for those aged 45-64 years old. Despite the effect that in-hospital mortality is lower for this age group (also shown in panel A of Figure 6), it is not enough to offset the increased number of deaths at private homes.

Regarding persons older than 65 years (panel B), our DiD estimates (columns 1-4) also suggest that mortality at home is significantly increased, while deaths at hospitals are significantly fewer. This is also confirmed in column 5. Unlike the case of those 45-64 years old, increased mortality at homes is offset by lower in-hospital mortality (see panel B of Figure

6). Regarding deaths at care homes, they are marginally fewer when considering the total period since the pandemic onset in each region.

[Table 5 here]

To test about pre-trends, we run an event-style analysis as in Eq. 6. We consider weekly death counts (not due to COVID-19) for places of death and age groups that mostly accounted for the observed change in 2020. Figure 8 focuses on persons 45-64 years old. Regarding deaths at home (panel A), there are no detectable trends before the onset in each region. However, since the first deaths due to COVID-19 were registered in a given region, weekly death counts are significantly increased, particularly during the first weeks after the pandemic onset, and remain high until the end of the year. On the other hand, in-hospital mortality for this age group is lower during the first twenty weeks following the pandemic onset but it is significantly increased from week 26 onwards until the end of 2020 (panel B).

[Figure 8 here]

Figure 9 focuses on deaths not due to COVID-19 for those older than 65 years. Panel A shows results for deaths at care homes. There is a sharp increase during the first five weeks after the pandemic onset in each region (panel A). However, weekly death counts begin to from that point onward. They remain lower during the following weeks and they start increasing around 30 weeks after the pandemic onset. Deaths at home also climb sharply during the first weeks after the first deaths officially due to COVID-19. They decline after week 6, however, they remain higher throughout the year (panel B). In-hospital deaths from all other causes but COVID-19, decline sharply after the pandemic onset, and they are lower for this age group for 25 weeks since the first COVID-19 deaths in each region (panel C). However, towards the end of the year they become significantly higher relative to the reference week, following an upward trend as early as from week 10 after the pandemic onset.

[Figure 9 here]

5. Conclusions

An accurate estimation of excess mortality is difficult, but crucial in order to better understand how the pandemic affected public health. However, this depends on data granularity and on the procedure adopted to estimate a counterfactual death count number that would have been observed in a hypothetical, no-pandemic scenario. In this paper, we focus on excess deaths observed in England and Wales during 2020. So far, previous reports relied on pre-pandemic 5-year averages to calculate baseline death counts (ONS, 2021a; 2021b). Similarly, the related literature so far also used such averages as a counterfactual mortality measure and it only focused only on total mortality (Vandoros, 2020). Here we use detailed regional-level weekly panel data disaggregated by gender, age, cause of death, and place of death. In order to obtain counterfactual death counts, we modify a method proposed by Ruhm (2021; 2022) that adjusts for excess year-to-year volatility typically observed during the first weeks of each pre-pandemic year. Compared to estimates using counterfactuals based on 5-year averages or unadjusted series, our estimates of cumulative excess deaths are slightly higher and with tighter confidence intervals. Based on our findings, there were 82,428 (95% CI: 78,402 to 86,415) excess deaths during weeks 11-53 of 2020 in England and Wales, an estimate higher than the 76,000 excess deaths reported by the ONS (2022). Nearly 90% of those excess deaths were registered as due to COVID-19, a proportion slightly lower than the 97% that was originally estimated by the ONS for 2020 (2022), and lower than what was estimated by the COVID-19 Excess Mortality Collaborators study over the period 2020-2021 (2022). Although the differences may reflect methodological differences as well as they could be due to the fact that these studies considered a longer time period until the end of December 2021, our findings suggest than non-COVID-19 excess deaths may have been previously underestimated.

When looking at differences by demographic groups for overall excess mortality during the first year of the pandemic, we show that the main groups affected are males, those older than 65 years, and those living in London and in West Midlands. The findings are consistent with previous literature on excess mortality in England and Wales that revealed regional variations (Kontopantelis et al., 2021), and variations by gender and age (Joy et al., 2020). When focusing on excess deaths not due to COVID-19, excess mortality is unevenly distributed between genders, with males carrying the heaviest death toll. With respect to age, excess mortality from causes other than COVID-19 solely concern individuals over 45 years old. When looking at the place of death, 85.9% (95% CI: 84.9% to 87.1%) of all excess deaths happened in non-hospital settings, namely private homes and care homes. Our estimates suggest 43,127 (95% CI: 41,987 to 33,253) of all excess deaths during 2020 occurred in private homes, a number slightly higher than what was previously estimated (ONS, 2021c). Regarding deaths from causes other than COVID-19, there are 38,191 (36,203 to 40,200) fewer in-hospital deaths. However, the picture was reversed for deaths at home and care homes, with 39,945 (95% CI: 38,805 to 41,071) more deaths than those expected in a no-pandemic scenario. Cumulative excess mortality from other causes is also increased in care homes, especially during the first weeks after the pandemic onset, with 8,542 (95% CI: 7,542 to 9,530) more deaths.

Across all causes of death there was increased excess mortality from dementia and Alzheimer's disease, diabetes, Parkinson's disease and heart-related disease. This is consistent with previous research on cardiovascular diseases in England which found that the pandemic caused an increase in these conditions both direct (due to infection) and indirect effect (due to unprecedented system strain and associated behaviour changes) (Banarjee et al., 2021). What our findings add is that most of these deaths happened at home alongside death due to cancer, confirming previous evidence showing increase direct and indirect excess deaths in people with cancer in England (Lai et al., 2020). On the other hand, and at the same period there was a reduction in deaths from pneumonia and influenza, stroke as well as infectious diseases and accidents. When exploring non-COVID-19 related deaths, it is important to highlight the fact that in the beginning of the pandemic testing was not widely used in the community (non-hospital settings) in England and Wales (Iacobucci, 2020). Hence, COVID-19 may have been undiagnosed, a limitation widely recognised in the wider literature on excess deaths during the pandemic. Another limitation of our study is that we cannot attribute excess deaths directly to the pressure on the health system caused by the pandemic. Fetzer and Rauh (2022) provide an estimate on this topic. Specifically, their outcome variable is the Summary Hospital-level Mortality Indicator (SHMI), a ratio between the actual number of deaths which occurred in hospital or within 30 days of discharge and the number of patients that would be expected to die, calculated using linked ONS and Hospital Episode Statistics (HES) data. They show that for every 30 deaths that can be linked to COVID-19, there was at least one additional preventable death among hospital patients seeking medical care for reasons unrelated to COVID-19. This translated in 4,003 such excess deaths during the first twelve months of the pandemic. This might seem at odds with our evidence in Table 3 and Figures 5 and 6, showing that non-COVID-19 in-hospital mortality was lower than expected in 2020 after the pandemic onset. In our ONS death registry data, however, this sort of excess hospital mortality could be seen as deaths of patients who were discharged and died at home, care homes or elsewhere, within 30 days of discharge.[3]

Nevertheless, understanding excess mortality during the pandemic is more meaningful when these numbers are broken down by cause of death and demographic characteristics of the

[3] This could be the case because, according to the ONS, details collected at death registration (using the Medical Certificate of Cause of Death, MCCD) about the date and place of death are provided by an informant – usually a near relative of the diseased. Moreover, apart from counting deaths occurring up to 30 days from a patient being discharged from hospital, another issue with the SHMI is that it attributes deaths to the condition of the patient during their last admission to hospital, irrespectively of the actual death cause.

groups affected the most. Our findings offer insights towards this direction. Our results though cannot offer a causal link between policy responses during the pandemic and excess deaths. Further work exploring such links is needed.

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