Title: On measuring excess deaths

Date: 20-9-2022

Summary

The Covid-19 crisis led to several alterations in individuals' lifestyles and perceptions of risk for their day-to-day choices. It is important to contextualise the magnitude of impact of the pandemic so that lessons can be learned, and policy can be chosen that is based on the most accurate numbers possible. In this context, measuring excess deaths due to the SARS-CoV-2 pandemic (as well as policy interventions) is of high relevance.

Recent statistics from different national statistical offices are showing higher levels of deaths than would be expected (excess deaths). These statistical calculations are, in most cases, performed by comparing deaths in 2020, 2021 and 2022 with prior average deaths before 2020. Typically, excess deaths are reported as deviations from previous 5-year or 3-year averages in deaths (the baseline). Even though these comparisons provide a baseline for computing excess deaths, their accuracy can be compromised by changing population numbers as well as changing death rates.

In this report we estimate excess mortality by computing **changes in death rates** in relation to a given baseline instead of **changes in deaths**. We show that this measurement improves significantly the accuracy of estimating changes in mortality, and should be used as a preferred measure when making enquiries and policy decisions concerning excess mortality.

Contents

1. Methodology

In this study we analyse the dangers and pitfalls of using the standard measures for excess deaths and how they can lead to misguided policy decisions. In addition, we propose an alternative way of computing excess deaths based upon computing **excess death rates** instead of **excess deaths**.

First let's define the standard computation method for estimating excess deaths, which is typically used in the academic literature, as well as statistical offices worldwide:

1.1. Method 1 for estimating excess deaths.

$$ExcessDeaths_{ti}^{AG} = Deaths_{ti}^{AG} - \sum_{\Delta T=t1}^{tn}\left(\frac{Deaths}{n}\right) \quad \text{Eq. 1}$$

Where AG is the age cohort, ti= 2020,2021 or 2022 and ΔT is the time period for calculation of the baseline (from t1 to tn), which is typically 5 years. Consequently, for computing excess deaths in 2020, 2021, and 2022 we would compute the average number of deaths from 2015 to 2019 and subtract it from the deaths in 2020, 2021 and 2022, respectively.

1.2. Method 2 for estimating excess deaths.

The second method for estimating excess deaths first estimates the excess death rate and then multiplies that value by the estimated population of the age group. As we will show below, death rates tend to monotonically decline over time, for a given population age cohort, as living conditions have generally been improving since after the Second World War (with some exceptions).

Death rates are calculated by simply dividing the number of deaths in a certain age group over a given period of time, by the population of the respective age-group, as shown below:

$$DeathRate_{ti}^{AG} = \frac{Deaths_{ti}^{AG}}{Population_{ti}^{AG}} \quad \text{Eq. 2}$$

Death rates adjust the number of deaths to the population of a given age-cohort. They are consequently a more accurate measure to estimate societal changes in living conditions over time, or the impact of certain external events on the population (such as the introduction of a new pathogen in the human eco-system). Using the death rate in 2019 as a baseline to estimate excess death rates in 2020 to 2022 will tend to provide a conservative estimate for excess deaths (lower limit), as it assumes unchanged death rates going forward but in fact they tend to trend downwards. A more realistic assessment is to compute excess death rates in 2020 to 2022 relative to a baseline that adjusts 2019 death rates for average yearly rates of improvement in death rates, or, use a baseline that is the continuation of a previous trend in excess deaths. Each of these methods is detailed below.

1.2.1. Setting baseline for estimating excess deaths - Method 2A

This method measures the excess death rate by using the death rate for a given year as a baseline. The most reasonable year to use is the last year of available data before a given phenomenon occurs. In our particular case of measuring excess deaths due to the Covid-19 pandemic that started in 2020 we use 2019 as the baseline year for excess deaths, as shown in the formula below.

$$ExcessDeathRate_{ti}^{AG} = DeathRate_{ti}^{AG} - DeathRate_{2019}^{AG} \quad \text{Eq. 3}$$

Where AG is the age cohort, ti= 2020, 2021 or 2022. Note that this method of estimating excess deaths is likely to understate excess death rates as over time, death rates tend to decline with the improvement in living conditions.

1.2.2. Setting baseline for estimating excess deaths - Method 2B

This method adjusts the 2019 death rate for the compounded yearly decline in death rates over a given period of time, such as from 2010 to 2019.

$$ExcessDeathRate_{ti}^{AG} = DeathRate_{ti}^{AG} - DeathRate_{2019}^{AG} \cdot (1 + R_{\Delta T})^{n} \qquad \textit{Eq. 4}$$

Where AG is the age cohort, ti = 2020, 2021 or 2022 and n = ti-2019. $R_{\Delta T}$ is the compounded yearly rate of change (geometric average) for the death rate over a given period (from 2010 to 2019, for example).

1.2.3. Setting baseline for estimating excess deaths - Method 2C

This method uses a baseline that corresponds to the linear fit in death rates over a given period of time, such as from 2010 to 2019, and then extended into 2020, 2021 and 2022.

$$ExcessDeathRate_{ti}^{AG} = DeathRate_{ti}^{AG} - LinearFit_{\Delta T}^{AG} \qquad \textit{Eq. 5}$$

Where AG is the age cohort, ti = 2020, 2021 or 2022 and ΔT is the period over which the linear fit is performed for excess deaths (from 2010 to 2019, for example).

2. Data

In this study we use yearly population estimates and deaths from the UN population division[1]. As a case study we perform the analysis on a given country: United States of America.

[1] https://www.un.org/development/desa/pd/data-landing-page

3. Analysing of method 1 and method 2

3.1. Method 1 for estimating excess deaths.

This method is the standard method for estimating excess deaths, which is used in most academic studies and by most statistical offices worldwide. It is based in comparing deaths in a given year with the average deaths over a period of time. In our particular case, we're going to use the 5-year average deaths from 2015 to 2019 (see Eq. 1) as the baseline to compute excess deaths in 2020 and 2021.

Figure 1 shows the raw data on the yearly deaths for different age groups in the USA from 1960 to 2021.

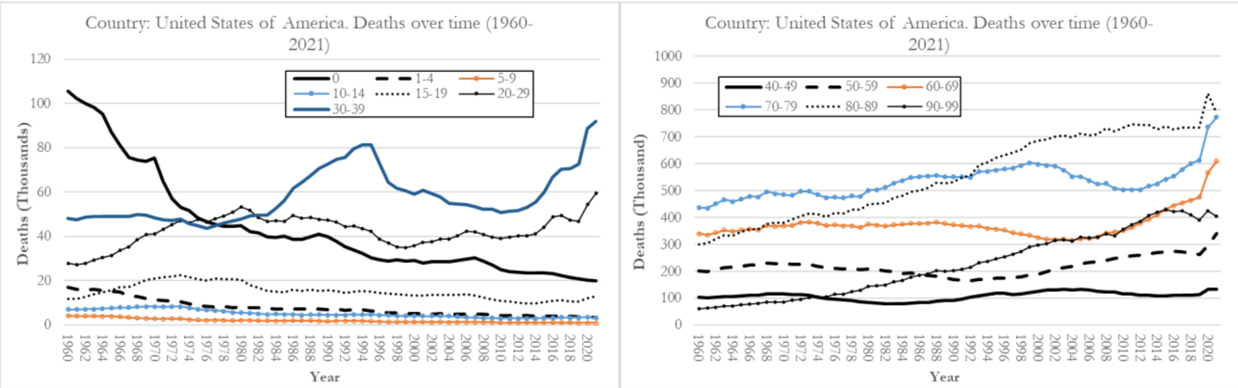

Figure 1 - USA - Yearly deaths for different age groups from 1960 to 2021. Left: younger age-groups. Right: Older age-groups.

We can observe that deaths for different age groups can trend upwards or downwards over time. As an example, when looking at the 30-39 age group on the figure on the left, we observe that deaths trended upwards from 45 thousand in 1975 to 80 thousand in 1995 and then downward until 2012 reaching about 53 thousand and since then, jumped up to about 90 thousand in 2021.

The changes in the number of deaths are highly influenced by the changes in the population over time of the numbers in each age group. Death rates also change, but as we'll show later on, they tend to decrease monotonically over time, with much lower variation over time. The implications of these observations is that when computing the baseline for estimating **excess deaths**, one will introduce a positive bias in periods when deaths are increasing and a negative bias in periods when deaths a decreasing.

The magnitude of the bias can be significant as during certain periods, deaths increase (or decrease) at a rate of 5% (or -5%) a year or greater in magnitude. Consequently, a five-year average could be offset by 12.5% or more, as the average would correspond to the value at the middle of the time period for which the baseline is measured.

To further illustrate the pitfalls on comparing deaths over different time spans, let's look at Figure 2, that shows the number of deaths for different population age groups, for singular years from 1960 to 2020. In general, death rates have decreased steadily for each age group from 1960 to 2020. However, the figure shows that the number of deaths for younger individuals (ages 5-9) decreased from 1960 to 2020 while deaths in older individuals (80-89) increased from 1960 to 2020. This was due to the effect in decreasing population numbers for 5-9 year-olds and increasing numbers for 80-89 year-olds, which subtracted (or added) to the overall reduction in death rates.

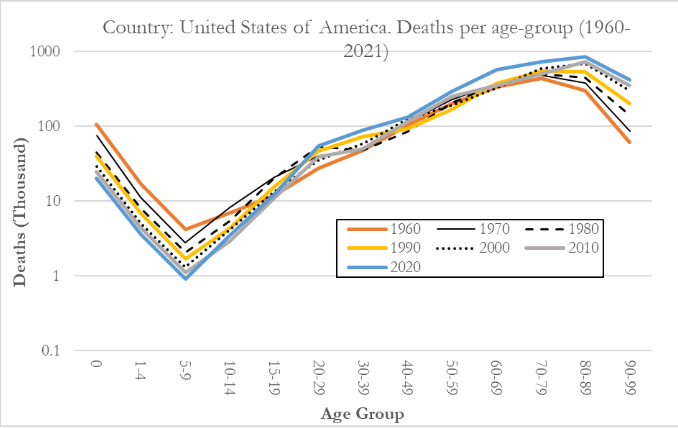

Figure 2 - USA - Yearly deaths per age group for selected years.

In summary, we believe that method 1 has significant pitfalls when used to estimate excess deaths. With those caveats, we'll next analyse the excess deaths relative to the prior 5-year average, from 1965 to 2021. The excess deaths for 2020 and 2021 were based upon a fixed baseline referring to the average deaths from 2015 to 2019. This is to avoid using the pandemic excess deaths in 2020 to estimate the excess deaths in 2021. These results of the analysis are illustrated in Figure 3 where the time series of excess deaths from 1960 to 2021, computed using method 1 is shown for older age groups. The figure on the left shows the time series of excess deaths in percentage while on the right, the normalise excess deaths are shown. The normalisation is achieved by assuming excess deaths are normally distributed.

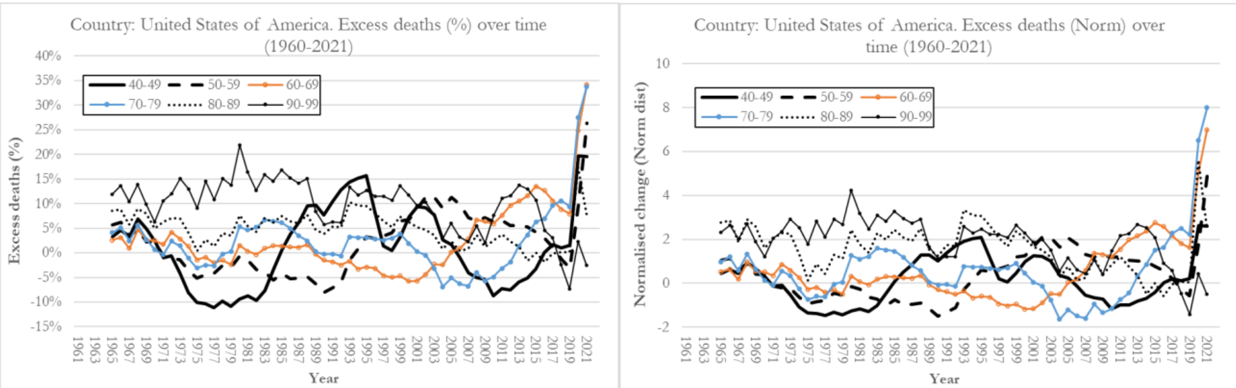

Figure 3 - Yearly excess deaths relative to 5-year prior average from 1960 to 2021. Left: Percentage of excess deaths. Right: Normalised excess deaths.

By using method 1 for computing excess deaths we can observe that there is a large variation for excess deaths over time (Figure 3 - Left). Excess deaths of -10% to +10% were relatively normal over the period of 1960 to 2021. We can also observe that there are noticeable trends in excess deaths which track rising or falling deaths (due to population increases/decreases) in given age groups. For example, we can observe that for the 40-49 age group excess deaths tended to be -10% in the 1970s but above 10% in the 1990s. These variations are likely due to the baby boom generation passing by this age group during the 1990s, which led to a correspondent trend in increase in deaths.

We can also observe that 2020 and 2021 were abnormal events as excess deaths reached 25% to 35% in age cohorts from 40 to 79. This occurred both in 2020 and 2021, a time when Covid-19 vaccinations were already rolled out. Curiously, the Covid-19 pandemic did not seem to lead to significant excess deaths in older age groups of 80-89 and 90-99. The 80-89 age group does show that excess deaths are statistically significant in 2020 with a jump that corresponds to more than 5 standard deviations of normal change.

When looking at normalised excess deaths (Figure 3 - Right), we can observe that the jump in excess deaths during the pandemic years corresponded to 3 to 8 standard deviations, with the exception of the 90-99 age group that looked unaffected by the pandemic in terms of excess mortality.

We should now emphasise that, it will be clear when comparing excess deaths using method 1 (using prior N-year average of deaths as baseline), with those using method 2, that method 1 is inappropriate in estimating excess mortality. The volatility of the changes in excess mortality as well as the problem that age group populations oscillate over time, make this measurement inaccurate. This could then lead to misguided assessments and consequently erroneous policy actions.

We will now perform the same analysis as before by using method 2 (based on changes in death rates) for estimating excess deaths.

3.2. Method 2 for estimating excess deaths.

This method is based on comparing death rates in a given year with a **baseline** that is an estimate for the expected death rate during that year. In this section, we're going to use 3 different methods for establishing the baseline (see Eq. 2 to Eq. 5) to then compute excess death rates in 2020 and 2021. The 3 methods are refinements of the central idea of using a death rate baseline to estimate **excess death rates** instead of **excess deaths**. Once excess death rates are estimated, we can then compute excess deaths by multiplying by the age group population.

Figure 4 shows the computed yearly death rates for different age groups in the USA from 1960 to 2021. The figure on the left corresponds to younger age groups while on the right, older age groups are shown. Death rates are shown in logarithmic scale because they tend to exponentially decline over time, as a consequence of improving living conditions for most age groups.

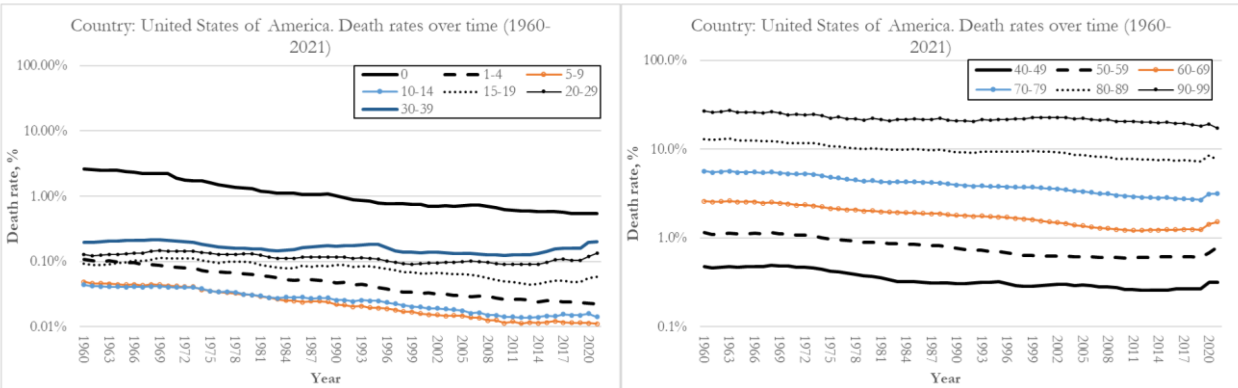

Figure 4 - USA - Yearly death rates for different age groups from 1960 to 2021. Left: younger age-groups. Right: Older age groups.

The first observation we can make is that death rates for different age groups decline almost monotonically over time. The lines are almost straight and their slope corresponds to the rate of improvement in death rates for a given age group. Interestingly, for the US, for the given time period (1960 to 2021), death rates for the age groups 20-29 and 30-39 do not show a substantial improvement over time. It is not the topic of this report to discuss the social phenomena that might be at the origin of this effect, but it could be related to drug use, the AIDS epidemic and the consecutive wars that the US has been involved in over time.

When comparing Figure 4 with the equivalent Figure 1 for US deaths, we observe that death rates are much better behaved as they do not show big upward or downward trends, tend to decline monotonically and have much less volatility from year to year. This pattern can be clearly seen in Figure 5 that shows the death rates for different population age groups, for singular years from 1960 to 2020.

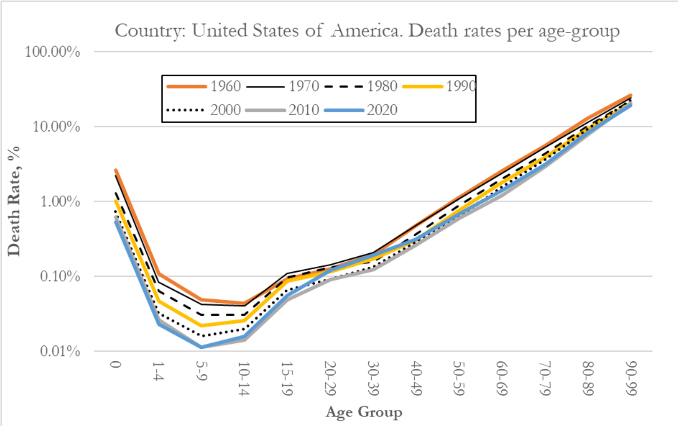

Figure 5 - USA - Yearly death rates per age group for selected years.

By adjusting deaths by the population of the respective age group, the overall trends in improving living conditions become clear. By looking at Figure 5 we observe that in 1960, 10-14 was the age cohort with lowest death rates, while in 2020, 5-9 was the age cohort with lowest death rate. This reflects a faster rate of improvement in risk reduction for the 5-9 age group from 1960 to 2020. Figure 6 shows the compounded yearly changes in death rates from 1960 to 2019 for different age groups. It shows that the greatest improvement occurred for the younger age groups from ages 1 to 9, with a about 2.5% yearly improvement. As mentioned previously, individuals of ages 20 to 39 had the lowest yearly decline in death rates of only about -0.4% per annum. For older ager groups the yearly improvement was around 1% per year.

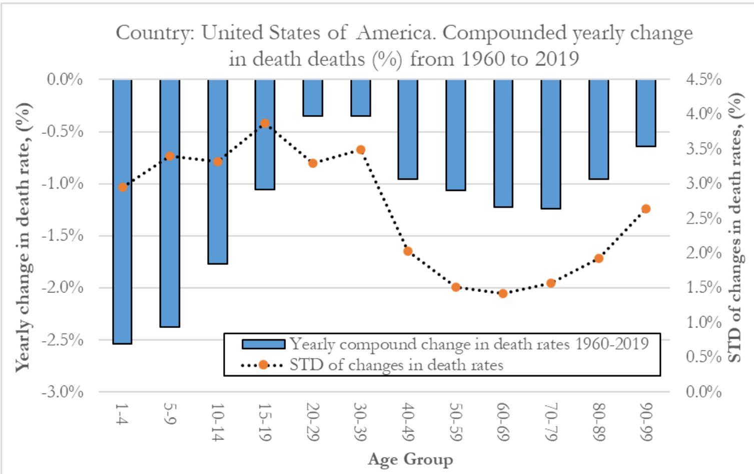

Figure 6 - USA - Yearly compounded improvement (% decline) in death rates from 1960 to 2019 for different age groups. The standard deviation of yearly changes in the death rates are also shown (right hand scale).

Figure 6 also shows standard deviation of yearly changes in the death rate from 1960 to 2019, for each age group. It can be observed that the younger age groups (1 to 39) have almost double the year-to-year variability in death rates compared to older age groups (40 to 89). This is important to bear in mind once we normalise our calculation of excess death rates in our analysis below.

When comparing method 1 to method 2 we observe trends in death rates have a much more stable and predictable behaviour when compared to deaths. Death rates tend to decrease monotonically over time, while deaths can trend upwards and downward due to population changes. Furthermore, yearly changes in death rates have about 25% less volatility than changes in deaths, as shown in Figure 7, which plots the standard deviation of percentage changes in deaths and death rates from 1960 to 2019.

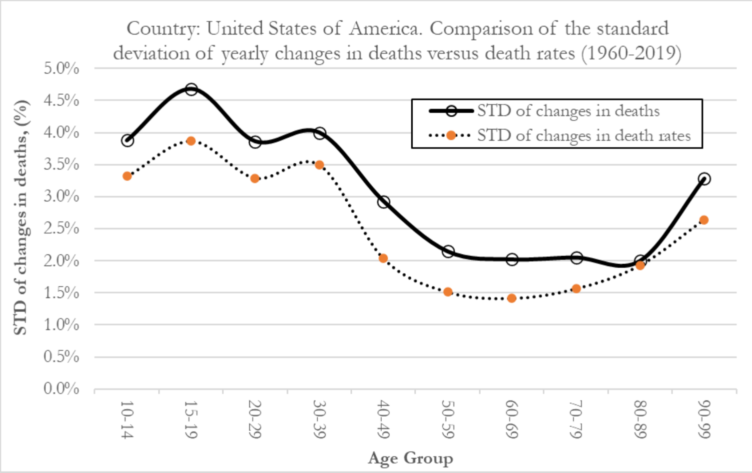

Figure 7 - USA – Comparison of the standard deviation of yearly changes in the death rates versus deaths, from 1960 to 2019 for different age groups.

Taking these factors into consideration we're now going to estimate excess death rates using 3 different approaches as previously mentioned (Method 2A, 2B and 2C) formulated by equations 3 to 5.

3.2.1. Computing excess death rates using method 2A

This method measures the excess death rate by using the death rate for a given year as baseline. The most reasonable year to use is the last year of available data before a given phenomenon occurs. In our particular case of measuring excess deaths due to the Covid-19 pandemic that started in 2020 we use 2019 as the baseline year for excess deaths.

These results of the analysis are illustrated in Figure 8 where the time series of excess deaths from 1960 to 2021, computed using method 2A, is shown for older age groups. The figure on the left shows the time series of excess death rates in percentage while on the right, the normalised excess death rates are shown. The normalisation is achieved by assuming excess death rates are normally distributed.

The results show that there is a much lower variability in excess death rates from 1960 to 2019 than the variability in excess deaths for the same period calculated using method 1 (see Figure 3). Excess death rates vary between -5% to 5% per year from 1960 to 2019. In 2020 and 2021 however, excess deaths had a large jump. We can observe that 2020 and 2021 were abnormal events as excess deaths reached 20% to 30% in age cohorts from 40 to 79. This occurred both in 2020, and in 2021, a time when Covid-19 vaccinations were already rolled out. The Covid-19 pandemic did not seem to lead to significant excess deaths in older age groups of 90-99. These results are in line with the rise in excess deaths in 2020 and 2021 computed using method 1, however, the overall background noise is much lower when using method 2A.

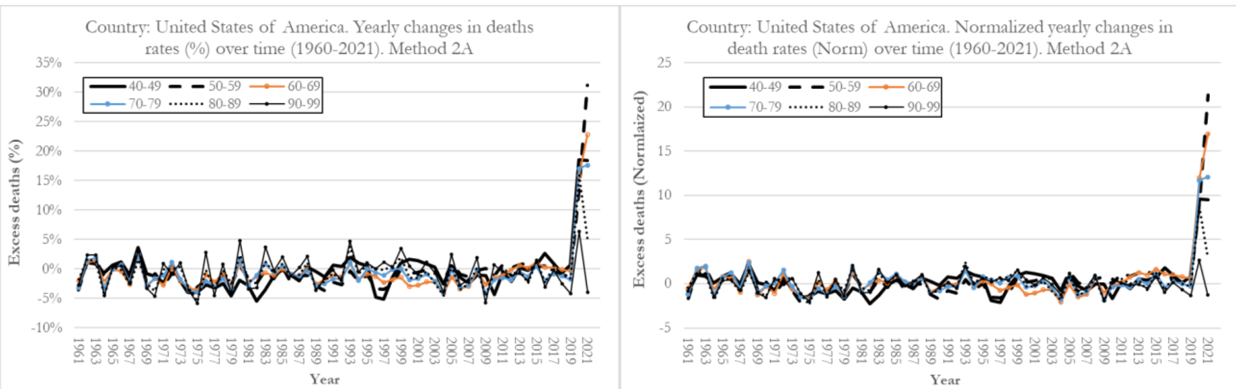

Figure 8 - Yearly excess death rates relative to prior year from 1960 to 2021. Left: Percentage of excess death rates. Right: Normalised excess death rates. Excess death rates for 2020 and 2021 use death rates in 2019 as a baseline.

When looking at normalised excess death rates (Figure 8 - Right), we can observe that the jump in excess death rates during the pandemic years corresponded to 10 to 20 standard deviations, with the exception of the 90-99 age group that looked mostly unaffected by the pandemic in terms of excess mortality. The signal strength of the effect of the pandemic is much stronger than when using method 1.

It is abundantly clear when comparing excess deaths using method 1 (using prior N-year average of deaths as baseline), with those using method 2, that method 2 is much more accurate in estimating excess mortality. The adjustment of deaths to the population of the age group reduces the volatility of the changes in excess mortality as well as solving the problem of changing populations over time. This method should be preferred when making assessments on excess mortality and implementing policy actions.

Excess death rates in 2020 and 2021 using method 2A.

When investigating the excess death rates in 2020 and 2021 relative to 2019, shown in Figure 9, we observe that for individuals aged 15 to 79, death rates saw larger rises in 2021 than in 2020. We might have expected that the introduction of the Covid-19 vaccines, and improvements in acute Covid treatments, would have reduced the excess mortality in 2021 compared to 2020.

For 2021, the highest rises in death rates relative to 2019 occurred for the 50-59 age group (of about 30%) and the 20-29 age group (of 28%). Individuals from 15 to 79 experienced a rise in excess death rates ranging from 15% to 30%. Only for the 10-14 age group and the 90-99 age group did death rates in 2021 drop from 2019 levels.

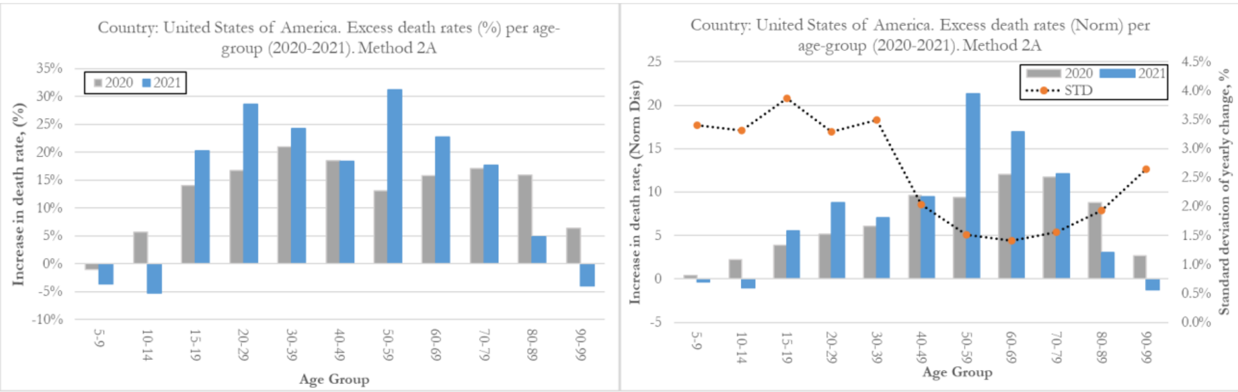

Figure 9 - Excess death rates for 2020 and 2021 using method 2A. Left: Percentage of excess death rates. Right: Normalised excess death rates. The chart also shows the standard deviation of changes in excess death rates from 1960 to 2019.

By looking at the data in terms of the normalised change in death rates (Figure 9 - Right), we observe that the rise in death rates in 2021 for 50-59 age group corresponds to a 22 standard deviation event while the rise in the excess death rates for ages 15-79 are above 5 standard deviations. This is a very strong signal for these age groups.

Furthermore, it is interesting to observe that excess deaths rates in 2020 (the first year of the Covid-19 pandemic) for the 10-14 and 90-99 age groups were positive but had a weak statistical significance; and for the 5-9 age group negative excess deaths were recorded both in 2020 and in 2021.

3.2.2. Computing excess death rates using method 2B

Method 2B calculates the excess death rate by adjusting the 2019 death rate for the compounded yearly decline in death rates over a given period of time. In this particular example we use the compounded rate of improvement in death rates from 1960 to 2019 to estimate the baseline for 2020 and 2021 according to Equation 4.

Excess death rates in 2020 and 2021 using method 2B.

Figure 10 shows the increase in excess death rates for 2020 and 2021 when using the baseline adjustment defined in method 2B. The results are very similar as when using method 2A with some minor differences. Again, we observe that for individuals aged 15 to 79 death rates saw larger rises in 2021 than in 2020 which is inconsistent with the introduction of Covid-19 vaccines and improved treatments.

For 2021, the highest rises in death rates of close to 35% occurred for the 50-59 age group and 30% for the 20-29 age group. Individuals from 15 to 79 experienced a rise in excess death rates ranging from 20% to 35%. Only for the 10-14 age group and the 90-99 age group did death rates in 2021 drop below the adjusted baseline.

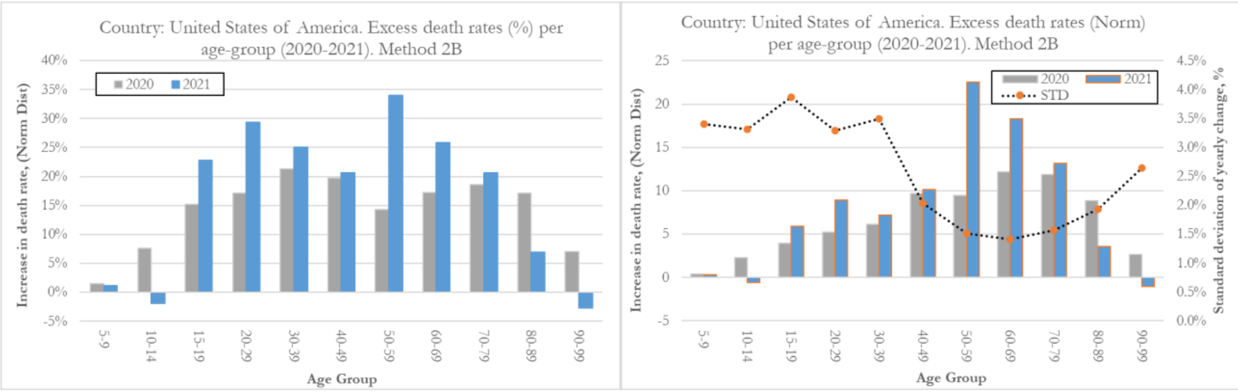

Figure 10 - Excess death rates for 2020 and 2021 using method 2B. Left: Percentage of excess death rates. Right: Normalised excess death rates. The chart also shows the standard deviation of changes in excess death rates from 1960 to 2019.

By looking at the data in terms of the normalised change in death rates (Figure 10 - Right), we observe that the rise in death rates in 2021 for 50-59 age group corresponds to a 23 standard deviation event while the rise in the excess death rates for ages 15-79 are above 6 standard deviations. This is a very strong signal for these age groups.

3.2.3. Computing excess death rates using method 2C

Method 2C calculates the excess death rate by using a baseline that corresponds to the linear fit in death rates over a given period of time, such as from 2010 to 2019, and then extended into 2020 and 2021.

As one might expect, one of the difficulties of using this method is setting the time period over which the regression is performed. If a long time period is used[2], the regression will capture trends in deaths rates, that might not be relevant for estimating excess deaths on the most recent data. On the other hand, if one uses a very short time period for estimating the regression parameters, the extrapolation might capture temporary trends that could lead to small biases in computing the excess death rates. Considering both these factors we chose to use shorter regression periods ranging from 5 years to 20 years prior to 2019. In particular, next we're going to analyse excess death rates using a linear regression with data from 2000 to 2019 (20 years),

These results of the analysis are illustrated in Figure 11 showing the time series of excess deaths from 2000 to 2021, computed using method 2C, for older age groups. The figure on the left shows the time series of excess death rates in percentage while on the right, the normalised excess death rates are shown. The normalisation is achieved by assuming excess death rates are normally distributed. Excess deaths from 2000 to 2019 are in-sample while excess death rates for 2020 and 2021 are based on the baseline that extrapolates the liner regression from 2000 to 2019.

[2] For instance using the whole 1960 to 2019 period.

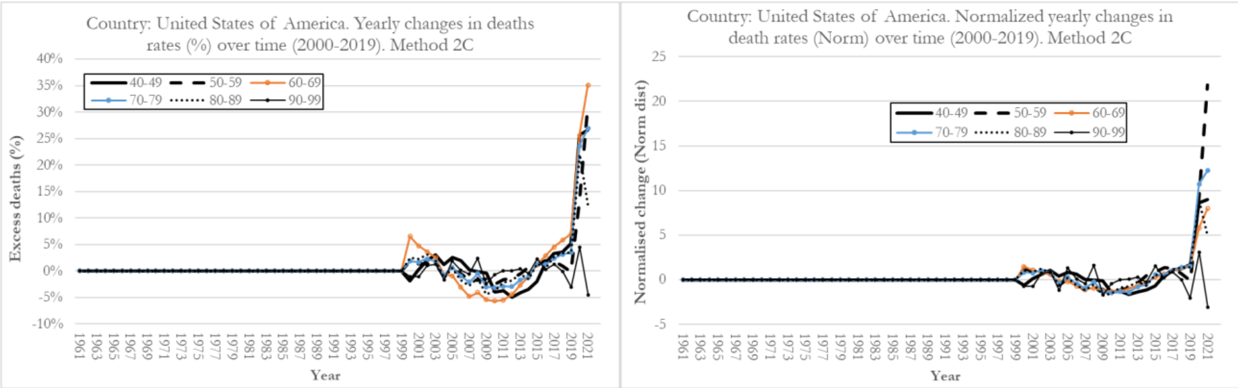

Figure 11 - Yearly excess death rates relative to regression fit from 2000 to 2019. Left: Percentage of excess death rates. Right: Normalised excess death rates. Excess death rates for 2020 and 2021 are computed by extrapolating the regression fit for the in-sample period.

Excess death rates vary between -5% to 5% per year from 2000 to 2019. In 2020 and 2021, as similarly observed with the previous methods for establishing the baseline, excess deaths had a large jump. We can observe that 2020 and 2021 were abnormal events as excess deaths reached 20% to 35% in age cohorts from 40 to 89. These changes had a high statistical significance as shown in Figure 11 – Right.

Excess death rates in 2020 and 2021 using method 2C.

Figure 12 shows the increase in excess death rates for 2020 and 2021 when using the baseline adjustment defined in method 2C. The results are very similar as when using method 2A and 2B with some minor differences. Again, we observe that for individuals aged 15 to 79 death rates saw larger rises in 2021 than in 2020 which is inconsistent with the introduction of Covid-19 vaccines and improved treatments.

For 2021, the highest rises in death rates of close to 40% occurred for the 15-19 age group, 35% for the 60-69 age group and 33% for the 30-39 age group. Individuals from 15 to 79 experienced a rise in excess death rates ranging from 25% to 40%. Only for the 90-99 age group did death rates in 2021 drop below the adjusted baseline.

By looking at the data in terms of the normalised change in death rates (Figure 12 - Right), we observe that the rise in death rates in 2021 for 50-59 age group corresponds to a 23 standard deviation event while the rise in the excess death rates for ages 15-89 are about 5 standard deviations or more. This is a very strong signal for these age groups. For younger age groups 5-9 and 10-14 the excess death rates have a low statistical significance, in similarity with the older 90-99 age group.

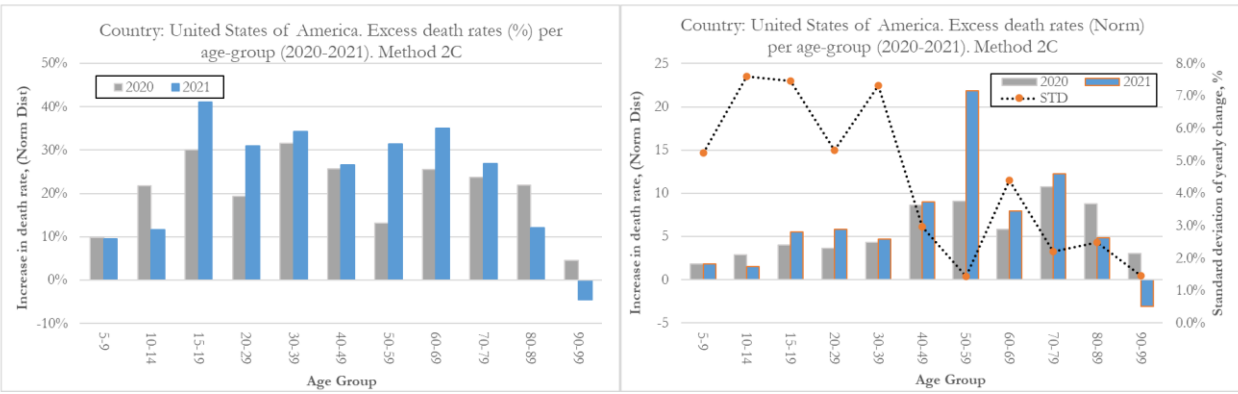

Figure 12 - Excess death rates for 2020 and 2021 using method 2C. Left: Percentage of excess death rates. Right: Normalised excess death rates. The chart also shows the standard deviation of changes in excess death rates from 2000 to 2019.

4. Comparing method 1 with method 2

In this section we'll compare the excess mortality (in percentage) computed using method 1 and method 2. Table 1 and Table 2 show the comparison between excess deaths in 2020 and 2021 (using method 1) with excess death rates (using the different approaches of method 2).

As previously mentioned, the three different approaches when using method 2 estimate excess death rates using slightly different assumptions. Approach 2A is a conservative estimate (lower bound estimate) of excess death rates as the baseline used is the 2019 death rate[3]. Method 2C on the other hand could be too aggressive in estimating excess deaths rates as it extrapolates existing trends in death rates over a given time period. We believe that method 2B is a moderate estimate for excess mortality as it adjusts the 2019 baseline for the average compounded rate of decline in death rates. As each approach for method 2 captures a slightly different previous trend in death rates, it is reasonable to calculate a composite method 2 estimate for excess mortality that averages the three approaches.

2020					
Approach	**Method 1**	**Method 2A**	**Method 2B**	**Method 2C**	**Av Method 2**
Age group	Excess deaths	Excess death rate	Excess death rate	Excess death rate	Excess death rate
5-9	-10.1%	-1.0%	1.4%	9.8%	3.4%
10-14	7.6%	5.7%	7.6%	21.8%	11.7%
15-19	13.6%	14.1%	15.2%	30.1%	19.8%
20-29	15.1%	16.8%	17.1%	19.4%	17.8%
30-39	30.4%	21.0%	21.4%	31.6%	24.7%
40-49	19.7%	18.5%	19.7%	25.7%	21.3%
50-59	9.7%	13.1%	14.3%	13.1%	13.5%
60-69	24.9%	15.8%	17.2%	25.6%	19.5%
70-79	27.5%	17.1%	18.6%	23.7%	19.8%
80-89	17.4%	16.0%	17.1%	21.9%	18.3%
90-99	2.3%	6.4%	7.1%	4.5%	6.0%

Table 1 - USA - Comparison of the different methods for computing excess mortality for 2020.

The results shown in Table 1 illustrate the points made previously, namely, that excess deaths computed using method 2A are lower than those using method 2B and 2C. The results also show that method 1 produces much higher variability in excess deaths among the different age groups, due to small positive or negative biases introduced by the baseline. The 60-69 and 70-79 age groups show almost double excess mortality when compared to method 2A. This is because the large number of post-World War II baby boomers are rapidly increasing population size in these age groups, which introduces a positive bias in excess deaths. Similarly, the decline in the population in younger age groups (5-9 and 10-14) leads to generally lower estimates using method 1 than method 2.

Now, interpreting the results shown in Table 1 we're going to using the average of the method 2 estimates (last column in the table). We observe that all age groups exhibited positive excess mortality in 2020, albeit the 5-9 and 90-99 were low and without statistical significance. Age groups from 15 to 89 all showed rises in death rates between about 15% and 25%. Excess death rates in the 10-14 age group were about 12%. An interesting observation when looking at Table 1 is that the older age group 90-99 was not the one most affected by the SARS-CoV-2 pandemic, and that the most affected age group was 30-39, who are individuals at their prime.

When looking at Table 2 we observe that age groups from 15 to 89 all showed rises in death rates between about 20% and 33%, which was higher than in 2021. This result is strange as, assuming Covid-19 as the main cause of excess mortality in 2020, we would expect that natural immunity and the introduction of Covid-19 vaccines and

[3] This is a conservative estimate because death rates tend to decrease monotonically over time with improvements in life conditions and overall risk management knowledge.

treatments should have reduced excess mortality in 2021 relative to 2020. Excess death rates in the young 5-9 and 10-14 age groups were very low at about 1% - 2%, and negative for the older 90-99 age group.

2021					
Approach	**Method 1**	**Method 2A**	**Method 2B**	**Method 2C**	**Av Method 2**
Age group	Excess deaths	Excess death rate	Excess death rate	Excess death rate	Excess death rate
5-9	-13.0%	-3.6%	1.1%	9.5%	2.3%
10-14	-4.7%	-5.3%	-1.9%	11.6%	1.5%
15-19	20.2%	20.3%	22.7%	41.1%	28.0%
20-29	26.2%	28.6%	29.4%	30.9%	29.6%
30-39	35.0%	24.3%	25.1%	34.3%	27.9%
40-49	19.5%	18.4%	20.7%	26.6%	21.9%
50-59	26.4%	31.2%	34.1%	31.3%	32.2%
60-69	34.2%	22.8%	25.9%	35.1%	27.9%
70-79	33.8%	17.6%	20.6%	26.9%	21.7%
80-89	7.9%	4.9%	6.9%	12.1%	8.0%
90-99	-2.5%	-3.9%	-2.7%	-4.5%	-3.7%

Table 2 - USA - Comparison of the different methods for computing excess mortality for 2021.

Figure 13 compares method 1 and method 2 (average estimate) for the estimates of excess mortality in 2021. The figure allows us to visualise the previously mentioned differences between both methodologies. First, method 1 estimates are much more volatile from age group to age group while method 2 is much more stable. Furthermore, one can clearly observe the positive bias in excess mortality for age groups 60-69 and 70-79 due to increases in population in those age groups; and the negative bias in excess mortality in younger age groups, due to decreasing populations. Overall, we believe that method 2 is much more accurate and robust in estimating excess deaths. However, caution is required as population estimates are just that, estimates, and can vary substantially depending on the data source.

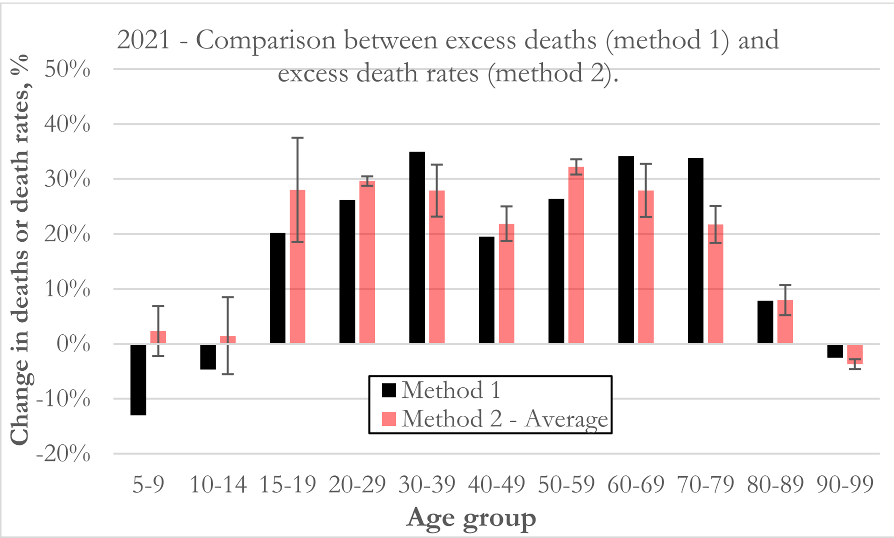

Figure 13 – USA: Comparison of method 1 with the average of method 2 approaches for computing excess mortality for 2021.

5. Concluding remarks

In this study we analyse the dangers and pitfalls of using the standard measures for excess deaths and how they can lead to misguided policy decisions. In addition, we propose an alternative way of computing excess deaths based upon computing **excess death rates** instead of **excess deaths**.

We show that using prior N-year average of deaths as baseline (method 1) is inappropriate in estimating excess mortality. The volatility of the changes in deaths as well as the problem of age group populations oscillating over time, makes this measurement inaccurate, leading to severe biases. This could then lead to misguided assessments and consequently erroneous policy actions.

Death rates tend to decline over time, for a given population age cohort, as living conditions have generally been improving since after the Second World War (with some exceptions). Estimating excess mortality by computing excess death rates obtains a much clearer signal, this is, a much more accurate estimate for excess mortality. This is because changes in death rates do not trend upwards and downwards over time and are much less volatile from year-to-year than changes in deaths.

Consequently, by using the death rate in 2019 (method 2A) as a baseline to estimate excess death rates in 2020 to 2022 will tend to be a lower limit on excess deaths. A more realistic assessment is to compute excess death rates in 2020 to 2022 relative to a baseline that adjusts 2019 death rates for average yearly rates of improvement in death rates (method 2B), or, use a baseline that is the continuation of a previous trend in excess deaths (method 2C).