December 6, 2020

Dean V. Williamson
dvwilliamson@economicdesign.net

COVID Mortality in the United States:
Did It or Did It Not Induce Excess Mortality?

- I examine weekly counts of fatalities publicly posted by the Centers for Disease Control (CDC) for the weeks ending January 10, 2015 through October 10,2020.
- The year 2020 war emerging from a mild 2019/20 cold-and-flu season and was not generating mortality in excess of (estimated) baseline mortality until the advent of COVID-19 in April 2020.
- Excess mortality through October 10 amounts to very nearly 250,000. Given 2020 was emerging as a mild year, it is not unreasonable to pose the assumption that one can attribute all excess mortality to the COVID phenomenon. Yet, the phenomenon is complex in that it appears to have induced a non-trivial volume of non-COVID fatalities in addition to a volume of fatalities attributed directly to COVID.
- The CDC attributes very nearly 195,000 fatalities to COVID through October 10, 2020.
- Nearly 160,000 people who died with a COVID infection or even by COVID itself would have died anyway (as of October 10, 2020).
- We would like to know how many people who had succumbed to COVID would have died anyway, but the data do not support point estimates of such a number. The best we can do is frame that number. That number could range from zero to 160,000. That 160,000 is the same 160,000 who died "with" or "by" COVID and would have died anyway.
- COVID fatalities account for excess fatality ranging from a high of 195,000 to a low of 35,000 (which is 195,000 less the 160,000).
- Nearly 410,000 people who died had been infected with COVID. The deaths of about 215,000 of these people were attributed to other, non-COVID causes.
- Excess mortality exceeds COVID fatalities by about 55,000 through October 10. It also turns out that non-COVID mortality tracks the peaks and troughs of COVID fatalities. Why would this be? As some observers have argued, some people may not have secured care that they otherwise would have secured; they ended up succumbing to otherwise avoidable non-COVID events. Alternatively, some number of these people may have been infected with COVID. The extra immunological burden of COVID may have contributed to their deaths even though they would appear as non-COVID fatalities. The data do not support exercises that could disentangle the effects of forgone care or extra immunological burden.
- Excess mortality accounts for nearly 10% of all mortality through October 10. Less than 1% of the population perishes each year.

- Comparisons of COVID-19 to the Spanish Flu of 2018 are inappropriate in that (1) the median age of death attributed to Spanish Flu was 28 whereas the median age of death attributed to COVID is about 80; (2) the death toll from Spanish Flu was a much larger.
- Results reported here depend on the assumption that the susceptibility of the population to disease and mortality from one year to the next is comparable, but one can imagine that a population emerging from a sequence of two mild cold-and-flu seasons, such as the population that entered the COVID pandemic, would be less healthy and more susceptible to COVID. Had the previous cold-and-flu seasons been harsher, the effects of COVID may have been markedly diminished.
- Total mortality in 2021 will likely be diminished and will likely trace a trajectory well below the estimated benchmark mortality, because COVID will have already taken away the most vulnerable people.

In November John Hopkins University posted a notice about a study that purported to demonstrate that fatalities attributed to COVID-19 have *not* appreciably contributed to total mortality in the United States. Indeed, the researcher, economist Genevieve Briand, went on to suggest that, during the peak of COVID fatalities in April, an appreciable volume of non-COVID fatalities had actually been attributed to COVID. Among other things, an appreciable volume of fatalities from heart attacks and other circulatory conditions appear to have gone underreported at just the time that COVID fatalities were ramping up. Taken all together, the COVID phenomenon amounted to a relabeling of fatalities that would have occurred in 2020 absent the advent of COVID. Thus, while COVID fatalities might have appeared to spike, total fatalities might not have changed much. One is invited to conclude (it seems) that while the spike in COVID fatalities would appear to be a source of much merited distress, the reality is that a proper accounting of total fatalities shows no appreciable increases. The distress is not merited.

I have not had a chance to see an actual paper, but I have stumbled upon Dr. Briand's video presentation of November 11. The presentation, titled "COVID-19 Deaths: A Look at U.S. Data", is posted here: https://www.youtube.com/watch?v=3TKJN61aflI

Over the previous day I have taken some time to review much the same data that Dr. Briand had secured. Dr. Briand and I both work out of data publicly posted by the CDC. The CDC sits on top of much richer data and would be much better situated to study the effects of COVID-19 on total mortality, but those of us outside of the CDC must venture forth with the data we have, not with the data we wish we had.

In this short note I advance some conclusions, observations and hypotheses that may yet inform further research. I offer conclusions that I think the data can support. I offer observations about patterns in the data that can inform how we think about the processes that generate mortality statistics. I then pose some ideas about how one might expect mortality statistics to evolve over the coming year.

My first conclusion is that it is hard *not* to discern an effect of COVID-19 on total mortality in 2020. The year 2020 appears to have been emerging from a mild 2019/2020 cold-and-flu season and was on pace to generate nothing more than a baseline count of total fatalities – one cannot discern evidence of "excess" mortality in early 2020 – but in April 2020 that changed. At the same time, however, the mortality data are consistent with what everyone already knows: COVID's toll has been concentrated on people who were already bearing a heavy disease burden. No surprise these people tended to be elderly or otherwise immunosuppressed. Yet, the conclusion that COVID did induce an increase in total mortality would imply that these most vulnerable people would have lived a little longer – but not obviously much longer. How much longer remains a question: one month, one year, two more years in a nursing home?

The data examined here will not support a finely-tuned answer to the question of "How much longer?", but just asking it is important, because it imposes some discipline on our characterization of the burden of the disease on society. Many observers have breathlessly compared the coronavirus phenomenon to the Spanish Flu of 1918. The comparison reflects something less than discipline. The CDC estimates that the Spanish Flu took away about 675,000 Americans. Proportionally, that would come to about 2.3 million Americans in 2020. The greatest part of the tragedy, however, was the fact that the median age of death attributed to the Spanish Flu was about 28. The Spanish Flu took away people just coming in to their physical prime. Indeed, one might be shocked to know that more American soldiers fighting in France in 1918 succumbed to Spanish Flu than had succumbed to German bullets and shells. No less shocking is the fact that these young people were the opposite of immunosuppressed. Their strong immune systems induced "cytokine storms", immune responses so strong that the victims ended up drowning in fluids accumulating in their lungs.

Meanwhile, the median age of death attributed to coronavirus is either 79, 80, 81, 82 depending on what country one looks at. (In Italy its 82.[1]) In all cases the median age of death attributed to COVID-19 is very nearly the median age of death from plain old death. In other words, COVID really is taking away the most vulnerable. Harsh, but not as harsh as Spanish Flu in that the Flu deprived people of decades of life and imposed disability on many of the young survivors. Indeed, the age distribution of COVID fatalities is more forgiving than even that of a harsh flu season in the United States in that the flu will take away a high proportion of young children – and we do not close schools to accommodate the flu. American soldiers in France and a modest number of young people at home during, say, the 2017/18 cold-and-flu season may have been deprived of 50, 60, 70 years of life. Comparing COVID to Spanish Flu is worse than "not helpful".

To recount: COVID has taken a toll of people who yet had some modest amount of time left to live. If all of these people really were on the absolute verge of death – if they were likely to have imminently died anyway – then COVID would have had no effect on total mortality. But it has

[1] As of December 2, 2020: https://www.epicentro.iss.it/en/coronavirus/bollettino/Report-COVID-2019_2_december_2020.pdf

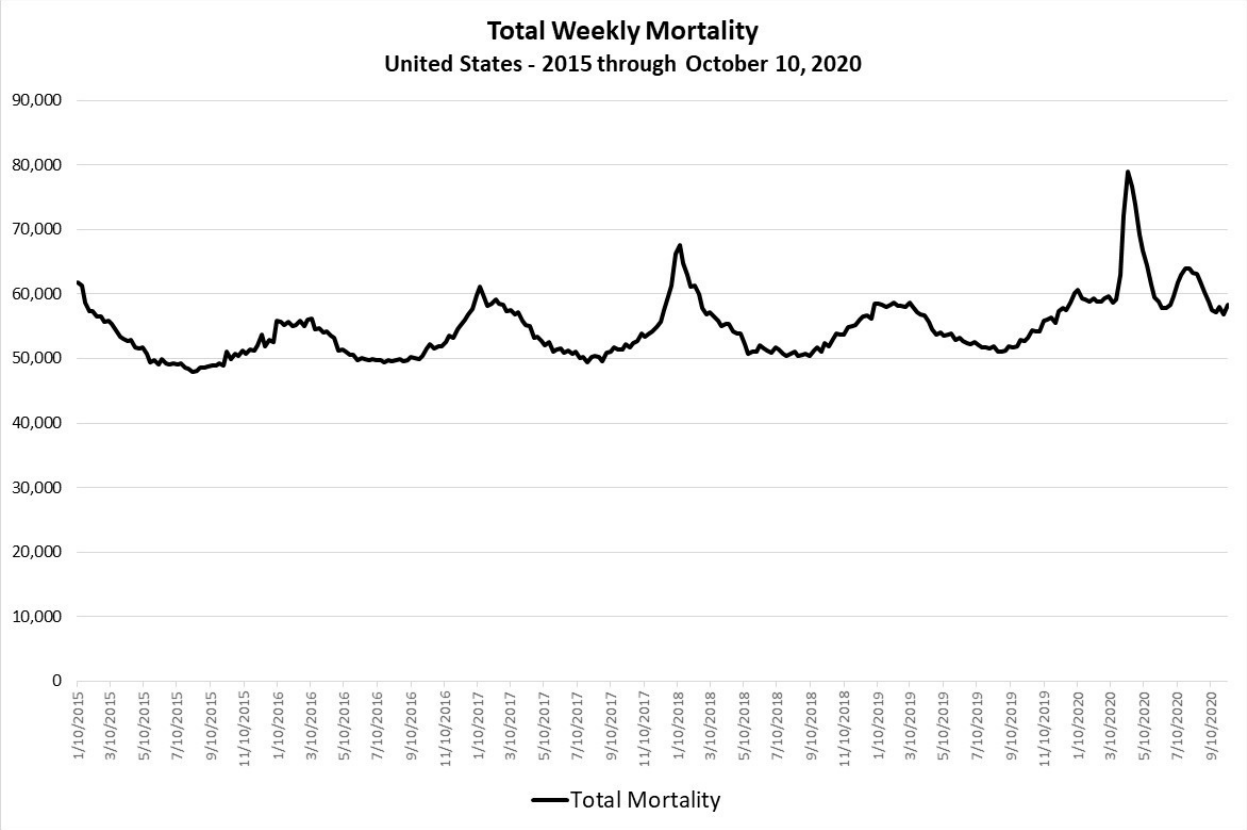
had some discernible effect. The data are consistent, however, with that effect being far less harsh than a simple count of fatalities might suggest. The people who have succumbed to COVID-19 may, on average, have had some time yet to live, but it is not obvious that they would have had much time. Getting a finely-tuned estimate of the time they would have had would at least require a thoughtful accounting of underlying morbidity and age. It is something the CDC would be better equipped to pursue given its superior access to data.

My principal observation is that mortality data exhibit obvious seasonality across the most prominent causes of death. That alone might strike one as a little surprising. Why, for example, should cancers exhibit seasonality? More striking, however, is the fact that seemingly distinct causes of death exhibit much the *same* seasonality. Respiratory conditions like flu or pneumonia may exhibit certain expected seasonality with deaths rising in the colder seasons and retreating in the warmer months. But deaths attributed to circulatory events (heart attacks, strokes and such) exhibit the same seasonality. Even cancers exhibit the same seasonality albeit less dramatically.

One thing one can get from this is that a salient aspect of old age is immunosuppression. Even cancers reflect immunosuppression. Before effective treatment protocols for HIV became available, the people who acquired AIDS – Acquired Immune Deficiency Syndrome – did not die from AIDS. Not directly. They succumbed to opportunistic infections and unusual cancers. And this raises a question about how we should account for fatalities induced by AIDS. Did a person die of AIDS or from Kaposi sarcoma (a cancer)? Alternatively, did that person succumb to an unusual pneumonia? It is no accident that the medical field innovated concepts like "AIDS related cancers". Assigning causes of death is an imperfect business.

The data are consistent with the idea that that people, immunosuppressed or not, are under more duress in the colder months. Immunosuppressed individuals, already under the duress of dealing with heart conditions or other conditions, find themselves under even more duress. They get a bad cold, and the added stress of the infection kills them. Maybe the cold induces a heart attack. But, if we are to assign a single mode of death, what should it be? A generic diagnosis of "old age" would have something to recommend it insofar as one could credit death to immunosuppression. Immunosuppression would also account for the tight correlation of the frequency of seemingly disparate modes of death.

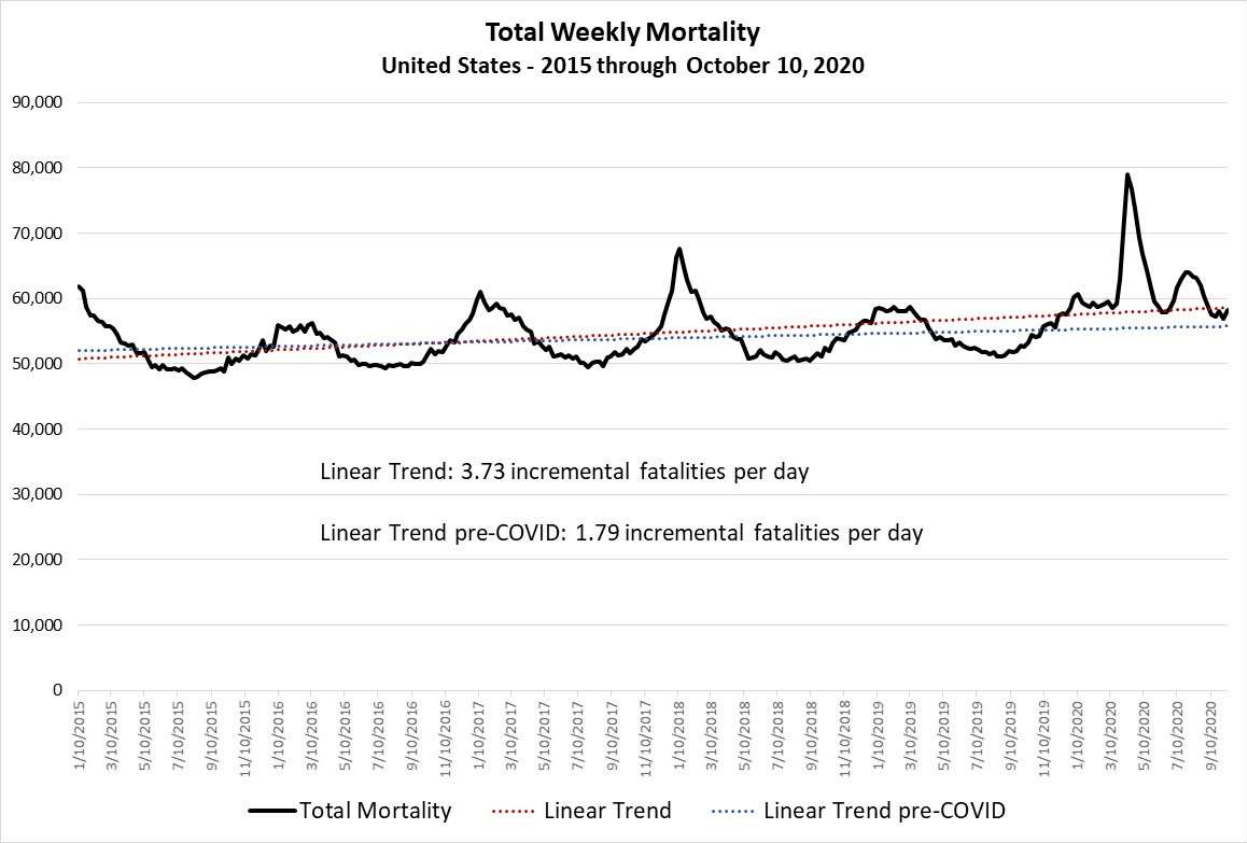
On to the data: I build up results through a series of graphs. The first represents total weekly mortality in the United States for weeks ending January 10, 2015 through October 10, 2020. I ignore data available after October 10, because they appear incomplete as of the writing of this note.



What would a Martian just landing on Earth today make of this graph? Visual inspection alone reveals obvious seasonality in the data. Fatalities peak during "cold-and-flu season" and moderate through the warmer months. The living is easier in summertime with fatalities in each year coasting to a nadir in August. Mortality tends to peak in January. That peak can be conspicuous, as in January 2015, January 2017 or January 2018. In contrast, the cold-and-flu seasons of 2015/16, 2018/19 and even 2019/20 appear modest. Meanwhile, the year 2020 does stand out in that the 2019/20 cold-and-flu appears to have been modest, but mortality then spiked in April 2020. This spike is the first discernible evidence of COVID-19.

Mortality peaks twice in 2020, in April and then again in August. In August one might have expected total weekly fatalities to have settled on a seasonal nadir a little over 50,000. Instead, fatalities peaked at nearly 65,000. Something was happening.

One way to begin characterizing whether or not mortality had increased after COVID injected itself in the population is to compare trends. For starts, I illuminate linear trends pre-COVID and with COVID. Consider the following graph.



In this graph I add two linear trends, a "pre-COVID" trend line fitted to data ranging from January 2015 through March 2020, and another linear trend line encompassing all data from January 2015 through October 10, 2020. The linear trend line rises at a rate of 3.73 extra fatalities per day. Evidence that mortality is increasing, on average, day-by-day is uninteresting given that population is growing appreciably year-to-year. Of some interest, however, is the fact that the linear trend before the advent of COVID was 1.79. Is the more than doubling of the trend from 1.79 to 3.73 interesting? The comparison of the one trend line to the other does not conform to an orthodox analysis of a structural change in the underlying processes that generate mortality, but the doubling suggests that there had, in 2020, been an important innovation in those processes. It is not obvious, however, that that innovation amounts to more than a passing episode (the coronavirus comes once and then goes away, say) or becomes an established feature of the mortality process. But, even if it does become established for the long term, it is not obvious that the mortality process may induce adaptations (broad-based immunity, for example) that relegate the virus to little more than noise in the data. It would be nice to be able to forecast the evolution of the mortality process, but the available data really don't support any reliable exercises.

Barring forecasts, can one at least craft a plausible counterfactual?: Absent the advent of the coronavirus phenomenon, what would total mortality have looked like to date in 2020? I would affirmatively suggest that the data can support the crafting of a benchmark – something much

better than a mere linear trend – against which one might contrast the recent and short experience of COVID-induced mortality. Specifically, in place of a linear trend, I use the pre-COVID data to craft a more elaborate benchmark. The benchmark curve accommodates the seasonality of mortality processes and makes some accommodation for at least one dynamic aspect of the mortality process, population growth. The idea is that, so long as the profile of age and morbidity in the population is comparable for one year to the next, then total mortality should roughly track changes in population. As a rough approximation, such an assumption might be reasonable. I revisit this issue further below.

I crafted a benchmark based on a non-linear regression that accommodated seasonality in a mechanical way: it includes of sine wave. Accommodating a sine wave requires the inclusion of three variables, one each to accommodate a good fit for amplitude, frequency and a phase shift. The regression does not include any explicitly dynamic components (it features no lagged variables or lagged error processes). It amounts to a purely descriptive exercise. But, does it fit the pre-COVID data well, and does it provide a plausible benchmark against which to contrast six months of COVID experience? I would suggest, yes.

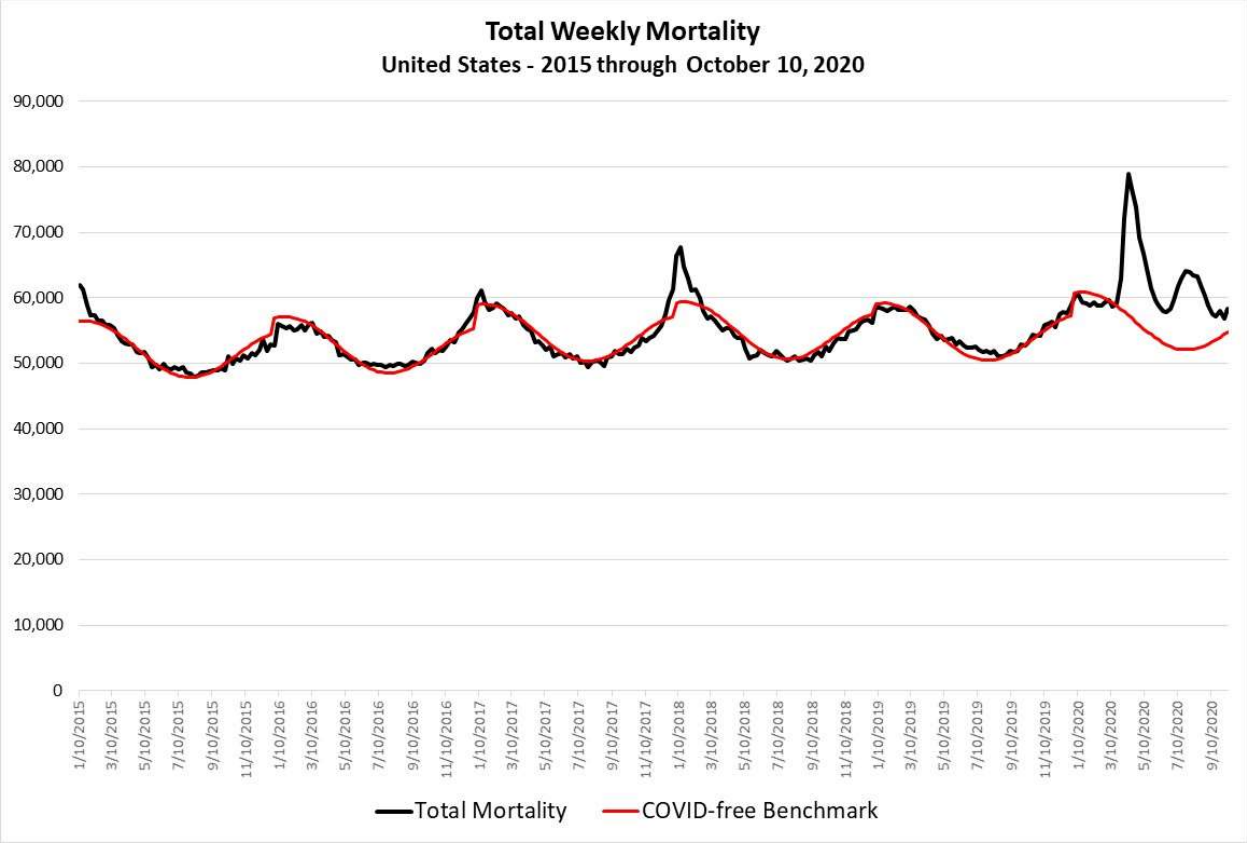
I fit the following equation to weekly data for the weeks ending January 10, 2015 through October 10, 2020:

$$\text{Total Mortality}_t = \alpha + \theta\text{Population}_{year} + \beta t + \gamma\text{Population}_{year}\sin\left((\delta + \sigma t)\frac{2\pi}{365.25}\right) + \varepsilon_t$$

where t = week ending date and Population is indicated by year.

Given the scaling factor $\frac{2\pi}{365.25}$, one can expect the estimate of the frequency coefficient σ to be very close to 1. (The 99% confidence interval of the point estimate is [0.9925 – 1.0103].) The phase shift coefficient δ will indicate the phase shift enumerated in days. (It shifts the curve 56 days left of January 1, 2015. The curve thus hits inflection points roughly in early November and early May.) The term $\gamma\text{Population}_{year}$ accommodates the prospect that the amplitude of the sine wave will increase as population increases. It captures a difference between maximum weekly mortality and minimum weekly mortality of about 8,000 in a given year.

I append the mortality benchmark to the following graph:



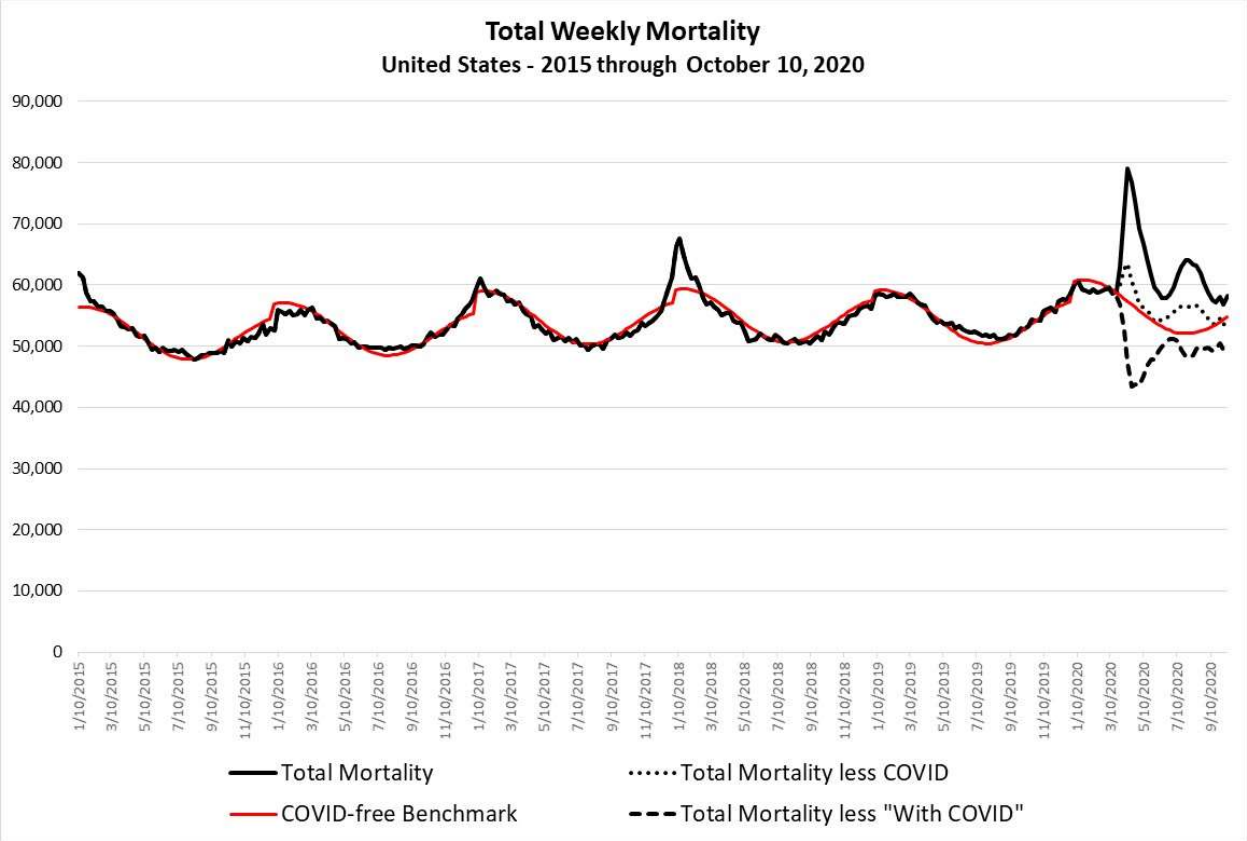
The benchmark does not capture spikes such as the spikes in January 2015, January 2017 or January 2018, but it does capture the seasonal trend, and it goes some way toward capturing population growth. The value of the benchmark, however, is in its contrast with actual mortality after the advent of COVID. The extent to which actual mortality exceeds the benchmark constitutes a measure of "excess mortality". The 2017/18 cold-and-flu season featured an episode of excess mortality. The COVID experience induced a more severe episode of excess mortality. In other words, the COVID experience really does appear to have induced mortality in excess of what one might have expected were 2020 to have proceeded unperturbed from its modest cold-and-flu season early in the year. But 2020 was perturbed, and that perturbation (COVID-19) shows up conspicuously in the data. Even so, COVID is not a great plague like the great plagues of the 14th or 17th centuries. Those *actually* great plagues could take away well more than half of a population over a sequence of a few years. In contrast, COVID fatalities may account for 0.059% of the population in 2020, a toll nearly 900 times lower than that of a given great plague.

I note that the population that entered April 2020 may have been particularly susceptible to COVID. That population was coming off of a sequence of two mild cold-and-flu seasons. The population would thus enter April 2020 both older and sicker than a population that would have had to put up with harsher cold-and-flu seasons in 2018/19 and 2019/20. One would need access to richer data in order to craft controls for changes in the underlying susceptibility of the

population to infectious disease from season to season. All of the results reported here thus depend on the assumption that populations from one year to the next are comparable. But, given the (likely) prospect that the population entering April 2020 was sicker than the populations of 2019 and (especially) 2018, the results will appear worse than they would otherwise be. I note, for example, that excess mortality (as estimated here) in January - February 2018 was very nearly 27,500 whereas mortality was *not* in excess in either January - February 2019 or January - February 2020 by over 5,000 and 10,000, respectively. One could suggest that fuel for the fire had been building up for two years. I do note, however, that I make some effort to control for population growth, the idea being that larger populations are more likely to produce more fatalities. Controls for population growth may accommodate, if not entirely resolve, the matter of the accumulation of "fuel for the fire".

Conspicuous or not, the COVID phenomenon is not the great plague that journalists or even the experts in government would make it out to be. The gap between the benchmark and mortality during the COVID episode through October 10 represents 249,737 fatalities. Given it appears that 2020 was on track to be a mild year, one can reasonably argue that one can attribute all of those 249,737 fatalities, directly or indirectly, to the coronavirus experience. It turns out, however, that only 195,092 of those fatalities have been attributed directly to COVID. Another 54,645 emerge as fatalities indirectly induced by COVID. Specifically, it appears that individuals and governments made adaptations that induced harm well beyond the COVID toll itself.

To see this, consider the following graph:



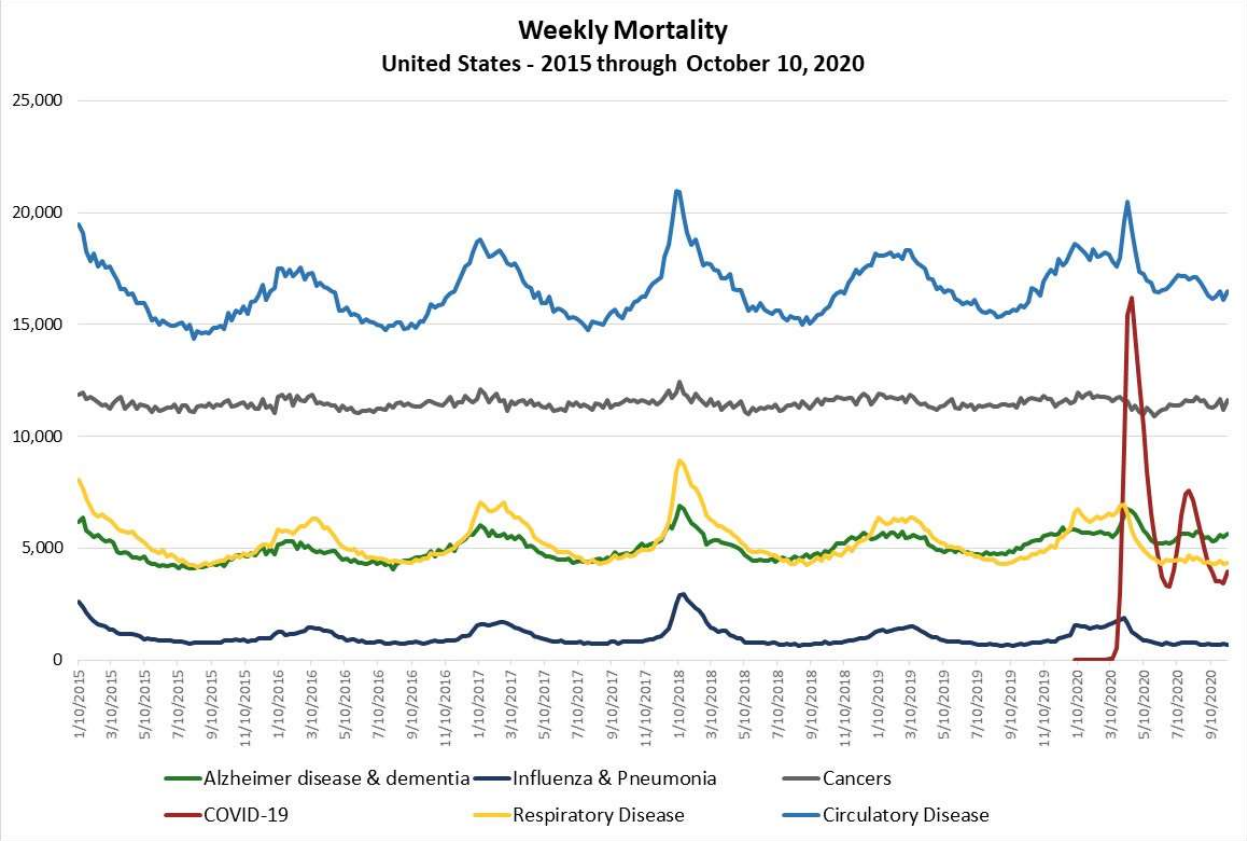
This graph features two extra trajectories: total mortality less mortality attributed to COVID ("Total Mortality less COVID") and total mortality less all mortality of people who died with COVID infections whether or not they had actually succumbed to COVID ("Total Mortality less 'With COVID'"). Note that there is a gap between the benchmark and Total Mortality less COVID. That gap represents the 54,645 in excess fatalities not attributed to COVID. (Let's call them "excess non-COVID fatalities".) Meanwhile, the gap between benchmark mortality and Total Mortality less "With COVID" indicates 158,010 people who had been infected with COVID but would have died even absent the advent of COVID in April 2020. Note, however, what that number 158,010 does *not* imply. It implies neither that any particular 158,010 people had been infected with COVID nor that some of those 158,010 had not actually succumbed to COVID. It does imply that as many as 158,010 deaths may have been attributed to COVID, but those same people would have died (by some other cause) anyway.

What is going on? If one accepts the benchmark as a reasonable measure of expected mortality since the advent of COVID in April 2020, then one has to conclude that excess mortality from April 2020 through early October 2020 was nearly 250,000. COVID had a discernible effect. It is not the case that COVID fatalities supplanted fatalities that would have otherwise happened on a one-for-one basis. But COVID could have supplanted a large number of fatalities – indeed, as many as 158,010. Not likely, but how about 80,000? That is not implausible, but absent much

more elaborate data, it's hard to impose more structure on this question: How many people who did succumb to COVID would have died from some other cause absent COVID?

But, note what else is going on. Non-COVID fatalities also spike just when COVID fatalities spike. The data alone do not provide explanations, but two explanations would seem obvious. First, some observers have suggested that COVID might indirectly induce non-COVID fatalities were people to forego the healthcare that they would regularly and otherwise secure. They might neglect to secure care, because healthcare providers had denied them care (in order to preserve capacity to accommodate a prospective surge in demands for COVID care), or they themselves might have been too afraid to venture out of the house to healthcare facilities to secure care. Another rationalization would be that many of these non-COVID fatalities were actually "with COVID". Specifically, individuals may have been infected; the extra immunological strain of the infection may have aggravated other conditions; Actual COVID infections may have ultimately contributed to many fatalities without being identified as the principal cause of fatality.

To see this last rationalization in the data, consider the next graph:



The CDC data afford some insight into the more prominent modes of fatality. No surprise these modes comprise the conditions that generally befall the elderly. In this graph I aggregate

respiratory conditions, cancers, and circulatory conditions. I do report "Influenza & Pneumonia" separately, even though they comprise respiratory conditions. I also feature "Alzheimer disease & dementia" as well as deaths attributed to COVID-19.

Putting aside COVID-19: A striking feature of these data is that they all feature seasonality – even "Cancers" exhibits seasonality – and each trajectory features the same seasonality. Fatalities generally peak in January, and the living is easy in August. Note, however, that "Alzheimer disease & dementia" as well "Circulatory Disease" track the COVID peaks in both April and August. The living might normally be easy in August, but not in 2020. People are succumbing to heart conditions and dementia just as the country is experiencing its "second wave" of COVID fatalities. People were also more likely to succumb to heart conditions and dementia during the first wave of COVID fatalities in April.

Discussion –

Coming in to this exercise I was open to the idea that COVID fatalities were largely displacing fatalities that would have occurred absent the advent of COVID in 2020. That is the kind of proposition that Dr. Briand has advanced in her own analysis of the CDC data. Evidence that total mortality in 2020 had not appreciably increased would be abundantly consistent with that proposition. To explore this proposition, one would have to craft a counterfactual: How many people would have died absent the emergence of COVID? I crafted a benchmark of weekly mortality. The difference between the benchmark and actual mortality constitutes a measure of "excess" mortality.

It is hard to *not* conclude that COVID has induced excess mortality in 2020. That said, the effects are complex. While the CDC attributes nearly 195,000 fatalities directly to COVID (through October 10, 2020), it is not immediately obvious that one can attribute all (or even most) of that toll to *excess* mortality. Absent COVID, as many as 160,000 of those 195,000 people may have died in 2020 from other causes. Suppose, however, that we do credit all 195,000 COVID fatalities to excess mortality. That would still leave nearly 55,000 excess non-COVID fatalities. Moreover, it looks like those 55,000 cases are disproportionately made up of heart conditions and cases of Alzheimer's/dementia. These fatalities peak at the same two times that COVID fatalities peak, in April and in August. August is particularly telling, because that's when fatalities by all major causes, including heart conditions and dementia, should be at their lowest for the year.

It is difficult not to conclude that the COVID induced as many as 55,000 non-COVID fatalities. Debate about the mechanisms driving those other, non-COVID fatalities remains open.

Let's revisit the 160,000 people who died "with" or "by" COVID but who would have died anyway in 2020. Suppose the deaths of 80,000 had actually been attributed to COVID. Then we could only attribute 195,000 – 80,000 = 115,000 of those direct COVID fatalities to toll of

excess fatalities. That would leave us with well more than 55,000 excess fatalities. Specifically, excess non-COVID fatalities would total 250,000 - 115,000 = 80,000 + 55,000 = 135,000. We might thus conclude that the burden of unusual peaks of non-COVID fatalities, especially from circulatory conditions and Alzheimer's/dementia, was severe. Indeed, this burden of 135,000 excess non-COVID fatalities would even exceed the 115,000 of excess fatalities directly induced by COVID.

Evidence of the indirect toll of excess non-COVID fatalities raises, as noted, the tricky question of the management of elder care during the pandemic. Were the vulnerable denied essential care? Were they discouraged from securing essential care? Was this really going on while public figures were carrying on about how we need to protect our most vulnerable populations?

The data cannot support point estimates of the toll of fatalities indirectly induced by COVID, but the suggestion is that that toll ranges between 55,000 and 215,000 (which is 55,000 + 160,000).

The COVID phenomenon is abundantly discernible in the "big picture" – but it does not comprise the entire picture. Not even close. I note that each week that about 58,000 people perish in the United States. That is like a Vietnam war – every week. We do not fetishize each of the 58,000 +/- 4,000 fatalities. We have only been fetishizing the COVID fatalities. A problem with that is that it creates demand for government to "Do Something!", but it is not obvious that government intervention has itself not induced more harm than benefit. As it stands, the CDC data reveal a sizable toll of non-COVID excess fatalities – a sizable toll of non-COVID fatalities that has nonetheless been induced by the COVID phenomenon. A question remains about what portion of those 55,000 derive from the poor management of elder care. A question also remains if as many as 215,000 fatalities could be characterized as "excess non-COVID fatalities". How many of those 215,000 fatalities were induced by poor management of elder care or by counterproductive government interventions?

Questions about the extent of the mis-management of elder care (if any) merely underscores the fact that our collective understanding of the COVID phenomenon remains poor. Characterizing the trajectory of the disease is hard enough, especially where there are competing political demands to both credit and dis-credit government interventions. The disease will diminish and may even disappear *on its own accord* with or without the application of vaccines. As it naturally diminishes, governments will demand some measure of undue credit.

One reason the disease will naturally diminish is that the population entering 2021 is likely healthier than the population that entered 2020. Excess mortality will likely be discernibly negative in 2021. Such a result would be consistent with (a) COVID having concentrated its toll on the most immunosuppressed (and, thus, vulnerable) part of the population in 2020 – we can likely agree that that is true – and (b) an appreciable share of that most vulnerable population would have lived to see 2021, but not much longer. Such a forecast would seem to be sharply contrary to the expectations that the chief of the CDC, Robert Redfield, seems intent on instilling in us. In a presentation hosted by the US Chamber of Commerce on December 2, the CDC chief

averred, “The reality is December and January and February are going to be rough times. I actually believe they’re going to be *the most difficult in the public health history of this nation*, largely because of the stress that’s going to be put on our healthcare system.”.[2] (Emphasis is my own.) But the country has seen more severe strains on less capable healthcare systems: Spanish Flu 1918? Asian Flu 1958? Hong Kong Flu 1969? And what of the perennial scourge of measles and polio and outbreaks of small pox? What of the scourge of malaria, which had been endemic all over the country into the early 20th century? The CDC’s original mission, in fact, was to mitigate malaria. The director should know better. Are there no adults anywhere?

Data Sources –

https://data.cdc.gov/NCHS/Weekly-Counts-of-Deaths-by-State-and-Select-Causes/muzy-jte6

https://data.cdc.gov/NCHS/Weekly-counts-of-death-by-jurisdiction-and-cause-o/u6jv-9ijr

https://www.census.gov/

https://www.epicentro.iss.it/en/coronavirus/bollettino/Report-COVID-2019_2_december_2020.pdf

[2] https://www.youtube.com/watch?v=3BAVCKNeHAc&amp%3Bfeature=emb_title