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PANDEMICS

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ABSTRACT

Covid-19 is the single largest threat to global public health since the Spanish Influenza pandemic of 1918-20. Was the world better prepared in 2020 than it was in 1918? After a century of public health and basic science research, pandemic response and mortality outcomes should be better than in 1918-20. We ask whether historical mortality from pandemics has any predictive content for mortality in the ongoing Covid-19 pandemic. We find a strong persistence in public health performance in the early days of the Covid-19 pandemic. Places that performed poorly in terms of mortality in 1918 were more likely to have higher mortality today. This is true across countries and across a sample of US cities. Experience with SARS is associated with lower mortality today. Distrust of expert advice, lack of cooperation at many levels, over-confidence, and health care supply shortages have likely promoted higher mortality today as in the past.

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A Note on Long-Run Persistence of Public Health Outcomes in Pandemics

May 6, 2020

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Abstract: Covid-19 is the single largest threat to global public health since the Spanish Influenza pandemic of 1918-20. Was the world better prepared in 2020 than it was in 1918? After a century of public health and basic science research, pandemic response and mortality outcomes should be better than in 1918-20. We ask whether historical mortality from pandemics has any predictive content for mortality in the ongoing Covid-19 pandemic. We find a strong persistence in public health performance in the early days of the Covid-19 pandemic. Places that performed poorly in terms of mortality in 1918 were more likely to have higher mortality today. This is true across countries and across a sample of US cities. Experience with SARS is associated with lower mortality today. Distrust of expert advice, lack of cooperation at many levels, over-confidence, and health care supply shortages have likely promoted higher mortality today as in the past.

1. Introduction

The Covid-19 pandemic is the single largest threat to global public health and the global economy since the Spanish Influenza pandemic of 1918-1920. Was the world better prepared in 2020 than it was in 1918-20? It might be expected that in the intervening 100 years societies would have made great progress in predicting, containing, mitigating and managing pandemics (Morens and Fauci, 2007). However, public health specialists, even prior to 2020, were cautious, citing the threats arising from "hubris, isolationism and distrust" (Parmet and Rothstein, 2018).

The most recent global public health scares such as SARS, MERS, Ebola, and H1N1 influenza in 2009 were largely successfully contained without extraordinary levels of excess mortality at the global level. This track record suggests high preparedness and ability to manage pandemics. On the other hand, society has changed in the last 100 years and even in the last decade since the 2009 H1N1 pandemic.

Geographic mobility has increased dramatically over time and significantly so with respect to the years 1918-1920. International inter-connections have continued to grow even since 2002, but international cooperation is waning as exemplified by recent US policy. Modern methods of communication like social media, which have emerged in the last decade, complicate the search for accurate content and often create confusion. Distrust of expert opinion has also heightened in the last decade. In many western societies, including the US, experts have often been replaced with political appointees and civil servants have been granted minimal leeway. Moreover, health infrastructure and accessibility in many countries, even developed and advanced economies, was widely predicted to be incapable of meeting surging demands induced by a pandemic. Such bottlenecks can raise cumulative mortality when health care provides viable means of treatment.

In this regard, the public health response to the Covid-19 pandemic represents a significant test of whether modern public health systems can do better than they have done historically. Evidently, SARS-CoV-2 and the 1918 H1N1 influenza have different etiologies and epidemiology. Nevertheless, the two pandemics seem to be roughly similar in the magnitude of their case fatality ratios. An estimate of the case fatality rate (CFR) for Covid-19 is 1.34% while the CFR for the 1918-20 influenza has been estimated to be ≥2.5% (Verity et al. 2020 and Short et. al, 2018).[1]

Given these numbers, and modern levels of knowledge and know how, one might strongly expect better performance today. Given the estimated fatality rates, most would predict lower mortality at this point in the pandemic than in 1918-20. After all, humanity has a century of public health research and practice, along with experience gained from SARS, MERS and Ebola. Contingency plans have been formulated at the behest of the WHO and through national initiatives. Non-pharmaceutical interventions designed to lower peak mortality have been investigated and shown to be effective (Bootsma and Ferguson, 2007; Hatchett et. al, 2007; Markel et. al, 2007).

Recent data make us less sanguine. Figure 1 illustrates that many countries, especially advanced western countries, have had a difficult time in keeping mortality rates below the frontier defined by US mortality rates from flu and pneumonia in 1918 at similar stages in the pandemic. Similarly, Figure 2 shows a number of US states also witnessed mortality rates per 100,000 population above those witnessed in 1918 at a similar stage. These statistics give us pause to re-consider the persistence of pandemic mortality.

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[1] Case fatality ratios for the 1957 and 1968 influenza pandemics were roughly 0.27 and 0.15 (Centers for Disease Control and Prevention, 2007).

We emphasize that our goal in this paper is not to assess the level of mortality in one pandemic versus the other. There are obvious problems comparing distinct diseases and many data measurement issues. Neither do we wish to argue that Covid-19 will be worse than 1918-20. Instead, we compare relative outcomes across time. We ask whether historical public health performance has any predictive content for public health performance in a recent pandemic. We find that historical experience does help predict recent experience.

Our main findings correlate population mortality rates for Covid-19 today with mortality rates from influenza and pneumonia in the 1918-20 pandemic and with SARS in 2002-03. We do so in a broad sample of countries and for a large sample of US cities.

We find a strong persistence in public health performance in the early days of the Covid-19 pandemic. Places that performed poorly in terms of mortality during the "Spanish flu" were more likely to have higher mortality today. This is true across countries and across a sample of US cities.

On the other hand, there has been some recent success consistent with the possibility of learning over time. Countries that were more strongly affected by SARS in 2002-03 are likely to have lower mortality rates today, thus far, from Covid-19. These places are mainly in East Asia and have a recent memory of a potentially highly lethal pandemic. As we detail in the discussion, these successes (and failures) when compared to history depend upon a number of deeper social and political determinants. In short "mis-trust, isolationism and hubris" matter. These may not be persistent but, whether by coincidence or not, they are arguably present now in the case of the many nations, especially in many Western nations.

2. Methods

2.1 Data Collection

We collect data on country–level population mortality from influenza in 1918-20 and from Covid-19. Our baseline sample covers 22 countries. The sample is determined by availability of estimated mortality rates from 1918-20 influenza, other control variables, and whether a country had established a first death case or confirmed case for Covid-19. Therefore, our sample for cross-country comparison covers those countries subjected to Covid-19 relatively early on.

Data on total deaths from Covid-19 are expressed in numbers per 100,000 (CSSE Johns Hopkins University ,2020). Data on mortality in the 1918-20 influenza pandemic are also expressed in numbers per 100,000 population (Johnson and Mueller, 2002). These latter figures refer to total mortality from influenza between 1918 and 1920. It should be noted that these are not always deaths from influenza and pneumonia nor are they excess deaths

from all causes.[2] Variable quality of underlying official statistics is our key constraint. We added several data points for the 1918 pandemic from secondary sources including Singapore, Hong Kong and Korea. Deaths and confirmed cases of Covid-19 were last updated for US cities on April 25, 2020 and on April 17, 2020 for our country-data. Our data begin on January 21, 2020. The inter-quartile range of mortality in 1918-20 is 430-710 deaths per 100,000 population with a median of 610 and a mean value of 649. This compares to the interquartile range (as of 17 April, 2020) for reported Covid-19 deaths of 0.39 to 15.44 per 100,000 and a median of 5.01.

We supplement the country mortality data with population mortality rates from SARS in 2002-03, GDP per capita in 2018, population density in 2019, some measures of cultural differences such as an index of individualism in a country, and a dummy variable for a tradition of Confucianism. Places coded as Confucianist include mainland China, Taiwan, Hong Kong, Singapore, Japan and South Korea.

We also explore a historical data base of 46 US cities (Collins et. al, 1930). Influenza became a 'reportable' in September 1918. Prior to this detailed only exist for a small handful of states and cities. The total population in these cities is equal to 20.4 million or about 18% of US population. Data cover all of the largest cities in the US.

The mortality from the 1918-1920 influenza pandemic in these cities is expressed as monthly or weekly excess mortality per 100,000 population of 1920. We use weekly data for the period 10 September 1918 to 13 November 1918, covering the first six weeks of the 1918-20 pandemic for US cities. The excess mortality rates were the differences between the actual mortality rates and median mortality rates from influenza and pneumonia in previous non-epidemic years in those cities. We refer to deaths from influenza and pneumonia since diagnoses were often inexact at the time with the influenza virus often causing apparent death from pneumonia. The excess mortality rate from influenza and pneumonia serves as a good measure of the severity of the 1918 pandemic. To make data even more comparable to our data from Covid-19, we convert the weekly excess deaths to daily observations by linear interpolation within the week and calculated daily cumulative excess deaths since the first week of September, 1918.

We match the cities with continuous historical data to modern city or county-level data. One issue associated with the long-run city-level comparison is that deaths and confirmed cases of Covid-19 are reported mostly at the county-level. While Covid-19 data are separately reported for some cities in our sample (New York City, St. Louis, Richmond, etc.) most data is reported at the county level. For cities in the historical sample without separately reported Covid-19 data at the city-level, we use data from today for the

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[2] Barro, Ursùa and Weng (2020) rely on an original database of excess mortality from influenza and pneumonia and also total excess mortality. Our results below are robust to using their mortality data in our cross-country-sample.

corresponding counties where the cities are located in. For example, we pair the city of Detroit with Wayne County.

We set a threshold level of mortality at the city level of 0.5 per 100,000 for each pandemic. Event time and observations begin as per this threshold mortality rate. This threshold was chosen since this is the lowest recorded threshold for excess deaths from influenza and pneumonia we have available in the historical city-level data in 1918-20.

2.2 Data Analysis

Our first test finds significant persistence of public health performance across countries. In Figure 3, we plot the mortality rates from influenza 1918-20 against the average daily growth rates of the total reported deaths from Covid-19 in the first five weeks after each country reported their first death from Covid-19. We condition only on mortality 1918-20 finding a positive and statistically significant correlation (robust t-statistic = 2.74, adjusted R^2 = 0.21)

The scatter plot reveals that some countries performing poorly in terms of mortality in the 1918 pandemic, such as Spain and Italy, also experienced fast mortality growth in the recent Covid-19 pandemic. However, the persistence between 1918 influenza and current Covid-19 pandemic might not be a universal phenomenon for all countries. We note that some places such as Japan, South Korea, and Taiwan, fall well below the regression line, suggesting these countries are performing much better than what their 1918 performance predicted.

We carry out more formal regression analysis by controlling for several country-level economic, demographic, and cultural characteristics. Besides the country-level mortality in the 1918-20 pandemic, we also include these countries' mortality during the 2002-03 SARS pandemic. Our baseline result is reported in column (3) of Table 1.

Mortality rates in 1918-20 are positively associated with the growth rates of reported deaths from Covid-19 in the first five weeks (point estimate: 0.166, p-value: 0.029, 95% C.I. 0.02 to 0.031). We also find that the mortality rate from SARS is negatively correlated with growth rates of reported deaths of Covid-19 (point estimate: -0.162, p-value: 0.003, 95% C.I. -0.255 to -0.068). Similar results on persistence emerge (columns 3-6 of Table 1) when we switch the dependent variable to be the growth of confirmed cases of Covid-19 in the six weeks after the 10th reported confirm case.

All of these findings suggest that, even after conditioning on a number of observable characteristics, countries performing poorly in the 1918-20 pandemic tended to fail to control mortality growth of Covid-19 in the first months of the outbreak. On the other hand. There is some evidence of learning. The negative correlation between SARS and Covid-19 performance reveals that the countries hit harder by the more recent epidemic have been more successful in slowing down the development of Covid-19 in the first several weeks and months. This is suggestive evidence that countries learned from their more recent experience.

Next, we examine the persistence of public health performance in a group of large U.S. cities. We compare the early trajectories of population mortality rates in the 1918 influenza and the contemporary Covid-19 pandemic. Data are for 46 cities for which we have high frequency data in 1918.

In Figure 4, we plot the trajectory of the mortality rate (excess deaths per 100,000 population) from influenza and pneumonia and Covid-19 over the days after total deaths crossed the 0.5 per 100,000 people in those cities. [3] The city-by-city comparison of historical and contemporary mortality trajectories reveals high similarity of the two epidemics in most cities, particular in the early phase.

Regression results indicate that Covid-19 deaths are positively correlated with total excess deaths from 1918 influenza (point estimate: 0.341, p-value: 0.000, 95% C.I.: 0.193-0.488). Baseline results are presented in column (2) of Table 2. Regressions control for city fixed effects, event time and the square of event time.

We also compare the growth of total deaths from the 1918 flu and total deaths from Covid-19 in the early weeks of the latter pandemic. In Figure 5, we plot the average daily growth rate of total deaths during the two epidemics in the first three weeks after mortality reached 0.5 per 100,000 population. The positive correlation suggests that the cities experiencing faster mortality growth in 1918 tend to experience the same issue in the early phase of Covid-19. Regressions are reported in Table 3. We find that conditional on geographic location and contemporary population density, this positive correlation still holds significantly in the first two, three, and four weeks after mortality rates reached the given threshold.

3. Discussion

What factors inhibit prompt response and success in the midst of a pandemic? Let us assume that they include "distrust, isolationism and hubris" (Parmet and Rothstein, 2018). In our discussion it will become clear that all of these factors mattered for performance in both 1918 and in 2020. These factors seem to be correlated over time across countries. It is not clear however whether these factors are recurrent features of societies which have been unfortunately timed with the outbreak of a new infectious disease like Covid-19 or whether these factors indeed persist over time.

Ackerknecht (1947) suggests that public health responses in the 19th century may have reflected political philosophies and even competing interest groups representing such dogmas.[4] "Contagionism" and quarantinism were often associated with a heavy handed

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[3] Excess deaths rates serve as good measurement of the severity of the 1918 pandemic across cities with potentially different seasonal influenza patterns. The threshold of 0.5/100,000 is chosen to attain a comparable starting mortality rates for two epidemics across cities. Most cities in our sample reached this threshold early in both epidemics. Our results are robust to other alternative thresholds such as 1/100,000.

[4] Baldwin (2005) expands upon the Ackerknechtian view.

approach to governance and antithetical to commercial/economic interests. The "sanitationists" who advocated behavioral approaches and better public hygiene stemmed from a more liberal tradition. While most social distancing policies and other NPIs like shelter-in-place today are a far cry from the lazarettos of the past, they may in fact be the modern day equivalents of quarantine and lockdown. These approaches would seemingly be more appealing or viable in nations with interventionist traditions. Mainland China for instance indeed opted for intensive quarantining during Covid-19 as has been well documented. On the other hand, the so-called red states of the US, but the US more generally in a comparative context, have resisted the call to implement long duration lockdowns. The US, has historically been more apprehensive of policies including lockdowns that interfere with the economy and people's own liberty. In sum, long-running political cleavages may be an integral part of the explanation for societal responses to pandemics

Whatever the case may be, history is surely not destiny nor does history repeat itself. We do not want to suggest either. The correlations we highlight in this paper emphasize that if public health objectives are to be met, societies must substitute innovative efforts to overcome adversity when other social and political forces such as "distrust, isolationism and hubris" handicap public health responses.

Still, historical experience has seemingly affected the path of mortality in the Covid-19 pandemic. First, in a positive sense. Experience with SARS is likely to have promoted societal learning and reaction. Meanwhile, where the mortality of the 1918 influenza was high, mortality is likely to be high today. Why? As we discuss below, local public health "traditions" may be historically persistent, but the timing of Covid-19 and the flu of 1918 have been somewhat unfortunate as well.

3.1 SARS and Recent History

East Asian nations, the places most affected by SARS in 2002-03 have been more likely to act quickly to mitigate spread and to have lower mortality from Covid-19 thus far. The searing lessons of SARS, along with particular national characteristics, appear to have positively influenced pandemic preparedness. The key national characteristics for success in battling a pandemic -- trust, cooperation, and a lack of hubristic over-confidence --- are present in these nations and they have provided a favorable environment for learning from the past. Are there other explanations?

It is plausible that experience with SARS obscures national characteristics since SARS had a limited geographic reach, largely affecting selected places in East Asia. Indeed, places in East Asia like Taiwan, Singapore, Hong Kong, South Korea, Japan, and mainland China have kept reported cumulative cases and deaths from Covid-19 at low levels especially when scaled by population. The population mortality rate has averaged 0.305 per 100,000 in these six places and if we exclude Japan and China it was 0.286. This is well below the average of 16.65 in other advanced economic nations in western Europe, the Americas and Australia as of 25 April ,2020 (Table 1).

We control for regional fixed effects and some religio-philosohical and cultural traditions including "Confucianism" and collectivism. None of these eliminate the statistically significant association between past pandemics and Covid-19. Neither of these "deep" cultural factors is statistically significant. Many of these places have been at the epicenter of recent pandemics like SARS but also including MERS and the recent Covid-19 pandemic. There is strong evidence that these places saw the threat of SARS due to recent experience. Meanwhile the western nations less affected by these recent pandemics "saw the threat through the lens of influenza" according to the editor of *The Lancet* Richard Horton. (Ahuja, 2020).

East Asian nations appear to have used their trusted and competent technocratic civil services to learn from recent past experience, and to develop a high level of preparedness for a pandemic. The pandemic preparedness plans for the East Asian nations most affected by SARS often mention recent local experience with SARS. Pandemic response to Covid-19 has been swift and forceful. A host of specialized protocols have been followed including border checks of travelers for illness, international travel bans from affected regions, high rates of testing and contact tracing, social distancing, using masks and raising public awareness.

Another plausible explanation for East Asian success in the recent period may be competency and trust in the civil service. China, Taiwan, Hong Kong, Japan and South Korea, the countries most affected by SARS, have an average percentage of people having "a great deal of trust" or "quite a lot of trust" in civil service of 56.68 % (std. dev. =13.96) according to the 2010-2014 World Values Survey. The average of western nations available in the sample (Australia, Germany, New Zealand, Spain, Sweden and the USA) was 45.9% (std. dev. = 5.06) and that for all other nations in the sample excluding these places was 42.5% (std. dev. = 19.18).

The salience of events in recent living memory combined with high trust and competence in the civil service most likely helped these nations to learn from past experience. East Asian success has been built upon the realization that a new pandemic was likely given the recent past experience. As one can see in Figure 1, many of these E. Asian nations are below the regression line implying better than expected performance during the early phases of Covid-19. In western nations pandemics had largely been relegated to history with influenza being the most recurrent issue. Population mortality rates from influenza have been significantly lower since 1918 and most influenza since then has had a CFR much lower than that of Covid-19.

3.2 Influenza Mortality in 1918-20 and Covid-19 Mortality: Countries

What then explains the positive correlation between influenza in 1918 and mortality in the early phases of Covid-19? At the country level, our regression analysis rules out

individualist cultural explanations and geographic/regional unobservables. One explanation may rely on deep-rooted tendencies and capabilities of the government and civil service in solving the problems of infectious diseases. The issues of distrust, hubris and isolationism return to the forefront and are evident in 1918 and now. Unfortunate timing may play a role in the persistence of these enabling factors. Recent research argues that the greater mortality in the 1918-20 pandemic generates lower trust in the long-run (Aassve et. al. 2020).[5] This may help explain some of the persistence we see in the data both across countries and within the US.

Today, many western nations have elected officials that have openly discussed abandoning international agreements of the post-World War 2 era. The US is not alone in this. So-called populist tendencies have emerged in many western democracies. Electoral success has risen, but many countries see this manifested in the strength of opposition parties like the AFD in Germany, the FN in France, and UKIP in the UK. These political movements also are amplifications of public mis-trust of officials and experts. The politicization of public health responses has been highlighted (Eichengreen, 2020).

In 1918 many countries in the West were involved in all-out war. Reporting on the influenza pandemic was minimized as most historians agree. The Italian interior minister was not alone in denying the spread of the pandemic (Martini et. al, 2019). In the US, politicians downplayed the menace of the flu. Similar responses have been heard today in Italy. The mayor of Milan promoted "Milan doesn't stop" on day 6 of the Covid-19 outbreak leaving bars, restaurants, and cafes open (McCann et. al, 2020). In the United States, the president declared Covid-19 to be a "hoax" in late February, 2020.

Another unfortunate similarity between today and in the past was the inadequate preparation of many health care systems for surge demand. During World War I, the US military had 300,000 physicians on duty which is over 1/5 of the total number of physicians in the USA at the time.[6] Other nations fighting in the war also had skewed their health infrastructure to war efforts. Today, a nearly constant discussion about equipment shortages, lack of PPE and beds in ICUs has been a common theme. Access to health care in the United States is problematic especially in places where poverty is high, inequality is high, and the social safety net is over-stretched. This characterizes the health care system in New York but in other localities in the US as well.

Finally, politics was on a knife-edge and highly polarized in many western nations in 1918. Many countries were fighting in the war, facing imminent revolutions or momentous political changes or both. Mussolini and fascists in Italy were rising to power, Spain was unstable, Russia was recovering from recent revolution. Even in the US, Woodrow Wilson's

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[5] The measure of trust is based on the General Social Survey question: "Generally speaking, would you say that most people can be trusted or that you can't be too careful in dealing with people?"
[6] Number of medical personnel in the military as of November 1918 300,000 (Statistical Abstract of the United States of America, 1919, p. 728). Number of physicians in the United states in 1920 1.542 million according to Carter et. al. (2006).

political mandate was handicapped by the narrow Republican victory in a New Mexico Senate race leading to Republican control of the Senate.

3.3 US Cities in 1918 versus Today

Perhaps the most striking correlation that we have uncovered is the apparent long-run correlation between mortality in 1918 and today in US cities. Again, the role of politics is manifest. Historians have found evidence that that non-pharmaceutical interventions (NPIs) mattered for peak mortality and cumulative death rates. Cities that adopted NPIs earlier and/or maintained them longer had some success in keeping these variables lower, especially peak mortality. Cities like Philadelphia which delayed and allowed a "Liberty Bond" rally to go ahead have been compared unfavorably to St. Louis which limited public gatherings and sustained school closures. St. Paul has been compared to Minneapolis and San Francisco has been compared to New York. In the former pair St. Paul delayed longer in implementing NPIs than Minneapolis suffering the consequences. San Francisco implemented a mask ordinance in mid-October 1918 while New York implemented light touch social distancing. At the time there was much debate about how far to go with these measures and about their effectiveness. For instance, the Anti-Mask League of San Francisco was a political force in late 1918. Opponents of William Hassler, the city Public Health Officer who promoted mask-wearing, also attempted to murder him such was their mis-trust and dislike of his public health policies. Dr. Anthony Fauci, director of the National Institute of Allergy and Infectious Disease, and a key proponent of social distancing, was given a security detail in late March against "un-specified threats" (Diamond, 2020).

Across US cities there has been political debate on the effectiveness of social distancing and NPIs. It is interesting that the mayors of San Francisco had opposing viewpoints in March on how to handle Covid-19. While mayor London Breed of San Francisco emphasized pandemic preparedness for a major disruption on 2 March, Mayor Bill de Blasio of New York was "encouraging New Yorkers to go on with your lives" on twitter even making a recommendation for watching a movie in a cinema. Historian John M. Barry has emphasized that Tammany (a corrupted political machine) was in control of New York in 1918 and had appointed Royal Copeland, a homeopath, as president of the New York City Board of Health. Copeland downplayed the epidemic at first and failed to close schools. Copeland went on to become a US Senator. Hassler would eventually become the president of the American Public Health Association.

None of this is to ascribe the correlations we have found to extreme persistence in public health capabilities and the politics of public. However, the coincidence of divergent opinions and political and social malaise in the west is notable. It is impossible to blame the disease on these issues. It may however be possible to credit slow response times and delayed action to these matters. In other words, while history has not repeated itself, certain

outcomes are remarkably similar. The success of East Asian nations in combating the spread of Covid-19 so far is testament to the idea that history is not destiny.

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## Figure 1 Mortality Rate per 100,000 Covid-19 and 1918-20 Influenza Pandemics: Cross-Country Evidence
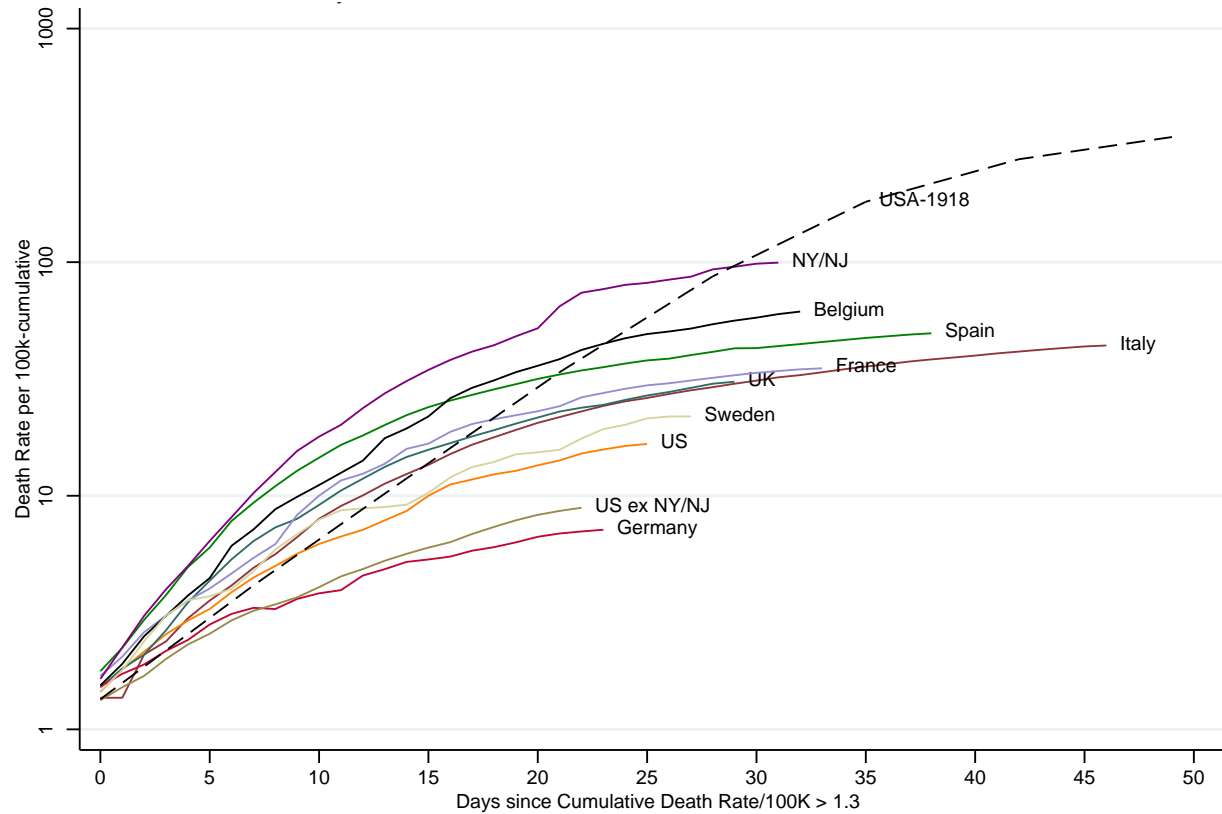
Notes: Figure shows the population mortality rates of Covid-19 based on data from CSSE Johns Hopkins. We break the data for the US into three parts: mortality for the entire US, mortality rates for the states of New York and New Jersey, the hardest hit states and for the US excluding these two states. Data for the Influenza pandemic of 1918 are for total weekly deaths per 100k from influenza and pneumonia for data from 46 cities in the USA (Collins et. al. 1930). Data are plotted for countries in 2020 that had reached a threshold of 1.34 deaths per 100,000. This is the first available level of mortality the mortality rate in the 1918 for the national level data for the USA.

Figure 2 Mortality Rate per 100,000 Covid-19 and 1918-20 Influenza Pandemics: US States
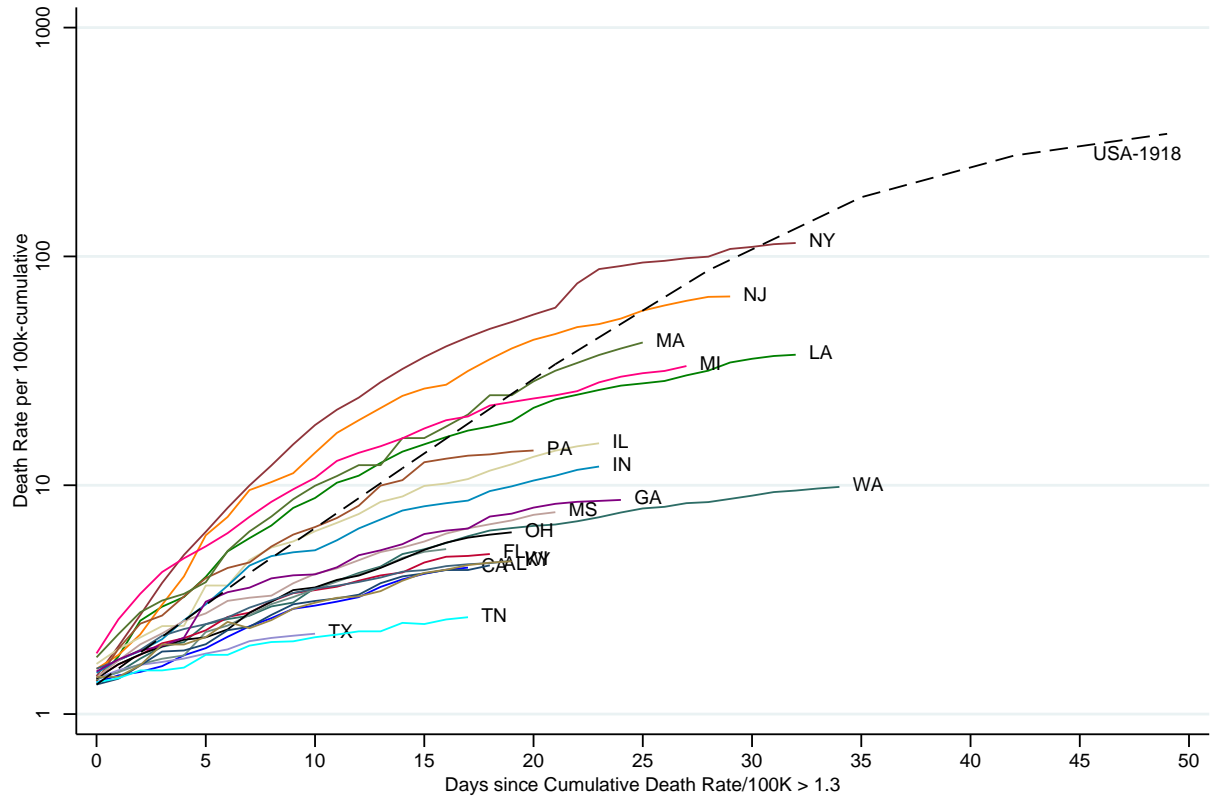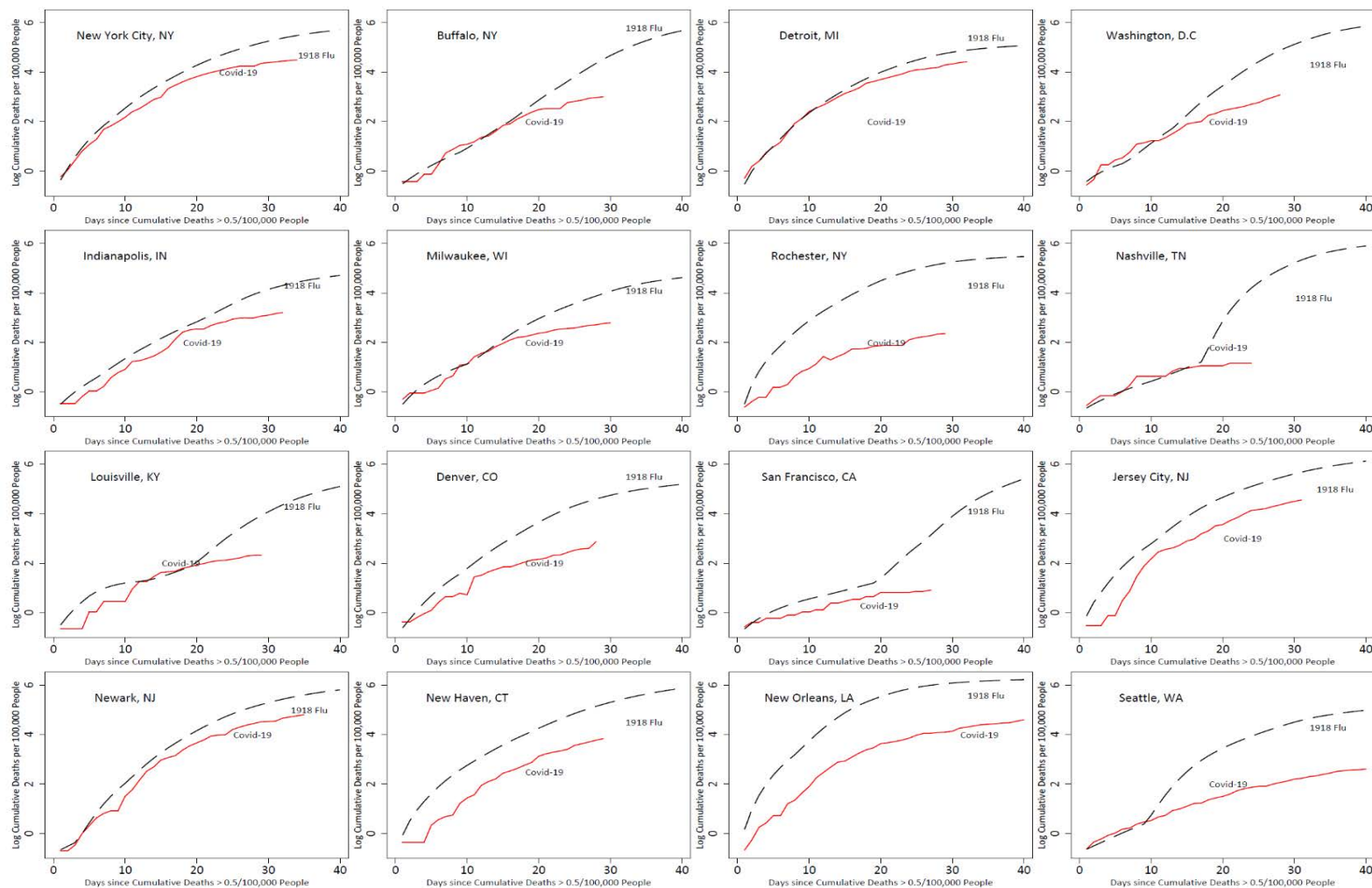

Notes: Figure shows the population mortality rates of Covid-19 based on data from CSSE Johns Hopkins. Data for the Influenza pandemic of 1918 are as described in the notes to Figure 1.

Figure 3 Mortality of 1918-20 Influenza and Covid-19 Pandemics, 22 Countries
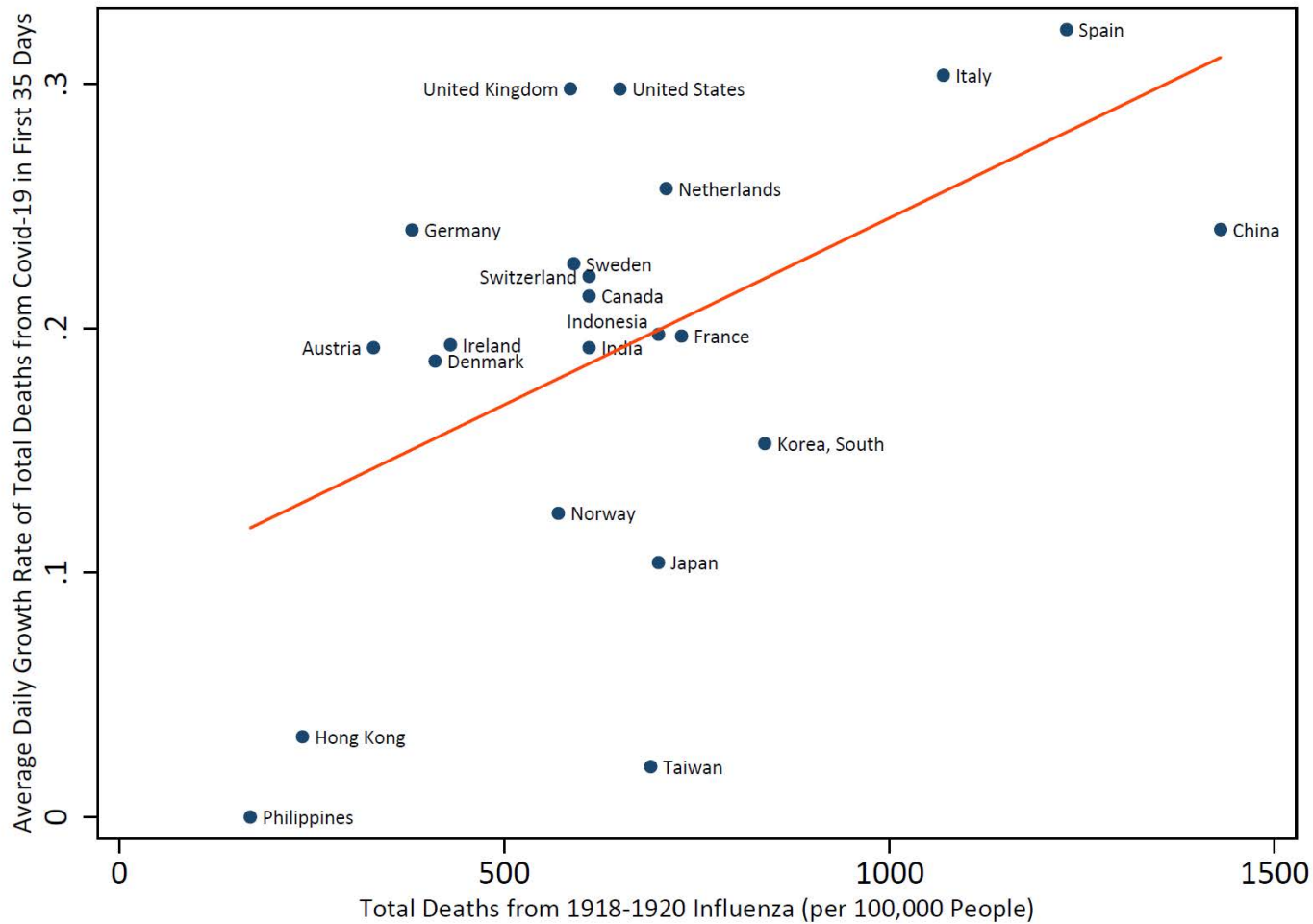
Notes: This graph plots the average daily growth rate of cumulative deaths from Covid-19 in the first 35 days since the first death in each country against the country-specific overall mortality rate from the 1918 Influenza pandemic. Data are described in the data appendix. The average growth rate of cumulative deaths for Covid-19 is calculated as $\sqrt[34]{cmdeath_{i35}/cmdeath_{i1}} - 1$. We include 22 countries with a sufficiently established mortality trajectory in this graph. The robust t-statistic for the coefficient on deaths from influenza in 1918 is =2.74, and the regression has an adjusted R^2 = 0.21.

Figure 4 Mortality Curves for Covid-19 and Influenza and Pneumonia in 1918 in Selected U.S. Cities

Notes: These charts provide city-by-city comparisons between the trajectory of the population mortality rate from influenza and pneumonia in 1918 and Covid-19 in 2020.. We plot the logarithm of total deaths per 100,000 (for Covid-19) or total excess deaths per 100,000 (for influenza and pneumonia) on the y-axis versus the number of days since mortality rates reached 0.5/100,000 population. The 16 cities are selected here the cities with the longest Covid-19 trajectories. Trajectories for other cities are available upon request from authors.

Figure 5 Average Daily Growth of Total Deaths from Covid-19 and Influenza and Pneumonia in U.S. Cities: First 21 Days
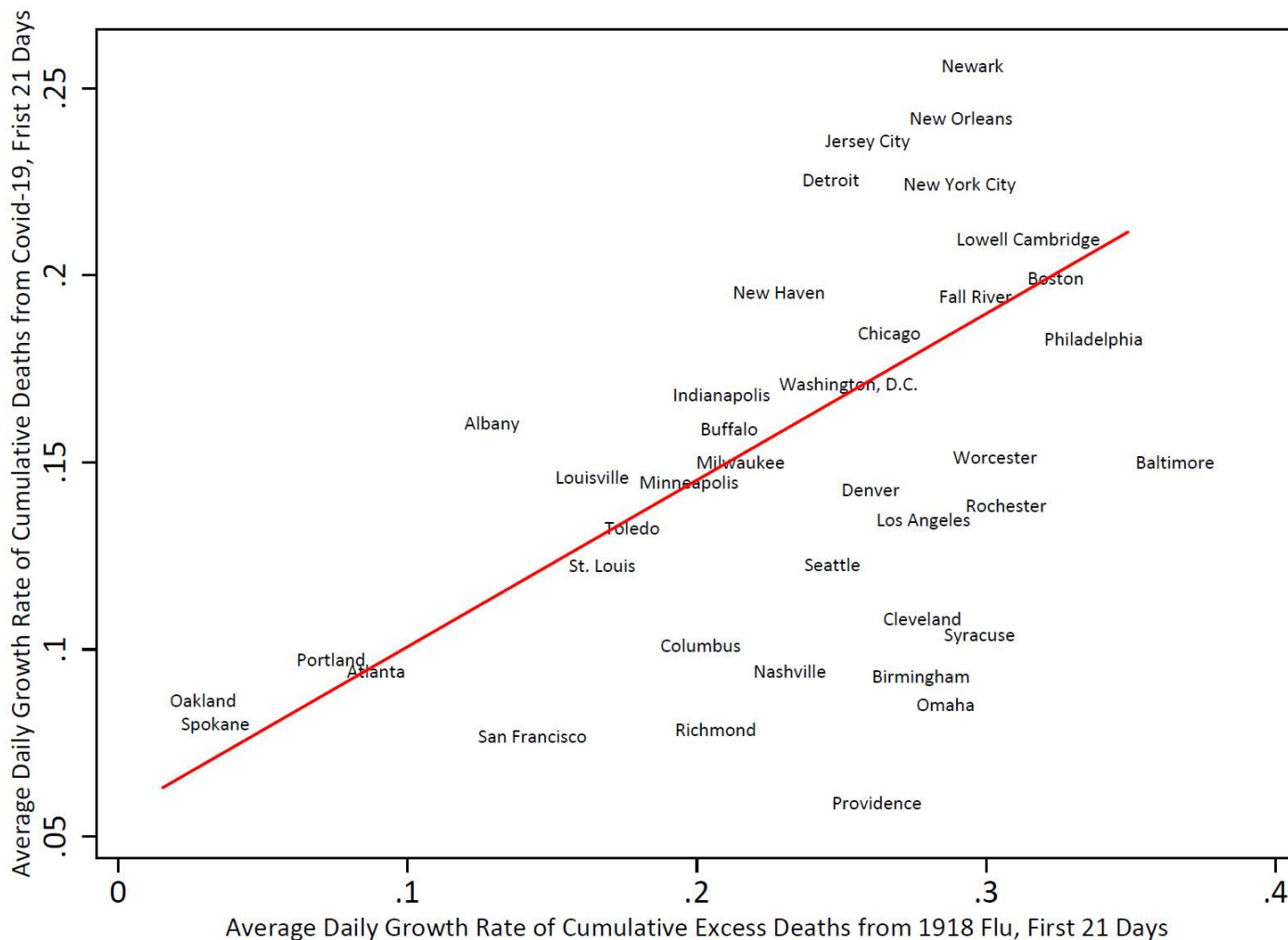
Notes: Chart shows the unconditional relationship between the average daily growth rate of total deaths during Covid-19 in the first 21 days compared to the average growth rate of excess deaths in the first 21 days of the 1918-20 pandemic. The coefficient of the regression (which includes a constant) is 0.355 with a robust t-statistic of 4.09 and a 95% C.I. of 0.179 to 0.531. The average daily growth rates of total deaths (or total excess deaths for 1918 influenza) in the first 21 days are calculated by $\sqrt[20]{cmdeath_{it}/cmdeath_{it-20})} - 1$. The first 21 days refer to the 21 days since the total deaths (for Covid-19) or total excess deaths (for 1918 Influenza) reached 0.5 for every 100,000 population.

Table 1 Mortality Rates of for Three Pandemics: 1918-20 Influenza, 2002-03 SARS, and Covid-19

Country	Mortality Rates of 1918-20 Influenza (per 100,000)	Mortality Rates of 2002-2003 SARS (per 100,000)	Mortality Rates of Covid-19 by April 17, 2020 (per 100,000)
Austria	330	0	4.81
Canada	610	0.131	3.62
Denmark	410	0	5.82
Finland	580	0	1.48
France	730	0.002	28.68
Germany	380	0	5.21
Ireland	430	0	10.86
Italy	1070	0	37.56
Netherlands	710	0	20.23
Norway	570	0	2.99
Spain	1230	0	42.80
Sweden	590	0	13.95
Switzerland	610	0	15.45
United Kingdom	586	0	21.61
United States	650	0	11.11
Average	676	0.006	16.65
	Asian Countries		
China	1430	0.027	0.32
India	610	0	0.04
Indonesia	700	0	0.19
Japan	700	0	0.15
Korea, South	838	0	0.45
Philippines	170	0.002	0.36
Singapore	706	0.79	0.19
Taiwan	690	0.799	0.03
Hong Kong	238	4.448	0.05
Average	1043	0.03	0.19
Average (ex. China and Japan)	620	0.04	0.09

Notes: Estimates of mortality rates of 1918 Influenza come from the recalculation and compilation by Johnson and Mueller (2002). See their paper for details. Mortality rates of 2002-2003 SARS come from WHO and include the deaths from cases from November 1, 2002 to July 31, 2003. Mortality rates for Covid-19 come from the CSSE of Johns Hopkins University. Population-weighted averages are presented for each region. Finland and Singapore are listed in this table, but not included in the regression in table 2, as these two countries have not reached their 35th day after first death.

Table 2 Covid-19 Pandemics and Mortality from 1918 Influenza and SARS, Country-Level Evidence

	(1) Average Daily Growth Rate of Total Deaths from Covid-19 — 35 Days since First Death	(2) Average Daily Growth Rate of Total Deaths from Covid-19 — 35 Days since First Death	(3) Average Daily Growth Rate of Total Deaths from Covid-19 — 35 Days since First Death	(4) Average Daily Growth Rate of Total Cases of Covid-19 — 42 Days since 10th Case	(5) Average Daily Growth Rate of Total Cases of Covid-19 — 42 Days since 10th Case	(6) Average Daily Growth Rate of Total Cases of Covid-19 — 42 Days since 10th Case
Total Mortality Rate from 1918-20 Influenza	0.165*** (0.0265)	0.167*** (0.0354)	0.165** (0.0666)	0.0957*** (0.0135)	0.0867*** (0.0106)	0.0677** (0.0226)
Total Mortality Rate from SARS	-0.199*** (0.0463)	-0.169*** (0.0276)	-0.161*** (0.0420)	-0.143*** (0.0290)	-0.130*** (0.0295)	-0.153*** (0.0260)
Population Density in 2019	0.0515*** (0.0116)	0.0459*** (0.00744)	0.0437*** (0.0100)	0.0367*** (0.00732)	0.0338*** (0.00753)	0.0394*** (0.00663)
Log (GDP per capita in 2018)		-0.0246* (0.0131)	-0.0286 (0.0415)		-0.0158** (0.00530)	-0.0261 (0.0163)
Confucianism Tradition (0/1)			0.0116 (0.123)			0.0315 (0.0545)
Individualism Index (0/100)			0.000305 (0.000984)			-0.000531 (0.000609)
Observations	22	22	22	20	20	20
R^2	0.810	0.843	0.845	0.873	0.905	0.919

Notes: Dependent variables in columns (1)-(3) is the average daily growth rate of cumulative deaths from Covid-19 in the first 35 days since the first death case. Dependent variable in columns (4)-(6) is the average daily growth rate of cumulative cases of Covid-19 in the first 42 days since the 10th confirmed cases. Estimation is by OLS. The estimated coefficients and standard errors on the total mortality rate of 1918-20 influenza were multiplied by 1000 for presentational purposes. All regressions control for region fixed effects (we categorize countries into 7 regions: East Asia, South Asia, Africa, Europe, North America, South America, and Oceania). Robust standard errors reported in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 3 Total Deaths and Confirmed Cases from Covid-19 and 1918 Influenza in 46 U.S. Cities, Daily Data

	(1) Log Total Deaths per 100,000 Covid-19	(2) Log Total Deaths per 100,000 Covid-19	(3) Log Total Deaths per 100,000 Covid-19	(4) Log Total Cases per 100,000 Covid-19	(5) Log Total Cases per 100,000 Covid-19	(6) Log Total Cases per 100,000 Covid-19
Log Total Excess Deaths per 100,000, 1918 Flu	0.300*** (0.0547)	0.341*** (0.0733)	0.407*** (0.105)	0.224*** (0.0630)	0.232*** (0.0531)	0.188*** (0.0428)
Event Days	0.121*** (0.00968)	0.108*** (0.0121)		0.0544*** (0.0102)	0.0493*** (0.0138)	
(Event Days)^2	-0.00150*** (0.000232)	-0.00137*** (0.000217)		-0.000355*** (0.0000848)	-0.000290 (0.000294)	
Observations	1244	1244	1235	1244	1244	1235
R^2	0.931	0.962	0.974	0.899	0.964	0.981
Covid-19 Calendar Date Fixed Effects	No	No	Yes	No	No	Yes
State Fixed Effects	Yes	No	No	Yes	No	No
City Fixed Effects	No	Yes	Yes	No	Yes	Yes
# Cities	46	46	46	46	46	46

Notes: Dependent variables are listed at the top of each column. These and total excess death rates from the 1918-20 influenza are at the daily level. All specifications control for city fixed effects. Event days are defined as the days since cumulative death rates per 100,000 (for Covid-19) and cumulative excess deaths (for 1918 Influenza) reached 0.5/100,000 population. The data on Covid-19 were last updated on April 25, 2020. The full list of cities can be found in the public health reports by Collins et. al (1930). All regressions are weighted by population in 2019 and standard errors are clustered at the state level for column (1) and (4). For the rest of columns, standard errors are clustered at the city level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4 Growth of Total Deaths from Covid-19 and 1918 Influenza in U.S. Cities

	(1)	(2)	(3)
	Average Daily Growth Rate of Total Deaths, Covid-19 First 14 Days	Average Daily Growth Rate of Total Deaths, Covid-19 First 21 Days	Average Daily Growth Rate of Total Deaths, Covid-19 First 28 Days
Average Daily Growth Rate of Total Excess Deaths, 1918 Flu, First 14 Days	0.242*** (0.0576)		
Average Daily Growth Rate of Total Excess Deaths, 1918 Flu, First 21 Days		0.269*** (0.0540)	
Average Daily Growth Rate of Total Excess Deaths, 1918 Flu, First 28 Days			0.511*** (0.135)
Population Density in 2019	0.214*** (0.0503)	0.170*** (0.0407)	0.0455 (0.0293)
# Cities	46	40	20
R^2	0.616	0.682	0.792

Notes: The average daily growth rates of total deaths for first n days are calculated by $\sqrt[n-1]{cmdeath_{it}/cmdeath_{in-1}} - 1$. The first n days refers to the number of days since total deaths (for Covid-19) and total excess deaths (for 1918 Influenza) reached 0.5 for every 100,000 people. All specifications also control for latitude and longitude of cities. All regressions are also weighted by population in 2019. Robust standard errors are reported in the parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Data Appendix

Cross-Country Data, 1918

Mortality rates: Johnson and Mueller (2002) . Data for UK are for England, Wales and Scotland. Date for Ireland are for Eire; Singapore deaths from Lee et. al. (2007); Korea from Hong et. al (2017); Hong Kong data from Cheng and Leung (2007). Hong Kong population in 1919 calculated from Swee-Hock and Wing King (1975); Singapore, population Dodge (1980)

Excess mortality: Murray, Lopez, Chin, Feehan, Hill (2006)

Population density, GDP per capita: Data underlying Clemens and Williamson (2004). All data for 1919.

Population (000s) and GDP per capita (1990 real US Dollars) from Maddison when unavailable Clemens and Williamson (2004). Interpolated where necessary.

Land Area from google searches when unavailable in Clemens and Williamson (2004). Land area in square miles.

Covid-19 Data, 2020

Data for cases and deaths by country for Covid-19 on 16 April

https://data.europa.eu/euodp/en/data/dataset/covid-19-coronavirus-data/resource/55e8f966-d5c8-438e-85bc-c7a5a26f4863 downloaded on April 27, 2020.

DOL Initial jobless claims:

https://oui.doleta.gov/unemploy/claims.asp

Employment by industry

US Bureau of Labor Statistics. "OES Research Estimates by State and Industry" all occupations.

Downloaded from https://www.bls.gov/oes/current/oes_research_estimates.htm

 (not sure about this)

https://www.bls.gov/oes/current/oes_research_estimates.htm on 4/7/2020

Employment for the following Industries:

Mining, Quarrying, and Oil and Gas Extraction, NAICS 21
Wholesale Trade, NAICS 42
Retail Trade, NAICS 44-45
Arts, Entertainment, and Recreation, NAICS 71
Accommodation and Food Services, NAICS 72

Share of Jobs that can be "worked from home" or via telecommuting

"How Many Jobs Can be Done at Home?" by Jonathan I. Dingel and Brent Neiman. NBER wp. 26948

Downloaded from github https://github.com/jdingel/DingelNeiman-workathome

For MSAs spanning state borders we simply use the population weight given by total MSA population in such an MSA relative to population all other MSAs including this cross-state MSA.

Populations for MSA from US Census bureau

https://www.census.gov/data/tables/time-series/demo/popest/2010s-total-metro-and-micro-statistical-areas.html

Metropolitan and Micropolitan Statistical Area Population Estimates and Estimated Components of Change: April 1, 2010 to July 1, 2019 (CBSA-EST2019-alldata.csv)

<u>**Employment by MSA**</u>

https://www.bls.gov/web/metro.supp.toc.htm

Data file is ssamattab.zip .We use total employment for February 2020 to weight the telecommuting index from Dingel and Neiman.

1918-1919 Influenza Pandemic in U.S. Cities

The mortality date in 47 major U.S. cities come from the public health reports (Collins, 1930). We calculate the cumulative deaths. We interpolate the weekly excess deaths and median deaths by linear interpolation. The cumulative deaths are calculated from the date of first officially reported case of influenza in the 1918-1919 influenza pandemic.

The timing of Nonpharmaceutical interventions across cities are from Markel et al. (2007).

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