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ABSTRACT

As a way of slowing COVID-19 transmission, many countries and U.S. states implemented shelter-in-place (SIP) policies. However, the effects of SIP policies on public health are a priori ambiguous as they might have unintended adverse effects on health. The effect of SIP policies on COVID-19 transmission and physical mobility is mixed. To understand the net effects of SIP policies, we measure the change in excess deaths following the implementation of SIP policies in 43 countries and all U.S. states. We use an event study framework to quantify changes in the number of excess deaths after the implementation of a SIP policy. We find that following the implementation of SIP policies, excess mortality increases. The increase in excess mortality is statistically significant in the immediate weeks following SIP implementation for the international comparison only and occurs despite the fact that there was a decline in the number of excess deaths prior to the implementation of the policy. At the U.S. state-level, excess mortality increases in the immediate weeks following SIP introduction and then trends below zero following 20 weeks of SIP implementation. We failed to find that countries or U.S. states that implemented SIP policies earlier, and in which SIP policies had longer to operate, had lower excess deaths than countries/U.S. states that were slower to implement SIP policies. We also failed to observe differences in excess death trends before and after the implementation of SIP policies based on pre-SIP COVID-19 death rates.

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1. INTRODUCTION

The COVID-19 pandemic has caused an unprecedented policy response from public health officials and governments. As of May 8, 2021, approximately 3.2 million deaths worldwide and 581,000 deaths in the United States were attributed to COVID-19 (Johns Hopkins Coronavirus Resource Center 2021). To slow COVID-19 transmission, many countries and United States localities implemented non-pharmaceutical interventions (NPIs), one of the most common of which is “shelter-in-place” (SIP) policies. These policies are designed to reduce COVID-19 transmission by restricting non-essential mobility.

Conceptually, the impact of SIP policies on public health is ambiguous and complex. The effect of SIP policies depends on both behavioral responses and the efficacy of behavioral responses in averting COVID-19 transmission. Early evidence suggests that SIP policies slowed COVID-19 transmission early in the pandemic in the United States (Courtemanche et al. 2020) and globally (Ge et al. 2021). However, more recent studies suggest that individuals changed behavior in response to the severity of the pandemic and the enactment of SIP policy implementation lagged this individual behavior change. While social distancing is an important mechanism to avoid COVID-19 spread, the studies that use mobility tracking data find only modest additional social distancing responses following SIP policies (Cantor et al. 2020; Berry et al. 2021; Askitas, Tatsiramos, and Verheyden 2021; Xu 2021; Nguyen et al. 2020). Individuals concerned about COVID-19 risk may change behavior even in the absence of regulations or shelter-in-place advisories. Thus, it is unclear how much change in COVID-19 risk mitigation is due to formal SIP policies, compared to risk mitigation that would have occurred in the absence of these policies.

At the same time, even if SIP policies reduce COVID-19 transmission, their impact on overall health is unclear, as SIP policies likely have several important unintended consequences (Correia, Luck, and Verner 2020). SIP policies might lead to unemployment or reduced economic activity (S. Chen et al. 2020). SIP policies may increase stress and anxiety due to social isolation (Xie et al. 2020; Patrick et al. 2020), potentially leading to increased substance use and suicides (Mason et al. 2021; Holland et al. 2021). Reduced physical mobility may have also caused increases in child abuse and domestic violence (Leslie and Wilson 2020; Cappa and Jijon 2021), which can adversely affect health in both the short and long run (Sonu, Post, and Feinglass 2019). Recent work also suggests that SIP policies reduced use of high value non-COVID care such as cancer screenings and vaccinations (Cantor et al. 2020; Whaley et al. 2020; McBain et al. 2021). These complex effects suggest that SIP policies might reduce COVID-19 related mortality, but might also increase mortality from other causes. This naturally raises the question: What is the impact of SIP policies on all-cause mortality?

In this paper, we examine the impacts of SIP policies, both internationally at the country-level and in the U.S. at the state-level on excess mortality. A key measure of all-cause mortality is excess deaths, which compares deaths from all causes in a given geography at a given point in time to expected deaths from all causes based on historical data (Krelle, Barclay, and Tallack 2020). Using excess deaths as a key outcome captures both potential reductions in COVID-19 deaths and potential increases in non-COVID deaths. Using excess deaths, rather than confirmed COVID-19 deaths, also alleviates concerns about the accurate classification of COVID-19 deaths. While emerging evidence, summarized below, has documented increases in excess deaths during the pandemic, the existing literature has not systematically examined the role of SIP policies in averting or contributing to excess deaths. Further, no studies have compared the impact of SIP policies between countries and compared these impacts within U.S. states.

To do so, we use data from 43 countries that implemented SIP policies and all 50 U.S. states. We estimate the effect of SIP policies using an event study approach. We also examine the change in excess deaths following the introduction of SIP policies separately for each country and U.S. state. We also compare differences in excess mortality based on the timing of SIP policy implementation.

In both settings, we fail to find that SIP policies saved lives. To the contrary, we find a positive association between SIP policies and excess deaths. We find that following the implementation of SIP policies, excess mortality increases. The increase in excess mortality is statistically significant in the immediate weeks following SIP implementation for the international comparison only. At the U.S. state-level, excess mortality increases in the immediate weeks following SIP implementation and then trends below zero following 20 weeks of SIP implementation.

It is possible that the timing of SIP policies is endogenous. For example, if SIP were implemented when excess deaths were rising then the results from the event study would be biased towards finding that SIP policies lead to excess deaths. However, we find the opposite: countries that implemented SIP policies experienced a decline in excess mortality prior to implementation compared to countries that did not implement SIP policies. We find no pre-existing trends in excess mortality prior to implementation of SIP policies in U.S. states.

It is also possible that the average effects in our event studies might hide heterogeneity in the impact of policies across countries and U.S. states. For example, SIP policies might be more effective when implemented early in the pandemic or SIP policies might work better when community transmission is high. Therefore, we estimated separate event studies for each country or U.S. state and separate event studies for groups of countries and states with high COVID-19 transmission in the two weeks prior to the implementation of the SIP policy. Overall, we find little evidence of heterogenous effects except that SIP policies seem to be more effective in island nations or the island U.S. state of Hawaii.

The rest of the paper proceeds as follows. We first review the prior literature on SIP policies and health outcomes. Next, we present the data on SIP polices and excess deaths and methods for estimating the impact of SIP policies on excess deaths. Finally, we discuss results, limitations and implications for public policy, and future research.

2. LITERATURE REVIEW

This study adds to a growing literature that has examined the effect of NPIs on the number of COVID-19 cases, deaths, and social distancing behaviors. Some existing studies have used cellular phone mobility tracking and have found that the implementation of SIP policies leads to small changes in mobility with weaker effects on mobility in the U.S. compared to Europe (Berry et al. 2021; Singh et al. 2021; Askitas, Tatsiramos, and Verheyden 2021; Xu 2021). Within the U.S. context, there were important differences based on income, with larger increases in physical distancing for individuals in high-income neighborhoods than individuals in low-income neighborhoods (Jay et al. 2020; Singh et al. 2021).

Studies have also estimated the impacts of SIP policies on COVID-19 cases and deaths. Berry et al. (2021) finds that implementation of SIP policies did not lead to reductions in new COVID-19 cases or deaths, while Singh et al. (2021) finds that SIP policies reduce COVID-19 cases by 163 cases per 100,000.

At the same time, recent work predicts that the COVID-19 pandemic and the associated economic recession may lead to a significant increase in the number of deaths of despair in the U.S. (Mulligan 2020). These deaths of despair are due to economic stagnation and social isolation associated with the pandemic and include deaths due to causes such as suicide and substance use disorder (Petterson, Westfall, and Miller 2020). Within the U.S. the number of drug overdoses, unintentional injuries, and homicides increased between March and August 2020 (Faust et al. 2021).

Prior research also documents disparities in the impact of the pandemic on health. In California specifically, there was a large increase in the number of excess deaths for Latino and Black residents, those without a high school degree, and younger adults. Increased excess deaths for these populations may be due to occupational exposure, crowded housing, and inadequate access to testing or treatment (Y.H. Chen et al. 2020). Similarly, Krieger et al. (2020) used data for zip code tabulation areas (ZCTA) in Massachusetts to conclude that the mortality rate during the peak of the pandemic was higher for areas that are poorer, denser, racially segregated, and have a higher share of minority race individuals (Krieger, Waterman, and Chen 2020). Other U.S. studies have examined excess mortality during the COVID-19 pandemic and find 87,000 excess deaths between March and August 2020, with COVID-19 responsible for 67 percent of these deaths (Woolf et al. 2020). By the end of the year, the authors revisit their findings and conclude that in 2020 there were 522,368 excess deaths, and that the number of excess deaths was higher for non-Hispanic Black than non-Hispanic White or Hispanic populations (Woolf et al. 2021). Relatedly, a different study used Social Security data and finds that excess all-cause mortality was highest in Black people and lowest for White people. There was also significant variation by state in the disparities of excess death by race (Polyakova et al. 2021). Finally, a

U.S. study using mortality data from the National Vital Statistics System found that the largest increases in excess death by October 2020 were found for those between the ages of 25 and 44 and among Hispanic or Latino persons (Rossen et al. 2020).

Outside of the U.S., other studies have found increases in excess mortality of 61 percent in Spain, 56 percent in the United Kingdom, and five percent or lower in Germany, Denmark, and Norway (Morgan et al. 2020). Other work finds increases in excess deaths in England, Wales, France, Italy, Netherlands, and Portugal (Félix-Cardoso et al. 2020). Aleman et al. 2020 estimates the effects of Spain's national lockdown by comparing deaths in Madrid (which was in a later stage of the pandemic) to other parts of Spain one week after implementation of lockdown (Aleman et al. 2020). They find that during this one-week period the lock down led to a 19% reduction in deaths. Similarly, Ciminelli and Garcia-Mandico (2020) find that the effects of Italy's national shutdown on deaths varied with the share of essential businesses in different municipalities, with municipalities with a lower share of essential businesses experiencing a decline in deaths after the lockdown relative to municipalities with a higher share of essential businesses (Ciminelli and Garcia-Mandico 2020).

3. DATA

3.1. Data on Social Distancing Policies

To measure the impact of state-level SIP or Stay-at-Home requirement policies, we use data from the Oxford COVID-19 Government Response Tracker (OxCGRT), Blavatnik School of Government for both national-level country data (Hale et al. 2021), and U.S. state-level data (Hale et al. 2020). Related work has used eleven categorical variables from the OxCGRT dataset to estimate the impact of containment and closure interventions on COVID-19 transmission across countries, and found none of the interventions had a statistically significant effect (Rannan-Eliya et al. 2021). The data contains information on 16 indicators of government response that are publicly available; however, for our analysis we used the SIP indicator recorded for each day. It is an ordinal index scaled from zero to three. A value of zero indicates no measures, one indicates recommended not leaving house; two indicates required not leaving house with exceptions for daily exercise, grocery shopping, and essential trips; and three indicates required not leaving house with minimal exceptions—for example, leave only once a week, etc. We average the daily SIP order value for the seven days of a week to create a weekly SIP value for each week. The SIP indicator for the week is assigned a value of 0 if the daily average SIP value for that week is less than 0.5 and the SIP indicator for the week is assigned a value of 1 if the daily average SIP value for that week is greater than equal to 0.5.

3.2. Deaths Data

3.2.1. Country: National-level Weekly Excess Deaths

The data on the national-level weekly death for each country is downloaded from the Our World In Data (OWID) (Giattino et al. 2021). OWID uses all-cause mortality data from the Human Mortality Database and the World Mortality Dataset. Excess deaths for each week of 2020 is the difference in total deaths in a given week of 2020 and the average of total deaths in that week from 2015 to 2019.

$$\textit{Excess Deaths}_{(\textit{Week n, 2020})} = \textit{Total Deaths}_{(\textit{Week n, 2020})} - \textit{Average Deaths}_{(\textit{Week n, 2015 – 2019})}$$

The full dataset contains 82 countries; however, only 43 countries have data available on total deaths for each week of 2020. The remaining 39 countries have monthly data of total deaths that occurred in 2020. Therefore, in our study we focused on the 43 countries that have total deaths data for each week of 2020 as this study analyzes the weekly trend.

3.2.2. Country: National-level Weekly Covid-19 Deaths

We used the weekly COVID-19 death data to identify the week of first COVID-19 death for our analysis. The data on COVID-19 deaths, which are a subset of the total deaths described above, for countries are obtained from the OWID (Ritchie et al. 2020). The national-level country dataset contains the number of deaths caused by COVID-19 on each day for 192 countries. We used data for 43 countries that we analyze for excess deaths and filtered out the rest. With these data, the weekly deaths caused by COVID-19 in each country was calculated by summing the daily COVID-19 deaths in seven days of each week.

3.2.3. U.S. States: State-level Weekly Excess Deaths and Weekly COVID-19 Deaths

To capture the severity of the COVID-19 pandemic on total deaths in the U.S., we used number of excess deaths for each state and the District of Columbia for each week of 2020 from The Economist COVID-19 excess deaths tracker GitHub repository (The Economist 2020). Moreover, we used the same dataset to identify the week of first COVID-19 death in each state. The data for the U.S. are generated by The Economist using information from the Centers for Disease Control and Prevention (CDC), USAFacts, and NYC Health. The data track the total number of excess deaths in each state and the District of Columbia for each week.

Lastly, as our unit of analysis is “excess deaths per 100,000 population,” we calculated excess deaths per 100,000 people for both country-level and U.S. state-level analysis. The data on the population of each 43 countries in our study come from the same COVID-19 deaths dataset obtained from OWID, and the data on the population of 50 U.S. states and the District of Columbia are included in The Economist excess deaths dataset.

4. ESTIMATION APPROACH

4.1. Effects of Social Distancing Policies on Excess Deaths

This study analyzes the impact of the implementation of a SIP policy on excess deaths per 100,000 population at both the country-level and U.S. state-level. Using the data on COVID-19 deaths, we identified the week in which the first COVID-19 death occurred in each of the 43 countries in our study and in the 50 U.S. states and the District of Columbia. Then, we calculated the total excess deaths per 100,000 population in the 24 weeks (or 6 months) after the week of first COVID-19 deaths in each country and U.S. state.

We then measured the speed of the implementation of SIP policy and the length of the implementation of SIP policy during our period of analysis, i.e. the 24 weeks after the first COVID-19 death. To measure the speed of the implementation of SIP policy, we estimate the number of weeks a country or a U.S. state took to implement the first SIP policy from the week of first COVID-19 death. The duration or length of the implementation of the SIP policy was measured as the number of weeks the SIP policy was in place from the week of first COVID-19 death in a given country or a U.S. state to 24 weeks after the first COVID-19 death.

We start by descriptively estimating the association between excess deaths and speed of implementation of SIP policies. To do so, we produce a scatter plot with the total number of excess deaths per 100,000 population during the 24 weeks after the week of first COVID-19 death on the y-axis and speed of the implementation of SIP policy on the x-axis. We estimate separate scatter plots for countries and for the U.S. states in our study. We similarly compare the total number of excess deaths per 100,000 population during the 24 weeks after the first COVID-19 death with the duration of implementation of SIP policy in 25 weeks, i.e., the week of first COVID-19 death and 24 weeks from that first week.

Furthermore, to formally estimate the effect of SIP policy on excess deaths per 100,000 we used an event study approach. For the U.S. analysis, we included state and week fixed effects. For the international analysis, we used country and week fixed effects. We analyzed the pre- and post-SIP implementation trends for excess deaths per 100,000 population. For each event study, we estimated a regression model of the form:

$$Y_{it} = \alpha + \sum_{j=2}^{m} \beta_j \, (Lag\ j)_{it} \ + \sum_{k=1}^{n} \lambda_k (Lead\ k)_{it} + \gamma_i + \delta_t + \ \varepsilon$$

In this model, the outcome of interest *Y* is excess deaths per 100,000 population. Lags and leads indicate that the given state is a number of weeks away from the time when the policy is implemented. Lags represent the pre-treatment period, while the lead terms represent the post-treatment period. The first lag period is chosen as the baseline period; hence it is omitted from the model specification. γ_i and δ_t are unit (state or country) and week fixed effects, respectively. Here, *i* represents a given unit, i.e., a country for the country-level analysis and a state for the U.S. state-level analysis, *t* represents the week number, and ε is the error term. We cluster standard errors at the respective geographic unit (country or U.S. state).

These event studies provide estimates of the mean effect of SIP policies on excess deaths. However, there still may be differences in the effect of SIP policies based on the trajectory of the COVID-19 pandemic. As an additional test, we examine differences based on COVID-19 death rates in the two weeks prior to the implementation of a SIP policy. We categorize each country or U.S. state as having COVID-19 deaths above or below the median rate in the two weeks prior to the implementation of a SIP policy and separately estimate event studies for each classification.

5. RESULTS

5.1. Association Between SIP Policies and Excess Mortality

Figure 1 compares excess deaths per 100,000 population (y-axis) against the number of weeks each country/U.S. state took to implement the SIP policy following the first COVID-19 death in that country/U.S. state (x-axis). If SIP policies impact the trajectory of the COVID-19 pandemic, then regions that implement SIP policies sooner after initial exposure to the pandemic are likely to experience lower deaths. When comparing across countries, we observe the expected relationship. A one-week increase in the week in which a country implements a SIP policy (i.e., a one-week delay in the implementation of a SIP policy), is associated with a 7.3 (95% CI: -1.2 to 15.9) increase in excess deaths per 100,000 population. When comparing between U.S. states, we find the opposite relationship—a 0.4 (95% CI: -7.8 to 7.0) decrease, but the association is small in magnitude and the confidence interval is large.

Figure 2 presents similar descriptive evidence on the duration of the implementation of SIP policies following the first COVID-19 death in each country/U.S. state, as measured by the number of weeks with an active SIP policy in the 24 weeks post first COVID-19 death, and the number of excess deaths per 100,000 population in that country/U.S. state. For each geography, the figure plots the number of weeks between the implementation of SIP policies and excess deaths per 100,000 population in the 24 weeks following the first COVID-19 death. If SIP policies reduce excess deaths, then there should be a negative association between the length of time a SIP policy has been implemented and cumulative deaths. However, when comparing across countries, we observe a general upward trend, indicating that countries with a longer duration of SIP policies are the ones with higher excess deaths per 100,000 residents in the 24 weeks following a COVID-19 death. Across countries, a one-week increase in the duration of

SIP policies is associated with a 2.7 (95% CI: 1.1 to 4.3) increase in excess deaths per 100,000 population. In the U.S. comparison at the state-level, the association is smaller in magnitude and the confidence interval overlaps with zero. A one-week increase in the duration of SIP policies is associated with a 1.3 (95% CI: -0.5 to 3.1) increase in excess deaths per 100,000 population.

These descriptive figures suggest that the implementation of SIP policies does not lead to reductions in excess mortality. In fact, a positive association was observed both when accounting for the expedience of the SIP implementation and the duration of SIP policies. However, while suggestive, these figures are challenging to interpret causally. Countries and U.S. states endogenously implement SIP policies in response to their exposure to the COVID-19 pandemic. In addition, a variety of unobserved factors (e.g., political leanings, age structure, economic stability, socioeconomic status, experience with prior pandemics, etc.) might influence the decision to implement a SIP policy and also might be correlated with excess deaths.

To more formally estimate the effects of SIP policies on excess deaths, event studies that estimate trends in excess mortality before and after the implementation of SIP policies are presented in Figure 3. For both the country (Panel A) and U.S. state (Panel B) comparison, we find that following the implementation of SIP policies, excess mortality increases. The increase in excess mortality is statistically significant in the immediate weeks following SIP implementation for the international comparison. For the within-U.S. comparison, excess mortality trends below zero following 20 weeks of SIP implementation.

The results from the event study regression models suggest that difference in excess mortality between countries that implemented SIP versus countries that did not implement SIP was trending downwards in the weeks prior to SIP implementation. Had this pre-existing difference in mortality trends continued, we would expect lower excess mortality in the weeks following SIP implementation in countries that implemented SIP policies relative to countries that did not implement policies. However, we find that the pre-existing trend reversed following implementation of SIP policies. This suggest that our estimates of the effects of SIP on excess mortality are conservative as pre-existing trends are biased towards finding a protective effect of SIP. We find no evidence of pre-existing differences in trends in excess mortality across U.S. states prior to implementation of SIP. However, similar to international comparisons, we find that SIP implementation was associated with an increase in excess mortality.

In further analyses, results in the Appendix present additional event studies that separately estimate the effects of SIP policies in each country/U.S. state. When comparing across countries, the only countries in which we observe the introduction of SIP policies negatively changes the trajectory of excess deaths are Australia, Malta, and New Zealand. All three countries are islands. In every other country, we observe either no visual change in excess deaths or increases in excess deaths. The results are similar for U.S. states. We observe small reductions in excess deaths for Hawaii, which is also an island, following the implementation of a SIP policy. The other U.S. states either show no change in excess deaths, or in many U.S. states, spikes in excess deaths following the implementation of SIP policies. Further, we do not see that countries or U.S. states that implemented SIP policies earlier, and thus in which SIP policies had more time in effect, had lower excess deaths than countries/U.S. states that were slower to implement SIP policies.

Figure 4 presents results that separately estimate event studies for countries/states with pre-SIP COVID-19 death rates below and above the median rates. For both the countries (Panel A) and U.S. state (Panel B) comparisons, we do not observe differences in excess death trends before and after the implementation of SIP policies based on pre-SIP COVID-19 death rates. In all four cases, we do not observe that the implementation of SIP policies leads to reductions in excess deaths. This finding suggests that the effect of SIP policies is not differentially impacted by the trajectory of the COVID-19 pandemic across regions.

6. DISCUSSION

In response to the COVID-19 pandemic, many countries implemented social distancing and SIP policies. These policies are designed to slow COVID-19 transmission by limiting physical interaction. While early U.S. and international evidence suggests that these policies did slow COVID-19 transmission (Aleman et al. 2020; Courtemanche et al. 2020), the longer-run and more comprehensive effects of these policies are not fully understood (Berry et al. 2021). We used data from 43 countries and all U.S. states and find the introduction of SIP policies did not lead to reductions in excess deaths.

This study is not without limitations. First, how COVID-19 deaths are defined is not standard across countries (Beaney et al. 2020). For this reason, we rely on total mortality, instead of cause-specific mortality. However, total mortality can also suffer from measurement error. For example, there could be a lag in registering deaths and upward revision of mortality data is common in many countries. It is also possible that deaths are simply undercounted especially in developing countries or rural areas due to lack of resources. Second, enforcement and implementation of SIP policies could vary across countries or U.S. states and our main analysis does not implement heterogenous treatment effects—although the country by country and state by state event studies suggest that the findings were qualitatively similar other than for a few island countries and Hawaii. For this reason, we emphasize that our results should be interpreted using an intent-to-treat framework. We do not estimate the effect of "ideal" SIP policies or of improved compliance with SIP policies, but rather evaluate the "real world" impact of SIP policies that were implemented. Third, it is possible that SIP policies were implemented with other policies related to the pandemic and we cannot completely isolate the causal effects of SIP policies. Finally, the counterfactual trajectory of the pandemic in the absence of SIP policies is difficult to estimate and might vary across countries and states, which could bias estimates. However, we do not find differences in the impact of SIP policies based on the trajectory of the COVID-19 pandemic when policies were implemented.

Nonetheless, the implementation of SIP policies does not appear to have met the aim of reducing excess mortality. There are several potential explanations for this finding. First, it is possible that SIP policies do not slow COVID-19 transmission. As discussed earlier, prior studies find only a modest effect of SIP policies on mobility. A potential reason for the modest impact on mobility may be that individuals change behavior to avoid COVID-19 risk even in the absence of SIP policies. It is also unclear whether modest reductions in mobility could slow the spread of an airborne pathogen. Second, it is possible that SIP policies increased deaths of despair due to economic and social isolation effects of SIP policies. Recent estimates in the U.S between March and August 2020 show that drug overdoses, homicides, and unintentional injuries increased in 2020, while suicides declined (Faust et al. 2021). Third, existing studies suggest that SIP policies led to a reduction in non-COVID-19 health care, which might have contributed to an increase in non-COVID-19 deaths (Cantor et al. 2020; Ziedan, Simon, and Wing 2020). For example, one study in the United Kingdom predicts that there will be approximately an additional 3,000 deaths within five years due to a delay in diagnostics because of the COVID-19 pandemic (Maringe et al. 2020).

In light of this evidence, continued reliance on SIP policies to slow COVID-19 transmission may not be optimal. Instead, the best policy response may be pharmaceutical interventions in the form of vaccinations and therapeutics when they become available. Early evidence suggests that initial vaccination efforts have led to large reductions in COVID-19 incidence (Christie 2021; X. Chen et al. 2021; Haas et al. 2021). Policy efforts to promote vaccination are thus likely to have large positive impacts.

7. REFERENCES

Aleman, Christian, Christopher Busch, Alexander Ludwig, and Raül Santaeulàlia-Llopis. 2020. "Evaluating the Effectiveness of Policies Against a Pandemic." SSRN Scholarly Paper ID 3736778. Rochester, NY: Social Science Research Network. https://doi.org/10.2139/ssrn.3736778.

Askitas, Nikolaos, Konstantinos Tatsiramos, and Bertrand Verheyden. 2021. "Estimating Worldwide Effects of Non-Pharmaceutical Interventions on COVID-19 Incidence and Population Mobility Patterns Using a Multiple-Event Study." *Scientific Reports* 11 (1): 1972. https://doi.org/10.1038/s41598-021-81442-x.

Beaney, Thomas, Jonathan M. Clarke, Vageesh Jain, Amelia Kataria Golestaneh, Gemma Lyons, David Salman, and Azeem Majeed. 2020. "Excess Mortality: The Gold Standard in Measuring the Impact of COVID-19 Worldwide?" *Journal of the Royal Society of Medicine* 113 (9): 329–34. https://doi.org/10.1177/0141076820956802.

Berry, Christopher R., Anthony Fowler, Tamara Glazer, Samantha Handel-Meyer, and Alec MacMillen. 2021. "Evaluating the Effects of Shelter-in-Place Policies during the COVID-19 Pandemic." *Proceedings of the National Academy of Sciences of the United States of America* 118 (15). https://doi.org/10.1073/pnas.2019706118.

Cantor, Jonathan, Neeraj Sood, Dena M. Bravata, Megan Pera, and Christopher Whaley. 2020. "The Impact of the COVID-19 Pandemic and Policy Response on Health Care Utilization: Evidence from County-Level Medical Claims and Cellphone Data." Working Paper 28131. National Bureau of Economic Research.

Cappa, Claudia, and Isabel Jijon. 2021. "COVID-19 and Violence against Children: A Review of Early Studies." *Child Abuse & Neglect*, April, 105053. https://doi.org/10.1016/j.chiabu.2021.105053.

Chen, Sophia, Deniz O. Igan, Nicola Pierri, and Andrea F. Presbitero. 2020. "Tracking the Economic Impact of COVID-19 and Mitigation Policies in Europe and the United States." 2020/125. *IMF Working Papers*. IMF Working Papers. International Monetary Fund. https://ideas.repec.org/p/imf/imfwpa/2020-125.html.

Chen, Xiao, Hanwei Huang, Jiandong Ju, Ruoyan Sun, and Jialiang Zhang. 2021. "Impact of Vaccination on the COVID-19 Pandemic: Evidence from U.S. States." *MedRxiv*, May, 2021.05.08.21256892. https://doi.org/10.1101/2021.05.08.21256892.

Chen, Yea-Hung, M. Maria Glymour, Ralph Catalano, Alicia Fernandez, Tung Nguyen, Margot Kushel, and Kirsten Bibbins-Domingo. 2020. "Excess Mortality in California During the Coronavirus Disease 2019 Pandemic, March to August 2020." *JAMA Internal Medicine*, December. https://doi.org/10.1001/jamainternmed.2020.7578.

Christie, Athalia. 2021. "Decreases in COVID-19 Cases, Emergency Department Visits, Hospital Admissions, and Deaths Among Older Adults Following the Introduction of COVID-19 Vaccine — United States, September 6, 2020–May 1, 2021." *MMWR. Morbidity and Mortality Weekly Report* 70. https://doi.org/10.15585/mmwr.mm7023e2.

Ciminelli, Gabriele, and Silvia Garcia-Mandico. 2020. "Business Shutdowns and COVID-19 Mortality." SSRN Scholarly Paper ID 3683324. Rochester, NY: Social Science Research Network. https://doi.org/10.2139/ssrn.3683324.

Correia, Sergio, Stephan Luck, and Emil Verner. 2020. "Pandemics Depress the Economy, Public Health Interventions Do Not: Evidence from the 1918 Flu." SSRN Scholarly

Paper ID 3561560. Rochester, NY: Social Science Research Network. https://doi.org/10.2139/ssrn.3561560.
Courtemanche, Charles, Joseph Garuccio, Anh Le, Joshua Pinkston, and Aaron Yelowitz. 2020. “Strong Social Distancing Measures In The United States Reduced The COVID-19 Growth Rate.” *Health Affairs*, May, 10.1377/hlthaff.2020.00608. https://doi.org/10.1377/hlthaff.2020.00608.
Faust, Jeremy M., Chengan Du, Katherine Dickerson Mayes, Shu-Xia Li, Zhenqiu Lin, Michael L. Barnett, and Harlan M. Krumholz. 2021. “Mortality From Drug Overdoses, Homicides, Unintentional Injuries, Motor Vehicle Crashes, and Suicides During the Pandemic, March-August 2020.” *JAMA*. https://doi.org/10.1001/jama.2021.8012.
Félix-Cardoso, J., H. Vasconcelos, P. Pereira Rodrigues, and R. Cruz-Correia. 2020. “Excess Mortality during COVID-19 in Five European Countries and a Critique of Mortality Data Analysis.” *MedRxiv*, May, 2020.04.28.20083147. https://doi.org/10.1101/2020.04.28.20083147.
Ge, Yong, Wen-Bin Zhang, Haiyan Liu, Corrine W. Ruktanonchai, Maogui Hu, Xilin Wu, Yongze Song, et al. 2021. “Effects of Worldwide Interventions and Vaccination on COVID-19 between Waves and Countries.” *MedRxiv*, April, 2021.03.31.21254702. https://doi.org/10.1101/2021.03.31.21254702.
Giattino, Charlie, Hannah Ritchie, Max Roser, Esteban Ortiz-Ospina, and Joe Hasell. 2021. “Excess Mortality during the Coronavirus Pandemic (COVID-19) - Statistics and Research.” Our World in Data. 2021. https://ourworldindata.org/excess-mortality-covid.
Haas, Eric J., Frederick J. Angulo, John M. McLaughlin, Emilia Anis, Shepherd R. Singer, Farid Khan, Nati Brooks, et al. 2021. “Impact and Effectiveness of MRNA BNT162b2 Vaccine against SARS-CoV-2 Infections and COVID-19 Cases, Hospitalisations, and Deaths Following a Nationwide Vaccination Campaign in Israel: An Observational Study Using National Surveillance Data.” *The Lancet* 397 (10287): 1819–29. https://doi.org/10.1016/S0140-6736(21)00947-8.
Hale, Thomas, Noam Angrist, Rafael Goldszmidt, Beatriz Kira, Anna Petherick, Toby Phillips, Samuel Webster, et al. 2021. “A Global Panel Database of Pandemic Policies (Oxford COVID-19 Government Response Tracker).” *Nature Human Behaviour* 5 (4): 529–38. https://doi.org/10.1038/s41562-021-01079-8.
Hale, Thomas, Laura Hallas, Ariq Hatibie, Saptarshi Majumdar, and Monika Pyarali. 2020. “VARIATION IN US STATES’ RESPONSES TO COVID-19.” BLAVATNIK SCHOOL WORKING PAPER. https://www.bsg.ox.ac.uk/research/publications/variation-us-states-responses-covid-19.
Holland, Kristin M., Christopher Jones, Alana M. Vivolo-Kantor, Nimi Idaikkadar, Marissa Zwald, Brooke Hoots, Ellen Yard, et al. 2021. “Trends in US Emergency Department Visits for Mental Health, Overdose, and Violence Outcomes Before and During the COVID-19 Pandemic.” *JAMA Psychiatry* 78 (4): 372–79. https://doi.org/10.1001/jamapsychiatry.2020.4402.
Jay, Jonathan, Jacob Bor, Elaine O. Nsoesie, Sarah K. Lipson, David K. Jones, Sandro Galea, and Julia Raifman. 2020. “Neighbourhood Income and Physical Distancing during the COVID-19 Pandemic in the United States.” *Nature Human Behaviour* 4 (12): 1294–1302. https://doi.org/10.1038/s41562-020-00998-2.
Johns Hopkins Coronavirus Resource Center. 2021. “COVID-19 Map.” Johns Hopkins Coronavirus Resource Center. 2021. https://coronavirus.jhu.edu/map.html.

Krelle, Holly, Claudia Barclay, and Charles Tallack. 2020. “Understanding Excess Mortality.” The Health Foundation. May 6, 2020. https://www.health.org.uk/news-and-comment/charts-and-infographics/understanding-excess-mortality-the-fairest-way-to-make-international-comparisons.

Krieger, Nancy, Pamela D. Waterman, and Jarvis T. Chen. 2020. “COVID-19 and Overall Mortality Inequities in the Surge in Death Rates by Zip Code Characteristics: Massachusetts, January 1 to May 19, 2020.” *American Journal of Public Health* 110 (12): 1850–52. https://doi.org/10.2105/AJPH.2020.305913.

Leslie, Emily, and Riley Wilson. 2020. “Sheltering in Place and Domestic Violence: Evidence from Calls for Service during COVID-19.” *Journal of Public Economics* 189 (September): 104241. https://doi.org/10.1016/j.jpubeco.2020.104241.

Maringe, Camille, James Spicer, Melanie Morris, Arnie Purushotham, Ellen Nolte, Richard Sullivan, Bernard Rachet, and Ajay Aggarwal. 2020. “The Impact of the COVID-19 Pandemic on Cancer Deaths Due to Delays in Diagnosis in England, UK: A National, Population-Based, Modelling Study.” *The Lancet Oncology* 21 (8): 1023–34. https://doi.org/10.1016/S1470-2045(20)30388-0.

Mason, Maryann, Sarah B. Welch, Ponni Arunkumar, Lori Ann Post, and Joseph M. Feinglass. 2021. “Notes from the Field: Opioid Overdose Deaths Before, During, and After an 11-Week COVID-19 Stay-at-Home Order — Cook County, Illinois, January 1, 2018–October 6, 2020.” *MMWR. Morbidity and Mortality Weekly Report* 70. https://doi.org/10.15585/mmwr.mm7010a3.

McBain, Ryan K., Jonathan H. Cantor, Anupam B. Jena, Megan F. Pera, Dena M. Bravata, and Christopher M. Whaley. 2021. “Decline and Rebound in Routine Cancer Screening Rates During the COVID-19 Pandemic.” *Journal of General Internal Medicine*, March. https://doi.org/10.1007/s11606-021-06660-5.

Morgan, David, Junya Ino, Gabriel Di Paolantonio, and Fabrice Murtin. 2020. “Excess Mortality: Measuring the Direct and Indirect Impact of COVID-19,” October. https://doi.org/10.1787/c5dc0c50-en.

Mulligan, Casey B. 2020. “Deaths of Despair and the Incidence of Excess Mortality in 2020.” w28303. National Bureau of Economic Research. https://doi.org/10.3386/w28303.

Nguyen, Thuy D., Sumedha Gupta, Martin Andersen, Ana Bento, Kosali I. Simon, and Coady Wing. 2020. “Impacts of State Reopening Policy on Human Mobility.” 27235. *NBER Working Papers*. NBER Working Papers. National Bureau of Economic Research, Inc. https://ideas.repec.org/p/nbr/nberwo/27235.html.

Patrick, Stephen W., Laura E. Henkhaus, Joseph S. Zickafoose, Kim Lovell, Alese Halvorson, Sarah Loch, Mia Letterie, and Matthew M. Davis. 2020. “Well-Being of Parents and Children During the COVID-19 Pandemic: A National Survey.” *Pediatrics*, August. https://doi.org/10.1542/peds.2020-016824.

Petterson, Stephen, John M. Westfall, and Benjamin F. Miller. 2020. “Projected Deaths of Despair During COVID-19.” Well Being Trust. https://wellbeingtrust.org/areas-of-focus/policy-and-advocacy/reports/projected-deaths-of-despair-during-covid-19/.

Polyakova, Maria, Victoria Udalova, Geoffrey Kocks, Katie Genadek, Keith Finlay, and Amy N. Finkelstein. 2021. “Racial Disparities In Excess All-Cause Mortality During The Early COVID-19 Pandemic Varied Substantially Across States.” *Health Affairs (Project Hope)* 40 (2): 307–16. https://doi.org/10.1377/hlthaff.2020.02142.

Rannan-Eliya, Ravindra Prasan, Nilmini Wijemunige, J. R. N. A. Gunawardana, Sarasi N. Amarasinghe, Ishwari Sivagnanam, Sachini Fonseka, Yasodhara Kapuge, and Chathurani P. Sigera. 2021. "Increased Intensity Of PCR Testing Reduced COVID-19 Transmission Within Countries During The First Pandemic Wave." *Health Affairs (Project Hope)* 40 (1): 70–81. https://doi.org/10.1377/hlthaff.2020.01409.

Ritchie, Hannah, Esteban Ortiz-Ospina, Diana Beltekian, Edouard Mathieu, Joe Hasell, Bobbie Macdonald, Charlie Giattino, Cameron Appel, Lucas Rodés-Guirao, and Max Roser. 2020. "Coronavirus Pandemic (COVID-19)." *Our World in Data*, March. https://ourworldindata.org/coronavirus.

Rossen, Lauren M., Amy M. Branum, Farida B. Ahmad, Paul Sutton, and Robert N. Anderson. 2020. "Excess Deaths Associated with COVID-19, by Age and Race and Ethnicity - United States, January 26-October 3, 2020." *MMWR. Morbidity and Mortality Weekly Report* 69 (42): 1522–27. https://doi.org/10.15585/mmwr.mm6942e2.

Singh, Surya, Mujaheed Shaikh, Katharina Hauck, and Marisa Miraldo. 2021. "Impacts of Introducing and Lifting Nonpharmaceutical Interventions on COVID-19 Daily Growth Rate and Compliance in the United States." *Proceedings of the National Academy of Sciences of the United States of America* 118 (12). https://doi.org/10.1073/pnas.2021359118.

Sonu, Stan, Sharon Post, and Joe Feinglass. 2019. "Adverse Childhood Experiences and the Onset of Chronic Disease in Young Adulthood." *Preventive Medicine* 123 (June): 163–70. https://doi.org/10.1016/j.ypmed.2019.03.032.

The Economist. 2020. "The Economist's Tracker for Covid-19 Excess Deaths (Online)." 2020. https://github.com/TheEconomist/covid-19-excess-deaths-tracker.

Whaley, Christopher M., Megan F. Pera, Jonathan Cantor, Jennie Chang, Julia Velasco, Heather K. Hagg, Neeraj Sood, and Dena M. Bravata. 2020. "Changes in Health Services Use Among Commercially Insured US Populations During the COVID-19 Pandemic." *JAMA Network Open* 3 (11): e2024984.

Woolf, Steven H., Derek A. Chapman, Roy T. Sabo, Daniel M. Weinberger, Latoya Hill, and DaShaunda D. H. Taylor. 2020. "Excess Deaths From COVID-19 and Other Causes, March-July 2020." *JAMA* 324 (15): 1562–64. https://doi.org/10.1001/jama.2020.19545.

Woolf, Steven H., Derek A. Chapman, Roy T. Sabo, and Emily B. Zimmerman. 2021. "Excess Deaths From COVID-19 and Other Causes in the US, March 1, 2020, to January 2, 2021." *JAMA*.

Xie, Xinyan, Qi Xue, Yu Zhou, Kaiheng Zhu, Qi Liu, Jiajia Zhang, and Ranran Song. 2020. "Mental Health Status Among Children in Home Confinement During the Coronavirus Disease 2019 Outbreak in Hubei Province, China." *JAMA Pediatrics* 174 (9): 898–900. https://doi.org/10.1001/jamapediatrics.2020.1619.

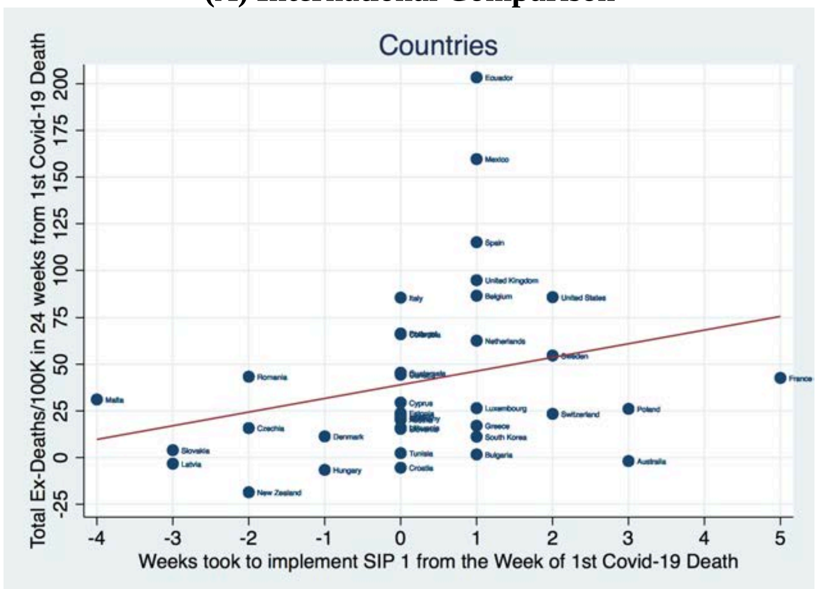
Xu, Dafeng. 2021. "Physical Mobility under Stay-at-Home Orders: A Comparative Analysis of Movement Restrictions between the U.S. and Europe." *Economics and Human Biology* 40 (January): 100936. https://doi.org/10.1016/j.ehb.2020.100936.

Ziedan, Engy, Kosali I Simon, and Coady Wing. 2020. "Effects of State COVID-19 Closure Policy on NON-COVID-19 Health Care Utilization." Working Paper 27621. Working Paper Series. National Bureau of Economic Research. https://doi.org/10.3386/w27621.

8. TABLES AND FIGURES

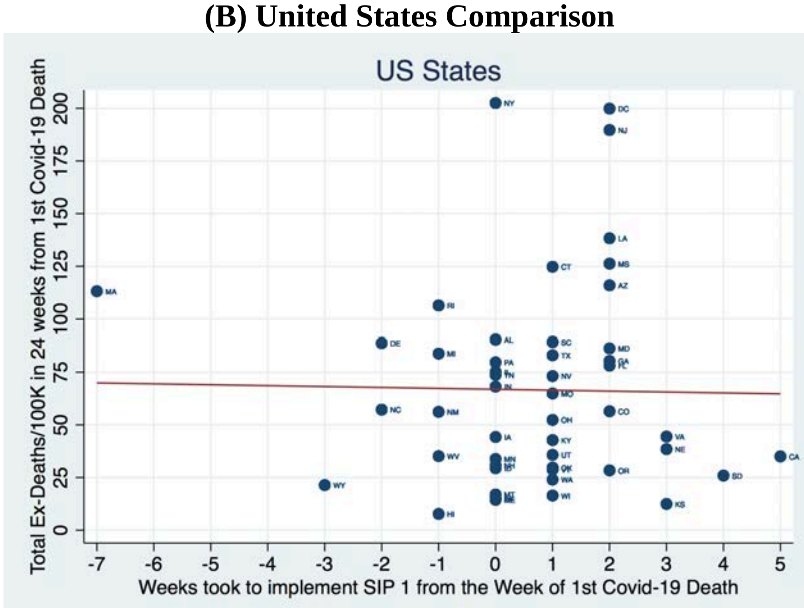
Figure 1: Total excess deaths per 100,000 population after 24 weeks from the first COVID-19 death, compared to number of weeks countries/states took to implement first SIP policy from the week of first COVID-19 death

(A) International Comparison



Note: The above graph does not include Ireland, Taiwan and Norway because these countries did not implement SIP in the period of our analysis, i.e., 24 weeks from the week of first COVID-19 death.

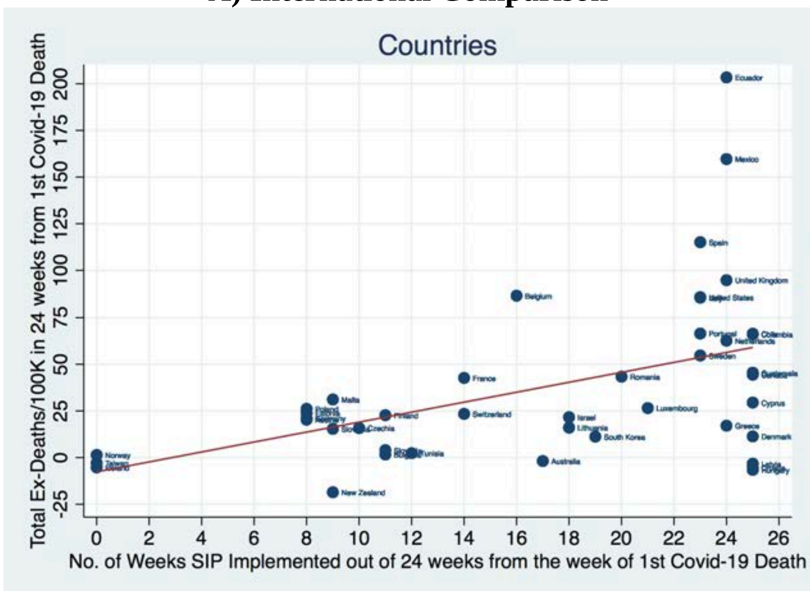
(B) United States Comparison



Note: The above graph does not include Arkansas and North Dakota because these two states did not implement SIP in the period of our analysis, i.e., 24 weeks from the week of first COVID-19 death.

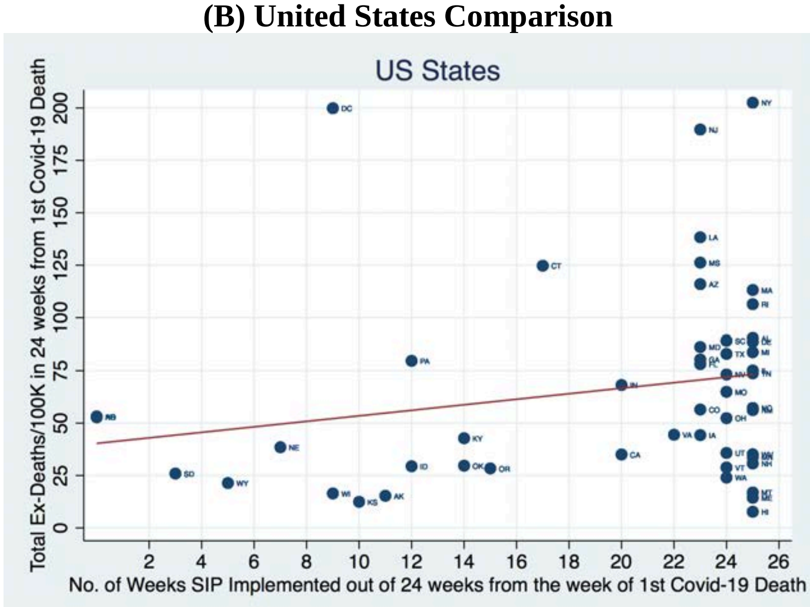
Figure 2: Total excess deaths per 100,000 population after 24 weeks from the first COVID-19 death, compared to number of weeks SIP policy was implemented by countries/states from the week of first COVID-19 death until twenty fifth week from the first week

A) International Comparison



Note: The above graph indicates Ireland, Taiwan and Norway at X = 0 because these countries did not implement SIP in the period of our analysis, i.e. 24 weeks from the week of first COVID-19 death

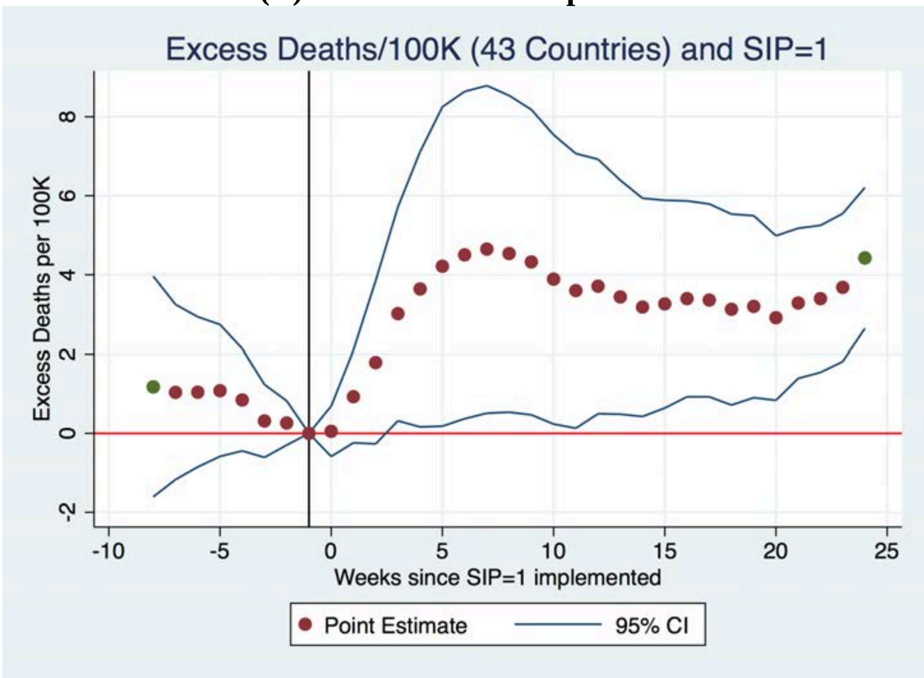
(B) United States Comparison



Note: The above graph indicates Arkansas and North Dakota at X = 0 because these two states did not implement SIP in the period of our analysis, i.e., 24 weeks from the week of first COVID-19 death

Figure 3: Event study estimates of changes in excess deaths per 100,000 population, before and after shelter-in-place policies

(A) International Comparison



(B) United States Comparison

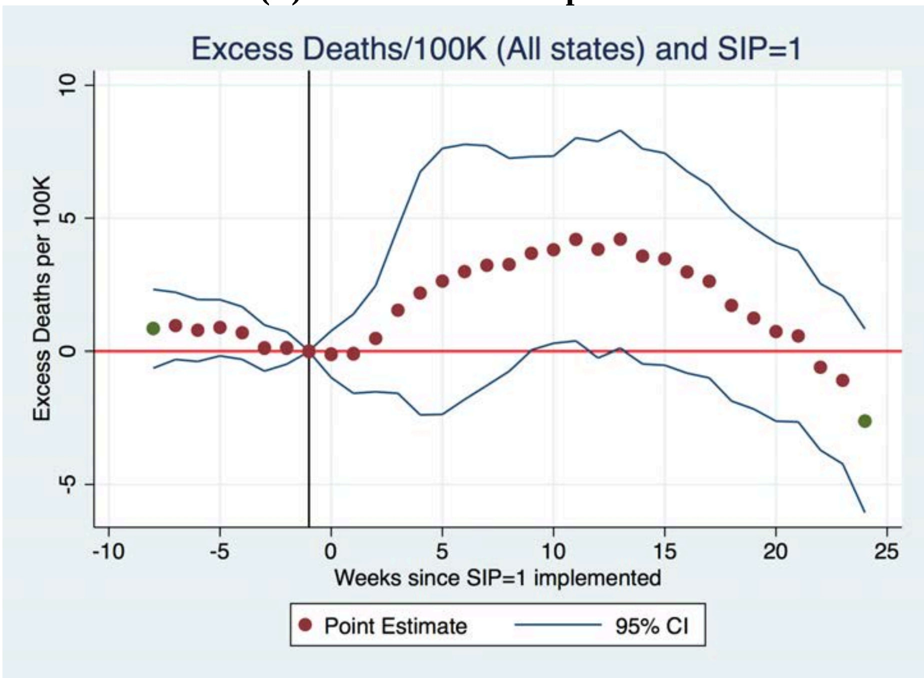
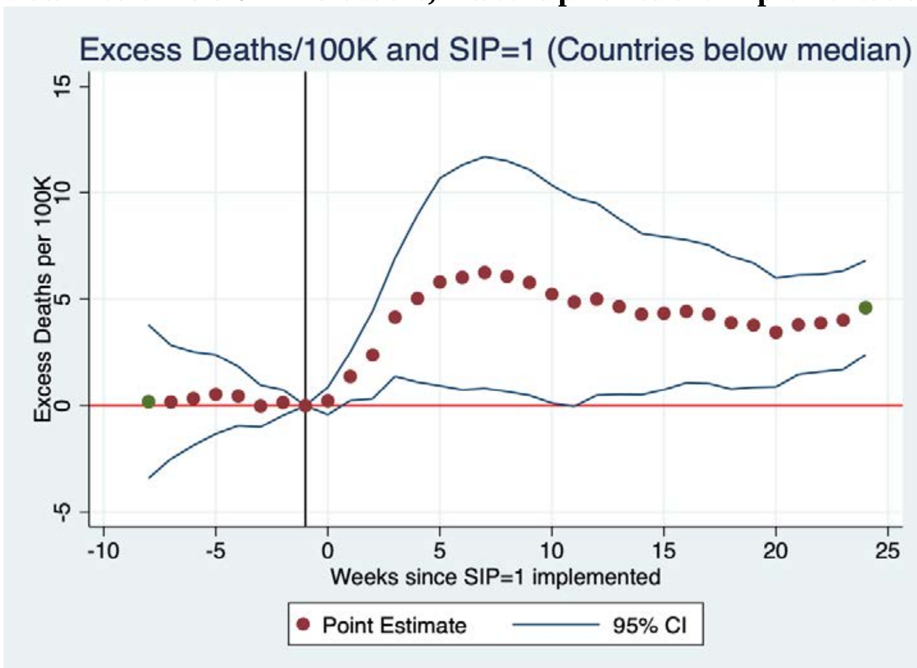


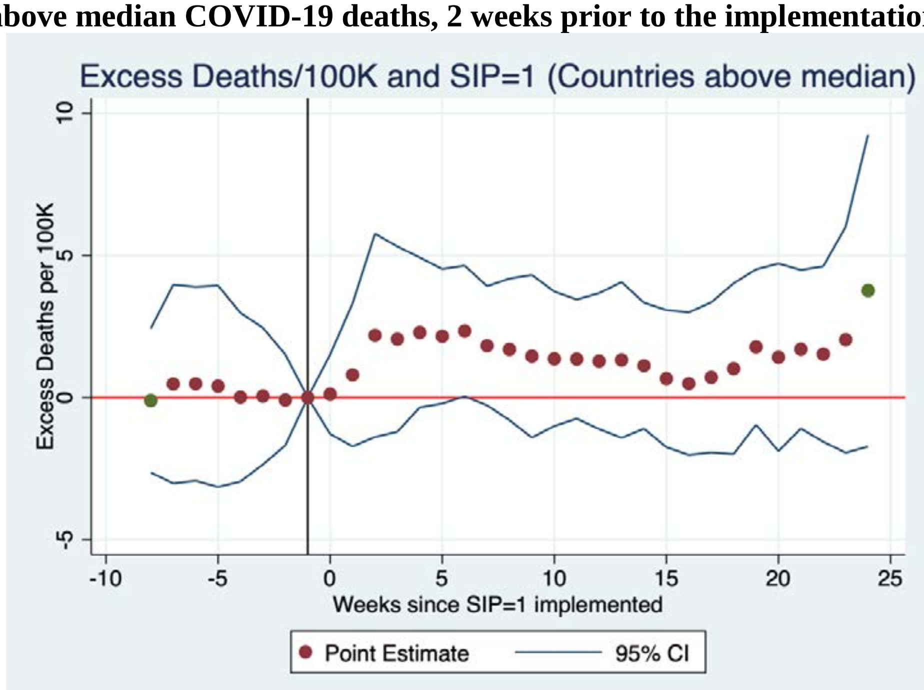
Figure 4 Event study estimates of changes in excess deaths per 100,000 population, before and after shelter-in-place policies, and based on COVID-19 deaths prior to policy implementation

(A) International Comparison

Countries below median COVID-19 deaths, 2 weeks prior to the implementation of SIP

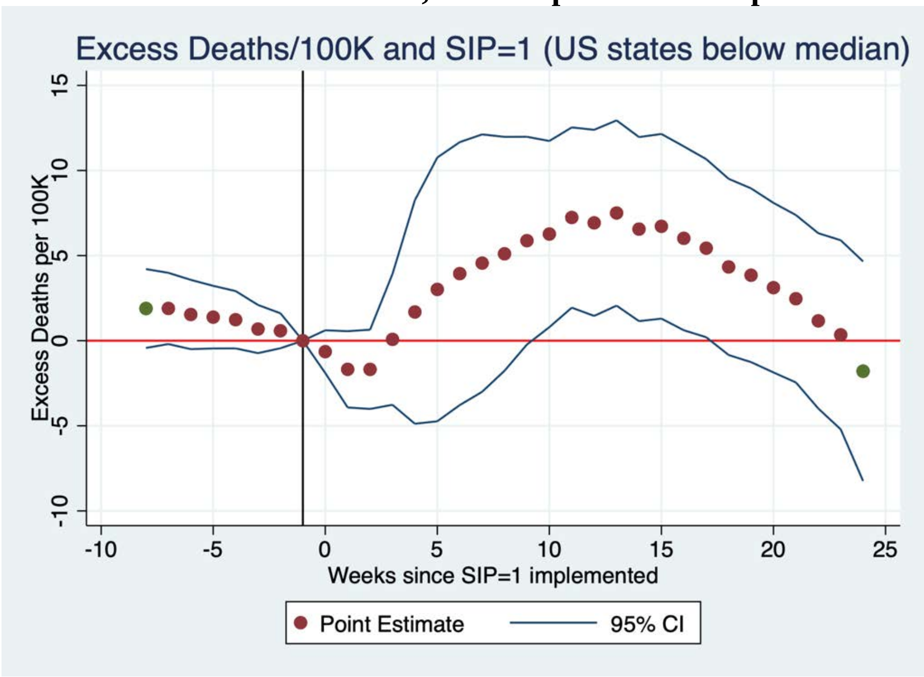


Countries above median COVID-19 deaths, 2 weeks prior to the implementation of SIP

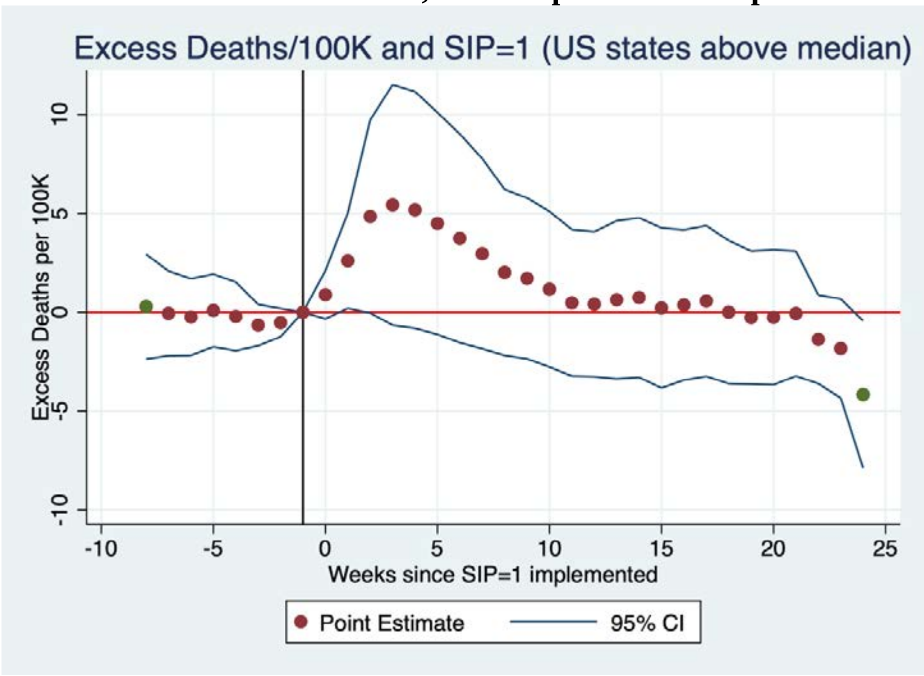


(B) United States Comparison

US States below median COVID-19 deaths, 2 weeks prior to the implementation of SIP

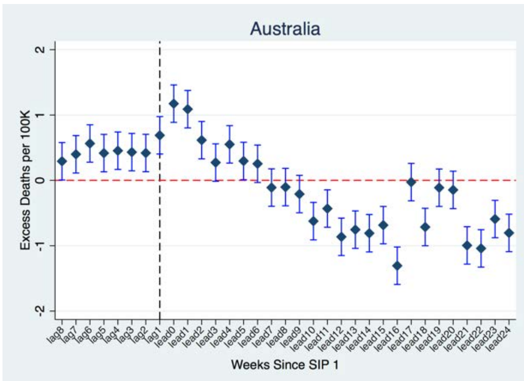


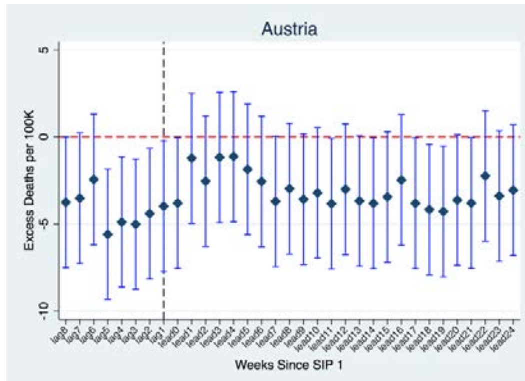
US States above median COVID-19 deaths, 2 weeks prior to the implementation of SIP

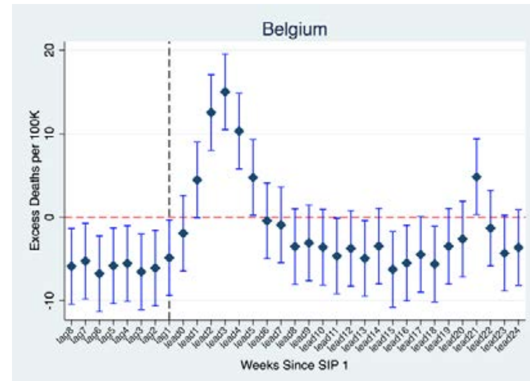


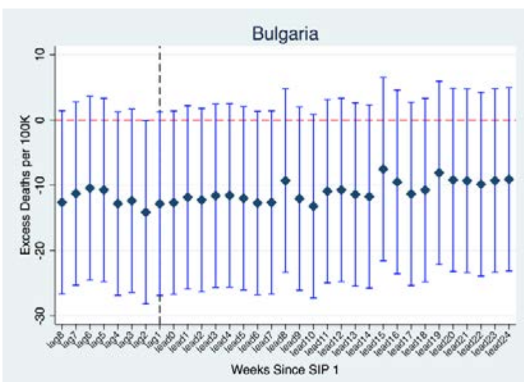
9. APPENDIX

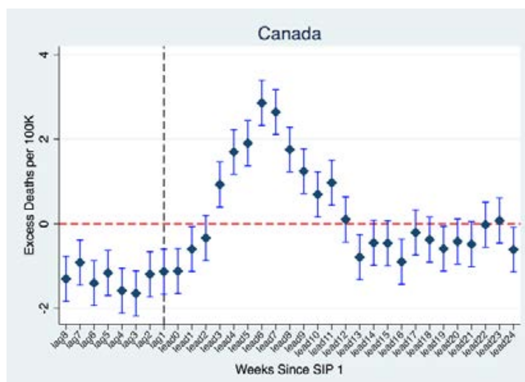
9.1. Individual Country Comparison

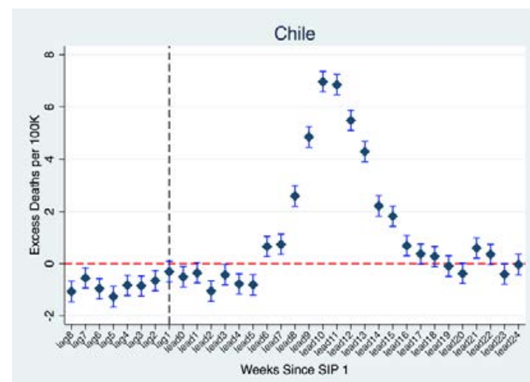


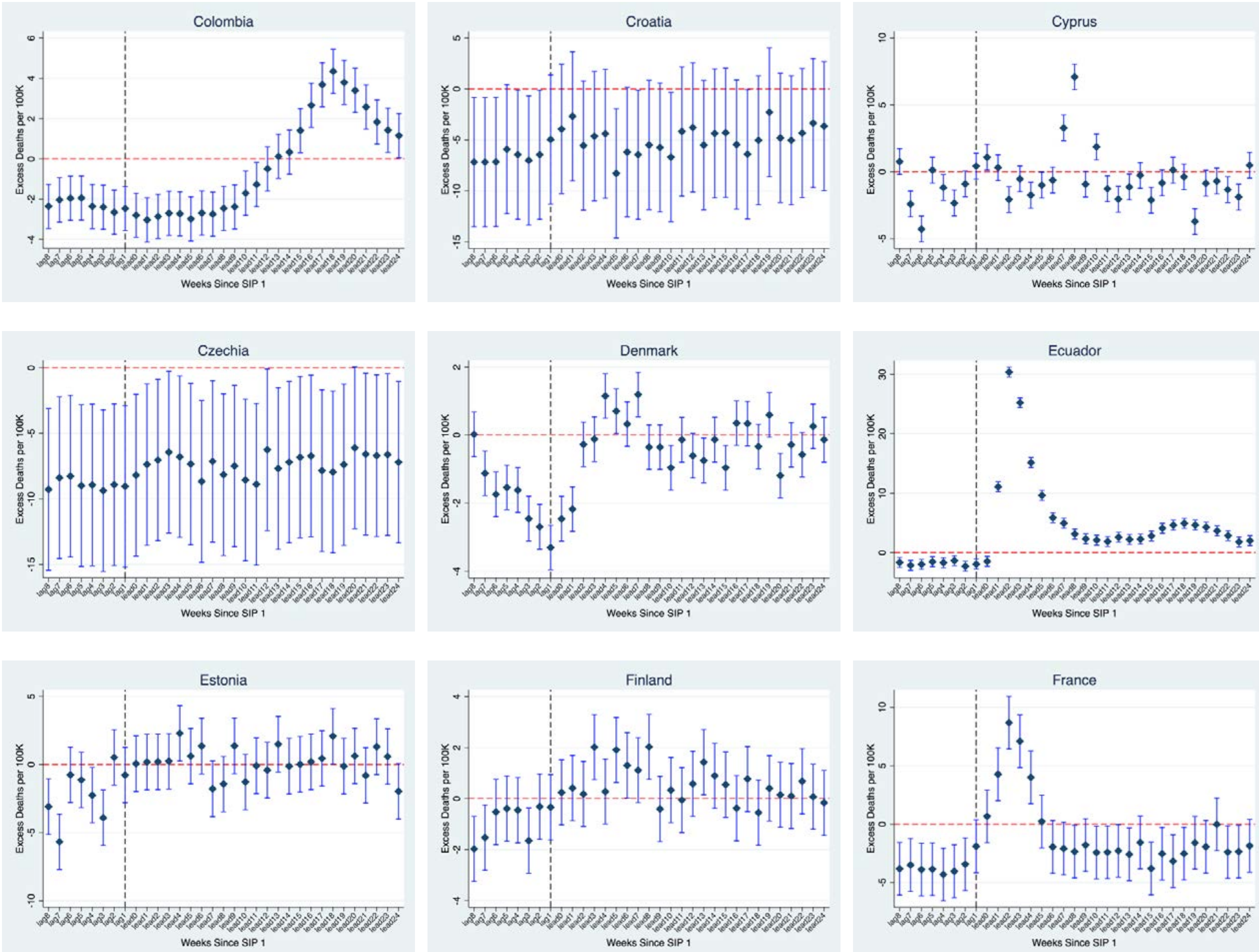


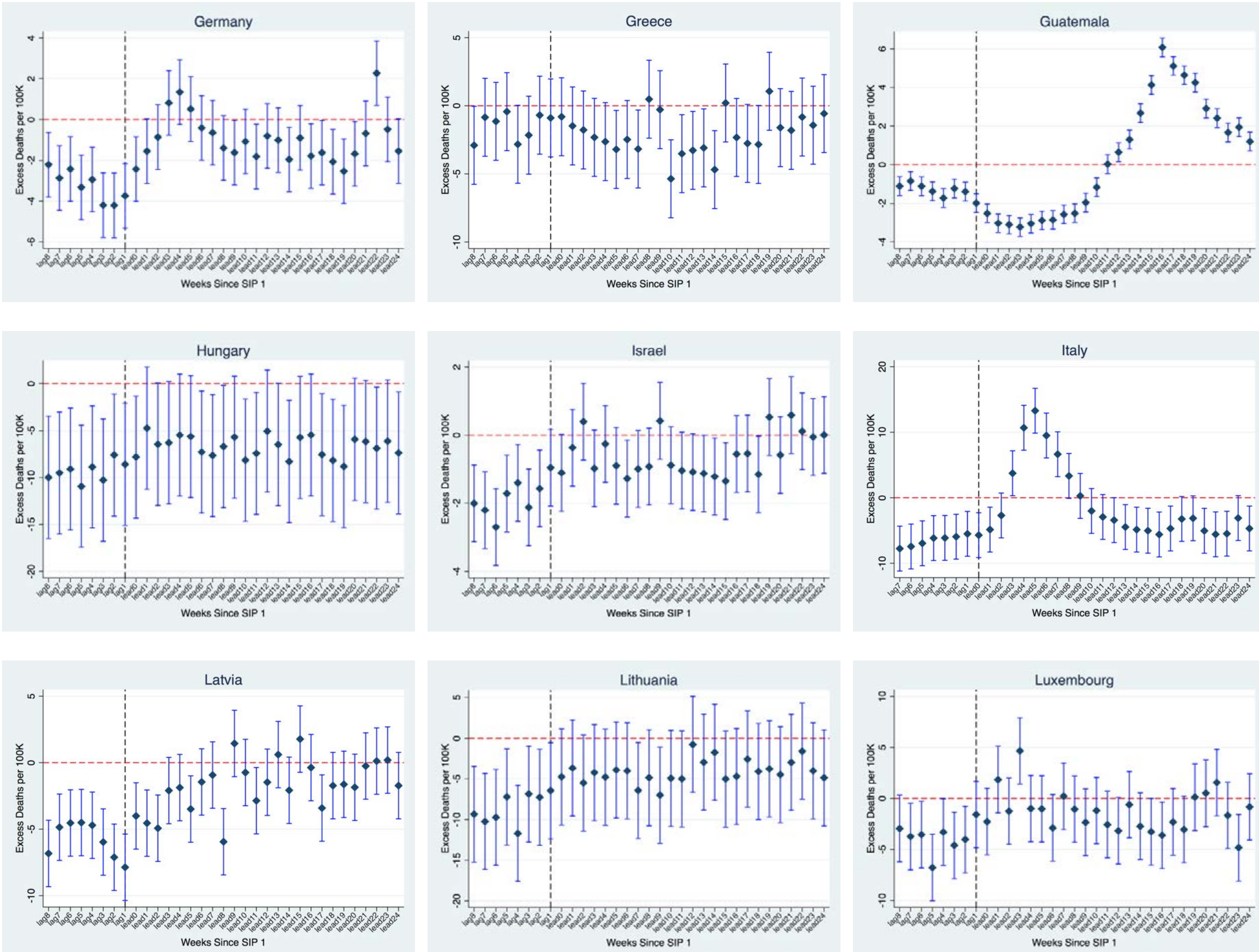


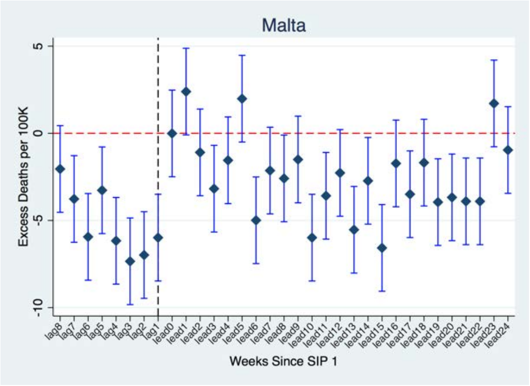


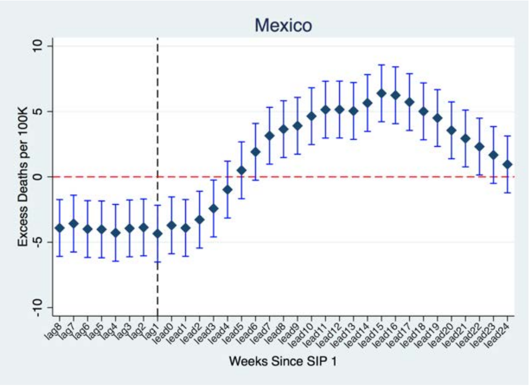


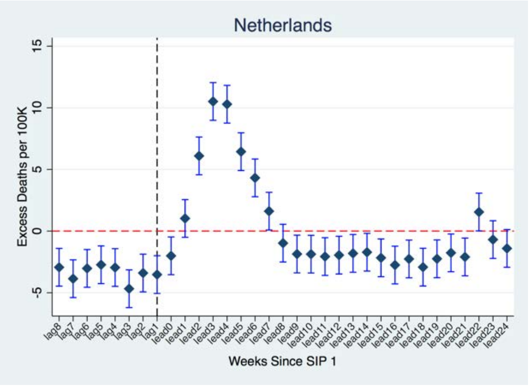


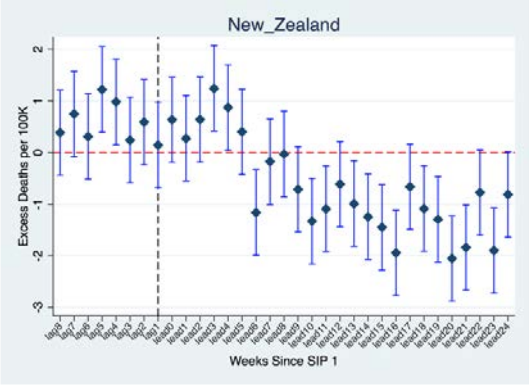

Colombia
Croatia
Cyprus
Czechia
Denmark
Ecuador
Estonia
Finland
France
Excess Deaths per 100K
Weeks Since SIP 1

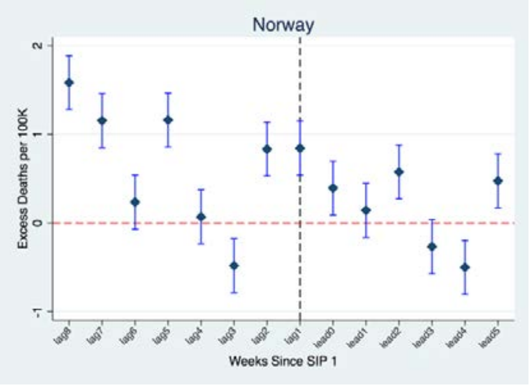

Germany
Greece
Guatemala
Hungary
Israel
Italy
Latvia
Lithuania
Luxembourg
Excess Deaths per 100K
Weeks Since SIP 1

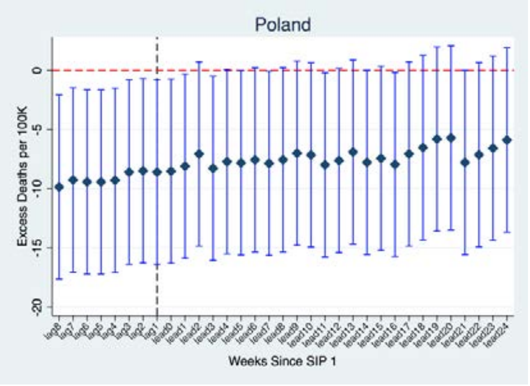

Malta
Excess Deaths per 100K
Weeks Since SIP 1

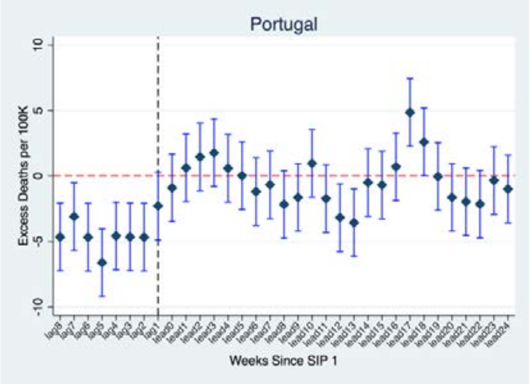

Mexico
Excess Deaths per 100K
Weeks Since SIP 1

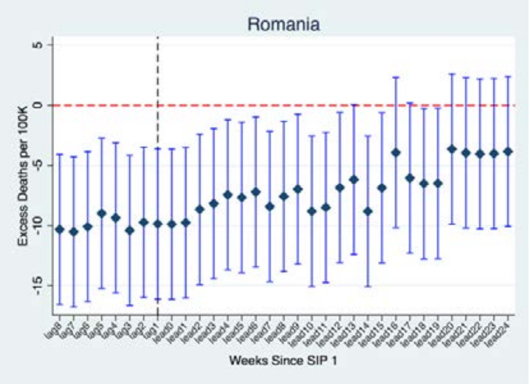

Netherlands
Excess Deaths per 100K
Weeks Since SIP 1

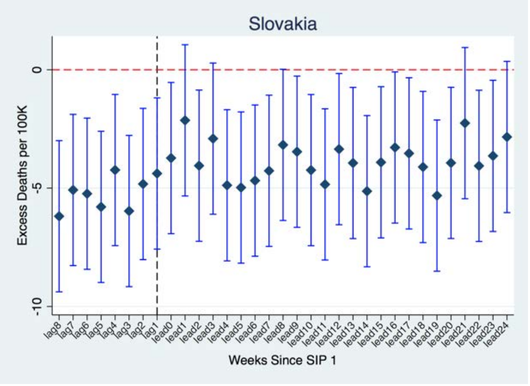

New_Zealand
Excess Deaths per 100K
Weeks Since SIP 1

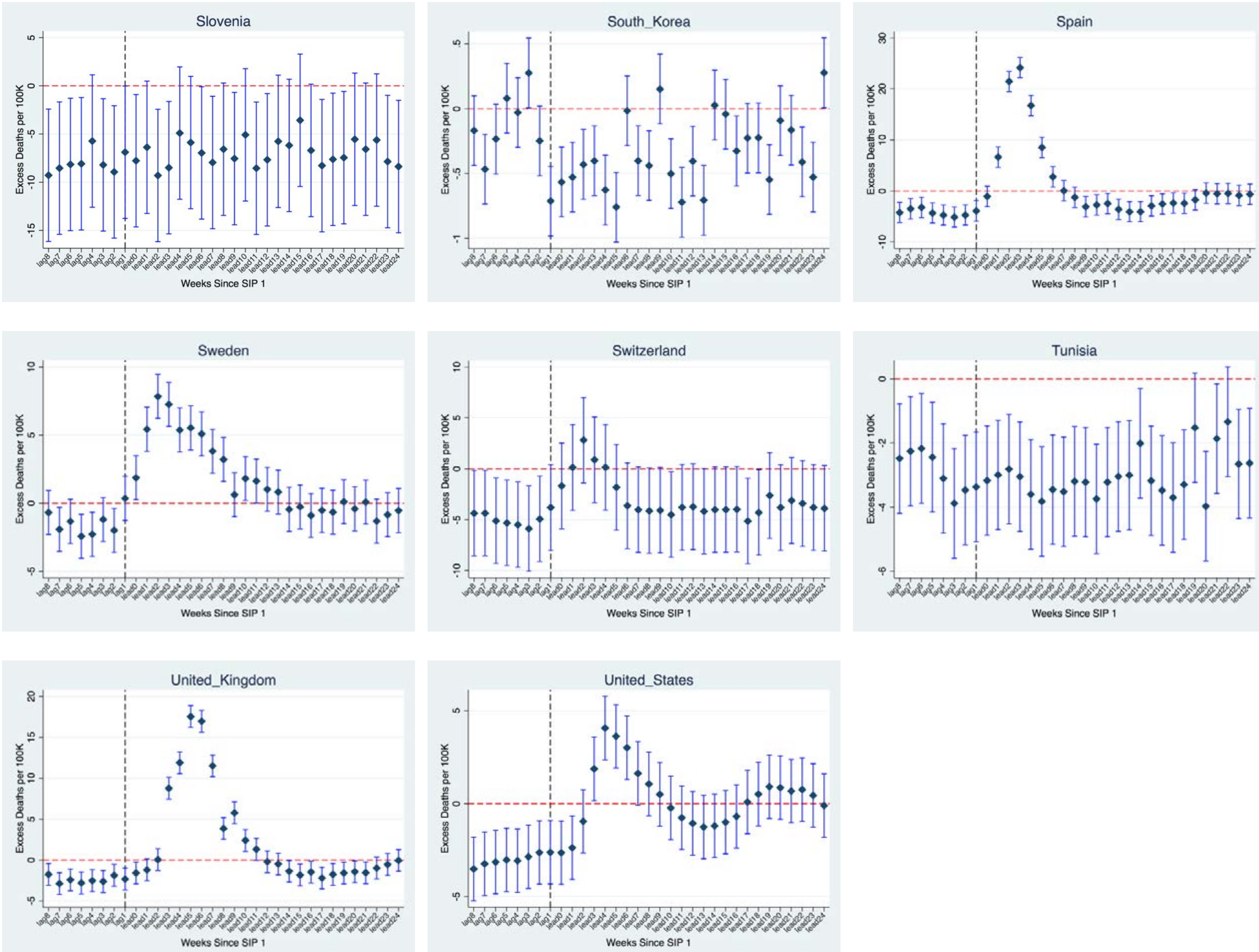

Norway
Excess Deaths per 100K
Weeks Since SIP 1


Poland
Excess Deaths per 100K
Weeks Since SIP 1

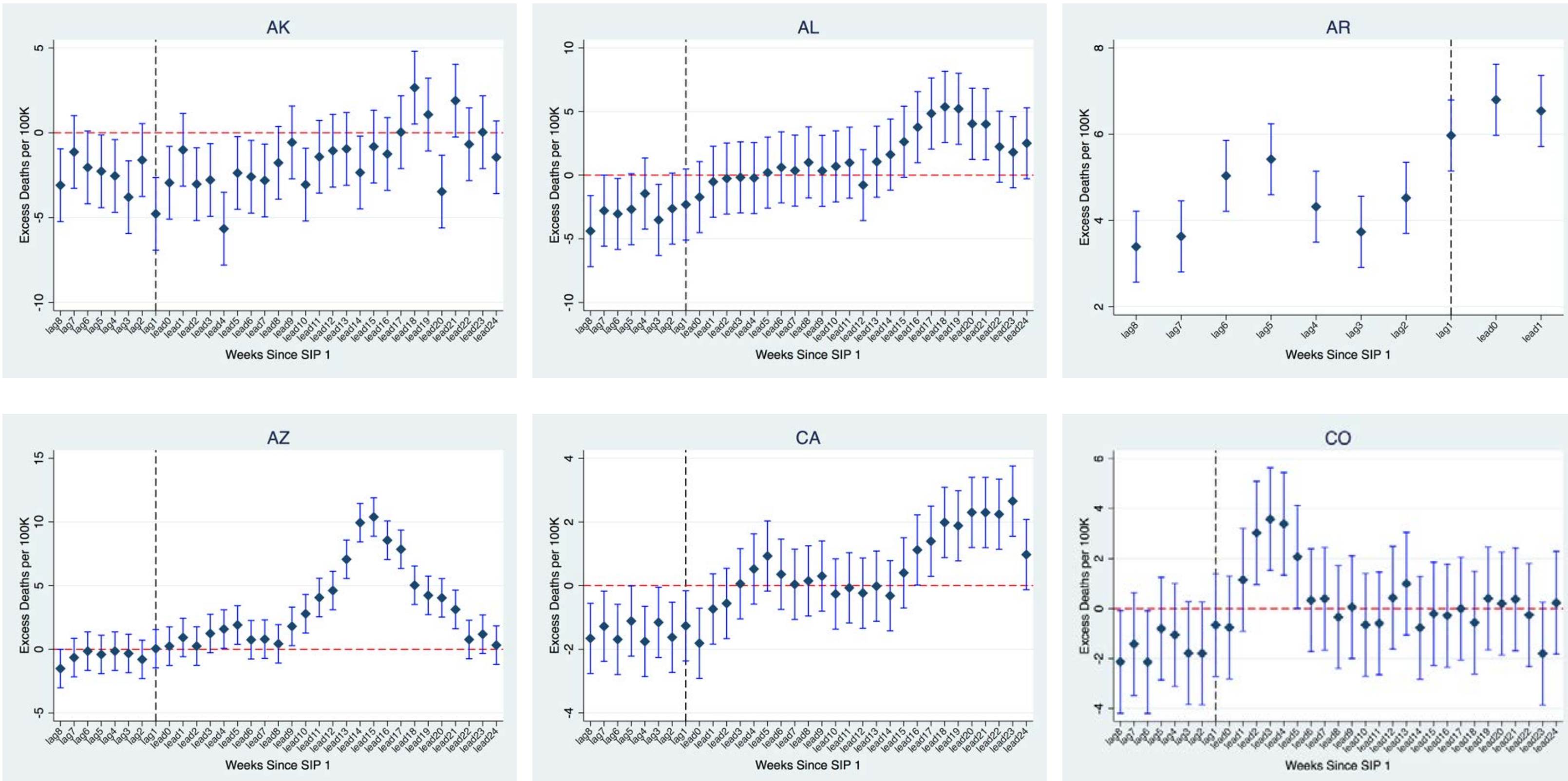

Portugal
Excess Deaths per 100K
Weeks Since SIP 1

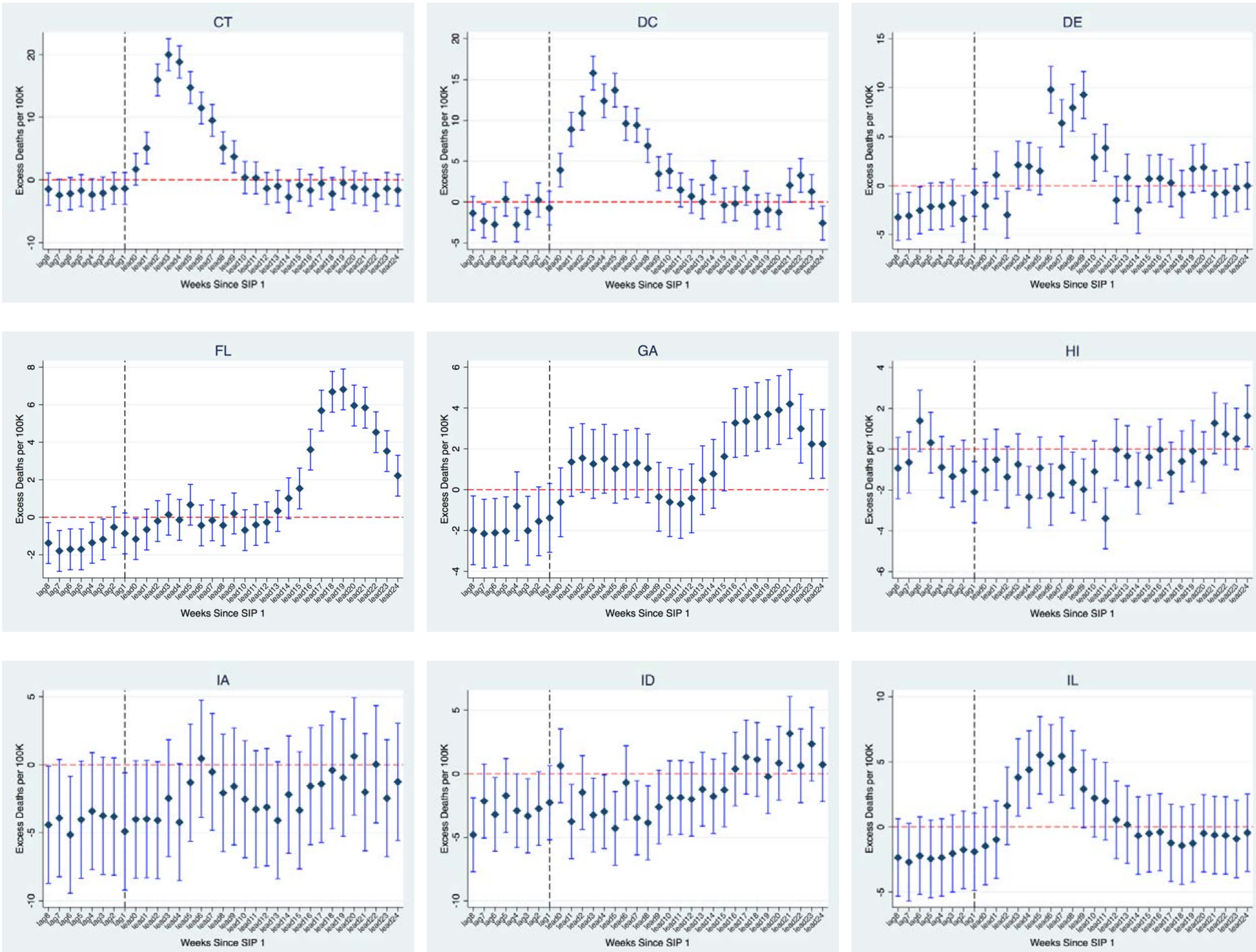

Romania
Excess Deaths per 100K
Weeks Since SIP 1

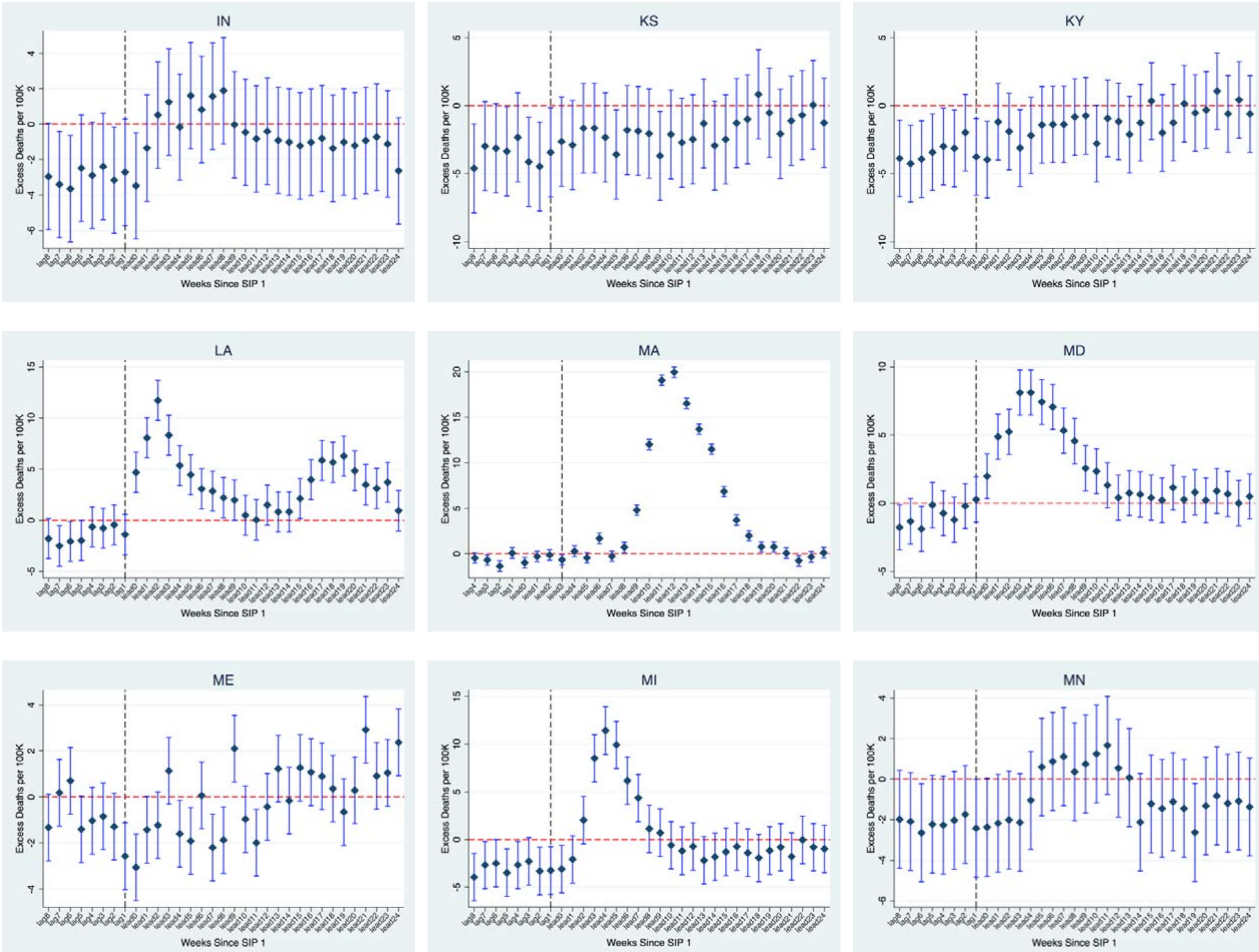

Slovakia
Excess Deaths per 100K
Weeks Since SIP 1

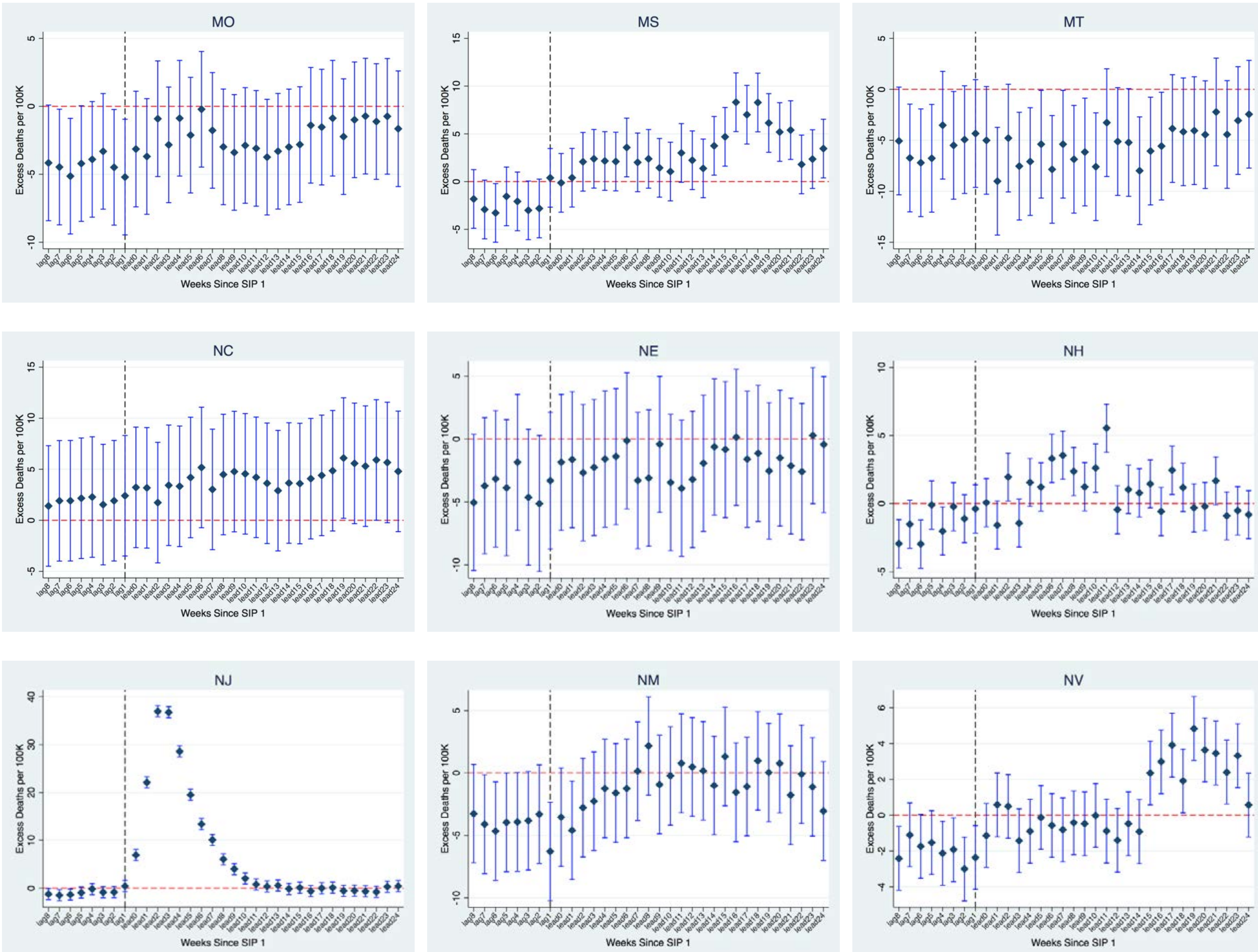

Slovenia
South_Korea
Spain
Sweden
Switzerland
Tunisia
United_Kingdom
United_States
Excess Deaths per 100K
Weeks Since SIP 1

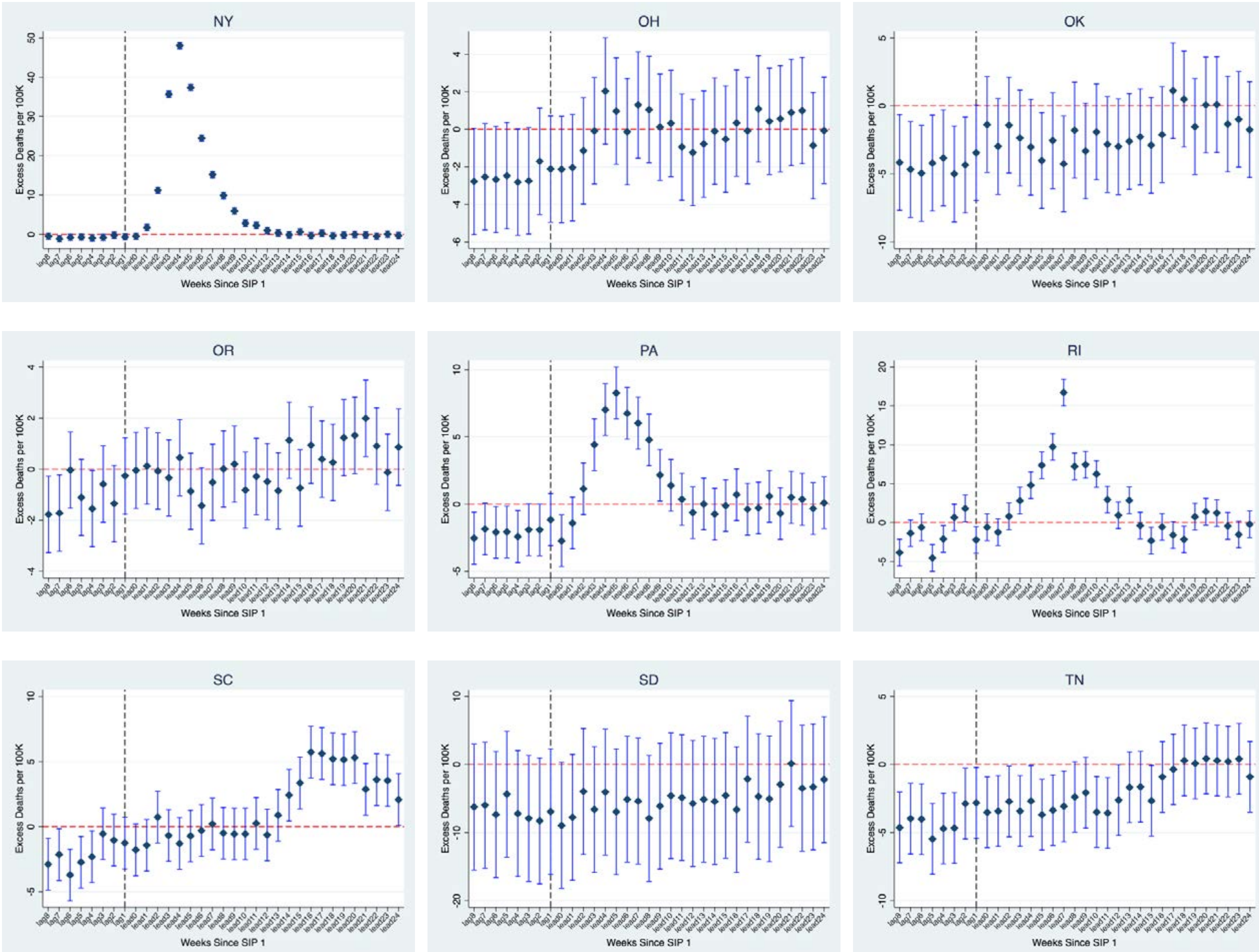
9.2. US State Comparison

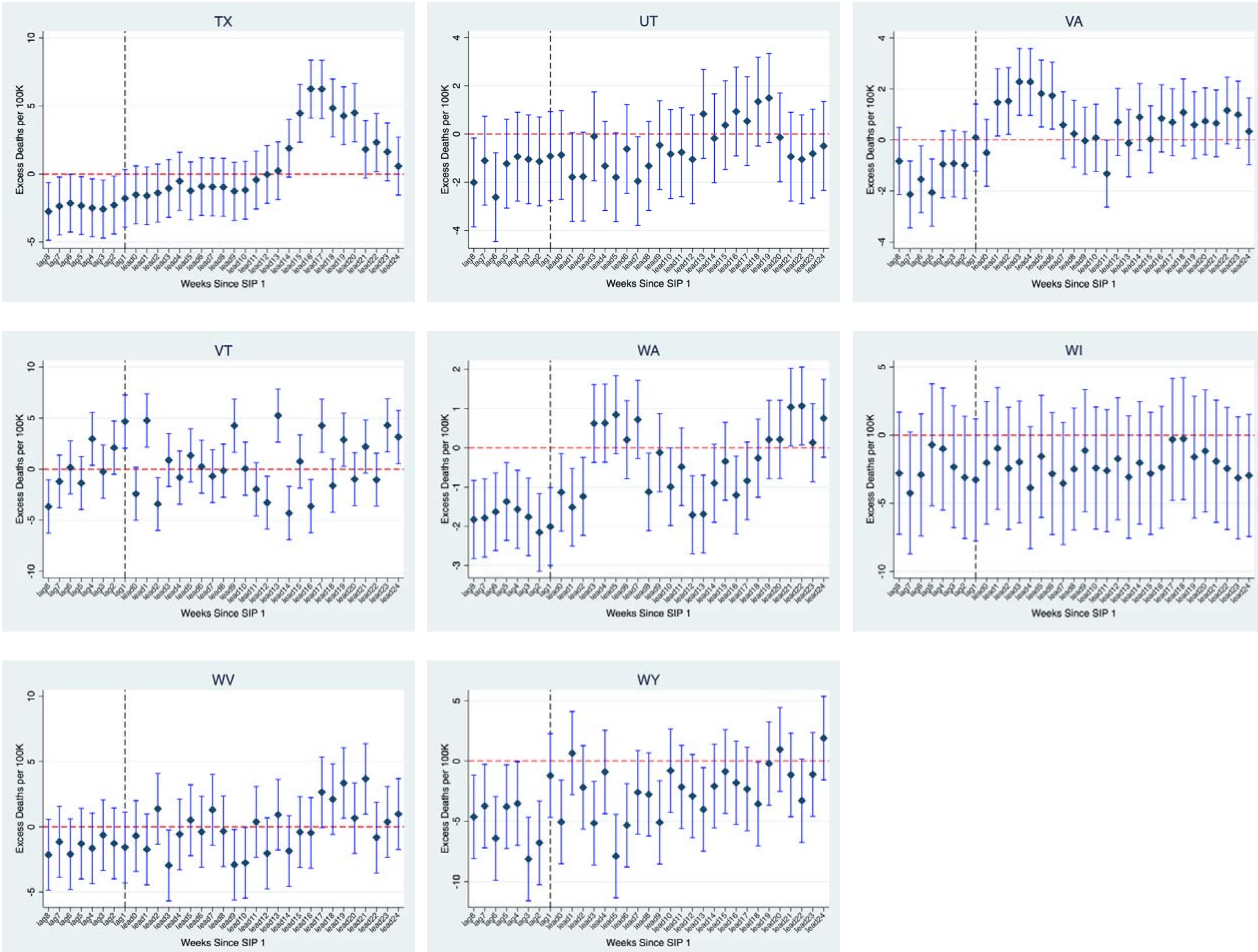



CT
DC
DE
FL
GA
HI
IA
ID
IL
Excess Deaths per 100K
Weeks Since SIP 1


IN
KS
KY
LA
MA
MD
ME
MI
MN
Excess Deaths per 100K
Weeks Since SIP 1


MO
MS
MT
NC
NE
NH
NJ
NM
NV
Excess Deaths per 100K
Weeks Since SIP 1


NY
OH
OK
OR
PA
RI
SC
SD
TN
Excess Deaths per 100K
Weeks Since SIP 1


TX
UT
VA
VT
WA
WI
WV
WY
Excess Deaths per 100K
Weeks Since SIP 1