

**National Profiles of Coronavirus Disease – 2019 Mortality Risks  
by Age Structure and Preexisting Health Conditions**

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**Conflicts of Interest**

None.

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## Abstract

*Background and Objectives:* Although individual age and preexisting health conditions are well-documented risk factors for Coronavirus Disease 2019 (COVID-19) mortality, it is unclear whether these two factors capture unique dimensions of risk for epidemic severity at the national level. In addition, no studies have examined whether national distributions of these factors are associated with epidemic experiences to date.

*Research Design and Methods:* Drawing on surveys of older adults from 42 countries and estimated case fatality ratios by age and preexisting health conditions, we document and compare national profiles of COVID-19 mortality risks among older adults. We develop two measures of national risk profiles: one based on age structures and another based on distributions of preexisting health conditions. Our analysis compares these constructs and documents their associations with national COVID-19 mortality rates.

*Results:* National profiles of COVID-19 mortality risk based on age structure and preexisting health conditions are moderately uncorrelated, capturing different aspects of risk. Both types of national risk profiles correlate meaningfully with countries' COVID-19 mortality experiences to date.

*Discussion and Implications:* Measures of population age structure are readily available for every country in the world, while cross-national measures of older adult population health are more limited. In the COVID-19 crisis, these factors give different pictures of the countries with high and low risks of COVID-19 mortality. Moreover, our results suggest that both types of national risk profiles based on population health reflect current COVID-19 mortality severity in several countries, highlighting the need for more cross-national comparative data on older adult population health.

**Keywords:** Coronavirus Disease – 2019; Cross-national; Demography; Aging; Population Health

## Introduction

Although much remains unknown about what predicts mortality from Coronavirus Disease – 2019 (COVID-19), recorded deaths in numerous countries are concentrated in older adults and among those with preexisting health conditions (Jordan et al., 2020). Because of the strong relationship between COVID-19 mortality and the most basic demographic variable, age, demographers have contributed several important cross-national comparisons highlighting variation in the risks COVID-19 poses for different countries (Dowd et al., 2020a; Esteve et al., 2020; Goldstein & Atherwood, 2020; Nepomuceno et al., 2020). What this variation implies for COVID-19 mortality risks is understudied, however, with the primary contributions using modeled national prevalence estimates of preexisting health conditions prevalence from the Global Burden of Disease study (Clark et al., 2020), whose quality is debated (Byass et al., 2013), or tests of such processes in only two or three countries (Dowd et al., 2020a; Nepomuceno et al., 2020). Despite the aforementioned (and other) contributions to understanding how age structure and preexisting health conditions independently or jointly *might* influence national severity of the COVID-19 crisis, a few important questions remain unaddressed. First, we hypothesize that national risk profiles for COVID-19 mortality based on age structures differ from the risks based on preexisting health conditions. Further, although there is substantial emphasis on different social factors in explaining the severity of COVID-19 mortality in different countries, such as intergenerational living arrangements (Arpino et al., 2020; Balbo et al., 2020; Esteve et al., 2020), no studies have assessed associations between current crisis severity and national risk profiles based on age structures or preexisting health conditions. This begs a second hypothesis: national age structure and population health profiles are associated with *observed* COVID-19 mortality rates.

There are important reasons that gerontologists must consider these two research questions. First, in spite of wide knowledge of cross-national variation in later life morbidity (e.g., Crimmins et al., 2010), it is unclear the extent to which this variation aligns with different countries' age profiles, especially in light of this disease. This matters because many countries and subnational locales have been "slow to raise the alarm" when transmission occurs in low risk groups (Dowd et al., 2020a:9696). Transmission among high risk groups is more visible than among low risk groups due to the increased mortality prevalence. Deaths are highly visible events, they are easier to ascertain than other disease outcomes (Kobayashi et al., 2020) and create visceral reactions among the many they leave bereaved (Verdery & Smith-Greenway, 2020; Verdery et al., 2020). This visibility could result in a greater policy response in scenarios where transmission is occurring among high risk groups rather than low risk groups. Many countries may remain at risk of unraised alarms owing to undetected and uncontrolled spread, with fewer mitigation procedures in place, ultimately worsening the global outbreak. If these two dimensions of risk (age structure and population health) are closely correlated for this disease, then there is effectively only one risk dimension because those who lack one risk tend to lack the other. On the other hand, if these dimensions are weakly correlated, then a much larger fraction of the population could be at high risk – either suffering mortality risks owing to their age or suffering them owing to their health. Second, in the context of COVID-19, studies show media reports in numerous countries stressing nearly exclusive risks to older adults and harsh expressions of ageism (Lichtenstein 2020). Further understanding national vulnerability to the disease because of factors other than age may reduce such negative sentiments.

In this brief report, we document and compare national profiles of COVID-19 mortality risks among older adults in 42 countries from around the world. We evaluate how age structure or distribution of preexisting health conditions may capture different

dimensions of risk. We first construct national risk profiles for COVID-19 mortality based on the distributions of older adults by age and preexisting conditions in each country. Second, we test for differences between these two types of national risk profiles by examining their correlation and a bivariate linear regression of their relationship. Third, we assess whether and how closely the natural logarithm of current crude COVID-19 mortality rates are associated with national risk profiles based on age structure and preexisting health conditions, which we also test using correlations and bivariate linear regressions that compare mortality rates against each of the national risk profiles.

## **Methods**

### *Data and Samples*

We use data from 16 studies of older adults in 42 countries around the world (Austria, Belgium, Brazil, Bulgaria, China, Costa Rica, Croatia, Cyprus, Czech Republic, Denmark, England, Estonia, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Israel, Italy, Japan, Latvia, Lithuania, Luxembourg, Malta, Mexico, New Zealand, Poland, Portugal, Republic of Korea, Romania, Russian Federation, Slovakia, Slovenia, South Africa, Spain, Switzerland, Sweden, Thailand, and the United States of America). In 2020, these countries contain 73% of the world's population over 50 years old (United Nations, 2019). As of August 1, 2020, they contained 79.5% of all registered COVID-19 deaths in the world (John Hopkins, n.d.). To be clear, we concentrate on the population age 50 and above for two reasons. First, the vast majority of observed COVID-19 deaths have been among those aged 50 plus; the most recent estimates from a database that tracks observed age-specific COVID deaths highlight these age patterns in numerous countries: China (94% of deaths over age 50), Germany (99%), Italy (99%), South Korea (98%), Spain (98%), and the United States (95%; Dudel et al., 2020). Second, we believe gerontologists have much to contribute to

understanding this disease. As older adults have been responsible for most COVID-19 deaths, we are able to explore the potential role of meaningful heterogeneity other than age within this group. Though this heterogeneity is being actively debated in the literature (Dowd et al., 2020a, 2020b; Nepomuceno et al., 2020), this debate has primarily relied on theoretical discussions and two-country case studies. Using the wealth of surveys specifically focused on older adults around the world, we can advance these discussions. We review data sources in Supplementary Material A and provide details on the waves used, weights, and specific measures of preexisting conditions in Supplementary Material B. Most selected datasets are “International Sister Studies” of the Health and Retirement Study (<https://hrs.isr.umich.edu/about/international-sister-studies>) and have been harmonized by the Gateway to Global Aging (<https://g2aging.org/>), facilitating cross-national comparison. We also include harmonizable data from Russia and New Zealand.

We use data on population age structure among older adults (United Nations, 2019). We use these data rather than the survey data on age distributions because the survey results are less current than U.N. estimates from 2020, the U.N. estimates are more likely to be accurate owing to sampling variance in the surveys, and some studies we examine are not nationally representative (see Supplementary Material A). Our conclusions are robust to this decision. Additionally, we use data of case fatality rates (count of deaths among confirmed COVID-19 cases) by age group and by preexisting conditions from estimates in China (Roser et al., n.d.). We create crude COVID-19 death rates for each country by dividing the reported COVID-19 deaths in each country as of June 6, 2020 (John Hopkins, n.d.) by 100,000 people in each country (United Nations, 2019).

## *Measures*

We create two new indicators of each country's structural risks of COVID-19 mortality, which we call national risk profiles. These risk profiles can be interpreted as the percent of older adults expected to die from COVID-19 if all older adults were confirmed cases and the case fatality ratios by age group and by preexisting health conditions were observed. Although assuming that mortality risks for the different age groups or preexisting health conditions are comparable across countries is a clear simplification, it is common practice in demographic approaches to understanding mortality severity in different locales (Preston et al., 2000), including as applied to the COVID-19 crisis (Dowd et al., 2020a, 2020b), and allows us to model the potential unique contributions of age structures and population health across contexts.

The "age risk profile" is based on the age structure of the population. Each country's age risk profile is the weighted average of the age-specific COVID-19 mortality rates in that country, with the weights coming from the share of the population in each age group in the United Nations age data (United Nations, 2019) and the age-specific COVID-19 mortality rates as follows: 50-59=1.3%; 60-69=3.6%; 70-79=8.0%; 80 plus=14.8% (Roser et al., n.d.).

"Preexisting health conditions (PHC) profiles" are based on the share of the population with relevant preexisting health conditions. Each country's PHC risk profile is the weighted average of the preexisting health conditions mortality rates in that country, with the weights coming from the weighted (if applicable) share of the population in each survey with each preexisting health condition and the preexisting health conditions mortality rates as follows: cardiovascular disease=10.5%; diabetes=7.5%; chronic respiratory disease=6.3%; hypertension=6.0%; cancer=5.6%; none of the above=0.9% (Roser et al., n.d.). Note that we calculated each country's share of older adults experiencing these preexisting health



conditions by analyzing the surveys with survey weights that adjust for attrition, nonresponse, and population structure, where applicable (see Supplementary Material B). In addition, it is important to emphasize that we coded preexisting health condition risks in a mutually exclusive fashion, privileging the higher risk category (e.g., someone with both diabetes and cancer would be subjected only to the diabetes risk). Accordingly, our characterization of preexisting health condition risks are likely conservative. Supplementary Material B contains details on the health measures in each survey.

### *Analytical Strategy*

First, we examine to the correspondence between age and PHC risk profiles in these countries (Table 1 and Figure 1). Second, we assess the association between the severity of national COVID-19 mortality and the national risk profiles. Here, we compare the natural logarithm of the crude COVID-19 death rates against the age and PHC risk profiles (Figure 2). For both analyses, we also examine correlation coefficients and the slope and statistical significance of linear regressions.

### **Results**

Table 1 shows the rankings of countries in terms of the two national risk profiles. Unsurprisingly, countries with the highest age risk profiles are those with older populations (e.g., Japan, where almost 15% of the population is over 75), and those with the lowest age risk profiles are those with younger populations (e.g., Indonesia, where only 21% of the population is over 50). Among high PHC risk profile countries, several are well-known examples of particularly poor health, such as the Russian Federation and the United States of America. Interestingly, we find some countries with inverted positions on these two risk profiles. Consistent with their older populations but relatively low morbidity prevalence (Ikeda et al., 2011), Japan has the highest age risk profile but has among the lowest PHC risk

profiles. In contrast, the Russian Federation and the United States of America are in the lower half of the age risk profiles but have the highest PHC risk profiles.

Figure 1 displays the relationship between national age and PHC risk profiles. These forms of population risk are significantly correlated but far from collinear ( $r=0.36$ ;  $p<0.05$ ). As seen in the scatterplot, we find PHC risk and age risk are approximately comparable on average ( $\bar{X}=5.00$  and  $4.95$ , respectively) across the countries sampled. However, the relationship between them is weak. Age risk is significantly linearly associated ( $\hat{b}=0.30$ ,  $p<0.05$ ) with PHC risk, but it explains limited variance ( $R^2=0.13$ ).

To assess whether these national risk profiles correspond to the severity of the ongoing COVID-19 mortality crises in different countries, Figure 2 plots the relationships between COVID-19 mortality (natural logarithm of reported COVID-19 deaths per 100,000 population as of July 31, 2020) and these national risk profiles. The figure shows moderate correlations between reported mortality and both age profile risk ( $r=0.43$ ,  $p<0.01$ ) and PHC risk ( $r=0.32$ ,  $p<0.05$ ). Ordinary least squares coefficient estimates for these associations offer a similar interpretation (age:  $\hat{b}=1.20$ ,  $p<0.01$ ; PHC:  $\hat{b}=0.75$ ;  $p<0.05$ ), with age risks explaining slightly more variance (age:  $R^2=0.19$ ; PHC:  $R^2=0.11$ ). Because we model the log mortality rates, unlogged mortality rate associations are non-linear. In terms of unlogged mortality rates, using appropriate techniques (Huber, 2019), the expected mortality rate is 0.12 per 100,000 at 1% age risk, 1.36 per 100,000 at 3% age risk; and 14.99 per 100,000 at 5% age risk. PHC risks differ, with a higher baseline but a slower increase. Respectively, the numbers are at 1% PHC risk: 0.80 per 100,000; at 3% PHC risk: 3.57 per 100,000; at 5% PHC risk: 15.89 per 100,000. Despite differences in the associations, predicted mortality rates are comparable over the range of observed risks.

## Discussion

At the individual level, risks of dying from COVID-19 are strongly related to age and preexisting health conditions. However, at the population level, there is a weak relationship between the structural risks countries face from their profiles of age and preexisting conditions. These two types of national profiles identify different countries as being at high or low COVID-19 mortality risk based on the fact that some countries are older populations with low levels of preexisting conditions (e.g. Japan) and others are younger populations with high levels of preexisting conditions (e.g. United States). In spite of significant attention to age (Dowd et al., 2020a) and preexisting health conditions (Clark et al., 2020) as defining features of population risk, not enough studies have compared these dimensions of risk. Certainly, they do not overlap identically. On one hand, the distinction between these population risks means few countries are likely to have widespread, undetected risk among low-risk older adults. On the other hand, that these risks are not perfectly overlapping increases the set of older adults at risk. National risk profiles based on preexisting health conditions among older adults have meaningful associations with the severity of the different countries' current reported mortality, just as do those of age. These results further underscore that age structure is not the only national risk factor (Nepomuceno et al., 2020), which may indicate more countries are at high risk of epidemic severity but also may reduce ageist assumptions associated with COVID-19. Future work should attempt to disentangle these two influences on epidemic severity. Additionally, other risk factors should be investigated such as health care quality and governmental responses to the pandemic that might also drive mortality variations between countries. For instance, some countries experienced extremely elevated mortality owing to policies regarding residents in long term care facilities (Stevis-Gridneff, Apuzzo, and Pronczuk, 2020). These results highlight the importance of accounting

for cross-national differences in population health, differences which cannot simply be reduced to a dimension of age structure.

This analysis has limitations, which can be addressed as more data on the pandemic become available. First, deaths due to COVID-19 are likely undercounted, as COVID-attributable mortality calculated from excess mortality approaches is only available in select countries (e.g., Banerjee et al., 2020; Docherty et al., 2020; Nogueira et al., 2020). Second, because the pandemic is still ongoing, there is heterogeneity in national epidemic progression, yielding differences in death rates owing to the extent of SARS-COV2 infection rates. Third, mortality risk data cross-classified by age and preexisting conditions is lacking, precluding development of hybrid risk profiles; the same issue precludes analyzing differences by gender. Fourth, we assume that comorbidities are mutually exclusive, which is an obviously imperfect representation of risk, albeit likely conservative. Last, we cannot currently ascertain whether national profiles based on age structure or PHCs better fit the mortality data because we have a limited range of countries in our sample, because right censoring may bias any conclusions given the epidemic is ongoing, and because other factors, such as national wealth and hospital capacity, would need to be accounted for to accurately estimate the predictive validity of these different forms of national profiles.

Moving forward, population health is vital to understand national COVID-19 risks. The harmonized data from available surveys of aging are critical resources, but there are too few of them. To better understand COVID-19's potential toll in different settings, to gauge which mitigation strategies have been particularly effective, and to increase preparedness for future global health crises, there is a critical need for more data on indicators of older adult population health in a much larger range of countries.

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**Table 1. Country Rankings by Age Risk Profiles and PHC Risk Profiles**

Age Risk Profile			PHC Risk Profile	
Rank	Country	Risk	Country	Risk
1	Japan	6.3	Russian Federation	6.4
2	Greece	5.7	United States of America	6.2
3	Italy	5.6	Portugal	6.1
4	Poland	5.5	Lithuania	5.9
5	France	5.5	Poland	5.8
6	Finland	5.5	Hungary	5.7
7	Sweden	5.5	Israel	5.7
8	Estonia	5.5	Bulgaria	5.6
9	Luxembourg	5.5	Slovenia	5.5
10	Germany	5.4	Czech Republic	5.5
11	Spain	5.4	Estonia	5.4
12	Belgium	5.3	Germany	5.4
13	Republic of Korea	5.3	England	5.4
14	England	5.3	Spain	5.3
15	Latvia	5.3	Croatia	5.3
16	Croatia	5.3	Cyprus	5.3
17	Denmark	5.2	Latvia	5.3
18	Bulgaria	5.2	Finland	5.2
19	Slovenia	5.1	Romania	5.2
20	Czech Republic	5.1	France	5.1
21	Switzerland	5.1	Brazil	5.1
22	Hungary	5.1	China	5.1
23	Austria	5.1	Ireland	5.1
24	New Zealand	5.1	Costa Rica	5.0
25	Romania	5.1	New Zealand	5.0
26	Israel	5.0	Malta	5.0
27	United States of America	4.9	Austria	4.9
28	Mexico	4.9	Belgium	4.9
29	Ireland	4.8	Sweden	4.8
30	Cyprus	4.8	Greece	4.8
31	Russian Federation	4.7	Luxembourg	4.8
32	Slovakia	4.7	Japan	4.6
33	Lithuania	4.7	Mexico	4.6
34	Portugal	4.4	Italy	4.5
35	Costa Rica	4.3	Republic of Korea	4.5
36	Thailand	4.2	Denmark	4.4
37	Brazil	4.1	South Africa	4.2
38	Malta	4.0	Slovakia	4.1
39	China	3.8	Switzerland	4.0
40	India	3.7	Thailand	3.9
41	South Africa	3.6	India	2.9
42	Indonesia	3.5	Indonesia	2.8

Figure 1. Scatterplot of two types of COVID-19 national risk profiles. Note, these risk profiles can be interpreted as the percent of older adults who would be expected to die from COVID-19 if all older adults were confirmed cases and the age- or PHC-specific case fatality ratios were applicable in that context. Notes: We label all countries in the figure using United Nations three letter country codes (UN Trade Statistics, 2016; note, for England we use “ENG” rather than “GBR,” which represents the United Kingdom). AUT-Austria; BEL-Belgium; BGR-Bulgaria; BRA-Brazil; CHE-Switzerland; CHN-China; CRI-Costa Rica; CYP-Cyprus; CZE-Czech Republic; DEU-Germany; DNK-Denmark; ENG-England; EST-Estonia; ESP-Spain; FIN-Finland; FRA-France; GRC-Greece; HRV-Croatia; HUN-Hungary; IDN-Indonesia; IND-India; IRL-Ireland; ISR-Israel; ITA-Italy; JPN-Japan; KOR-Republic of Korea; LTU-Lithuania; LUX-Luxembourg; LVA-Latvia; MEX-Mexico; MLT-Malta; NZL-New Zealand; POL-Poland; PRT-Portugal; ROU-Romania; RUS-Russian Federation; SVK-Slovakia; SVN-Slovenia; SWE-Sweden; THA-Thailand; USA-United States of America; ZAF-South Africa.

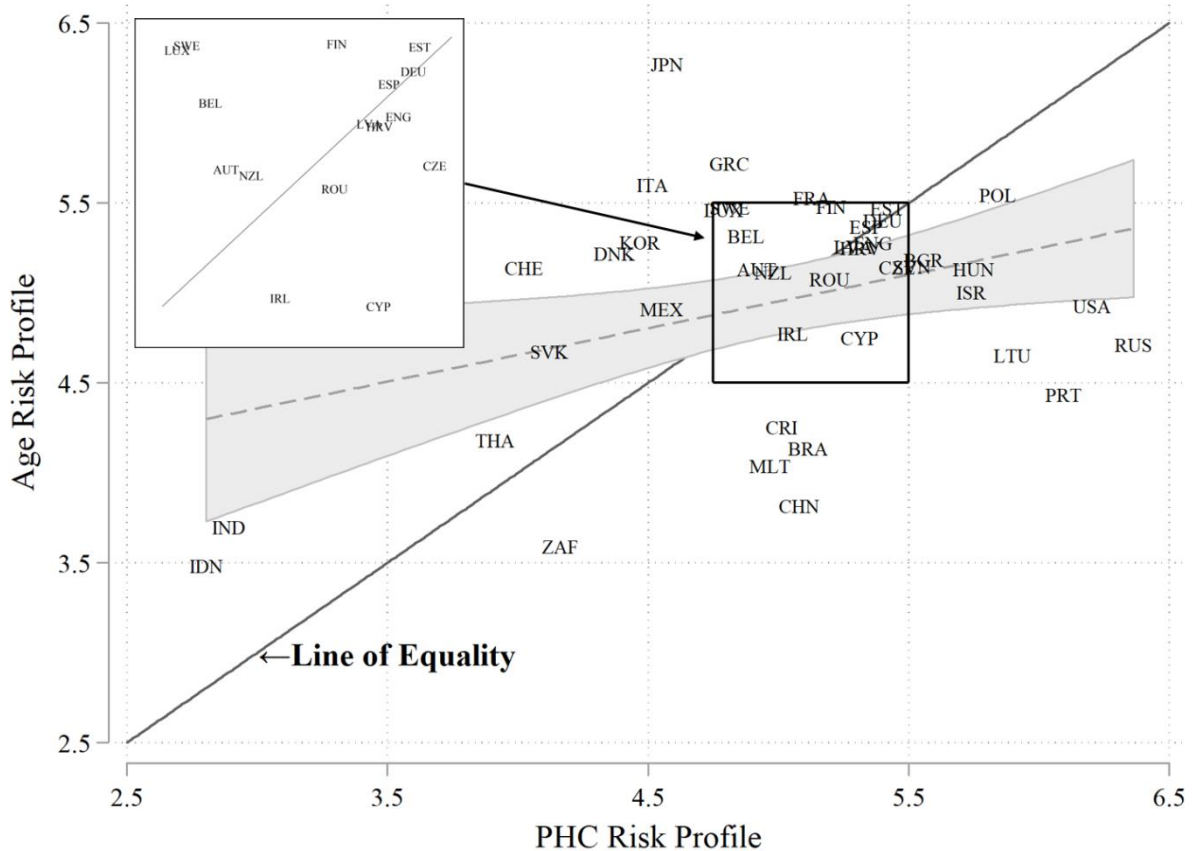
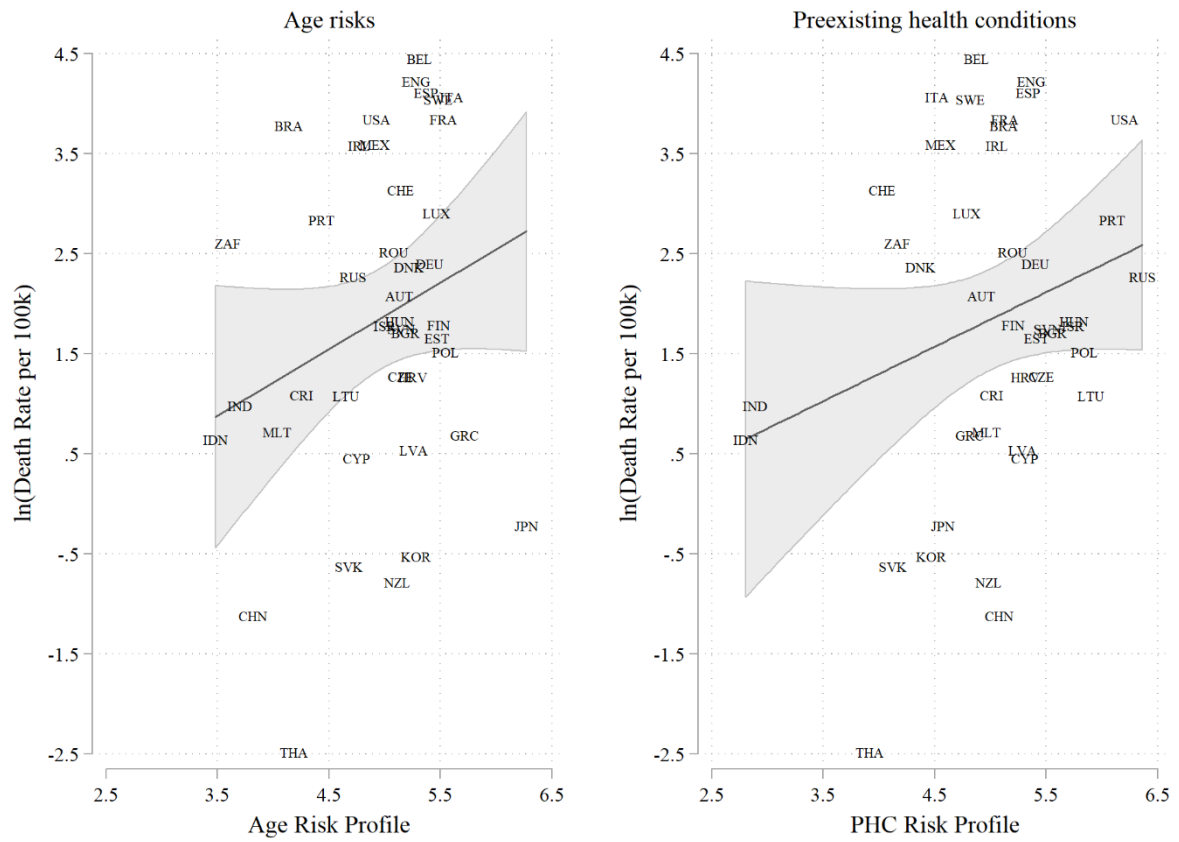


Figure 2. Scatterplots of logged crude COVID-19 death rates against the two types of national risk profiles. Notes: See figure 1 for country code labels.



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