1 Introduction

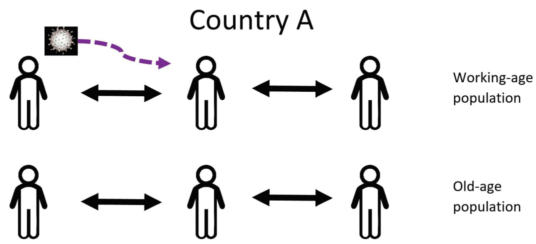
COVID-19 is spreading around the world and has reached the state of a worldwide pandemic. First estimates suggest that together with the large numbers of deaths, there will be also large economic consequences at orders of magnitude known from the financial crisis or even above. At the same time, evidence from the Spanish flu suggests that fighting the pandemic itself can help with the later recovery (Correia et al., 2020). Our research aims at highlighting the role of social networks in spreading the virus to most vulnerable strata of the population.

It has been established now that, also unlike the Spanish flu (see, e.g. Taubenberger et al., 2001), COVID-19 is particularly deadly for the elderly (see e.g. Wu and McGoogan, 2020) and over-proportionally creates the need for intensive care in these groups. In fact, Dowd et al. (2020) argue that the high prevalence of infected elderly is key to understand high Italian fatalities.

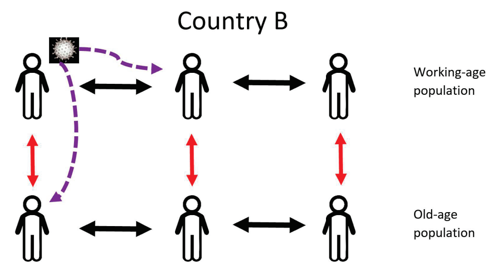
The hypothesis of the present paper is that differences across countries in inter-generational social interactions play a key role in the transmission to this high-risk population groups – at least in the initial outbreak dynamics. We explore cross-country differences in household structures that we use as description of inter-generational social contacts (vertical social interaction). If the initial infection happens among the working-age population and social interaction is *intra*-generational (horizontal social interaction) like in Figure 2(a), we can expect the disease to spread more slowly into the older strata of the population. On the contrary, if there are many *inter*-generational contacts (vertical social interaction) like for country B in Figure 2(b) the virus spreads quickly in the high-risk older strata of the population leading to initially high CFRs in country B. The assumption of original infection in the working age population reflects that COVID-19 was most likely *imported* to other countries from China through work-related travel and also transmission across other countries has likely happened through working age adults.

The reasons for differences in social structures are complex. They can stem from cultural or institutional differences, like the prevalence and affordability of childcare facilities, the legal rules of not leaving children unaccompanied, the labor market and economic situation of young workers across countries, or the scarcity of housing. In the light of current policy measures, in particular school closures, taken around the world, social structures might quickly reshuffle if grandparents move or visit close to their grandchildren to accommodate a families' needs for child care. Understanding better how such intergenerational interaction

Figure 1: Schematic country differences in inter- and intra-generational social interactions



(a) Horizontal social interaction



(b) Horizontal & vertical social interaction

relates to fatality rates is therefore an important concern for policymaking. Existing research has already emphasized the importance of social contacts for the spread of infectious diseases (Mossong et al., 2008) also including some very recent work for the current crisis (Liu et al., 2020; Bi et al., 2020). The two latter studies explicitly look at within household transmission and suggest that very close contacts, for example, among household members are of particular importance. Mossong et al. (2008) by contrast shows for a limited sample of countries large differences in contacts of the non-working age population with working-age persons, while within working-age contacts are rather similar across countries.

2 Data

We rely on data from *European Centre for Disease Prevention and Control* (ECDC) on the total number of diagnosed COVID infections and the number of deceased patience around the globe.[1] Data on family living conditions have been obtained using the online data analysis tool of the *World Value Survey* (WVS) (`http://www.worldvaluessurvey.org/wvs.jsp`). Our main data source is the sixth wave of the survey conducted between 2010 and 2014. For countries without information in the sixth WVS, we have been supplemented data from the fifth WVS survey data or the *European Value Survey*.

ECDC data start on December 31, 2019 and latest numbers are for March 24, 2020. Data are daily on newly confirmed cases and deaths. We sum all cases over the observation period and derive CFRs as the ratio of deaths over confirmed cases. We restrict our analysis below to countries with at least 200 diagnosed cases by March 15. For the data from the WVS, we

[1]ECDC data have been downloaded on March 15 at 2:50 pm (CET) from `https://www.ecdc.europa.eu`.

restrict the sample to respondents of age 30 to 49 and report the share of households in this sample who live with their parents. For our baseline analysis, we use the most recent data for all countries except for China, Iran, Italy, South Korea, and Spain, where we use restrict the data to the last day at which total infections are below 5,000 cases. We do this to deal with concerns that testing capacities might become insufficient once the outbreak becomes large scale. A large spread can have further secondary effects on CFRs when the local health system runs into capacity constraints if, on average, an infection of an elderly patient has a much higher congestion externality than the infection of a young patient. We therefore choose the 5,000-case threshold to avoid these effects from capacity constraints in the health system. This sample restriction allows us to focus more closely on the hypothesis that for the *initial* dynamics of the outbreak the form of the social network is key for spreading the virus to the elderly as a high-risk group. We also run an alternative data treatment, where we use the most recent data for all countries. Results are by-and-large similar.

3 Analysis

Figure 2(a) shows estimates of CFRs based on the ECDC data (baseline sample). We find large differences in case-fatality rates (CFR). We estimate the highest CFR for Italy with somewhat over 4 percent while we estimate for countries like Norway, Denmark, Sweden, and Germany low CFRs that are still close to or at zero. There are many reasons for CFRs to differ across countries during an ongoing outbreak such that they are imperfect measures of the underlying probability of dying from an ongoing infection at the time the CFR is calculated. Examples are division bias if the total number of infections is underdetected or differences in the definition of a fatality *due* to COVID across countries. However, such imperfect measurements of the underlying mortality risk of the average infected patient matters for our regression analysis that follows only insofar it would correlate with the social structure.

To measure the extend of inter-generational interaction across countries, we use data on the share of people between age 30-49 who live with their parents. These data are taken from the WVS data. Figure 2(b) shows that this share varies dramatically across countries. From shares below 5 percent in countries like France, Switzerland, and the Netherlands, to cases like Japan, China, South Korea, and Italy with shares above 20 percent. Combining data from Figures 2(a) and 2(b) let us explore our key hypothesis.

For the quantitative analysis, we restrict the country sample to countries with more than 200 confirmed cases (as of March 15). We run a simple linear regression where we weight countries by the square root of the number of cases.[2]

$$CFR_i = \alpha + \beta x_i + \gamma_i + \varepsilon_i \tag{1}$$

where the index i is for countries, x_i denotes the country measure for vertical social interaction, and γ_i denotes a dummy for the East Asian countries that we include in some specifications discussed below.

Figure 2(c) shows the result graphically. It shows that, in line with our hypothesis, countries with more inter-generational interaction within a household show a higher initial CFR. We show regression results from equation (1) for all of industrialized countries for which we have data[3] and for the same set excluding Italy. We run a regression on a worldwide set of countries, and the same again including a dummy for the East Asian countries, γ, in the regression in equation (1).[4] The dummy picks up the different standards of hygiene and social norms in contacts in East Asia. The two fitted lines for the case with the East Asia dummy are separate predictions for the Asian and Non-Asian countries in the sample. Table 1 show the results for the four regressions.

What we find is that those countries with more inter-generational contacts, proxied by the share of multi-generation households, show a significantly higher case fatality rate (β) (see Table 1). We interpret this as supporting evidence for our hypothesis that the structure and norms of social interactions shape the likelihood of COVID-19 to break into elderly strata of the population. As Table 2 shows the results extend to the data treatment where we use most recent data for all countries without imposing the 5,000-cases threshold.

[2] The reason behind this weighting scheme is that in countries with low case numbers, the point estimate for the CFR is less precise. We restrict to countries with 200 or more cases because of the potentially large effects of indivisibility in aggravating this problem. To get a grasp for the size of this uncertainty, recall that for a 200 draws binomial distribution with 3% probability to draw a one, 90% of all cases have a sample mean between 1% and 5%, for 2000 draws the interval shrinks to 2.4-3.6%.

[3] These are Australia, Austria, Belgium, Canada, Switzerland, Denmark, Spain, France, Germany, Italy, Netherlands, Norway, Sweden, the United Kingdom, and the United States.

[4] We include China, Japan, Singapore, and South Korea in the East Asia group.

Table 1: Regression results

	(1) baseline	(2) industrialized countries	(3) ind. countries w/o Italy	(4) baseline w/ East Asia dummy
Living w/ parents (β)	0.0496*	0.154***	0.107^{+}	0.109***
	(0.058)	(0.000)	(0.119)	(0.002)
Asia dummy (γ)				-2.037**
				(0.013)
constant (α)	0.936**	0.417	0.621^{+}	0.653*
	(0.026)	(0.222)	(0.149)	(0.085)
N	24	17	16	24
adj. R^2	0.116	0.553	0.105	0.312

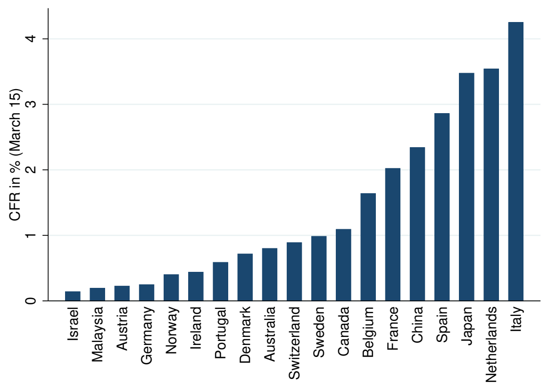
Notes: Linear regression results. Country observations are weighted by the square root of the number of infected. See notes to Figure 2(c) for further details. ***,**,*,+ indicates significance at the 1, 5, 10, and 15 percent level, respectively.

Table 2: Regression results

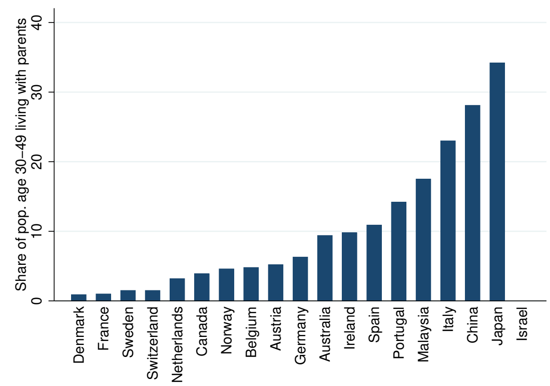
	(1) baseline	(2) industrialized countries	(3) ind. countries w/o Italy	(4) baseline w/ East Asia dummy
Living w/ parents (β)	0.124***	0.336***	0.0883	0.269***
	(0.006)	(0.000)	(0.156)	(0.000)
Asia dummy (γ)				-4.256***
				(0.001)
constant (α)	0.858	-0.422	0.672*	0.0420
	(0.282)	(0.372)	(0.098)	(0.948)
N	24	17	16	24
adj. R^2	0.263	0.817	0.077	0.562

Notes: Linear regression results. See notes to Figure 2(c). Here the ECDC data as of March 15, 2020 is used for all countries. ***,**,*,+ indicates significance at the 1, 5, 10, and 15 percent level, respectively.

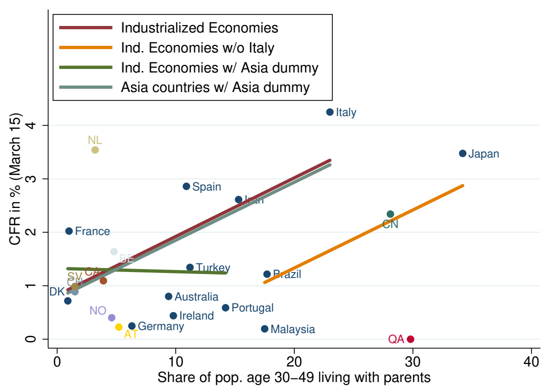
Figure 2: Case-fatality rates and share of working-age population living with parents across countries



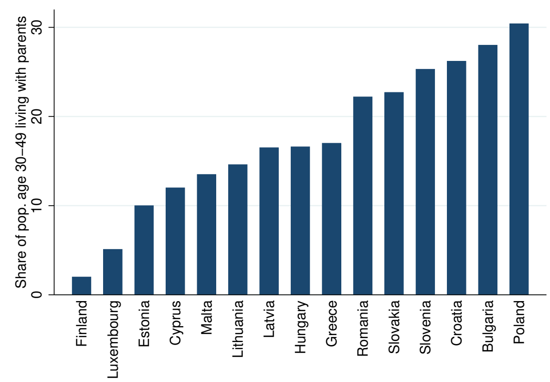
(a) CFRs



(b) Share living w/ parents



(c) Vertical social interaction and CFRs



(d) Share living w/ parents further EU countries

Notes: Top left panel: Case-fatality rates across countries. Data as of March 15, 2020. Authors' own calculation based on data from the ECDC. Top right panel: The figure shows the share of the survey participants aged 30-49, who answer that they live with at least one parent in the same house in the WVS 2010-14. Based on the 6th wave of the world value survey for those countries included, the latest wave of the European value survey, and the fifth wave of the World Value Survey, for the remainder. Only countries with more than 200 reported COVID-19 infections. Bottom left panel: Scatter plot of the CFRs by country against the share of the population age 30-49 living with a parent in the same house. Only countries with at least 200 reported infections. The CFRs are calculated on the March 15 data for all countries with less than 5000 infections and for countries above 5000 infections for the day they reached this limit (Spain, Italy, China, South Korea). The two fitted lines for the case with the East Asia dummy are separate predictions for the Asian and Non-Asian countries in the sample from the regression in equation (1). Bottom right panel: Working-age population living with parents in European Union countries not included in Figure 2(b) (2010-14). See that figure for further details.

4 Implications

The first observation we make is that Italy takes on extreme values in both dimensions of social interactions across generations and in the current CFR estimate. We hope and expect the latter to go down in the end once more data on the infected has been taken into account. Similarly, we expect the effect we highlight to also decrease over time for those countries with less vertical social integration once the virus will slowly find its way into the elderly population and can then spread in the group of the elderly because the elderly are typically strongly connected horizontally in all countries.

Given this, those countries with low fatality rates, like the Scandinavian countries or Germany, should take this as a warning sign. Likely the low initial fatality rates are unfortunately not here to stay, once the virus spreads.

At the same time, we hope this data analysis in the midst of the ongoing crisis helps us to better understand, how pivotal it is to keep the elderly uninfected and what role social networks and links play in this. What is more, it may provide a warning sign for those countries where the elderly and the young live close together, how important it is to contain the virus there early on. The WVS data allow us to identify these countries. Within the European Union the countries we consider to be particularly at risk are Poland, Bulgaria, Croatia, and Slovenia based on the data shown in Figure 2(d). In fact, the numbers that are currently coming in for Poland and Bulgaria point towards CFRs in the range of and above 3% – with of course the caveat in mind that there is an enormous uncertainty regarding these numbers with detected infections below 100 cases. Still, we think our analysis can be helpful in identifying societies that are particularly vulnerable.

5 Conclusions

Medical research and treatment are front and center to combating this current crisis and as scientists we believe in the power of medical research and science. Yet, we as social scientists thought about how we can help combating the crisis.

As social scientists, we know how important behavioral responses are and what critical role social networks have. This research highlights the role of vertical connections across generations in spreading COVID-19 to elderly population strata relatively early during an outbreak.

We hope this research helps to identify where most efforts are needed to reduce social interactions to keep contagion low. Similarly, it might help to design measures to improve the resilience of society as a whole to the outbreak. We understand that what we can add as economists is very limited, however, we do understand that beyond the individual risk being high for the elderly, any infection of a high-risk person imposes a much more substantial congestion externality to the health system as a whole, such that efforts need to focus on reducing these infections.

Importantly, this implies in light of schools closing in many countries, that efforts need to be high to explain or even force the older generation *not* to step in as caretakers for children. Instead, extrapolating from our findings and taking into account the role of networks more generally, we consider it key to design social interactions in a way that keep clusters of interacting people small and as unconnected as possible.

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