Socio-economic vulnerability and epidemic risk by age
Implications for the exit strategy from COVID-19

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Abstract

In designing an exit strategy from COVID-19, governments need to balance the risks posed by possible recrudescence of the epidemic when lifting containment measures, which is higher for vulnerable groups of populations, against the urgency to reopen established economic activities and reduce the social and psychological vulnerability of the population subjected to unprecedented social distancing measures.

In this note we try to quantify, on the one hand, vulnerability from a socio-economic and psychological perspective and the epidemiological risk associated with the patterns of social contacts, on the other. For both aspects we have adopted a demographic perspective, looking in particular at the distribution of vulnerability and social contact patterns by age.
Key messages

- While the elderly are without a doubt exposed to the worst health consequences from the disease, they seem to be less affected from the potential negative economic and psychological consequences of confinement, according to the indicators that we have considered.
- Social contact matrices indicate that most contacts take place between people of the same age groups and that the intensity of contacts is higher for children of school age.
- With respect to a situation with complete lockdown, the reopening of schools and activities for children would have the worst impact in terms of increase of epidemic spread potential to the rest of the population.
- Differences are noticeable in the structure of contacts by age and place across countries, for instance between generations in the home environment. However, differences are less pronounced when considering contacts at work, which could mean that the lifting of social distancing at work could have similar effects across the countries included in the analysis.
- Our analysis faces two main limitations: in the case of vulnerability, given the unprecedented nature of the situation, there are few references in previous studies to select the most appropriate indicator and therefore our selection is subjective; in the case of risk we are simulating the effect on epidemic spread from the lifting of social distancing measures only looking at the structure of social contacts; we ignore any possible disease age specific parameter by considering a uniform susceptibility and infectiousness of COVID-19 across all age groups.
Introduction

Knowledge of vulnerability is a policy priority in the design of an appropriate exit strategy from an epidemic. Vulnerability is linked to risk exposure and differs by age and gender: generally, children and elderly population are more vulnerable and exposed to risk than adults [1]. Moreover, other socio-economic characteristics can render populations more or less vulnerable such as poverty, occupation, lack of sanitation, etc.

Studies [2] estimated that the reduction in social contacts would cut COVID-19 burden by half, and save 20 million lives. Yet, national health systems have been rapidly overwhelmed and the spread of coronavirus has reached the epidemiological criteria to become a pandemic affecting people at global level, and vast containment measures have been adopted by national authorities. This approach, mainly based on the national trends, has produced disparity in responses to the pandemic across countries, also linked to the different timing in the start of the disease.

Considering the deep economic implications of the current worldwide standstill, there is a strong pressure to improve our understanding on pandemic evolution and a clear need for a coordinated exit strategy joining efforts to design the future recovery of our societies.

Social contacts between individuals fit into large, sometimes invisible networks. Intergenerational contacts may facilitate the spread of pathogens and amplify their effects: epidemic severity varies by age group, and fatalities are disproportionately distributed across generations [3]; co-morbidities are likely to increase by age and exacerbate COVID-19 symptoms through contact patterns. Although empirical analyses have been conducted on HIV and sexually transmitted diseases, few studies have been devoted to respiratory infections [4] and therefore relevant to the COVID-19 epidemic.

Following a socio-demographic perspective, Southern European Member States, such as Italy, may be potentially more exposed [5] to the COVID-19 recurrence than Northern countries, because of the strong family ties and intergenerational contacts, for instance between grandparents and grandchildren. Culture has played a role in shaping these differences that are also reflected in co-residence and household structures.

Policy makers are debating alternative solutions for an exit strategy, from the extension of lockdown for an additional specified period of time, or indefinitely [6] until a vaccine will be trialled and distributed, to a progressive reduction of isolation linked to the testing of large segments of the population. The main challenge that governments are facing when planning how to gradually lift lockdown measures, is the balance between the urgency to reopen the economy and the need for preventing additional epidemic waves, limiting the risk of exposure for populations and ensuring specific protection for vulnerable groups.

The scope of this note is a preliminary assessment of vulnerability, from a socio-economic and psychological perspective and the epidemiological risk associated with the patterns of social contacts, using a demographic perspective to investigate the age-specific distribution of vulnerability and contact patterns.
The assessment of vulnerability is based on a set of indicators derived from the European Union Statistics on Income and Living Conditions (EU-SILC) by age group and EU MS. In addition, we present the age distribution of opinions on the psychological impacts from Coronavirus from a survey recently conducted by the WagelIndicator Foundation.

To assess the changes in epidemiological risk, we rely on social contact matrices representing the intensity of contacts across age groups by place (school, work, transport and leisure) for nine countries. These matrices are commonly applied in epidemiological analyses to estimate the consequences in terms of epidemic spread of measures aimed at restricting contacts in selected places or for certain age groups. In order to inform policy makers about the potential impact of various exit strategies, we reverse the perspective to show the effect on epidemic spread potential when mitigation measures are adopted, reopening selectively contacts from a situation of complete lockdown.

Waiting for a pharmaceutical response, the modelling of social contacts provides insights on the implications in terms of risks of getting back to normal societal and economic functioning. Findings from the simulation show a country-specific vulnerability in the risk exposure of population targets according to different scenarios. When the hypothesis of school reopening is formulated, the risk of new epidemic waves increases, particularly in countries where intergenerational dynamics are higher.

**Box 1. How to measure infection transmissibility by social contacts**

Epidemiologic analyses conventionally assess social contacts using the reproductive number (R0), which is an indicator of the infection transmission by individual [7]. R0 represents the mean of infections generated by an infected person over the course of infection. When R0 is higher than 1, the infection increases; when R is less than 1, the epidemic declines. In the absence of interventions, R peaked at 4 during the acute phase in the Wuhan region, and declined to below 1 after the adoption of control measures.

Changes in R0 can result from different factors due to social and physical distancing measures, but also to the increase in testing cases and development in contact tracing. Differences in testing capacity produce different proportions of detected positive cases over time and across countries. This is particularly relevant for COVID-19 due to the underestimated effects of asymptomatic positive cases. For this reason, experts [8] have recommended a random test population to improve accuracy of current statistics on the infection evolution.

In the model, the time-varying of R0 can be assessed as a function of the adopted policy measures. For example, school closures can differently drive the decrease of the average number of infections at a given interval of time, when compared to effects due to mobility restrictions or working lockdown. From a macro level perspective, higher values of R are associated with lower rates of immunity acquisition; yet, the correlation should be confirmed by individual antibody tests.
Vulnerability by age

The health risks of epidemics vary at the individual level. Moreover, epidemics could cause deep economic and social damages that can have a disproportionate effect on the vulnerable groups of the population. The social distancing measures introduced with the COVID-19 pandemic were unprecedented in terms of severity, involving for the first time a complete lockdown of entire countries. This poses a challenge for the assessment of these measures, also in view of the vulnerability of different groups.

While in the social-psychology and economic literature, some studies look at the social and individual impacts from quarantine measures during specific outbreaks, it is difficult to generalise from these limited case studies to a situation which is involving most of the socio-economic activities and for a duration which is expected to last for several months [7–9].

In the absence of a framework for the analysis of individual socio-economic vulnerability in the Covid context, we present a selected number of statistics from EU-SILC which we believe could be most relevant to qualify physical, economic distress in a situation of prolonged confinement at home and interruption of work. The main purpose of these simple cross-tabulations is not to develop a composite indicator of vulnerability, but rather to grasp and explore differences across age groups considering several possible - and sometimes diverging - dimensions of vulnerability.

In the second part of the section, we complement the analysis with opinions on the impacts from the Coronavirus from a survey recently conducted by the WageIndicator Foundation, with the caveat that the survey is rather limited in the number of respondents and not statistically representative of the EU population.

Figure 1 presents an overview of different indicators of vulnerability in health, housing and economic conditions in the EU-27, by age groups and in 2017\(^1\). The EU-SILC surveys allow respondents to report on their health status and, in particular, whether they have a chronic (long-term) illness and have not received the necessary medical examinations or treatment. Individuals aged 65 and above generally report having more chronic diseases than young people and the presence of chronic diseases increases with age. On average, about 35% of people over 65 reported having a chronic illness, while about 5% of people aged 15-44 reported having a long-term illness or a health problem in 2017. Among EU Member States, the lowest prevalence of chronic diseases for the age group of 65 and over is observed in Belgium, Denmark, Italy, Luxembourg and the Netherlands, while the highest prevalence of chronic diseases is recorded in Greece, Hungary, Portugal, Estonia, the Czech Republic and Latvia (Figure 3). About 5% of the EU-27 population aged 15 and over stated that they needed healthcare, but these needs were not met due to financial barriers, distance or transport problems, long waiting lists or personal reasons. In 2017, middle-aged people (45-64 years old) were the most inclined to declare an unmet health care need. Among them, the high cost associated with the treatment was the main reason for the lack of medical care. A national breakdown (Figure 3) reveals that the share of the population with unmet health

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\(^1\) For all the descriptive tables, we use the sampling weights provided by the EU-SILC Survey to take into account the representation of the respondent in the sample.
needs was highest among the population aged 45-64 in Greece, Hungary, Latvia, Estonia. On the contrary, Germany, Luxembourg, the Netherlands and Austria have the lowest proportions of those reporting unmet health care needs, with no differences across age groups.

The vulnerability of the housing is measured through the overcrowding rate and the lack of Internet access at home for personal use. The overcrowding rate indicates the percentage of people living in an overcrowded house, and is determined by the number of rooms available for the household, the size of the household, the age of its members and the family situation. In 2017, around 25% of the EU-27 population aged 15-44 faced a severe housing deprivation. The overcrowding rate for the population aged 45-64 was around 15%, followed by the rate of the oldest population (10%). The highest overcrowding rates among EU Member States (Figure 4) were recorded in Romania, Bulgaria and Hungary. On the other hand, Cyprus, the Netherlands, Germany, Luxembourg, Spain, Greece and Finland have the lowest rates. The lack of internet access in the home environment is a socio-economic indicator showing the percentage of people in each household who cannot have internet access for personal use over the entire population. This concerns the use of various devices through which the respondent can use the internet, including smartphones, tablet, video games, laptop, PC, etc. In 2017, the total share of EU-27 households claiming not to have access to the internet was around 20%. Data indicate a significant digital age divide leading to an uneven distribution of Internet access in the population. In 2017, the percentage of individuals aged 65 and over who do not have access to the Internet for private use was 50%, while it was around 15% and 8% for the population of 44-64 and 15-44 years respectively. Regarding the differences in the lack of internet access across Member States, the highest rates for the population of 65 and over are in Bulgaria, Czechia, Greece, Hungary and Romania.

According to Eurostat, being at risk of poverty or social exclusion means being in at least one of these three conditions: at risk of poverty after social transfers (income poverty), in conditions of severe material deprivation or living in households with low work intensity. In 2017, around 20% of people aged 15-44 were at risk of poverty or social exclusion, followed by a rate of 16% for people aged 45-64 and 13% for people over 65. Although the risk of poverty or social exclusion has declined in the most recent years and after 2009, young people continue to be the group most at risk of poverty and social exclusion. There is a persistent economic gap between generations and the increase in intergenerational inequalities is hampering social mobility. People aged 20-24 have the highest rates of poverty and social exclusion (22%), thus presenting the risk of being the most unequal generation. Lack of job security increases the risk of poverty and social exclusion. For the working age population (15-64), the graph on temporary jobs shows the percentage of respondents with a temporary job, for different age groups. In 2017, the percentage of individuals aged 45-64 in temporary employment was about 15%, while it was 30% for people aged 15-44. In this age group, the highest percentages of temporary work are observed among the youngest respondents\(^2\). In 2017, the majority of the population at risk of poverty or social exclusion were in Bulgaria, Romania, Greece, Lithuania and Hungary; at the other end of the scale, the lowest percentages were recorded in Slovakia, Finland, Czechia (Figure 5).

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\(^2\) Moreover, men in temporary jobs account for 16% of the sample, while women account for 19%.
Figure 2 shows responses to coronavirus-induced changes in living, working and psychological conditions. We explore the micro-data from the WageIndicator Foundation, which conducts online surveys on coronavirus effects in over 110 countries around the world. The results show that for the majority of respondents, and for all age groups, the coronavirus outbreak has certainly influenced and changed the job and work environment. The youngest group (15-44) feels the psychological burden of the virus containment measures more than other age groups, reporting the highest percentages of depression, distress from a complete turnaround in life, and loneliness. Fear of the risk of infection affects everyone, but the highest percentages are among individuals between 45 and 65 years of age. The elderly population over the age of 65 seems less affected by emotional distress compared to other groups, possibly due the initial situation of that population in terms of social distancing and attitudes to physical and psychological health.

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It should be considered that the sample varies greatly from country to country and that the number of people interviewed is not representative of the national population. Therefore, caution should be taken in the interpretation of these results.
Figure 2 Percentage of respondents reporting adverse consequences in the WageIndicator Survey of Living and Working in Coronavirus Times 2020

Figure 3 Unmet medical needs and Chronic illness rates, by country and age group, 2017
Figure 4: Overcrowded housing and Lack of internet rates, by country and age group, 2017.

Figure 5: At risk of poverty or social exclusion and Temporary job rates, by country and age group, 2017.
Social contacts by age

Close contact is the most important factor for the spread of the virus and the reason why social distancing was identified as the main effective instrument to cut all the assumed paths of transmission. Contacts occur in the context of social interactions, which vary along macro- (e.g. culture, wealth, access to technology) and micro-parameters (e.g. age, gender, type of occupation, character traits).

Figure 6 shows the frequency of contacts occurring between individuals of different ages on a daily basis averaged across 8 European countries \[4,10\]⁴. They are split between different settings: home, work, school, leisure and transport. Some patterns clearly emerge: First of all, that contacts are highly assortative with age. The role of children and adolescents in an epidemic is clearly shown by the important mixing occurring in school and with their parents at home, which is the place where most physical contacts occur between different generations, also with the elderly.

The difference in transgenerational mixing between the countries studied is quite striking, with countries like Italy showing high patterns of mixing while other countries such as Belgium, Finland, Germany and the Netherlands, showing less mixing with the elderly population (see also [11]) (Figure 7). The strong family ties including several generations could be one of the explanatory factors behind the higher number of fatality cases among the elderly population in some countries, especially when family members are asymptomatic. For the working age population, the frequency of contacts are substantial at the workplace, but also in the context of leisure.

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⁴ The countries are the following: Belgium, Germany, Finland, France, Italy, Luxembourg, Netherlands, Poland, United Kingdom. The data were mostly collected in the framework of the POLYMOD project (2005-2006), except for France where it was conducted in the context of Comes-F (2015).
Figure 6 Intensity of social contacts by age of respondents (vertical axis), age of the contacted persons (horizontal axis) and place of the contact. Total for all the countries included in the dataset.

Figure 7 Intensity of social contacts taking place at home by age of respondents (vertical axis), age of the contacted persons (horizontal axis) and country.
The frequency of contacts depending on the context shows important differences at national level with the number of contacts being overall more limited across all ages in some countries like France and Germany, and more important in others, especially Italy, Luxembourg, the Netherlands and Poland (Figure 8). In those countries, contacts at school for the youth (up to the age of 25 in Poland) are substantial and similarly at work. In Italy and the Netherlands, leisure seems to result in more countries in early adulthood compared to other countries.

Figure 8 Intensity of contacts by age or respondent (vertical axis), place of contact (colors) and country. The contacts are summed for all ages of the contacted persons.
The variety and intensity of social contacts will be one of the key information to define and plan the exit strategy. With most European populations being in a situation of confinement, we simulate how infection rates would increase looking at different exit scenarios derived from several mixing patterns. The indicator is the increase in the reproduction number (R0), meaning the increase in the average number of secondary infections caused by a single infectious individual. The first simulation (Figure 9) demonstrates how the reproduction number would be affected by reopening separately each of the places for social interactions, i.e., school, work, leisure, transport and others, while the other activities stay restricted, and home being the place of confinement. Not surprisingly and related to what we have shown in terms of frequency of contacts linked to children and adolescents, reopening school would lead to the highest increase in reproduction number in almost all nine countries considered. The increase would be largely over 50% in Finland, Italy, the Netherlands and Poland, and around the 50% mark in Great Britain and Luxembourg. The evidence is more mixed and varies more between countries when considering other activities, but the effect on the infection reproduction number is generally less substantial than with schools. For instance, the reopening of workplaces would lead to around 30% increase in reproduction number in Poland and Luxembourg, while it would be less important in Great Britain and in Italy. Leisure seems to be more conducive to an increase in infection in France, Germany and the Netherlands than it is elsewhere. Most importantly, transport seems to have very little impact on increasing reproduction numbers in all the countries that were considered, possibly as an illustration of more people using private means of transportation than public ones at the country level.

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5 See annex for details on the calculation of R0.
6 The reproduction number assumes equal infection susceptibility by age. Therefore it does purely reflect the effect of differences in social interaction by age.
Figure 10 Increase in R0 after simulating a reopening of contacts for specific ages in respect of a baseline scenario of total closure. Contacts at home are kept open.

We have simulated what would happen for the entire population when each age group is independently allowed to resume activities while the other age groups are still confined at home (Figure 10), for instance 40-44 year olds are allowed all activities in terms of work, leisure and transport while other age groups are on lockdown. The most obvious result is that allowing the youth to resume activities (mostly in terms of going back to school) would lead to the largest increase in reproduction number of the infection in most of the selected countries. It is especially visible in Italy where the infection rate has been elevated among the elderly, probably in conjunction with intergenerational contacts to youth enrolled in school. In France, the increase would be more spread across ages as a sign of different patterns of social interactions related to leisure and other activities.
Annex

Data sources

The European Union Statistics on Income and Living Conditions (EU-SILC) are one of the European sample surveys, based on nationally representative samples for each European Member State. The analysis is based on the 2017 datasets and focuses on selected indicators of vulnerability.

The Survey of living and working in coronavirus times is an on-line survey conducted by the WageIndicator Foundation. The official launch took place on March 30. WageIndicator has been a partner in several EU-funded FP6, FP7 and Horizon 2020 projects, and is currently a community partner in the Social Sciences and Humanities in the European Open Science Cloud (SSHOC) project [9]. The sample composition is presented in Figure 11; the sample is not representative of national populations.

![Table showing sample size of the WageIndicator Survey of Living and Working in Coronavirus Times 2020 by country](image)

*Figure 11. Sample size of the WageIndicator Survey of Living and Working in Coronavirus Times 2020 by country*

The datasets of social contacts matrices were mostly collected in the framework of the POLYMOD project (2005-2006) funded by the EU FP6 [4]. The matrices are based on information collected from 7,290 participants about the recorded characteristics of their 97,904 contacts with different individuals during one day, including age, sex, location, duration, frequency, and occurrence of physical contact. For France, data were gathered in the context of Comes-F (2015) (Beraud et al. 2015) which is similar in scope to POLYMOD.
The analysis focuses on the following countries: Belgium, Germany, Finland, France, Italy, Luxembourg, the Netherlands, Poland, and the United Kingdom
Method for the calculation of R0 in the simulations

The calculation of the reproduction number R0 on the basis of contact matrices follows the approach of next generation matrix \cite{12} and social contact hypothesis \cite{13} along the steps described in \cite{14}.

According to these approaches, the introduction of an infected individual in a susceptible population is expected to produce a number of secondary infections \( n \) proportional to the duration of the infectiousness \( D \), the intensity of contacts \( m \) between individuals of a certain age of origin \( i \) to the individuals of a certain age of destination \( j \), the infectiousness \( i \) of individuals by age \( i \), the susceptibility \( s \) of individuals by age \( j \), and other specific characteristics of the disease \( q \) as described in the following equation:

\[
  n_{ij} = D \cdot c_{ij} \cdot i_i \cdot s_j \cdot \hat{q}
\]

The largest eigenvalue of the so-called next-generation matrix \( n \) can be taken as the basic reproduction number in a compartmental model of the spread of the disease.

According to this framework it is possible to calculate the R0 using the contact matrix with all contacts “open” and simulating closure of contacts for specific portions of the contact matrix.

Similarly measures can be simulated by closing contacts at school, workplace, transport etc. considering the respective place-specific matrices.

The ratio between the baseline R0 and the one calculated on the closed contact matrix gives an assessment of the impact of social distancing measures. Conversely, by assuming the complete closure of the structure of contacts, it is possible to simulate the effects of re-opening.

Some essential pieces of information in this calculation are the specific \( s \) and \( i \) parameters which may have themselves an age characterisation. In the absence of estimates of these parameters specifically for COVID-19, the simulations are only showing the age specific effects linked to the structure of contacts assuming a uniform distribution of susceptibility and infectiousness across ages.
References

3. Fabrizio NATALE, Daniela GHIIO, Dario TARCHI, Anne GOUJON, Alessandra CONTE. COVID-19 Cases and Case Fatality Rate by age. JRC; 2020.
Acknowledgements

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