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IZA DP No. 15396

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ABSTRACT

The Unequal Impact of the COVID Pandemic: Theory and Evidence on Health and Economic Outcomes for Different Income Groups

This paper studies how wealth and health inequalities have interacted with the Covid-19 epidemic in a way that has reinforced inequalities in income, savings, epidemic risk and even individual preventive behaviors. We present in more detail two papers and their theoretical and empirical results. Recovery and contamination rates are functions of an individual's health status and capacity to access quality healthcare. Poorer individuals, who face budget constraints, have a higher risk of loosing their income because of contamination. Data on six countries confirm a disproportionate impact of the epidemic on the poorest 60% of the population.

JEL Classification: D0, H0, I1, I3, O1

Keywords: COVID-19, poverty, income quintiles, healthcare, behavior changes

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Introduction

The Covid-19 epidemic is a severe and deadly reminder of the dire consequences of imposing too much human pressure on our natural environment. Covid-19 is a zoonosis, and both its transmission rate and severity are increased by pollution. The pandemic therefore proves how excess deterioration of the environment can have drasting and immediate impacts on human lives and activities, and, among other features, on inequality. The links between environment and inequality have long been an object of study and concern. We know for instance that mitigating the adverse effects of climate change will be easier for richer individuals than for poorer ones. Epidemics have very different features and the Covid-19 pandemic has initially been seen as an "inequality leveler": richer individuals where apparently not better able to avoid the disease than poorer ones. This initial take has proven incorrect for many reasons. Covid-19 has induced a surge in inequality at many different levels (Patel et al. [2020]). Our research additionally shows that inequality in wealth and inequality in health status are *intricately linked* to both the monetary consequences and the behavioral choices in the face of the epidemic.

The Covid-19 pandemic constitutes a major worldwide shock, of unprecedented impacts over at least the past 50 years. The first impact is in lives directly lost due to the coronavirus: more than 6.208.700 deaths worldwide by April 21, 2022[4] (more than 990.000 in the US, 662.000 in Brazil, 522.000 in India, 366.000 in Russia, 324.000 in Mexico, 145.000 in France). The impacts also range from full or partial disruption of many economic activities, massive budget deficits, to mental health issues and major disruptions in the everyday life of a large proportion of the world population. While epidemiologic and sanitary impacts were of primary interest at the beginning of the pandemic, concerns over economic impacts are increasingly taking precedence. Our focus in this paper is on the *strong interactions between poverty, health and the impact of the epidemic*.

In this section, we briefly recap the links between the environment and the Covid-19 epidemic, and then between inequality and the epidemic. The next sections focus on the models, theory and data supporting the view that there are *reinforcement loops* between health and wealth inequality, and the epidemic.

Interactions: Epidemics and the environment

The Covid-19 epidemic is associated to human pressure on the environment. It is now well known that the quality of our environment has direct consequences on our health, not only because of the many impacts of pollution, but also because of the rising frequency and severity of zoonoses. The source of diffusion of SARS-Covid from animals to humans is still under investigation but it is widely believed that it is one such zoonose, fostered by human pressure on the environment.

Global warming. Climate change shift wildlife habitat and increases the frequency of contacts between species. This effect of global warming could cause more than 15,000 new cases of transmission of viruses between different mammal species according to the results of a large

[4] Source: https://coronavirus.jhu.edu/map.html

study published in Nature (Carlson, Albery et al. [2022]). Global warming will push species towards cooler zones, which will tend to have high population density (as in India and Indonesia). Species that meet for the first time may exchange pathogens in a way that creates new epidemics.

Human activities. The destruction of animal habitat leads animals to live closer to cities. In the same way, the expansion of human activities (farming, construction,...) implies more proximity with animals and pathogens (Gibb et al. [2020]). Meat markets are also sources of zoonoses (Espinosa et al. [2020]).

Pollution. Pollution (particulate matter, nitrogen oxides and ground level ozone) increases both the severity and the likelihood of Covid-19 infections (Cole et al. [2020], Conticini et al. [2020]). The incidence and mortality from Covid-19 increase both for short-term and long-term exposure to air pollution (Ho et al. [2021]).

This impact of pollution, which applies at the individual level, is by itself a driver of inequality in the consequences of Covid-19: Pollution tends to be higher in large cities but also in industrial areas. Richer individuals can afford can afford to live far from industrial, polluted, areas, which is not the case for poorer ones.

Pollution, public health policies and income inequalities. Governments can increase public spending in order to contain and curb the epidemic. Because of the impact of pollution on Covid-19 propagation, public spending can be more or less effective, in particular for older individuals who face the most risks from Covid-19. Davin, Fodha and Seegmuller [2022] study precisely these interlinked effects. They show that public health policies can only eradicate the disease if pollution is not too intense. In the opposite case, Covid-19 becomes endemic. Because infected individuals cannot work, the epidemic creates income inequality. An essential result from Davin et al. [2022] (from our angle of approach) is thus that public spending and debt lead is needed to mitigate income inequality, whenever pollution is such that the epidemic cannot be eradicated.

In the remainder of this paper, we will concentrate on interactions between inequalities, public health and the epidemic, assuming prior income inequalities (that is: inequalities in addition to the inequality in earnings caused by an infection).

Interactions: Income inequality and the impact of Covid-19

• *Inequalities in the face of an economic crisis:* The Covid-19 epidemic has disrupted economies across the globe and has given rise to a massive economic crisis. As usual, this economic crisis has hit the most harshly, the individuals who were the most vulnerable, and especially the poorest. Because this effect is unrelated to the source of the shock (the epidemic), we do not elaborate on it further.

• *Inequalities across countries:* Less developed countries have been hit by both the epidemic and the change in international trade induced by it. Some countries, such as Brazil, Mexico and India, have paid an enormous price in terms of human lives. Others, including many African countries, have suffered relatively few deaths from the virus itself; but have suffered large human and economic costs from the prevention measures taken to contain its spread. Hunger has been exacerbated by the inability to go out, work and get food. India has imposed a full lockdown at a 4-hour notice, while large parts of its population lives in derelict buildings with scarce sanitation and overcrowded rooms.

Across the world, local markets are essential to provide outlets for subsistence activities for poor individuals. Closing these markets has impeded food access and this to a dangerous degree for the poorest (see e.g., Bargain and Aminjonov [2020], Aminjonov and Bargain [2021]).

Last, despite the COVAX initiativeThe Covid-19 Vaccines Global Access initiative, or COVAX, aims at ensuring equitable access to vaccines across the world and has been joined by 184 countries by Oct. 2021., access to vaccines is unequal to the extreme. In the lowest income countries, the vaccination rate (for the first dose) is estimated at 3.9% in the fall 2021 (cf. UN data).

• *Inequalities across groups and occupations:* Even in the most developed countries, inequalities are strikingly associated to the epidemic. In the US, the death toll of the epidemic has been higher for black citizens (Mahajan and Larkings-Pettigrew [2020]), and evidence suggests that this is due to a correlation with lower income rather than genetic vulnerability (Galea and Abdalla [2020]). It is associated to occupation: The Economic Policy Institute finds that Black and Hispanic workers are less likely to be able to work remotely, using data from the US Bureau of Labor Statistics (https://www.epi.org/blog/black-and-hispanic-workers-are-much-less-likely-to-be-able-to-work-from-home/).

In both population groups, individuals are more likely to work in "essential jobs" than do not admit of teleworking and involve (potentially contaminating) contacts: With the exception of doctors, essential jobs tend to be low-paid. Nurses and hospital staff, cleaning staff, public transportation drivers, cashiers in shops and supermarkets..., all tend to have lower incomes than the population average. Strikingly, 28.8% of U.S. workers can work from home but this varies with income: 62% of individuals at the the top income can work remotely, but only 9.2% of those at the bottom quartile (U.S. Bureau of Labor Statistics, https://www.bls.gov/news.release/flex2.t01.htm, U.S. Bureau of Labor Statistics [2018]). See also Gray and Moore [2020]. Occupation is thus a primary determinant of becoming sick, which is largely correlated with income.

This applies to rich and poor countries alike. Aminjonov and Bargain [2021] provide evidence of the link between maintained work mobility and poverty: They use data from 241 regions in 9 countries in Africa and Latin America. Higher poverty rates correlate with higher work mobility. Given this link, Aminjonov and Bargain provide an estimate of how higher poverty rates translate into a faster spread of Covid-19 cases. For Spain, Baena-Díez et al. [2020] find a positive correlation between the mortality rate in ten districts of Barcelona and the 2017 mean income in the district. Similar results are obtained by Marí-Dell'Olmo et al. [2021] also for Barcelona, with a higher Covid-19 incidence for women under 64 and in poorer neighborhoods. The poorest income quintile has a significantly higher Covid incidence, especially in the second epidemic wave. Wildman [2021], using coarser data, find a similar relationship between death rates and the Gini income inequality coefficient for O.E.C.D. countries.

• *Inequalities over prior health status:* The Covid-19 epidemic has been particularly severe for individuals with co-morbidities such as diabetes, asthma or cardio-vascular diseases and depression (https://www.cdc.gov/coronavirus/2019-ncov/need-extra-precautions/people-with-medical-conditions.html). These co-morbidities are more frequent in lower income groups (Mendenhall et al. [2017]) and even in lower-income neighborhoods (Gaskin et al. [2014]). These co-morbidities in poorer populations correspond to what is sometimes referred to as a “syndemic" (that is: a situation where “several sources of morbidity come together to produce interlinked and worse health outcomes”, Carlson and Mendenhall [2019]). Moreover, poorer individuals are more likely to be in a worse general health state that the remainder of the population, for reasons that range from inadequate nutrition and insalubrious lodgings, to physically strenuous jobs, to delaying care and prevention due to their costs.

The impact of poverty on health is an especially acute problem in some countries, such as the US where health care is particularly expensive, or developing countries lacking in extensive public health coverage. Because poorer individuals cannot afford physical check-ups and treatment for some diseases, their life expectancy is lower (see e.g., Chetty et al. [2016]) and their general health makes them more vulnerable to epidemics (Krieger, Waterman and Chen [2020], Liao and De Maio [2020], Oronce et al. [2020], Tan et al. [2021]).

Our approach: Healthcare access as amplifier of inequality

We focus on the inequality in prior health states that arises from income inequality. We show that the excess impact of Covid-19 on the poorer individuals would exist *even* if they held the same occupations as richer individuals. Inequality in (prior) health, alone, is enough to generate a strong inequality in the way Covid-19 affects income, savings and behaviors.

This is because worse general health translates into a longer expected recovery period (during which the individual is unable to work) and a higher probability of getting infected and experiencing the disease in a severe form, with handicapping symptoms, instead of a mild form (which might have gone unnoticed). This has a direct impact on labor and income for poorer individuals, and a less direct one because it affects their choices.

In our theoretical analyses, we abstract from the economic crisis (job allocation and wage impacts), in order to focus on mechanisms that are directly and specifically focused on the epidemics and interactions with healthcare. We assume no wage inequality and no inequality in access to labor (so the poor are not more likely to loose their jobs). In this set-up we use a standard labor supply and savings model, where health market variables determine epidemiological parameters. In this context, the Covid crisis is not equivalent to a standard adverse economic shock. We then use survey data collected, described and analyzed by a team of researchers (Belot et al. [2020], Belot et al. [2021], Papageorge et al. [2021]) to empirically show the link between suffering adverse outcomes and belonging to a lower income quintile, as well as consequences on preventive behaviors.

The remainder of this paper is structured as follows: In the next section (Modeling), we briefly discuss modeling alternatives and present two economic-epidemiologic models that show how health status can impact labor supply, savings and behavior. The third section (Theory) provides more detail on one of the theoretical models and its predictions. The last section (Data) analyses survey data from six countries that confirms that the poorer income quintiles suffer the most.

Modeling: Epidemiology, economic inequality and health

We first discuss the type of epidemiological model that is adequate depending on the objective of the analysis, before summarizing two models in which economic inequality and health interact in the presence of an epidemic.

Modeling: The epidemiological dynamic

Each epidemic has a specific dynamic. From the point of view of epidemiologists, it is essential to correctly represent this dynamic in order to make predictions as to the spread of the disease. Covid-19 has been characterized by a *very large degree of uncertainty*. This has made modeling extremely complicated. For months, it was unknown how exactly the disease was borne. Air transmission was only recognized officially by the World Health Organization in June 2020. Similarly, the duration of the latency phase (during which individuals can contaminate others without being recognized as sick) was badly known and was initially estimated to be about 15 days before being set at around 7 days and even less now. The strategy of 'collective immunity' was found to be inefficient once it was clear that re-infections were frequet. Yet, still now, the duration of the immunity brought about from catching the disease remains highly unknown.

The complexity of epidemiological models

From the point of view of economists, this uncertainty is more or less problematic depending on the type of questions studied. For instance, Aubert and Augeraud-Véron [2021] use an epidemiological model and real French data to calibrate it and simulate counterfactuals to assess the real value of the lockdown. They also simulate the impact of various public policies. A main value of the model is that it couples a realistic epidemiological dynamic with a Nash equilibrium over prevention efforts: Each individual chooses her distancing effort given the data she has on disease prevalence, in an equilibrium where the probability of catching the disease depends on the proportion of sick individuals but also on their own distancing behavior. Aubert and Augeraud-Véron [2021] show that the effect of public policies intended to limit transmission is limited by their very effectiveness: Because they reduce epidemic prevalence, individuals reduce their effort, which has a countervailing effect. A more effective policy makes individuals behave less cautiously, which partly undermines the value of the policy.

For this type of analysis, it is very important that the epidemiological model be as accurate as possible. A tractable but realistic model to represent Covid-19 is the SLIAR (Susceptible Latent Infected Asymptomatic Recovered) model. This epidemic model is used to model Covid-19 spread (Arino et al. [2006], Liu et al. [2020a], [2020b], Magal et al. [2020]) because it takes into account a crucial feature of Covid-19: the high proportion of asymptomatic but infectious individuals. In this model, the population is separated into *susceptible* individuals (in number $S(t)$ at date t) who can get infected, infectious *latent* individuals ($L(t)$), *asymptomatic* and mildly symptomatic infectious individuals ($A(t)$) and severe symptomatic *infectious* individuals ($I(t)$). $R(t)$ represents the number of recovered individuals. The model is useful to represent the complex adjustment of the epidemic spread to various policies and behaviors. In many economic applications however, a simpler model can be sufficient.

A simpler model: The SIR model

When researchers are mostly interested in economic variables, such as labor, investment, savings, sales,..., a simpler model is generally a good approximation. A very large part of the economics literature on the impact of Covid-19 used the SIR (Susceptible Infected Recovered) model, which completely obfuscates the issue of latency phases and asymptomatic individuals. While this does not allow a correct representation of the dynamics of the disease, it can be enough to study impacts on specific markets. Note that a variation consists in using a SIS model (as in Goenka et al. [2021b] or Davin et al. [2022]), Susceptible Infected Susceptible, to model that getting infected does not grant future immunity (a feature that can be appealing with the latest variants deriving from Omicron). However the SIS model has the drawback of having no mortality induced by the disease. The SIR has therefore been used most in the literature.

In our study of inequality, because we focus on individuals' choices over labor supply, savings and consumption, and behaviors (and not on factors affecting the epidemic dynamics), an SIR model is sufficient. We incorporate this model into a macroeconomic model of labor and savings over two periods, both periods being affected by the disease.

We provide the mathematical equations representative of the SIR model in the Appendix. In order to isolate the impact of prior health iequality, we will assume that the epidemiological parameters depend on health expenses: These epidemiology parameters are the contact rate (α in the Appendix), i.e., the average number of contacts of a person to catch the disease per unit time, and the recovery rate from the disease (Ψ).

Some related literature on health

For more details on how health variables can be incorporated in the dynamics of a macroeconomic model, see Goenka, Liu and Nguyen [2014], and for an application to Covid-19 with a SIR model, Goenka, Liu and Nguyen [2021a]. We draw on these models in our theoretical analysis. A pedagogical presentation of the SIR model for modeling distancing can be found in Garibaldi, Moen and Pissaride [2020]. Toxvaerd [2020] also uses it to study equilibrium distancing choices, while Giannitsarou, Kissler and Toxvaerd [2021] take into account the fact that catching the disease does not grand permanent immunity. Salanié and Treich [2020] use a simpler model to study the complementarity / substitutability between private and public prevention efforts.

Grossman [1972], analyzing an investment in health care which improves health capital, is the first to introduce the idea of a demand for health. In Grossman's model, an increase in the number of days that individuals are sick would result in reductions in their labor income and consumption. Our model similarly addresses the issue of endogenously labor supply under precautionary savings. The theoretical models on precautionary savings in literature (Kimball [1990], Courbage, Rey and Treich [2013]) have typically focused on how consumer's decisions affects saving and labour-supply under uncertainty or on how uncertainty affects healthcare demand and income in the absence of price discrimination on healthcare services. Our objective differs: we link income inequality and health inequality.

Modeling: Two models linking health, wealth and the epidemic

Consider an individual's decisions over two periods, 0 and 1. She chooses her labor supply and her savings, under an epidemic risk. This risk determines the dynamics of the active population in an SIR (Susceptible Infected Recovered) model. The parameters of the model are endogeneous to variables associated to income and health. Each individual may be unable to work in period 1 if she got sick in period 0 and did not recover fast enough (an adverse situation that is more likely is her health is bad). Income and health are thus linked. Two papers use this common framework with different ways of endogeneizing the epidemiologic parameters, based respectively on price discrimination and in investment in health.

Price discrimination in healthcare markets

Dang, Huynh and Nguyen [2020] study how savings evolve with the Covid risk, assuming that individuals in different quintiles pay different prices for health due to price discrimination in the market for healthcare.

Health care markets are indeed characterized by price discrimination: Richer individuals get larger "quantity" and "quality" of health care (shorter wait for appointments, better treatments, more screenings and tests, etc.) than poorer individuals and pay a lower "unit price". This was already noted by Kessel [1958]. The cost of healthcare services varies widely depending on the quality of care received and the type of patients. Following insights from the literature (Arrow [1963], De Nardi, French, and Jones [2010]), Dang, Huynh and Nguyen [2020] assume that individuals pay different unit prices for different levels of healthcare quality depending on their income. In particular, richer individuals choose more expensive care of a higher quality, so that there is a monotone and increasing relationship between the price of healthcare and income. As indicated in Arrow [1963], "The unusual pricing practices and attitudes of the medical profession are well known: extensive price discrimination by income (with an extreme of zero prices for sufficiently indigent patients". Analyzing survey data on outpatients HIV in Burkina Faso, Kazianga et al. [2015] find that more wealth is positively associated with higher up-front costs, which are defined as any fees that the patient paid at the health facility before seeing a health professional. Richer individuals are typically willing to pay higher prices in order to get faster access to some services (in the UK for instance, medical practitioners charge higher prices for their 'private' practice, with much shorter waiting time and more flexible hours than in their 'public' practice). The five income quintiles used in the empirical analysis thus face different health prices.

In the model, the recovery rate depends on the individual's access to health care. Because of price discrimination, richer individuals choose higher levels of healthcare services, which translates into a higher recovery rate. Richer individuals thus face a lower risk of losing their labor income due to the epidemic. Existing income inequality gets reinforced.

Moreover, price discrimination plays a complex role on savings: The fact that the unit price of health care decreases with wealth implies that savings can be either a decreasing or increasing function of income (contrary to the usual model in which savings always increase with income).

Investments in health state

Aubert, Nguyen and Dang [2021] focus on different consequences of inequality: They consider healthcare expenses and prevention efforts as determinants of health status (including prior to the epidemic outbreak). They also use a two-period model of labor and savings choice, and add to it both an epidemiologic dynamic and prior health investments. They use this model to study the impact of the epidemic on labor and savings according to wealth, and also on preventive efforts. In this model, the infection probability and the recovery rate can depend on the individual's health status, and on public health expenses. As in Dang, Huynh and Nguyen [2020], existing income inequality is reinforced by the Covid epidemic. Additional results are obtained on the role of public health expenses vs. private ones.

We sketch this model and the results obtained in Aubert, Nguyen and Dang [2021] in more detail in the next section.

Theory: Income inequality, health expenses and the epidemic

Theory: The set-up

In Aubert et al. [2021], we assume that the health state of a given individual is a function of public expenses in health in the country and of the individual's own expenses in health. While healthy people can work to increase their labor income today, they face a risk of becoming infected that can reduce their future labor income. This risk depends on the initial health state of the individual, and therefore on her health expenses and on public health services.

Macroeconomic aspects. The labor force is constituted by an active population whose size is normalized to 1. An individual is either healthy or infected by the disease. Only healthy individuals can work. The wage is the same for all individuals, rich or poor (to highlight the role of health). We assume (for simplicity and because this is enough to obtain insights) that individuals live for two periods. In period 0, each individual has an exogenous financial asset (wealth, that varies across individuals) and receives an exogenous wage (which is the same for all, an assumption that allows to isolate the impact of wealth). Each individual chooses consumption, health care quality, and savings. Health care quality can be understood in a broad sense: it includes medical visits and preventive scans, but can also represent household self-protection in health, including doing healthy activities such as exercising. In period 1, the household chooses labor supply and consumption.

Income inequality and budget constraints. A poorer individual has a higher shadow cost of her budget constraint: in other words, spending money on health is more costly for her than for a richer individual since money has more value for poorer individuals. The same relationship emerges under *imperfect credit markets*: In such markets, the cost of borrowing decreases in wealth, so that the budget constraint is less costly for richer individuals. This alone is enough to imply that poorer individuals will choose to invest less in their own health than richer individuals, everything else being equal.

Theory: Model predictions on labor, savings and inequality

In an equilibrium, three relationships emerge: i) Consumption is such that the marginal value of consumption today (period 0) is equal to the marginal value of consumption tomorrow (period 1) weighted by the interest rate. ii) The marginal value of health (more income due to improved recovery) is equal to the marginal cost of health (lost consumption at date 1 as one saves less in period 0 because there is a need to pay for health) given the interest rate. iii) Last, a third equation formalizes the trade-off between earning more (and therefore consuming more), and risking more to catch the disease when working at date 0 (because working implies more social contacts).

We obtain the following predictions regarding the impact of the epidemic, assuming credit constraints: i) Health care quality strictly increases in wealth. ii) Labor supply in both period 0 and period 1 strictly increases in wealth: The epidemic has more impact on the total labor supply from the poor in equilibrium. iii) Income loss in both period 0 and period 1 decreases in wealth: The poor are more affected in both the initial stage and the longer term.

If one considers *the poorest individuals*, one gets additional results: The poorest have no access to credit and therefore can only rely on labor income for subsistence. Their maximization problem over labor supply and savings is essentially the same as for richer households, except that they can never have negative savings (they cannot borrow). The poorest individuals therefore need to offer the same labor supply to meet the subsistence level as in the absence of an epidemic. There are not in a capacity to adapt. This implies that they catch the disease more often than if they had the ability to adjust their supply, so that they face an income loss even though their labor supply does not change, and wages do not change. Additional results concern the interplay between public and private health expenses.

Theory: Public and private investments in health

In Aubert et al. [2021], we assume that the health state of each individual i depends on both her own private expenses (in health-related activities, health coverage, preventive behavior, etc.) H^i, and on public, governmental expenses (in health facilities, hospitals, public coverage, prevention campaigns, access to free care, subsidized treatments,...) H^G. Both H^G and H^i determine the degree to which the individual is active, well-nourished, has adequate treatments, is cured early when a disease strikes, etc. The infection rate decreases in the sum $H^i + H^G$, and the recovery rate increases in it (healthier individuals are less likely to have very severe symptoms and are less likely to die from Covid-19). By assuming that what matters is the sum $H^i + H^G$, we are considering the case in which government spending has the same value as private spending, and no intrinsic superiority.

An important point to notice is that, since the individual's health state increases in both individual and public expenses, the individual has incentives to reduce her own expenses when the Government increases H^G: individual expenses H^i and public ones H^G are substitutes. This is amplified by our additive modeling, which represents perfect substitutability, but the intuition does not depend on this assumption.

In the absence of budget constraints, this means that an individual would care only for the sum $H^G + H^i$ and would always adjust her private expenses to complement for public ones and reach the total she wishes. Health states would not improve with an increase in public expenses, because this increase would be perfectly compensated by a reduction in private expenses. Similarly, a reduction in public spending would have no consequence on health states. However, budget considerations imply that public expenses do not simply crowd out private ones:

• The poorest individuals are budget constrained to such an extent that they cannot select the level H^i they would prefer.

• Less poor individuals still face a binding budget constraint, and will choose a level H^i which is affected by the shadow cost of the budget constraint, or the cost of borrowing. The stringiest the budget constraint, the highest the shadow cost of the constraint. They will choose lower levels H^i than the richest individuals for whom the health expenses are not affected by budget restrictions.

Due to these budget constraints, a variation in public expenses is *not* fully compensated for by opposite variations in private ones, except possibly for the richest individuals. Richer individuals will choose higher individual investments, and will benefit from a better health state overall. Thus, prior wealth differences lead to health state differences, which then imply differences in terms of lost income, sickness and recovery when the epidemics strikes.

The sum $H^i + H^G$ is not a constant, except for the richest individuals. For most of the population, it does increase in H^G. Health state and epidemiological parameters thus increase in H^G, and this is true even in the case of perfect substitutability that we consider (under our assumption of additivity).

A result from the theoretical model is thus that governmental health expenses help *limit the consequences of existing wealth inequalities*, not only on the health state of the individuals but also on their labor income. In addition, public expenses also *reduce the contamination rate*, as they help improve the health of poorer individuals who would otherwise face higher contamination probabilities.

Data: Evidence from a survey over six countries

Data source

We use data from the international survey on Covid-19 conducted by Belot et al. [2020a]. This survey covers 6,082 respondents from six countries in different regions and at different income levels: China, Italy, Japan, South Korea, the United Kingdom, and the United States. Data were collected between April 15 and April 23, 2020, offering a multi-country dataset on socioeconomics and behavioral changes in the Covid-19 pandemic. The survey provides nationally representative data for age, gender, and household income for all the six countries. Other analyses of survey data to study inequalities include Adams-Prassl et al. [2O20].

The median time to complete the questionnaire was around 14 minutes. The respondents mostly live in urban areas (48 percent) or sub-urban areas (37 percent), with only 13 percent living in rural areas. About half (48 percent) of the individuals in our sample are female.

Empirical strategy

As Dang et al. [2020], we estimate the impacts of the Covid-19 pandemic with a linear regression where outcome variables can be divided into two sets for each individual.

Outcomes to be explained

• The first set of outcome variables consists of the (self-reported) *changes to one's income and savings* due to Covid-19. There are three such variable: Household income losses, expected losses with respect to one's own labor income, and changes to one's savings (compared to January 2020).To address missing value issues and obtain a better model fit, we add one to these variables before converting them to natural logarithmic form. We change these variables to negative values (i.e., multiply them with -1) such that income losses are represented by a negative sign for easier interpretation. The variable changes to one's savings has five values ranging from 1 to 5, which respectively correspond to "a drop of more than 10%", "a drop of less than 10%", "no change", "an increase of less than 10%", and "an increase of more than 10%".

• The second set of outcome variables consists of two subsets of variables. The first subset includes four variables indicating the *immediate prevention measures against Covid-19*: "keep a 4-foot distance", "not touch one's face", "cover one's mouth with a tissue when sneezing", and "seek medical care when developing Covid-19-related symptoms". These variables have values ranging from 1 to 5, which respectively correspond to "never", "rarely", "sometimes", "very often", and "always".

The second subset includes a variable indicating whether individuals *change their behavior in response to Covid-19*. The survey also collects data on specific individual behavior variables before and after the outbreak, which also have the same 5 values as the first subset of outcomes with a higher value indicating a stronger level of frequency. Consequently, we create seven additional variables by subtracting the pre-outbreak behavior variables from the post-outbreak behavior variables. These variables indicate the *changes* to such specific activities as "wash one's hands", "wear a mask", "eat at least 5 portions of fruit and vegetables every day", "take vitamin", "do exercises", "video chat with one's relatives and friends", and "use public transportation" and have values ranging from -4 to 4.

It is important to remember that these variables are computed as changes relative to behavior before the Covid-19 outbreak: In some countries, a variable can take a relatively low value simply because the behavior was already quite frequent before the epidemic. For instance, wearing masks when sick was already customary in Asia. So even if individuals in China, Japan or Korea increased the frequency with which they wear a mask, the change is likely to be smaller than in other countries (which is indeed what we find in the data).

Explanatory variables

• Our main explanatory variables consist of the different *income quintiles*, where the richest quintile serves as the reference group. The vector of coefficients of interest is β, which measure the impacts of the pandemic on the different income quintiles.

• The other control variables include age, gender, and residence areas (i.e., urban, sub-urban, or rural residence). We also include the country dummy variables to control for the country fixed effects, with the United States serving as the reference country.

For easier interpretation, we use the OLS method to estimation, but Dang et al. [2020) and Aubert et al. [2021] also offer alternative modelling options (including the Tobit and ordered probit methods for robustness checks, cf. Wooldridge [2010]) and we provide heteroskedasticity-robust variance estimates of the error term.

Data Description

We focus on certain variables from this survey for our study (with a different focus from Papageorge et al. [2020], and Belot et al. [2020b]). The descriptive statistics for these variables are provided in Table 1 and Table 2.

Table 1: Summary statistics. Panel A: Continuous variables

Variable	Mean	Std. Dev.	Min	Max
Log(Lost income)	-4.31	4.97	-20.21	0
Log (EFLI)	-3.97	5.13	-22.33	0
Change savings	2.49	1.06	1	5
Keep 4 ft. distance	4.15	1.26	1	5
Not touch face	3.76	1.19	1	5
Cover mouth when sneezing	4.19	1.17	1	5
Seek medical care	3.25	1.72	1	5
Wash hand	0.78	1.03	-4	4
Wear mask	1.7	1.69	-4	4
Eat fruit	0.28	0.78	-4	4
Take vitamin	0.17	0.71	-4	4
Do exercise	0.01	1.01	-4	4
Video chat	0.31	1.23	-4	4
Public trans.	-0.79	1.18	-4	4
bottomrule				

Notes: The number of observations is 6,089 for all the variables.

We divide the variables into two groups of continuous variables and binary variables for better interpretation. Table1 suggests that individuals on average suffer lost household income and expect to lose income as well as have somewhat less savings because of the pandemic (Table 1, Panel A, rows 1 to 3).

Table 2: Summary statistics . Panel B: Binary variables

Variable	Mean	Std. Dev.	Min	Max
Variable	**Mean**	**Std. Dev.**	**% of 0**	**% of 1**
Poorest	0.18	0.39	81.33	18.67

quintile				
Second-poorest quintile	0.18	0.38	81.51	18.49
Middle-income quintile	0.2	0.4	79.16	20.84
Second-richest quintile	0.21	0.41	78.4	21.6
Richest quintile	0.18	0.38	81.89	18.11
Changed behaviors	0.86	0.34	13.73	86.27
Age group (18 to 25)	0.12	0.32	87.91	12.09
Age group (26 to 35)	0.17	0.38	82.31	17.69
Age group (36 to 45)	0.19	0.39	81.01	18.99
Age group (46 to 55)	0.18	0.38	81.41	18.59
Age group (56 to 65)	0.15	0.36	84.43	15.57
Age group (66 to 75)	0.12	0.33	87.42	12.58
Age group (Above 76)	0.04	0.2	95.58	4.42
Age group (Prefer not to say)	0	0.02	99.92	0.08
Urban	0.48	0.5	51.17	48.83
Sub-urban	0.37	0.48	62.33	37.67
Female	0.48	0.5	51.6	48.4
China	0.16	0.37	83.64	16.36
Italy	0.17	0.37	82.85	17.15
Japan	0.16	0.37	83.33	16.67
Korea	0.15	0.36	84.18	15.82
United Kingdom	0.16	0.37	83.31	16.69
United States	0.17	0.37	82.67	17.33

Notes: The number of observations is 6,089 for all variables.

The majority (86 percent) of individuals change their behavior because of the pandemic

(Table 2, Panel B, row 6). In particular, they implement prevention measures such as keeping a 4-foot distance, not touching one's face, covering one's mouth when sneezing, and seeking medical care more often (with the mean values for these activities being larger than 3; Table 1, Panel A, rows 4 to 7). Recall that these variables are computed as changes relative to behavior before the Covid-19 outbreak.

Individuals also do more health activities such as washing their hands, wearing a mask, eating fruit, taking vitamin, doing exercises, video-chatting with one's relatives and friends (with the mean values for these activities being positive; Table 1, Panel A, rows 8 to 13), and using the public transportation less (with the mean values for this activity being negative; Table 1, Panel A, row 14).

Our focus in what follows is: To what extent are these changes *related to the income quintile* the individual belongs to? To study this question, Aubert et al. [2021] regress the various outcome variables described above, over the explanatory variables, including income quintile. We describe the main results below.

Empirical Estimates

Impacts on Incomes and Savings

Table 3 provides estimation results on the impacts of the Covid-19 pandemic on the first set of outcome variables, which include household income losses, the expected losses with one's own labor income, and changes to one's savings. While our preferred model for interpretation includes the country fixed effects, we show estimates both without the country fixed effects (Models 1 to 3) and with the country fixed effects (Models 4 to 6) for robustness and comparison. It is reassuring to see that the estimation results are qualitatively similar whether we control for the country dummy variables or not. For subsequent analysis in Tables 4 and 5, we only show estimates that control for the country fixed effects.

An important element is that among the five countries covered by the survey, China has a much lower GDP per inhabitant than the other countries. One could worry that this drives the results we obtain. However, if China has such an impact, it would be captured in the country fixed effect (or we would obtain inconsistent results from one regression to the next). The consistency and signs of the coefficients we obtain indicate that the role of inequality does not stem from China alone. The significant coefficients are highly significant (at 1%) simultaneously for country dummies and income quintiles.

Table 1 shows that the outbreak has no statistically significant impacts on household income losses for the different income quintiles (Model 4), but it has statistically significant and negative impacts on some poorer quintiles. In particular, the outbreak results in a 63-percent reduction in the expected own labor income for the second-poorest income quintile compared to the richest quintile (Model 5). The impacts of the pandemic are most noticeable in terms of savings: all the four income quintiles have more reduced savings than the richest quintiles. The savings reduction ranges from 0.13 (the poorest quintile) to 0.18 (the second-poorest quintile) on a 1-to-5 scale. These figures approximately correspond to a 5 to 7-percent decrease compared to the mean value for savings of 2.49 (Table 2). The survey also collects data on the employment industries for those in the survey that work, but the sample size for these individuals is around two-thirds of the whole sample. Nevertheless, we re-run the estimates in Table 3 controlling for industry fixed effects. The estimation results are qualitatively similar. These estimation results on (expected) income loss are also qualitatively similar to the finding in Papageorge et al. [2020] and Belot et al. [2020b] that individuals in the richest income quintile are less likely to suffer income loss compared to those in the poorest income quintile.

Compared to the other richer income quintiles, the larger negative impacts for the poorest income quintile are marginally statistically different for income loss, and are strongly statistically significantly for the *expected loss in one's own labor income*.

Impact of age and gender

Compared to the age group 18-25, the older age groups (56 years old or older) expect their income to fall down less, perhaps because of better experience with managing their finance. The age groups 26-65, however, save less. We cannot offer comments on these results as different age groups differ in so many dimensions: occupation, place in the hierarchy ladder, household composition, lodging needs, caring for children or aged dependents,...

Women expect their own labor income to fall more than men, but they save more than men do. This higher savings rate is consistent with the higher degree of risk aversion in women that is generally found in experimental studies (cf. for instance the large-scale study by Vieder et al. [2015], or the global study by Falk et al. [2018]). The negative impacts on women are consistent with recent empirical evidence indicating that women might be more affected than men in the United Kingdom and United States (Alon et al. [2020], Hupkau and Petrongolo [2020]). But while these existing studies focus on one specific country, our estimates offer more general results in a multi-country setting.

Table 3: Inequality in lost income, expected fall in own labor income, and savings

	(Model 1)	**(Model 2)**	**(Model 3)**	**(Model 4)**	**(Model 5)**	**(Model 6)**
	Log(LI)	**Log (EFLI)**	**Change savings**	**Log(LI)**	**Log (EFLI)**	**Change savings**
Poorest quintile	0.028	0.141	-0.146***	0.17	0.211	-0.128***
	(-0.204)	(-0.208)	(-0.044)	(-0.201)	(-0.204)	(-0.044)
Second-poorest quintile	-0.223	-0.648***	-0.189***	-0.15	-0.628***	-0.175***
	(-0.205)	(-0.213)	(-0.043)	(-0.202)	(-0.209)	(-0.043)
Middle-income quintile	-0.218	-0.261	-0.160***	-0.161	-0.224	-0.143***
	(-0.198)	(-0.205)	(-0.042)	(-0.196)	(-0.203)	(-0.042)
Second-richest quintile	-0.186	-0.305	-0.042	-0.182	-0.326	-0.03
	(-0.2)	(-0.204)	(-0.042)	(-0.197)	(-0.202)	(-0.042)

Age group (26 to 35)	0.224	-0.09	-0.104*	0.123	-0.102	-0.117**
	(-0.237)	(-0.244)	(-0.055)	(-0.235)	(-0.244)	(-0.055)
Age group (36 to 45)	0.141	-0.165	-0.202***	0.08	-0.191	-0.208***
	(-0.235)	(-0.241)	(-0.054)	(-0.231)	(-0.24)	(-0.053)
Age group (46 to 55)	0.286	-0.141	-0.217***	0.245	-0.077	-0.227***
	(-0.238)	(-0.246)	(-0.053)	(-0.234)	(-0.243)	(-0.053)
Age group (56 to 65)	1.215***	0.705***	-0.091*	1.052***	0.677***	-0.114**
	(-0.244)	(-0.251)	(-0.055)	(-0.239)	(-0.249)	(-0.055)
Age group (66 to 75)	2.442***	2.448***	0.126**	2.289***	2.464***	0.110*
	(-0.246)	(-0.245)	(-0.058)	(-0.241)	(-0.241)	(-0.058)
Age group (Above 76)	2.623***	2.992***	0.078	2.511***	2.929***	0.061
	(-0.321)	(-0.299)	(-0.072)	(-0.318)	(-0.302)	(-0.072)
Age group (Prefer not to say)	-0.347	1.321	-0.642	-0.404	1.997	-0.646
	(-2.134)	(-1.586)	(-0.595)	(-2.363)	(-1.917)	(-0.55)
Female	0.035	-0.454***	0.060**	0.043	-0.426***	0.061**
	(-0.126)	(-0.13)	(-0.027)	(-0.125)	(-0.128)	(-0.027)
Urban	-0.800***	-0.254	-0.112***	-0.381**	-0.364*	-0.047
	(-0.19)	(-0.198)	(-0.041)	(-0.192)	(-0.2)	(-0.043)
Sub-urban	-0.114	0.156	0.032	-0.032	0.043	0.03
	(-0.192)	(-0.199)	(-0.042)	(-0.192)	(-0.199)	(-0.043)
China				-1.187***	0.268	-0.195***
				(-0.197)	(-0.194)	(-0.05)
Italy				0.196	-0.298*	-0.124**
				(-0.172)	(-0.176)	(-0.052)
Japan				-0.202	-1.574***	0.062
				(-0.219)	(-0.222)	(-0.044)
Korea				-1.799***	-2.197***	-0.067
				(-0.258)	(-0.263)	(-0.047)
United Kingdom				0.933***	0.633***	0.141***
				(-0.173)	(-0.171)	(-0.046)
Constant	-4.507***	-3.959***	2.704***	-4.389***	-3.384***	2.702***
	(-0.281)	(-0.286)	(-0.064)	(-0.303)	(-0.308)	(-0.071)
RMSE	4.878	5.02	1.054	4.801	4.92	1.049
Adjusted R^2	0.038	0.042	0.019	0.068	0.08	0.028

N	6089	6088	6089	6089	6088	6089

Notes: * < 0.1, ** < 0.05, *** < 0.01. Robust standard errors are in brackets. LI and EFLI stand for "lost income" and "expected fall in labor income". The reference groups are the richest quintile for income quintiles, age group 18-25 for age groups, rural residence for residence areas, and the US for countries.

Table 4: Inequality with changes in prevention measures against Covid-19

2[3]***Variables**	**(Model 1)**	**(Model 2)**	**(Model 3)**	**(Model 4)**
2-5	**Keep 4 ft. distance**	**Not touch face**	**Cover mouth when sneezing**	**Seek medical care**
Poorest quintile	-0.287***	-0.265***	-0.263***	-0.260***
	(0.05)	(0.05)	(0.05)	(0.07)
Second-poorest quintile	-0.231***	-0.191***	-0.173***	-0.141**
	(0.05)	(0.05)	(0.05)	(0.07)
Middle-income quintile	-0.154***	-0.137***	-0.077*	-0.206***
	(0.05)	(0.04)	(0.04)	(0.06)
Second-richest quintile	-0.037	-0.06	-0.005	0.018
	(0.04)	(0.04)	(0.04)	(0.06)
Age group (26 to 35)	0.06	0.128**	0.001	-0.156**
	(0.06)	(0.06)	(0.05)	(0.07)
Age group (36 to 45)	0.095*	0.177***	-0.044	-0.147**
	(0.06)	(0.06)	(0.05)	(0.07)
Age group (46 to 55)	0.117**	0.126**	-0.043	-0.488***
	(0.06)	(0.06)	(0.05)	(0.07)
Age group (56 to 65)	0.228***	0.211***	0.015	-0.538***
	(0.06)	(0.06)	(0.06)	(0.08)
Age group (66 to 75)	0.309***	0.195***	0.02	-0.499***
	(0.06)	(0.06)	(0.06)	(0.08)
Age group (Above 76)	0.231***	0.188**	0.004	-0.511***
	(0.09)	(0.08)	(0.08)	(0.12)

Age group (Prefer not to say)	0.135	0.652	-0.086	-0.929*
	(0.59)	(0.65)	(0.62)	(0.56)
Female	-0.220***	-0.183***	-0.242***	-0.064
	(0.03)	(0.03)	(0.03)	(0.04)
Urban	0.036	0.126***	-0.044	0.077
	(0.05)	(0.05)	(0.05)	(0.07)
Sub-urban	0.027	0	-0.014	0.039
	(0.05)	(0.05)	(0.05)	(0.07)
China	-0.388***	-0.019	-0.293***	0.235***
	(0.05)	(0.05)	(0.05)	(0.07)
Italy	0.242***	0.148***	-0.068	-0.970***
	(0.04)	(0.05)	(0.04)	(0.07)
Japan	-1.174***	-0.676***	-0.755***	-1.187***
	(0.06)	(0.05)	(0.05)	(0.07)
Korea	-0.526***	-0.238***	-0.220***	-0.158**
	(0.06)	(0.05)	(0.05)	(0.07)
United Kingdom	0.085**	-0.053	-0.127***	-0.260***
	(0.04)	(0.05)	(0.04)	(0.07)
Constant	4.513***	3.906***	4.688***	4.056***
	(0.08)	(0.08)	(0.07)	(0.10)
RMSE	1.157	1.146	1.132	1.616
Adjusted R^2	0.162	0.069	0.061	0.114
N	6089	6089	6089	6089

Notes: $* < 0.1$, $** < 0.05$, $*** < 0.01$. Robust standard errors are in brackets. The reference groups are the richest quintile for income quintiles, age group 18-25 for age groups, rural residence for residence areas, and the US for countries.

Conclusion

Data clearly confirms that the Covid-19 epidemic has disproportionately affected the poorer two-thirds of the population in the six countries studied. A simple theoretical analysis shows that such a disproportionate impact is to be expected for the simple reason that the poor have worse access to healthcare, and are therefore on average in a worse health condition than richer individuals when the epidemic strikes. While there are many other reasons, in particular associated to differences in job characteristics that explain this disproportionate impact, the prior inequality in health would be sufficient to generate a disproportionate impact. This militates strongly in favor of subsidized health access and specific public health policies.

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Appendix

The dynamics in the SIR model.

The diseases dynamics between period t and period $t+1$ following the standard SIR model are given by:

$$S_{t+1} = S_t - \alpha S_t I_t / N_t$$
$$I_{t+1} = I_t + \alpha S_t I_t / N_t - \Psi I_t$$
$$R_{t+1} = R_t + \Psi I_t$$
$$S_0, I_0, N_0 > 0 \text{ with } N_0 = S_0 + I_0$$

where S_t be the number of susceptible, I_t be the number of infectious, and R_t be the number of recovered or deceased individuals in period t.

The epidemiology parameters are the contact rate, α, i.e., the average number of contacts of a person to catch the disease per unit time and Ψ , the recovery rate from the disease. Assuming the proportion of the household in each disease status is identical to the corresponding population proportion. Thus in the household, $s_t = \frac{S_t}{N}$ be the fraction of healthy individuals, $i_t = \frac{I_t}{N}$ be the fraction of infected individuals, and $r_t = \frac{R_t}{N}$ be the fraction that that is recovered from the disease and no longer infectious where $1 = i_1 + s_t + r_t$.

The SIR model with endogenous health.

Starting from the SIR model described above, we define some epidemiological parameters as functions of investments in health.

Endogenous recovery rate.

In Dang et al. [2020] and Goenka et al. [2021], the recovery rate Ψ is a function of the quality of health services HQ, with $\Psi'(.) > 0$ and $\Psi''(.) < 0$. The recovery function increases in health quality, but at a decreasing rate (the benefit from health expenses is concave). Each individual then maximizes her utility over health expenses quality HQ, given the risk of losing her job if she gets sick. Investing in health (choosing a higher level for HQ, better health services, more renowned clinics and praticians, more expensive treatment and prevention...) reduces the average duration of unemployment if sick. In Dang et al. [2020], price discrimination implies that the rich pay a lower per unit price for health, and therefore choose to invest higher levels in their health, which partly protects them from the consequences of Covid. Denote by p_j the unit price of health and by HQ_j the health quality corresponding to health expenses in quintile j for each of the five quintiles, $j = 1,\ldots,5$. Due to price discrimination p_j decreases in j, HQ_j increases in j, and so does the recovery rate $\Psi(H_j)$.

The dynamics become, denoting H_j the health expenses in quintile j for each of the five quintiles, $j = 1,\ldots,5$,

$$S_{t+1} = S_t - \alpha S_t I_t / N_t$$
$$I_{t+1} = I_t + \alpha S_t I_t / N_t - \frac{\sum_j \Psi(HQ_j)}{5} I_t$$
$$R_{t+1} = R_t + \frac{\sum_j \Psi(HQ_j)}{5} I_t$$
$$S_0, I_0, N_0 > 0 \text{ with } N_0 = S_0 + I_0$$

By definition, each quintile has the same population (total population divided by 5) so that the average recovery rate is $\frac{\sum_j \Psi(HQ_j)}{5}$. Because health expenses only affect recovery, and not the probability of getting sick, the equations remain simple to solve.

The intuition behind our results is that, as health expenses increase the probability of recovery, they also increase expected wages for the individuals, as well as overall growth in the country (thanks to an increase in expected labor supply).

Endogenous infection rate.

In Aubert et al. [2021], the infection rate depends on the good health of the individual, prior to the start of the epidemics. This good health is a function of both public (governmental) and private (individual) investments in health, respectively H^G and H^i for individual i. The recovery rate can also depend on these investments.

Assuming that both type of expenses enter additively in the individual's health status, governmental expenses tend to crowd out private expenses (individuals substitute public expenses for private ones). However this is only true to the extent that individuals are free to choose their expenses H^i without bounds. As explained in the main text, this will in general not be so, due to budget constraints. Individuals will therefore not be able to choose a level of private health expenses that perfectly complements public ones. Total health expenses will therefore increase in H^G (under perfect substitutability, this would not have been the case, since H^i would have been reduced in an exact compensatory way for each increase in H^G). And so will the recovery rate. The transmission rate will be a decreasing function of H^G. This holds for the population globally, and for most income quintiles, except the richest ones.

Assume again that individuals in a given quitile j are identical so that each will chose the same equilibrium level H_j^i. The dynamics in this model write as

$$S_{t+1} = S_t - \mathbf{E}_j \alpha (H^G + H_j^i) S_t I_t / N_t$$
$$I_{t+1} = I_t + \mathbf{E}_j \alpha (H^G + H_j^i) S_t I_t / N_t - \Psi I_t$$
$$R_{t+1} = R_t + \Psi I_t$$
$$S_0, I_0, N_0 > 0 \text{ with } N_0 = S_0 + I_0$$

While the dynamics are more complicated than in the previous case, we obtain similar results: Higher health spendings increase the probability of not getting infected, which increases both individual expected income and overall expected labor supply. In addition to the previous case, health spendings reduce the contamination rate, which has a positive dynamic effect on the whole economy.