



Macroeconomic Effects of COVID-19 Across the World Income Distribution

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Abstract

The macroeconomic effects of the COVID-19 pandemic were most severe for emerging market economies, representing the middle of the world income distribution. This paper provides a quantitative economic theory for why emerging markets fared worse, on average, relative to advanced economies and low-income countries. To do so we adapt a workhorse incomplete-markets macro model to include epidemiological dynamics alongside key economic and demographic characteristics that distinguish countries of different income levels. We focus in particular on differences in lockdown stringency, public insurance programs, age distributions, health-care capacity, and the sectoral composition of employment. The calibrated model correctly predicts the larger output losses and greater fatalities in emerging market economies, matching the data. Quantitatively, emerging markets fared especially poorly due to their high employment share in occupations requiring social interactions and their low level of public transfers, which leads economically vulnerable households to continue working in the market rather than sheltering at home. Low-income countries fared relatively better due mainly to their younger populations, whom are less susceptible to disease, and larger agricultural sectors, which require fewer social interactions.

1 Introduction

While every country has been adversely affected by the coronavirus pandemic, the damage it has wrought varied widely around the world. In this paper, we investigate how and why the pandemic's macroeconomic consequences have differed (so far)

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across the world income distribution. We focus in particular on variation in output and excess mortality across three broad groups of countries: low-income economies, emerging markets, and advanced economies, as classified by the International Monetary Fund (IMF). As we detail below, data from a variety of sources reveal that the pandemic's cost in terms of lives and livelihoods was roughly U-shaped in national income, with emerging markets experiencing the worst public health and macroeconomic consequences. On average, GDP per capita in emerging markets declined by 6.7% from 2019 to 2020, compared to 2.4% in advanced economies and 3.6 percent in low-income countries. Excess mortality exhibits a similar pattern. According to estimates by *The Economist*, excess mortality was 75 percent higher in emerging markets than in advanced economies. While credible excess mortality data for low-income countries are still largely unavailable, the few existing estimates point to lower mortality rates.

We assess the extent to which variation in policy or preexisting economic and demographic characteristics can explain the cross-country GDP and mortality outcomes in the data. In part, these outcomes could stem from differences in government policy responses to combat the coronavirus pandemic. While most countries enacted similar “lockdown style” policies and expanded social insurance programs, the scope of such efforts varied substantially. According to the Oxford Coronavirus Government Response Tracker, the stringency of lockdown policies aiming to restrict individual behavior (such as school and workplace closures) was somewhat stricter in emerging markets. The generosity of social insurance programs, in contrast, was substantially higher in richer countries. Accounting for these differences in policy is important because they can directly affect both fatalities and growth during the pandemic.

The cross-country variation may also arise from stark underlying differences in economic and demographic characteristics that predate the pandemic. For instance, low-income countries may face very different public health risks than wealthier ones, as they have substantially younger populations but also less developed health-care systems. Moreover, systematic differences in the sectoral composition of employment make some countries better able to preserve income while mitigating health risks through social distancing or lockdowns. Low-income countries may benefit from their large agricultural sectors and rural populations, which provide a resilient source of income that can be sustained while limiting social contacts. On the other hand, Gottlieb et al. (2020) show that in urban areas, the ability to work from home is far more limited in lower income countries. Combining their estimates with data on urbanization rates, we can measure the total share of labor in *social sector* employment, as in Kaplan et al. (2020), to capture cross-country differences in the ability to work from home or with limited in-person interactions. The composite measure shows that emerging markets have the highest share of workers in social employment, due to their large urban workforce concentrated in high-contact sectors such as manufacturing and retail trade. In contrast, low-income countries have the smallest social employment shares, due to the predominance of rural agricultural work.

To investigate the extent to which these factors can explain observed differences in mortality and output, this paper follows the newly emerged literature on the



macroeconomics of pandemics by combining a variant of the SICK model standard in epidemiology with a workhorse macro model. In particular, our framework builds on the heterogeneous-agent incomplete-markets model of Aiyagari (1994), Bewley (1977) and Huggett (1996), which allows us to capture the individual-level trade-offs between consumption and health that have been the focus of most economic analysis during the pandemic. The model distinguishes between social and nonsocial jobs, differentiating individuals by their ability to work from home or while socially distancing. We incorporate age heterogeneity following Glover et al. (2020) and allow death rates to depend on a person's age, consistent with a vast medical literature. Our model also allows for a time-varying infection rate that captures, in a reduced-form way, the various other non-modeled determinants of disease progression, such as seasonal conditions, improved treatment, or virus mutation. Finally, we include constraints on peak healthcare capacity which represent limits on the ability of certain healthcare systems to treat many patients at once, due to factors like the availability of protective equipment, hospital beds, or supplemental oxygen.

In the model, the propagation of disease depends in large part on individual decisions to stay home during the pandemic or continue working in the market. The model therefore features a public health externality that creates space for welfare improving government interventions. We model lockdown policies in a simple way that is consistent with policy variation observed during the pandemic. Specifically, we feed in time-varying lockdown measures that replicate the changing stringency of government policies over the course of the pandemic, as measured by the Oxford Coronavirus Government Response Tracker (OxCGRT). In the model, lockdown stringency corresponds to the fraction of susceptible individuals who are confined to their home, where they are less likely to become infected but incur income losses depending on their job type. While we do not allow households to disobey lockdowns, individuals can voluntarily elect to work from home at any point in time. Households also receive time-varying public transfers to support or replace lost income. As with lockdowns, we set the level of public financial assistance to match the time-path reported in the OxCGRT financial support index.

To evaluate the quantitative importance of these channels in explaining the facts at hand, we parameterize the model to match key pre-pandemic economic and demographic characteristics of the USA. Parameters governing the epidemiological process are set using estimates from the relevant medical literature. We compute the model's equilibrium response to the COVID-19 pandemic as a surprise "MIT shock," where a small exogenous fraction of the population becomes infected with the virus, and then allow the disease to spread endogenously through the populous. We feed in the time series of vaccination rates, as reported by OxCGRT, allowing a random fraction of the population to be vaccinated in each period, consistent with rates we observe in the data. We set the nonparametric component of the infection probability so that the model's endogenous disease path (nearly) exactly replicates the time-path of fatalities from COVID-19 in the USA during the pandemic. We calibrate the productivity penalty incurred during lockdowns to match the cumulative 2019–2020 year-on-year employment loss in the USA. We also allow for a one-off



shock to aggregate total factor productivity (TFP), which is calibrated to match the cumulative 2019–2020 year-on-year decline in US real GDP per capita.

We use the calibrated model to simulate how the USA would have fared during the pandemic if it counterfactually had the characteristics of emerging market or low-income economies. Comparing the model's predictions to the actual outcomes allows us to assess the importance of each characteristic in explaining cross-country differences in GDP declines and mortality rates. Including all characteristics, the model is able to generate the U-shaped pattern in output losses and mortality rates observed across the world income distribution. The model can fully account for the relatively larger GDP declines and higher fatalities in emerging markets compared with advanced economies. Similarly, the model correctly predicts the more modest output losses and mortality in low-income countries, albeit to a quantitatively greater extent than what is observed in the data.

Simulating the contribution of each factor in isolation, we find that variation in the sectoral composition of employment is the most important factor in accounting for cross-country GDP declines. Emerging markets suffered the greatest output losses in large part because they had high employment shares in close-contact occupations. In contrast, output declines in low-income countries were substantially moderated by their large agricultural sector. The sectoral composition of employment also plays an important role in explaining cross-country mortality outcomes, along with variation in age demographics and the size of social insurance programs. In both low-income and emerging markets, low levels of public financial assistance during the pandemic substantially amplified fatalities by leading many economically vulnerable individuals to continue working in the market rather than sheltering at home during times of peak infection. Our counterfactuals predict that if the USA had implemented the more limited transfer programs in low-income and emerging market economies, cumulative fatalities from the pandemic would have been 50 percent greater. In low-income countries, these higher fatalities were avoided largely thanks to their substantially younger populations with greater natural immunity to infection and serious illness. High agricultural employment shares, where transmission is lower while working, also reduces mortality in low income countries. In contrast, emerging market economies experienced much greater mortality because they do not benefit from favorable age demographics and also have high social sector employment shares.

Following the counterfactual simulations, we conclude the analysis by reporting multiple correlations between cross-country changes in GDP per capita during the pandemic and covariates representing the various channels embodied in our model. Consistent with our findings, the data show that the agricultural employment shares are highly correlated with GDP changes during the pandemic, while lockdown stringency exhibits a strong negative correlation. Median age and indices of government economic support show weaker correlations. Altogether, the covariates greatly reduce the observed U-shape pattern in GDP declines across the world income distribution. The result suggests that this parsimonious set of variables, and the economic mechanisms they represent, are empirically relevant in explaining cross-country macroeconomic outcomes during the pandemic.



Taken together, our analysis suggests that the comparatively worse outcomes in emerging markets, and comparably better outcomes of low income countries, were in large part predetermined by underlying economic and demographic conditions, rather than specific policy decisions. This is especially true for cross-country output losses following the pandemic. In particular, differences in quasi-fixed features like age structure, the sectoral composition of employment, and ICU capacity alone can over-account for all output losses in low income and emerging markets economies. In contrast, if all countries adopted the lockdown and transfer policies of advanced economies, GDP declines would be 1.4 and 1.0 percentage points *larger* in emerging market and low-income countries, respectively.

Policy differences also appear to play a modest role in explaining cross-country mortality differences, with the exception of transfer policies in emerging markets. The quasi-fixed features of age, employment composition, and ICU capacity can over-account for the lower fatalities in low-income countries, but only explain roughly one-third of the higher fatalities in emerging market economies. The smaller and more limited public transfer programs in emerging markets can quantitatively account for much of their remaining variation in excess mortality. While not explicitly modeled, the result suggests that financial constraints which limit the ability of governments to enact large scale public transfer programs may be an important determinant of mortality globally and across countries. A valuable goal for future research would be to help refine the quantitative importance of different policy decisions across countries in determining macroeconomic outcomes during and after the pandemic.

Our work builds on the first generation of papers addressing the aggregate effects of COVID-19 in the developing world, which were largely written in the early months of the pandemic (Loayza and Pennings 2020; Alon et al. 2020; Alfaro et al. 2020; von Carnap et al. 2020; Djankov and Panizza 2020). The current paper differs in its efforts to explain observed macroeconomic outcomes through the first year and a half of the pandemic, in particular the larger declines in GDP and employment in emerging markets. Sanchez (2021) also notes the larger decline in GDP middle-income countries, but does not attempt to explain this finding. We also emphasize the inability of individuals in emerging market economies to work from home, following Gottlieb et al. (2020, 2021a), though we argue that low-income developing countries, on account of their large agriculture sectors, are better able to work without social interactions. As in Ma et al. (2021), we emphasize the stark difference in the age structure of the population across countries and the role this difference plays in quantitative impact of the pandemic and pandemic policies.

On the modeling front, our study most closely follows the structural macro work on the pandemic using models of heterogeneity in income, age, and occupation/sector of employment (e.g., Acemoglu et al. 2020; Bairoliya and Imrohorglu 2020; Kaplan et al. 2020; Glover et al. 2020; Brotherhood et al. 2021; Chopra et al. 2021). Our model of disease dynamics features endogenous behavioral responses to changes in infection rates, even in the absence of government intervention, as in Greenwood et al. (2019), Alvarez et al. (2020) and Krueger et al. (2020) and other studies. To our knowledge, ours is the first to evaluate the quantitative predictions of



a model of this sort for how the experience of emerging markets differed from richer (or poorer) countries.

Our study abstracts from many important features of reality that may also be relevant for the effects of the pandemic outside of the world's advanced economies, such as negative impacts through shocks to global supply chains (Cakmakli et al. 2020; Bonadio et al. 2021), the ability to issue sovereign debt (Arellano et al. 2020), or the ability to test and trace infections (Berger et al. 2020). We also abstract from differences in the prevalence of co-morbidities, such as diabetes and cardiovascular disease, and differential ability or willingness or ability to mask or get vaccinated. These issues would be valuable to consider in future studies trying to explain cross-country differences in the macroeconomic effects of the pandemic.

2 Macroeconomic Effects of the Coronavirus Pandemic by Income Level

This section presents the main facts regarding excess mortality and output losses across the world income distribution resulting from the coronavirus pandemic. Following the IMF classification, we focus in particular on three major income groups: low-income economies, emerging markets, and advanced economies. In 2019, the median GDP per capita of these three country groups was \$1,124, \$6,700, and \$43,144, respectively, in constant 2010 USD¹. While there is interesting variation even with these group, we focus the main part of our analysis on just the three aggregate groups. Section 5 of the paper looks at empirical patterns in the full set of countries for which data are available. Here, drawing on various data sources, we show that both output losses and excess mortality exhibit hump-shaped outcomes with middle income countries experiencing the worst. We then present in a systematic way the important differences in policy and underlying economic and demographic conditions. For each, we briefly discuss their relevance for the pandemic's impact in order to help motivate the model and quantitative analysis which follows.

2.1 The Impact of COVID-19

The first fact we highlight is the differential impact of the pandemic on output losses and employment declines across the world income distribution. Figure 1 displays the data by plotting changes in output and employment for low-income, emerging, and advanced economies. While there is considerable variance even within groups, a clear U-shaped pattern emerges in which output losses were greatest in emerging economies. GDP per capita fell by 6.7 percent and employment by 5.4 percent in emerging economies, considerably worse than both wealthier countries where output and employment losses were 4.6 percent and 2.4 percent, respectively, and lower

¹ At the time of this writing, these are the most recent available data for emerging market and low-income countries.



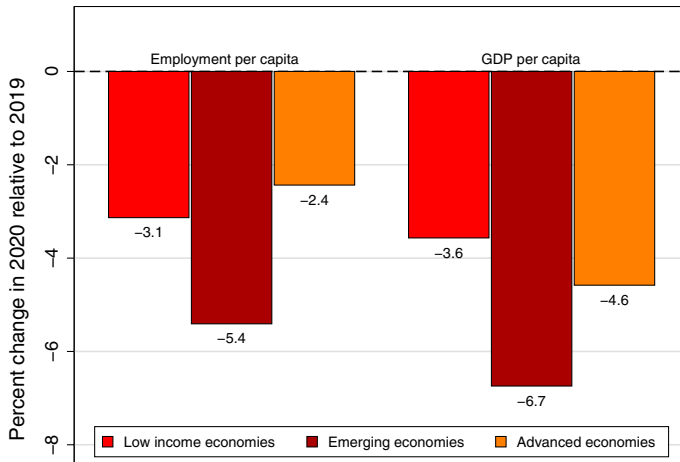


Fig. 1 GDP and Employment Growth from 2019 to 2020 by National Income. Note: Employment data come from the ILO Statistical Database and data on GDP per capita are taken from the World Bank World Development Indicators

income countries where those losses stood at 3.6 and 3.1 percent.² Such outcomes are surprising given the tremendous resources and technology that wealthy countries brought to bare in combating COVID-19, resources that low-income countries had no ability to marshal or match in any comparable way.

The second important fact pertains to the fatalities caused by COVID-19. These deaths are commonly measured using excess mortality, the difference between total deaths in a given month of the pandemic and those that would be normally expected, measured as expected deaths during the same month over the previous (typically five) years. Figure 2 displays the data by comparing mortality outcomes in advanced and emerging economies. As with output losses, we find that the emerging economies experienced the worst outcomes. According to estimates *The Economist*, excess deaths in emerging economies stands at 112.9 per hundred thousand people, which is around 75 percent higher than the average estimate for advanced economies, which experienced 64.1 excess deaths per hundred thousand. Estimates from the World Mortality Database of Karlinsky and Kobak (2021) show 164.5 excess deaths per hundred thousand people, or 65 percent larger than the 99.5 deaths per hundred thousand of advanced ones. The gap is even wider in the New York Times mortality tracker which records 148.1 deaths per hundred thousand in emerging economies, compared to 63 in advanced ones.

Internationally comparably data on excess mortality in low-income countries are more difficult to find. The most comparable statistics of which we are aware contain very few observations from low-income countries (see Appendix Figs. 15 and 16). These data, from *The Economist* and Karlinsky and Kobak (2021), have two and

² Appendix Figs. 12 and 13 illustrate that the relationship also holds in the un-binned data and Appendix Fig. 14 displays similar trends in cross-country consumption data.



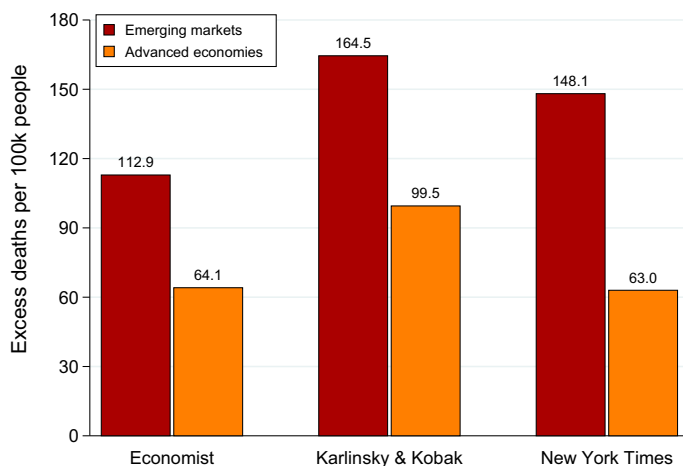


Fig. 2 Excess Deaths from 2019 to 2020. Note: Data sourced from the *New York Times* and *Economist* excess mortality trackers, and Karlinsky and Kobak's (2021) World Mortality Database

five observations from the low-income group respectively. Deaths for this small set of countries average around 100 excess deaths per hundred thousand people, putting them well below the level of the emerging markets. Official data on deaths from COVID-19 in low-income show remarkably low levels of fatalities (see, e.g., Appendix Fig. 17), though there is widespread belief that official statistics undercount deaths there. Our read of the literature is that there is still no clear consensus on what the true death rates have been in low-income countries, though it seems unlikely that they are worse than the high rates estimated in emerging markets such as India (Deshmukh et al. 2021; Ramachandran and Malani 2021), Mexico (Dahal et al. 2021), and Brazil (Yamall Orellana et al. 2021).

Taken together, the data reveal that the impact of the COVID-19 pandemic across the world income distribution has been highly nonlinear. Emerging economies have been hit the hardest most in terms of output losses and likely in terms of excess mortality as well. Equally surprising is that the data suggest that low-income countries have fared better than advanced economies in terms of output losses, and possibly also in terms of mortality rates, despite the far greater economic and technological resources mustered by the latter to combat the crisis.

2.2 Differences in Policy Response

A natural candidate explanation for the cross-country variation is that they reflect differences in policy responses to the COVID-19 pandemic. While nearly all countries implemented some sort of lockdown and transfer programs, they varied widely both in the stringency of restrictions and in the generosity of transfers. The policy distinction matters for how well countries manage the endogenous path of infections through the public health externality and for the ability of households to protect themselves by staying home for prolonged periods without income.



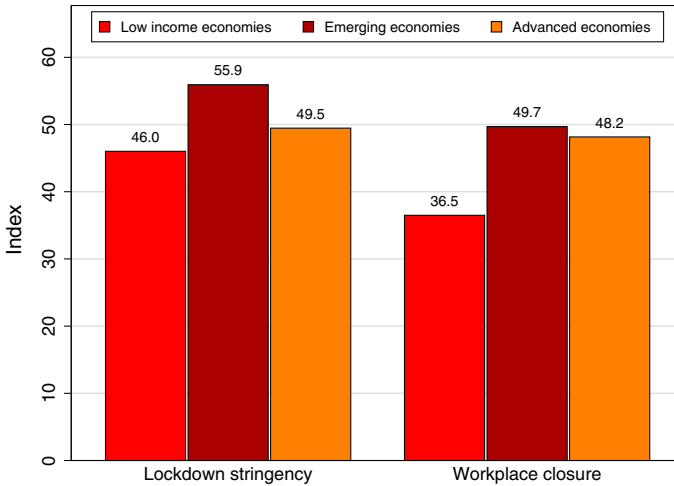


Fig. 3 Oxford Lockdown Stringency Index. Note: The Government Stringency Index is taken from the Oxford Government Response Tracker (OxCGRT). GDP per capita is expressed at PPP and taken from Penn World Table 9.1 (Feenstra et al. 2015).

By lockdown policies, we refer to those whose primary aim is to restrict individual behavior and social interactions to stem the spread of disease. These include school closures; workplace closures; public event cancellations; restrictions on public gatherings; closure of public transport; stay-at-home requirements; public information campaigns; and domestic and international travel restrictions. The Oxford Coronavirus Government Response Tracker's (OxCGRT) *stringency index* provides a parsimonious quantifiable measure of how strict these policies were across countries. Figure 3 plots the index of each country group, and shows that the most stringent lockdown policies were implemented by emerging economies (the un-binned data are displayed in Appendix Fig. 18). When we simulate lockdown policies, we implement them using the time series of workplace closures reported by OxCGRT to be consistent with how such policies are represented in the model. As cross-country and time-series data (see Appendix Fig. 19) show, the variation in workplace lockdowns is similar to the overall stringency of policies across countries. One concern is that these data only represent *de jure* differences in policies, and that *de facto* lockdowns actually varied markedly less. Google workplace mobility data suggest this is not the case, confirming that the largest gap in workplace mobility is between the richest and poorest countries (see Appendix Fig. 20).

Another important dimension of the policy response in nearly all countries was the expansion of social insurance payments, such as unemployment benefits. These payments are viewed as critical to offsetting lost income and make isolating at home economically feasible for those with low savings or little income. However, as the crisis unfolded it quickly became clear that governments in many developing countries lacked the fiscal capacity to sustain substantial transfers to major segments of their population for very long. Consequently, we observe substantially more



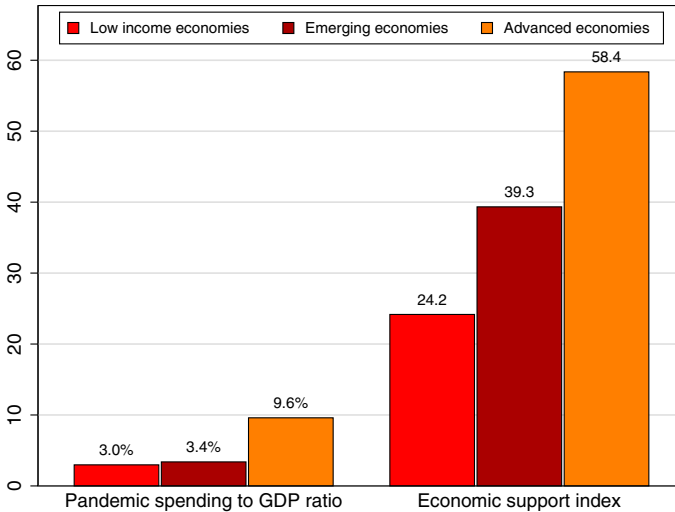


Fig. 4 Pandemic Spending and Economic Support. Note: The left side histogram plots the ratio of pandemic spending to GDP, taken from the IMF. The right side histogram displays the Oxford Economic Support Index available through the Oxford Coronavirus Government Response Tracker's (OxCGRT)

cross-country variation in the size and scope of social insurance programs than in lockdown policies.

Figure 4 provides two measures capturing the scope and generosity of transfer programs implemented in response to COVID-19 across the world income distribution. The left side histogram plots national pandemic spending as a share of GDP, which includes comprehensive measures of budgetary fiscal support to individuals and firms estimated by the IMF. While pandemic spending appears similar in low-income and emerging economies, they are only about one-third the spending undertaken by advanced economies which reached nearly 10 percent of GDP. The right side histogram displays the Oxford's Government *Economic Support Index* which records financial assistance programs such as income replacement and debt relief for individual citizens. The index should be interpreted as an ordinal measure of economic assistance for individual citizens in that it does not include support to firms or business and does not take into account the total fiscal value of economic support programs. Nevertheless, the data reveal a similar pattern with spending on economic support rising monotonically with national income.³

These cross-country differences in lockdown policies and public insurance programs are even more apparent when one examines the underlying components of the OxCGRT's indices which are displayed in Table 1. The first noticeable feature is that low-income countries have the least stringent policies in every lockdown category, and in all other categories except "Facial Coverings." The near

³ The greater cross-country variation in economic support policies, as compared to lockdown policies, is most apparent in these underlying data. See Appendix Figs. 21 and 22.



Table 1 Oxford Covid-19 Government Response Indices in 2020

Index	Country Income Group		
	Low-Income	Emerging Markets	Advanced Economies
Panel A: Included in both Stringency and Health & Containment Indices			
School closures	53.8	64.8	50.1
Workplace closures	34.6	47.0	45.1
Cancellation of public events	57.0	69.4	63.7
Restrictions on public gatherings	50.9	59.5	61.3
Closure of public transport	22.5	32.0	17.8
Stay at home requirements	25.0	35.7	24.9
Restrictions on internal movements	32.9	47.7	31.8
International travel controls	57.6	63.6	63.4
Public information campaigns	79.7	83.8	87.0
Panel B: Included only in Health & Containment Index			
Contact tracing policy	54.4	61.5	67.6
Facial coverings	43.8	46.4	37.3
Testing policy	37.9	52.2	58.8
Vaccination policy	22.8	31.3	35.3
Protection of the elderly	19.4	40.8	57.3
Panel C: Included only in Economic Support Index			
Income support	17.3	29.3	57.8
Contract/Debt relief	31.0	49.6	58.9
Observations	52	67	33

Countries are grouped into low-income, emerging markets, and advanced economies using the IMF's economic classification of countries. Data in the table are the average level of the Oxford Covid-19 government response tracker by country income group

opposite is true for emerging economies which have the most stringent policies across all sub-categories of lockdown measures (Panel A) except "Public Information Campaigns." The largest deviations in emerging economy lockdowns pertain to the closure of public transport, stay at home orders, and restrictions on internal movements. This is notable since these measures likely imposed the largest restrictions on commercial activity, especially in emerging economies where the ability to work from home is not widespread (see Sect. 2.5) and substituting to e-commerce and delivery services is limited by infrastructure. Finally, it is interesting to note that the stringency of emerging economy policies does not extend beyond lockdowns; as Panels B and C show, direct public health interventions and economic support policies were generally less encompassing in emerging economies. Taken altogether, the scope of differences in the stringency and



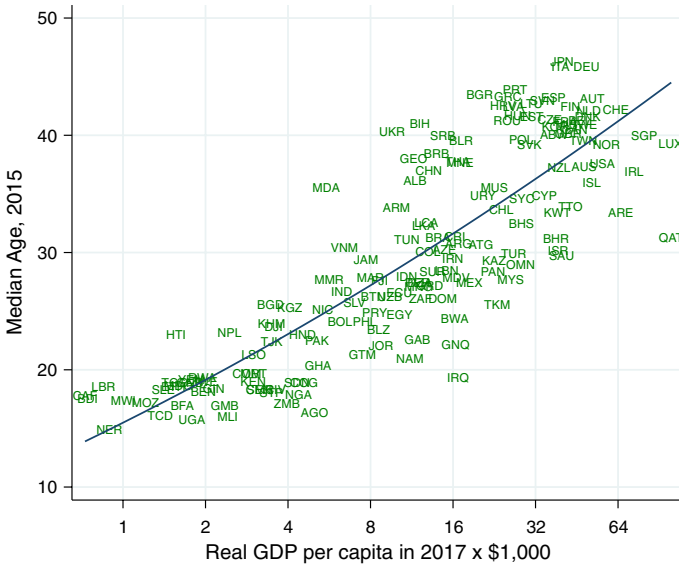


Fig. 5 Median Age of the Population. Note: Median age data corresponds to 2015 and is from the UN Population Division. GDP per capita is expressed at PPP and taken from Penn World Table 9.1 (Feenstra et al. 2015)

aim of policies across the world income distribution offer ample scope for them to drive the differences in outcomes we observe in the data.

2.3 Differences in Population Structure

It has been well known since the beginning of the pandemic that COVID-19 poses dramatically greater health risks to older individuals, in particular those over the age of 65 (Ferguson et al. 2020; Glynn 2020). Early centers of infection in the west, such as Italy, experienced health impacts concentrated on those in this older age range, with particularly severe fatality rates for those in their 80s and 90s. At the same time, the number of deaths linked to COVID-19 for those under 20 has been negligible, though certainly not zero.

A basic demographic difference between advanced and developing economies is that populations are far younger in the developing world. Since fatality rates from COVID-19 are very low for young individuals but rise sharply with age, these demographic differences suggest much smaller populations of vulnerable individuals in the developing world. One can see these demographic differences starkly when looking at cross-country data on the median age. Figure 5 plots the median age against GDP per capita in a set of 158 countries using data from UN Population Division and Penn World Tables. Data from the UN Population Division show that countries in the bottom quartile of the world income distribution have a median age of 19.1 years. Nigeria, Africa's most populous country, has a median age of 17.9, while countries like Angola and the Democratic Republic of



the Congo have median ages of just 16.4 and 16.8 years old. By contrast richer countries like Italy, the UK and France have median ages of 45.9, 40.2 and 41.2, respectively.

Another statistic indicative of the much smaller vulnerable population in the developing world is the cross-country data on the population above 65. In the world's poorest countries, the fraction of the population that is above age 65 is negligible, with an average of around 3 percent for countries in the bottom quartile of the world income distribution. The older population is much larger as a fraction of the total in richer economies, and reaches around one quarter of the population in Japan. Among countries in the top quartile of the world, the average is about 15 percent of the population being above age 65 (see Appendix Fig. 23).

It is hard to look at statistics like these and not see how different the impacts of COVID-19 will be in less developed countries. Concretely, while almost everything about COVID-19 suggests a more severe impact in less-developed countries, the far younger demographic is clearly in their favor.

2.4 Differences in Healthcare Capacity

Developing countries typically have substantially less ability to control disease than do richer countries. Sanitation and hygiene are more of an issue given the lack of widespread piped water and functioning sewage systems. Health infrastructure, especially hospital and health clinic capacity, is also less developed. For mild cases of COVID-19 infections, this may make little differences, as bed rest is likely to suffice in these mild cases. However, for critical cases, the lack of intensive-care capacity is a clear disadvantage for developing countries in their attempts to save lives during the pandemic.

Figure 24 plots the number of hospital beds per 10,000 people, as reported by the World Health Organization (WHO), against GDP per capita. The number of hospital beds is an imperfect measure of hospital capacity for many reasons, most importantly because it is not a bed per se that helps critical patients recover from COVID-19 but trained doctors, equipment like ventilators, and appropriate pharmaceuticals. Still, for lack of more comprehensive cross-country data, we take hospital beds as a proxy for medical care capacity.

By this metric, there are stark differences in healthcare capacity across countries. Richer countries, which have quite some range amongst themselves, average around 49 hospital beds per 10,000 people. Countries like Japan and Korea have even more beds per capita, having 134 and 115 beds per 10,000 people, respectively. This is still far higher than the capacity in developing countries, which is a paltry 12 beds per 10,000 people on average in the bottom quartile of the income distribution. In Appendix Table 9, we report the availability of intensive care unit (ICU) beds and per capita healthcare costs across a limited set of countries. Consistent with the patterns observed from the number of hospital beds, it appears that low-income countries possess significantly fewer ICU beds than high-income countries.



2.5 Differences in Sectoral Composition of Employment

It is widely known that the sectoral composition of employment varies systematically with economic development. These differences are important because commercial disruptions brought on by COVID-19 and the resulting lockdowns differed substantially by occupation. Nonessential jobs that could not be performed remotely or while socially distancing experienced the largest and most sustained drops in employment throughout the recession; in contrast, occupations that were amenable to working from home experienced minimal disruption and some even flourished during the pandemic. In our model, we highlight two systematic differences in the composition of employment between advanced and developing economies which are relevant to the pandemic's macroeconomic outcomes across countries: the share of rural employment and the extent to which the urban workforce can work from home.

It is well known that the share of agricultural employment varies widely with economic development (see Fig. 25). In the poorest countries, over 70 percent of the population is engaged in agricultural work on average, often subsistence farming on family plots; in advanced economies, that share is in the low single digits. The high agricultural share, while often considered a drag on economic modernization, offers a resilient source of income during pandemics. A good deal of agriculture in the developing world takes place on household-run farms, allowing it to continue during “stay-at-home” orders. Even in the absence of lockdowns, farming can often continue while socially distanced or with contact restricted to household members. Agricultural workers therefore do not face the same stark trade-offs in choosing between protecting their health or incomes since farming can often continue without substantially increasing the risk of infection. Consequently, while agricultural workers may be vulnerable because of low wages, their employment is more resilient to large losses from lockdowns or voluntary self-isolation.

Outside of the agriculture sector, labor markets in lower income countries are characterized by widespread informality and employment concentrated in high-contact sectors. Large informal sectors will generally make economies more vulnerable to COVID-19 since, like agriculture, these jobs generally pay low wages while, unlike agriculture, most informal jobs cannot be performed from home or while socially distancing. To summarize these effects at the country level, we follow Kaplan et al. (2020) and aggregate employment into *social* and *nonsocial* sectors. Social sector workers have limited ability to work from home and suffer large income losses during lockdowns, while nonsocial sector workers can substitute more easily to remote work. We calculate the nonsocial sector share to include rural employment and all urban jobs that can be worked from home. For the latter, we use the cross-country estimates of Gottlieb et al. (2021a) which are constructed using worker level data on the task-content of jobs in urban labor markets. Figure 6 displays the resulting estimates of nonsocial employment and illustrates that it varies substantially across countries. Emerging market economies have the lowest ability to work from home, with only 43 percent employed in nonsocial, low-contact jobs. In advanced economies, the nonsocial share is 60 percent, due to the greater number of high skill, professional jobs. However, the nonsocial share is largest in



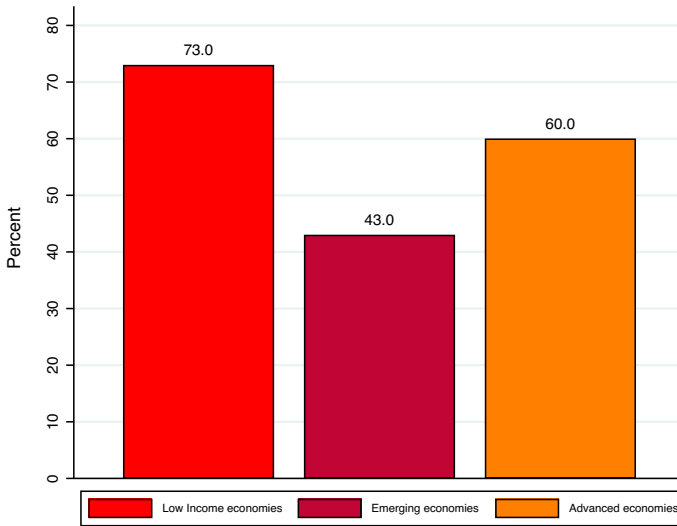


Fig. 6 Nonsocial Sector Employment Share. Note: The nonsocial sector includes rural employment and urban jobs that can be done from home, as estimated by Gottlieb et al. (2020). See text for details. GDP per capita is expressed at PPP and is taken from the Penn World Table 9.1 (Feenstra et al. 2015)

low-income countries, at 73 percent of aggregate employment, driven by the large agricultural labor force.

As a consequence of these differences in the sectoral composition of employment, emerging market economies are more exposed to economic losses during the pandemic. Having less jobs that can be done from home or while socially distanced leads to greater economic losses during lockdowns and workplace closures. Moreover, in the absence of robust transfers, many social sector workers can become desperate and so voluntarily elect to continue working, rather than shelter at home, during times of peak infection. Such decisions will generally provide only marginal income gains, while amplifying the infection risk for the whole population through the public health externality. Large social sector employment can therefore be a liability for emerging market countries fighting COVID-19, as these workers are particularly vulnerable with limited options to avoid increasing their risk of becoming infected, or infecting others.

3 Model

Our analysis draws on a quantitative heterogeneous-agent macroeconomic model, with epidemiology as in the SICR framework, to analyze variation in the macroeconomic consequences of the COVID-19 pandemic across the world income distribution. The model is equipped with several features that vary between advanced and developing economies that are relevant for the pandemic's impact, as motivated by the data presented in the previous section. These include uninsurable idiosyncratic health and income risks, age heterogeneity, government transfers and lockdown



policies, healthcare capacity, and the ability to work from home across sectors. This section now presents these features in detail.

3.1 Households and Preferences

The economy is populated by a unit mass of heterogenous individuals who make consumption and savings decisions subject to idiosyncratic income and health risks. Individuals differ in their age $j \in \{\text{young adult, old adult}\}$ and permanent labor productivity $z \sim G$. Time is discrete and each period represents two weeks. Preferences are given by:

$$U = \mathbb{E} \left[\sum_{t=0}^{\infty} \beta_j^t \left\{ \log(c_t) + \bar{u} \right\} \right], \quad (1)$$

where the discount factors β_j^t capture age heterogeneity in the population, and $\beta_{\text{young}} > \beta_{\text{old}}$. This specification follows the tractable formulation of Glover et al. (2020) that abstracts from explicitly modeling age, appealing to the logic that pandemics are sufficiently short-lived relative to entire lifetimes. It thus suffices to model only the expected number of years left to live, which is captured by the heterogeneity in discount factors. The term \bar{u} represents the flow utility value of being alive, following the specification of Jones and Klenow (2016), and represents the reason that model households try to avoid fatality risk. Once an individual dies, they receive a fixed utility level that potentially depends on their individual characteristics, as we describe below.

There are two sectors, which we denote as social ($s = S$) and nonsocial ($s = N$). Households in sector s supply labor to a representative firm where they can earn wage w_s per effective hour worked. We assume that households are born with the sector they supply labor to and cannot switch. The social sector represents the workers with occupations that provide limited ability to work remotely. Examples of these occupations in the social sector includes waitresses and hair dressers. The non-social sector represents occupations that can be done with low levels of social contact. Examples of such occupations include farmers in the agricultural sector who can work in their fields while distancing from others and college professors who can easily teach remotely.

At the beginning of life, workers draw their permanent productivity, $z \sim G$. Incomes in both sectors are also subject to idiosyncratic productivity shocks as in Bewley (1977), Huggett (1993) and Aiyagari (1994). Specifically, we assume that individual labor productivity in each sector is composed of the sector-specific permanent component z and an idiosyncratic component v following the stochastic process:

$$\log v_{t+1} = \rho_v \log v_t + \epsilon_{t+1}, \quad \epsilon_{t+1} \sim F(0, \sigma_v). \quad (2)$$

We include idiosyncratic income risk because developing countries are far from having full insurance, and so accounting for how people insure themselves in response



to policies which may keep them away from work for prolonged periods of time is a first order consideration.

After observing their income realization, households make consumption and savings decisions given the interest rate, r , and subject to a no-borrowing condition, $a \geq 0$. Formally, the budget constraint of a household in sector s before the pandemic is given by:

$$c + a' \leq (1 - \tau)w_s z v n + (1 + r)a + T \quad (3)$$

where τ is the income tax rate and T is government transfers.

3.2 Aggregate Production Technology

The economy produces a single final good by combining capital with labor services supplied by the three sectors. The aggregate production technology is given by:

$$Y = AL^\alpha K^{1-\alpha},$$

where A is the total factor productivity and $0 < \alpha \leq 1$ is labor's share of value-added. We abstract from the domestic capital market. The aggregate capital stock is composed entirely of foreign sources, $K = K^F$, which can be rented at an exogenously given international rental rate r^F and which depreciates at rate δ . Aggregate labor depends on the total supply of labor services from the social and nonsocial sector,

$$L = L_S + L_N.$$

The assumption that social and nonsocial labor are aggregated to produce a single consumption good is a simplifying one. While some labor may be social due to the production technology requiring social interactions with other workers, certainly a substantial portion of social sector labor requires face-to-face interactions with customers and thus require social interactions to consume. We abstract from these notions for simplicity and, to the extent they operate, we allow them to be absorbed by the exogenous component of the public health externality β_t^H and the pandemic's shock to TFP A (see Sect. 4.1). Furthermore, Appendix Fig. 26 plots the change in consumption-related mobility from the Google Community Mobility Report (Aktay et al. 2020) for advanced, emerging, and low income economies. The change in consumption-related mobility over the course of the pandemic looks very similar across country income groups, and so our assumption of a single consumption good likely does not distort our cross-country analysis.

3.3 Credit and Capital Markets

Credit market incompleteness prevents households from borrowing against future earnings. As a result, individuals must maintain nonnegative assets in formulating their consumption plans subject to (3), giving rise to hand-to-mouth consumers as well as a precautionary savings motive in response to idiosyncratic health and income risks. The precautionary motive is important for getting aggregate welfare



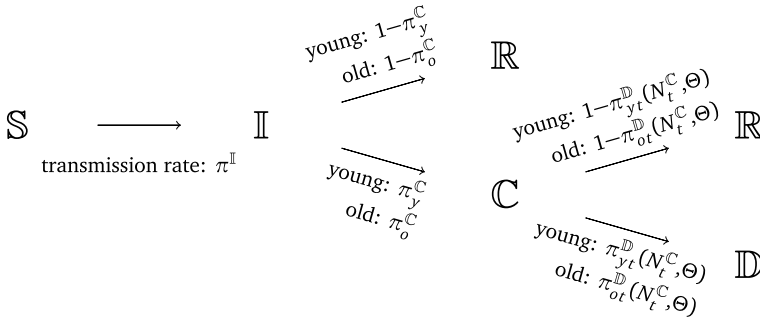


Fig. 7 Dynamics of Health States and Transition Probabilities

measurements correct since it creates another feedback between the epidemiological and economic dynamics, as individuals withhold some consumption to increase precautionary savings in response to the pandemic’s onset.

3.4 Public Health and Hospital Capacity

Households face idiosyncratic health risk which can reduce their labor productivity and increase the probability of dying. Susceptibility to infection is determined in part by economic decisions taken by households. Once infected, progression of the disease depends on an individual’s age and the availability of public health infrastructure offering treatments.

Health risks are modeled using an SICR epidemiological model with five health states: susceptible (S), infected (I), critical (C), recovered (R), and deceased (D). We denote by N_t^x the mass of individuals in each health state $x \in \{S, I, C, R, D\}$ at time t and use $\tilde{N}_t = N_t^S + N_t^I + N_t^C + N_t^R$ to measure the non-deceased population. Figure 7 illustrates how these states evolve:

The probability a susceptible person becomes infected is given by:

$$\pi_t^I = \beta_t^I \times \frac{N_t^I}{N_t}$$

where β_t^I is the time-varying infection rate, reflecting the disease’s natural progression (e.g., new variants), seasonal variations in infection rates, better medical treatments, and other un-modeled factors that change infection rates over time.

Individuals who contract the virus experience a proportional drop in productivity of $1 - \eta$ for one model period (two weeks), at which point they either recover or enter a critical health state. The probability of becoming critically ill depends on an individual’s age and is given by π_j^C . Those in critical health are unable to work and require hospitalization. The likelihood of recovery in the hospital depends again on their age in addition to the availability of public health infrastructure, such as ICU beds and ventilators. In particular, the fatality rate of a critically ill patient of age j is given by:



$$\pi_{jt}^D(N_t^C, \Theta) = \begin{cases} \pi_j^D & \text{if assigned ICU bed} \\ \kappa \times \pi_j^D & \text{if not assigned} \end{cases}$$

where π_j^D is a baseline fatality rate for age j individuals in critical health and κ governs the impact on fatality rates of strained hospital resources. Whether or not a critically ill patient receives an ICU bed depends on overall hospital capacity and the number of other patients. Specifically, letting Θ denote hospital ICU capacity, the probability a new patient receives an ICU bed is given by $\min\{\Theta/N_t^C, 1\}$. In other words, all critically ill patients receive an ICU bed if hospital capacity constraints are not binding, and beds are rationed amongst the critically ill with probability Θ/N_t^C when constraints bind.

3.5 Lockdowns and Voluntary Substitution Away from the Workplace

While the disease’s progression is exogenous, the probability a susceptible person becomes infected depends on endogenous economic decisions and the prevalence of infections in the population. To incorporate the feedback from economic behavior to infections, we allow individuals to lower their degree of exposure to the virus by voluntarily reallocating working time from the market to home. Specifically, in each period we allow workers to choose between going to the workplace or working remotely. Remote work involves less social contacts, providing protection from becoming infected, but leads to a productivity penalty.

In particular, the productivity penalty of working remotely depends on an individual’s sector of employment and is parameterized by ϕ_s , for $s \in \{S, N\}$. An individual who works n hours remotely in sector s provides only $\phi_s n$ units of effective labor, where $0 \leq \phi_s < 1$. We assume that $\phi_S < \phi_N < 1$ to capture the notion that jobs in the nonsocial sector are better suited to be conducted remotely. We parameterize the health benefits of remote work by lowering an individual’s probability of infection by proportion ξ when working from home. Consequently, the probability a susceptible person becomes infected is given by:

$$\pi_t^I = \begin{cases} \beta_t^I \times N_t^I/N_t & \text{if go to workplace} \\ \beta_t^I \times N_t^I/N_t \times \xi & \text{if work remotely} \end{cases}$$

Given the trade-offs between productivity penalties and lower infection risks, individuals optimally choose whether or not to go to their workplace each period according to,

$$V = \max\{V^w + \varepsilon_w, V^r + \varepsilon_r\}$$

where V^w and V^r represent the value functions of being in the workplace and of working remotely, respectively. For each of the two options, we also introduce a taste shocks ε_w and ε_r , which are drawn *i.i.d* from a Gumbel distribution with variance σ_g . The variance σ_g is calibrated to match the fraction of labor working remotely in the pre-pandemic steady state.



Lockdowns Infection rates can be further mitigated by containment policies, such as lockdowns. These policies reduce the virulence of infection by forcing some individuals to switch from market work to working from home, which reduces both their individual infection risk as well as the economy-wide infection risk through the public health externality. As in Kaplan et al. (2020), we model lockdown intensity as a certain fraction of the workforce being forced to work remotely through, for instance, stay-at-home orders. The stringency of lockdowns varies both across time and countries. Following Bick et al. (2020), we assume that 70 percent of the workers are forced to work from home under a full lockdown. We also assume lockdowns are not targeted and so are applied with the same intensity to all household groups.⁴

3.6 Vaccinations

Susceptible individuals can also obtain immunity through vaccination. In each period, every susceptible individual faces a nonnegative probability of receiving a vaccination. Once vaccinated, an individual receives immunity and joins the recovered population. The particular probability of vaccination in any period is taken from the actual time path of vaccinations administered in the USA. Details on the vaccination data series used are provided in the calibration section.

3.7 Government and Taxation

The government has power to tax, transfer, and impose economic lockdowns subject to running a balanced flow budget which satisfies,

$$B_t + \tau \int y(a, x, v) dQ = T$$

where $y(a, x, v)$ is pretax income for individual $(a, x, v) \sim Q$, τ is the prevailing tax rate, and T is aggregate transfers to households. In addition to tax revenue, we allow developing countries access to emergency bonds, B_t , which can be used to finance additional welfare transfers during government imposed lockdowns. The source of these funds is international donors and multinational institutions such as the IMF, World Bank, and World Health Organization. Funds borrowed for emergency transfers accrue interest at rate $1 + r^F$ until the pandemic ends, at which they are repaid through annual annuities. Formally, emergency transfers are given by:

$$B_t = \begin{cases} \bar{B} & \text{during the lockdown} \\ -\frac{r^F}{1+r^F} \times \sum_{t_1=t_s}^{t_1=t_e} (1+r^F)^t \bar{B} & \text{after pandemic ends} \\ 0 & \text{otherwise} \end{cases}$$

⁴ For example, if the lockdown intensity is 70 percent in a given period, then 70 percent of each group (young social, young nonsocial, old social, old nonsocial) are required to work remotely.



Table 2 Calibration of Economic Parameters

Var	Description	Value	Source/target
r^F	Exogenous interest rate	0.0006	Pre-COVID T-Bills rate 1.5%
ρ_v	Persistence of idiosyncratic income shock	0.91	Floden and Lindé (2001)
σ_v	SD of idiosyncratic income shock	0.04	Floden and Lindé (2001)
α	Labor share	0.6	Gollin (2002)
β_y	Discount factor for the young	0.9984	Glover et al. (2020)
β_o	Discount factor for the old	0.9960	Glover et al. (2020))
σ_g	Variance of remote / non-remote work taste shock	0.0101	Pre-COVID Remote Workers 8.2%
ϕ_n	Productivity remote work, nonsocial sector	1	Barrero et al. (2021)
ϕ_s	Productivity remote work, social sector	0.6	US COVID-19 Employment Declines-6.4%
$A(P)$	Pandemic Total Factor Productivity	1.02	COVID-19 Output Declines-4.6%

where \bar{B} is the size of per-period emergency transfers during lockdown, which we take parametrically, and t_s , t_e , and t_l index the lockdown's start, the lockdown's end, and the pandemic's end, respectively.

4 Quantitative Analysis

In this section, we discuss the calibration strategy, validate the model's fit, and present our counter-factual results. To evaluate the quantitative importance of each channel in explaining the cross-country variation in outcomes, we calibrate the model to match the US economy and then vary key economic and demographic characteristics of the USA to match those of low-income and emerging economies. For each variation, we display the dynamic path of output and fatalities predicted by the model. To identify the most salient channels, we report the cumulative effects of each counterfactual on the US economy compared to the calibrated benchmark.

4.1 Data Sources and Calibration

For expositional clarity, we divide the calibrated targets into three broad categories corresponding to those governing economic mechanisms, those controlling epidemiological dynamics, and those delineating differences between the advanced, emerging, and low-income countries.

Table 2 reports the parameters that govern the core economic dynamics of the model. Population demographics are modeled using age dependent discount factors accounting for differences in the remaining years of life for young and old workers. The age specific discount factors are taken from Glover et al. (2020), and the stochastic income processes are taken from Floden and Lindé (2001), who estimate similar income processes in the USA and Sweden. The taste shock for remote work σ_g is chosen so that 8.2 percent of the pre-pandemic labor force works remotely,



consistent with the estimates in Bick et al. (2020). Labor's share of income comes from Gollin (2002), and the rental rate of capital is set to the two-week return on pre-COVID Treasury Bills. We set the productivity penalty for remote work in the nonsocial sector, ϕ_n , to unity, consistent with evidence of small productivity losses for these workers in most cases, and potentially even productivity gains in some cases (Barrero et al. 2021). The penalty for remote work in the social sector, ϕ_s , is chosen to match the employment decline in the US. Ideally, this parameter would be chosen to match the observed average employment decline among all advanced economies of 2.4 percent; however, this decline is less than the average advanced economy output decline of 4.6 percent. Due to the assumption that production technology is Cobb–Douglas, the model is unable to generate a decline in output greater than the decline in employment. Hence, we opt instead to use the US number, which is consistent with the production technology.⁵ Finally, The TFP shock accompanying the pandemic $A(P)$ is chosen to match the aggregate 2019–2020 year-on-year output decline in advanced economies.⁶

Table 3 reports parameters controlling the epidemiological transmission of disease and their interactions with public health infrastructure and lockdown policies. We take parameters governing the fatality infection rates from Glynn (2020) and the rates of infected cases becoming critical from Ferguson et al. (2020). The reduction in infection probability is set to 0.6 to match evidence from Mossong et al. (2008) that about 40 percent of person-person contacts happen at the workplace. The effect of hospital congestion on disease fatality rates, κ , is taken from Glover et al. (2020). The productivity penalty of becoming infected, η , is set to match a 30 percent share of asymptomatic infection cases, as estimate in the meta-analysis of Alene et al. (2021). Such a choice is motivated by the observation that those known to be infected cannot work, and so have productivity of zero, while those who are infected but asymptomatic may continue to work unhindered. Finally, we choose the time-varying behavioral-adjusted infection probability, β_t^i , so that the model's endogenous path of fatalities precisely matches the experience of the USA. The simulated endogenous path of the virus also account the time path of vaccinations and lockdowns in the USA. Vaccination data is taken from the COVID-19 Data Repository by CSSE at John Hopkins University, and we assume vaccination rates continue to grow at 1% per period after the last available data point, until period 60. The time path of lockdown policies comes from the Oxford Coronavirus Government Response Tracker (see Appendix Figure 19). We assume lockdown policies are gradually lifted starting in the last period of available data until they are completely discontinued by period 60. Figure 8 plots the fitted results and validates the model's ability to replicate these dynamics exactly.

⁵ The larger decline in advanced economy output than employment may be reflective of the fact that many advanced economies implemented policies that explicitly rewarded employers that did not furlough workers, leading to many workers who were technically employed but idle. Notably, the USA did not implement many policies of this nature.

⁶ Appendix Table 10 summarizes the internally calibrated parameters and the model's fit to the data. Note that TFP in normal times, $A(N)$ is set to one, so that $A(P)$ should be interpreted as a relative TFP shock in effect during the Pandemic.



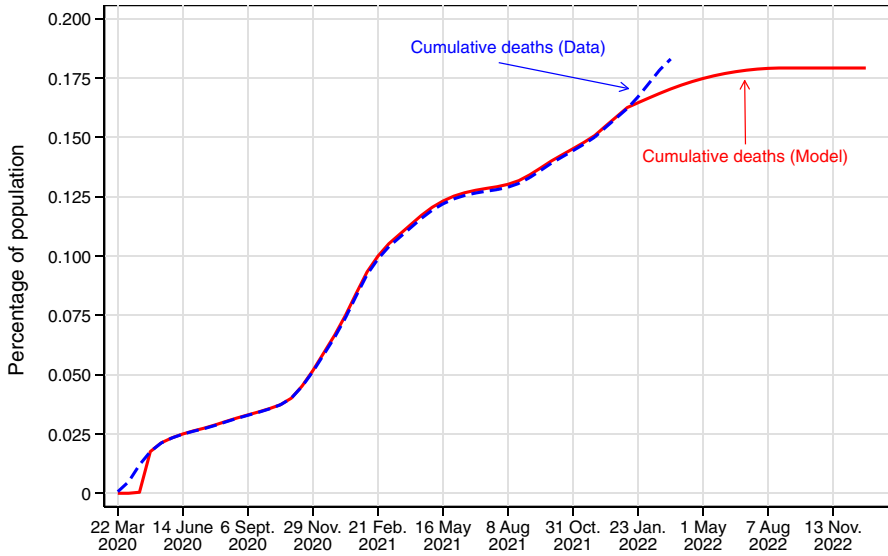


Fig. 8 Predicted and Actual COVID-19 Mortality in the Advanced Economies. Note: Time path of US COVID-19 mortality taken from the COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at John Hopkins University

Table 3 Calibration of Epidemiological Parameters

Var	Description	Value	Source or target
η	Effect of infection on productivity	0.3	Alene et al. (2021)
ξ	Reduction of infection probability by working from home	0.6	Mossong et al. (2008)
κ	Impact of hospital overuse on fatality	2	Glover et al. (2020)
π_y^C	Rate of young entering C from I	6.7%	Ferguson et al. (2020)
π_o^C	Rate of old entering C from I	38.0%	Ferguson et al. (2020)
π_y^D	Rate of young entering D from C	2.7%	Glynn (2020)
π_o^D	Rate of old entering D from C	9.0%	Glynn (2020)

The mortality dynamics (and output losses) are shaped by both government lockdown policies and voluntary household substitution away from market work and consumption. Figure 9 illustrates that both margins play an important role in the calibrated model by plotting the equilibrium population share under lockdowns or voluntarily sheltering from home. The dashed purple line represents the strictness of prevailing lockdowns, reporting the share of the susceptible population forced to stay home. Any mass above this “Lockdown” curve represents voluntary substitution to working from home. The figure shows that there is a considerable amount of voluntary sheltering at home, above and beyond what is required by lockdowns, especially during times of peak infection (such as in Winter of 2020-2021).



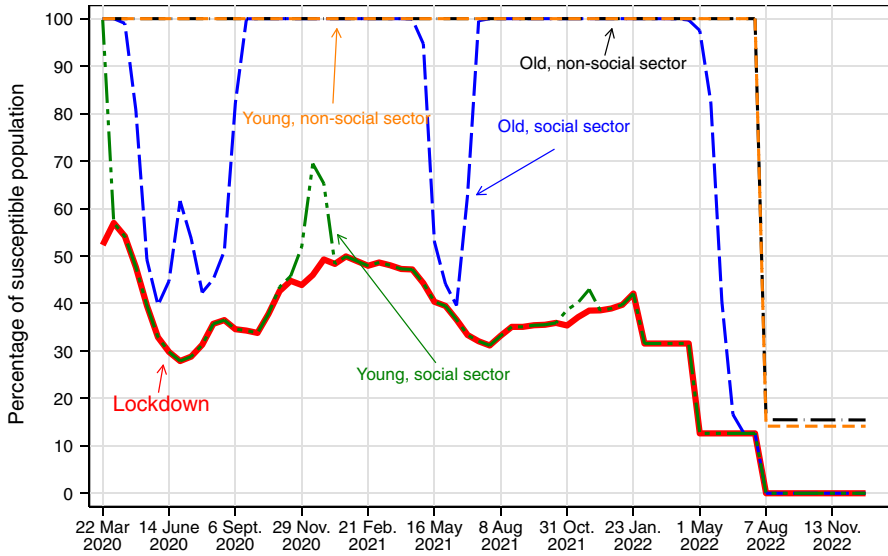


Fig. 9 Lockdowns and Voluntary Working from Home

Table 4 Calibration of Parameters Varying Across Advanced and Developing Economies

Var	Description	Advanced economies	Emerging economies	Low-income economies	Source or target
\bar{u}	Flow value of being alive	$11.4\bar{c}^{US}$	$11.4\bar{c}^{MID}$	$11.4\bar{c}^{DEV}$	Glover et al. (2020)
τ	Marginal tax rate	0.25	0.20	0.15	Besley and Persson (2013)
ω_y	Share of young in population	73%	84%	92%	UN Population Division
ω_s	Share of social sector workforce	40%	57%	27%	Gottlieb et al. (yyy)/IPUMS
Θ	Hospital capacity per capita	0.00042	0.00025	0.00011	Glover et al. (2020)/WHO

Voluntary substitution to working from home also varies substantially across age and sector of employment. Consistent with differences in health risks and economic costs, we see more voluntary working from home among the older population and in the social sector, where the health risks of the pandemic are most acute. The result also highlights the importance of accounting for heterogeneity in age and the sectoral composition of work alongside government policies in evaluating output and mortality dynamics throughout the pandemic.

As a simple sanity check of the model’s infection and mortality dynamics, we can compare the model-predicted proportion of COVID deaths occurring among those older than 65 to un-targeted data from the real world. According to the CDC,



this proportion is 74 percent.⁷ In the quantitative model, it is fairly close at 82 percent, providing confidence that the model's predictions for the distribution of deaths across age groups are closely aligned with reality.

Table 4 summarizes parameters which vary across advanced and developing countries. Although this is a parsimonious set of parameters, we argue that it captures the key fundamental differences relevant for COVID-19 that vary across countries. In Appendix 1, we explore the robustness of our quantitative results to variation in other parameters that one might intuitively expect to vary between countries of different income levels.

The tax rates for the advanced and developing countries are taken from Besley and Persson (2013). Age demographics ω_y come from the World Bank and measure the share of the population under 65. The youth share in advanced economies corresponds to the US economy, as it is our benchmark calibration, and we set the shares for emerging and low-income countries to their group averages. The share of workers in the social sector, ω_s , is constructed using estimates from Gottlieb et al. (2020) on the share of urban labor that can work from home and adjusting the ratio to account for the rural population. Specifically, using data on urban and rural labor supply from the UN Population Division, we include all rural jobs in nonsocial employment and then assign urban workers to the nonsocial sector based on the proportion who can work from home. From this we calculate ω_s . For example, Gottlieb et al. (2020) estimates that 7.4 percent of urban workers in Kenya can work from home, and 25.7 percent of the Kenyan population resides in urban areas, resulting in a social sector share of $0.257 \times (1 - 0.074)$ or 23.8 percent. For advanced economies (which are absent from the dataset of Gottlieb et al. 2020), we use the work-from-home estimates reported by Barrero et al. (2021).

The flow value of life, \bar{u} , is calibrated using the value of statistical life (VSL) approach. Following Glover et al. (2020), we set the per-period statistical value of life to \$515,000 for advanced economies, equal to 11.4 times average US consumption. The value for \bar{u} is then computed so that the behavioral response to a marginal increase in the risk of death is consistent with the VSL. Specifically, we get \bar{u} by solving,

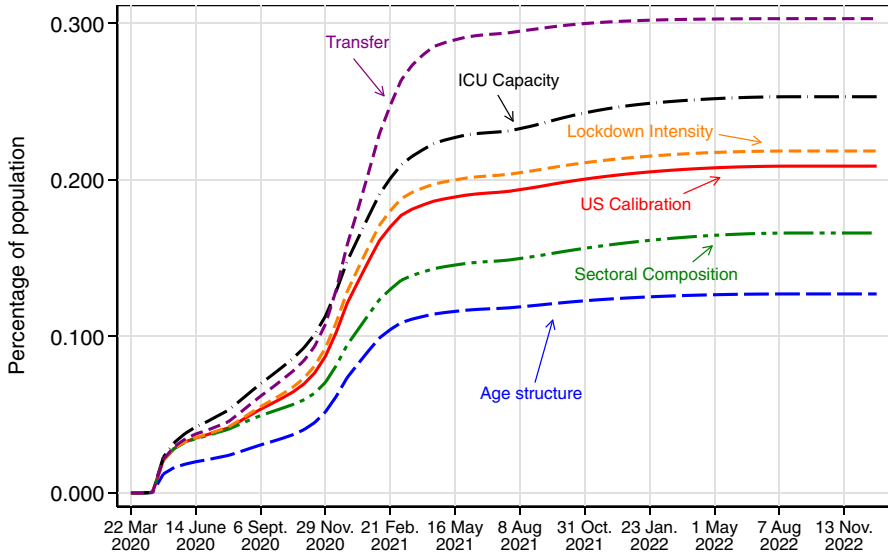
$$\text{VSL} = \frac{dc}{d\rho} \Big|_{E(u)=k, \rho=0} = \ln(\bar{c}) - \bar{u}$$

where ρ is the risk of death and \bar{c} is average consumption. Absent better evidence, we assume the VSL has unitary income elasticity and adjust \bar{u} for developing countries accordingly.

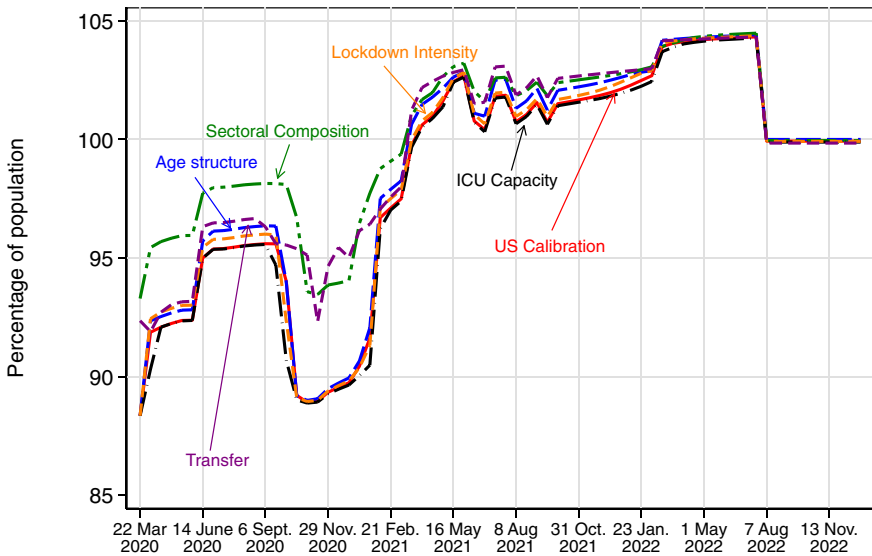
The final cross-country parameter to be set govern the ICU hospital capacity in developing and developed countries. One challenge is that while many countries report hospital bed capacity, few developing countries distinguish explicitly between general hospital capacity and ICU capacity in the data. To address this, we assume the ratio of hospital beds to ICU beds is constant across countries, and

⁷ Taken from <https://data.cdc.gov/d/vsak-wrfu/visualization>. Accessed May 26th, 2022.





(a) Cumulative Death, US with Low Income Economies' Features

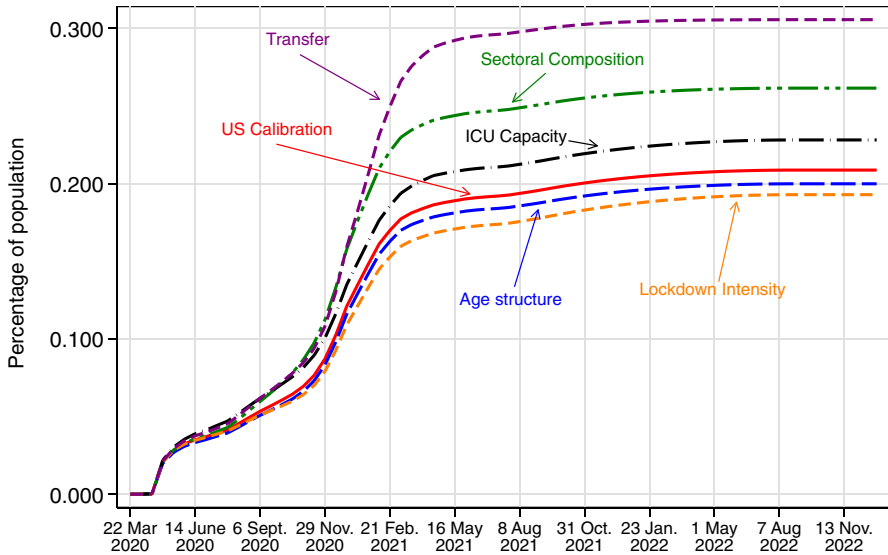


(b) GDP per capita, US with Low Income Economies' Features

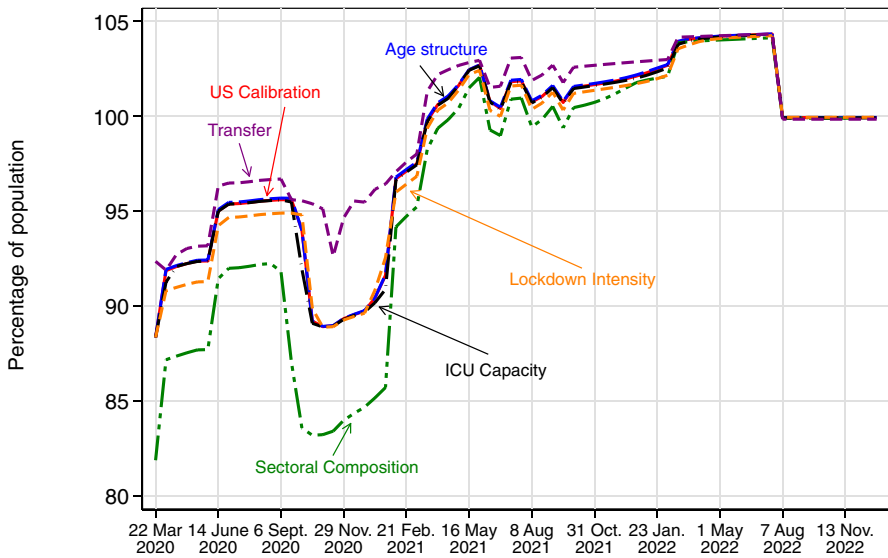
Fig. 10 Time Path of Cumulative Deaths and GDP: Low-Income Economies

calibrate Θ by adjusting WHO data on the availability of hospital beds in the top and bottom quartiles of country income levels (as in Fig. 24) by the ratio of hospital beds to ICU beds taken from Glover et al. (2020).





(a) Cumulative Death, US with Emerging Economies' Features



(b) GDP per capita, US with Emerging Economies' Features

Fig. 11 Time Path of Cumulative Deaths and GDP: Emerging Economies

4.2 Economic and Demographic Sources of Cross-Country Differences

Figures 10 and 11 plot the dynamic path of GDP per capita and fatalities as a percentage of the population during the COVID-19 pandemic in the USA in each of our



counterfactual simulations. The panels on top display cumulative fatalities and those on the bottom plot GDP. Each figure provides six simulated paths: the benchmark US calibration and the five counterfactual exercises which vary demographics, the sectoral composition of employment, public healthcare capacity, government transfer programs, and the stringency of lockdowns. Figure 10 reports counterfactuals that endow the US economy with the characteristics of

low-income countries; Figure 11 reports the results of endowing the USA with emerging market economy characteristics.

Looking across the panels, one can see that all five mechanisms play an important role to some degree, but differences in age demographics, the sectoral composition of employment, and the size of public transfer programs are the most quantitatively prominent. In both low-income and emerging market economies, low levels of public financial assistance during the pandemic lead to much higher levels of fatalities. Without transfers to support or replace income lost in the pandemic, many households are not able to shelter at home during times of peak infection and instead must work outside the home, further propagating the spread of disease which increases fatalities. Quantitatively, low levels of public transfers are the largest factor pushing fatalities higher outside advanced economies. The simulations show that if the USA scaled back its public transfer programs to the levels of low-income and emerging market economies, that alone would lead to cumulative fatalities from the pandemic to grow by 50 percent. Despite the effect of low transfers, fatalities in low-income countries remained modest because of the offsetting effect of its substantially younger population. The high agricultural employment share in low-income countries also substantially reduces fatalities. In contrast, emerging markets experienced far higher mortality rates because they do not benefit from the favorable demographics of low-income countries and have a high social sector employment share, making it difficult to control the spread of disease while working. ICU constraints exacerbated fatalities in both low and emerging economies, though played a secondary role overall. Differences in lockdown intensity play the smallest role, suggesting the more important cross-country policy difference during the pandemic was in the size of public insurance programs.

The output counterfactuals exhibit less variation than what we see in fatalities, suggesting that the mechanisms we study contribute more equally to observed economic declines. Among the channels, only the sectoral composition of employment and public transfers stand out as having an especially important quantitative role. In low-income countries, economic losses were moderated by a large agricultural sector that was minimally disrupted by lockdowns and social distancing requirements. In emerging markets, high levels of urban employment in jobs that cannot be done from home explains a substantial part of their larger economic losses. Somewhat perversely, the low levels of public transfers which amplify fatalities in low-income and emerging market economies also serve to *reduce* output losses by causing financially vulnerable households to continue working outside the home. The impact is most pronounced at times of peak infection, as is visible in the transition paths during the winter months of 2020.

To assess what may be driving the especially bad outcomes observed in emerging markets, Table 5 reports the cumulative effect of our counterfactuals on 2019–2020



Table 5 Cumulative Effect of the COVID-19 Pandemic in Emerging Markets (NEW)

	Data	Model	
		All features	Age/sector/ICU
Panel (a): GDP Changes from 2019 to 2020			
Advanced economies	- 4.6	- 4.7	- 4.7
Emerging economies	- 6.7	- 6.3	- 8.3
Ratio	1.47	1.34	1.77
Panel (b): excess mortality			
Advanced economies	100	105	105
Emerging economies	165	159	95
Ratio	1.65	1.51	0.90

year-on-year changes in GDP and fatalities. For comparison, the first data column displays the data for advanced and emerging economies discussed in the introductory sections (see Appendix Figs. 1 and 2). The second data column reports the model-predicted simulated outcomes for both the advanced and emerging market economies. The third column reports outcomes when we endow the advanced economy with only the age demographics, sectoral employment, and ICU capacity of emerging economies. We distinguish these features since we view them as largely immutable throughout the pandemic's duration. To facilitate comparisons, the final row of each column reports the ratio of outcomes in emerging markets relative to advanced economies.

In panel (a), we see that the model does relatively well at replicating variation in GDP. In the data, GDP in advanced economies contracted by -4.6 percent while emerging economies shrank by -6.7 percent. The benchmark model nearly replicates these data, predicting GDP declines of -4.6 percent and -6.3 percent in advanced and emerging economies, respectively. While the model predicts contractions in GDP that are slightly smaller than in the data, it accurately replicates the relative severity of the pandemic across countries. In the model, emerging markets experience contractions in GDP that are 34 percent larger, in line with the data, at 47 percent larger.

Panel (b) reports excess mortality per hundred thousand people in advanced economies and emerging markets, both in the data and full counterfactual. As with GDP, the model accurately reproduces total mortality in both advanced and emerging economies. The model also does a good job at replicating the relative severity of the pandemic in emerging markets. Endowing the advanced economy with all the features of an emerging market economy leads to a 51 percent rise in excess mortality. In the data, emerging market economies registered excess mortality that was on average 65 percent greater than advanced economies. The model can therefore almost completely account for the relatively higher number of fatalities in emerging markets during the pandemic.

Finally, in light of the particularly severe outcomes in emerging economies, it is natural to ask if there is anything governments in emerging markets could have done differently to improve their outcomes. While we do not model the optimality of



Table 6 Cumulative Effect of the COVID-19 Pandemic in Low-Income Economies (NEW)

	Data	Model	
		All features	Age/Sector/ICU
Panel (a): GDP Changes from 2019 to 2020			
Advanced Economies	- 4.6	- 4.7	- 4.7
Low-Income Economies	- 3.6	- 2.3	- 2.8
Ratio	0.78	0.48	0.60
Panel (b): Excess Mortality			
Advanced Economies	100	105	105
Low-Income Economies	-	43	38
Ratio	-	0.41	0.36

different policies, our framework allows us to study the extent to which differences in outcomes depend on features that are outside the control of policymakers. In particular, we view a country's age demographics, sectoral composition of employment, and healthcare capacity to be largely fixed over the duration of the pandemic. That governments cannot choose the age of their population is obvious. Similarly, it's generally widely held that the industrial composition of the economy is rigid in the short run. While public healthcare capacity can in principle be expanded (and was, rather rapidly in a few places like China), we believe that emerging market economies by and large only had limited ability to do so during the pandemic, especially given the concurrent global competition for medical equipment, oxygen, and protective gear.

The final column of Table 5 reports the cumulative counterfactual impact on output and fatalities if only these immutable characteristics varied between emerging markets and advanced economies while differences which depend on policy choices, namely transfers and lockdowns, remain fixed at advanced economy levels.

For output, the immutable characteristics alone predict a -8.3 percent decline in GDP for emerging markets, over-accounting for the -6.7 percent decline observed in the data. This simulation suggests that the especially large GDP declines in emerging markets may have been largely outside the control of policymakers, depending instead on prevailing demographic and structural conditions that cannot be easily changed. The larger GDP losses in emerging economies under advanced economy transfer and lockdown policies signifies that the number of workers induced to voluntarily stay home through more generous transfer programs in advanced economies more than outweighed the countervailing effect of their less stringent lockdowns.

For mortality, these fixed features lead to a 10 percent decline in mortality, a modest share of the 65 percent increase in mortality observed in the data. In the model, much of the mortality gap between advanced and emerging economies is accounted for by the smaller transfers implemented by emerging market economies (we discuss this in more detail in Sect. 4.3). Limited public financial assistance results in many lower-income households continuing to work outside the home



during the pandemic, propagating infections that lead to higher mortality. The result suggests that constraints on the ability of emerging markets to support large scale public transfer programs, such as limited fiscal capacity and borrowing costs, were an important determinant of the greater excess mortality they experienced during the pandemic.

Table 6 reports the cumulative counterfactual effects of the COVID-19 pandemic in low-income countries. The model correctly predicts the more modest GDP declines and mortality rates in low-income economies relative to advanced ones, as in the data, albeit with larger differences. In the counterfactual, low-income countries experience GDP declines that are 48 percent the size of contractions in advanced economies, while the data show declines that were 78 percent the size of advanced economy losses. The result suggests that there may be other important factors driving GDP declines in low-income countries that are not present in our current model, such as foreign demand shocks, supply chain disruptions, constraints on sovereign debt, and limited fiscal capacity. The model also predicts mortality rates in low income countries that are 41 percent the size of mortality rates in advanced economies, primarily due to their younger age demographic and higher agriculture employment share. While systematic data on COVID-19 fatalities in low-income countries is not yet available, the result is consistent with the limited evidence on excess deaths available for some countries in Africa (see Appendix Figures 15 and 16).

As with emerging markets, we can assess the extent to which outcomes were driven by policy choices or fixed short-run characteristics of low-income countries by comparing the cumulative counterfactuals in the last two columns of Table 6. Endowing advanced economies with only the immutable characteristics of low income countries generates a GDP declines of -2.8 percent compared to a decline of -2.3 percent in the full low-income economy. For mortality, these fixed factors alone lead fatalities to fall by 64 percent, accounting for slightly more than the entire model-predicted decline in mortality between advanced and low-income economies of 59 percent. Taken together, the results suggest that younger populations and high agricultural employment shares predisposed low-income countries to have fewer fatalities from COVID-19, but public lockdowns and transfer policies played an important role in moderating the economic fallout accompanying the pandemic.

4.3 Key Takeaways

Despite its simplicity, the model is able to accurately replicate the observed differences in macroeconomic outcomes following COVID-19 across the world income distribution. In this subsection, we summarize the key takeaways from the various outcomes and counterfactuals produced by the model.

The first takeaway is that the large output declines in emerging market economies were largely a function of pre-existing characteristics rather than cross-country differences in policy. The second column of Panel A in Table 5 reports a model-predicted GDP decline of 6.9 percent for the typical emerging market economy following typical lockdown and transfer policies. For comparison, the third column



Table 7 Cumulative Effect of the COVID-19 Pandemic: Counterfactual Scenarios

	GDP Changes	Excess Mortality
Panel (a): Emerging Economies		
Emerging Economies	- 6.3	159
With Advanced Economies Transfer	- 8.5	88
With Advanced Economies Lockdown	- 5.6	186
Panel (b): Low-Income Economies		
Low-Income Economies	- 2.3	43
With Advanced Economies Transfer	- 2.7	39
With Advanced Economies Lockdown	- 2.5	41

displays the decline in GDP for a typical emerging market economy (i.e., an economy with typical demographics, sectoral composition, and healthcare capacity) implementing the lockdown and transfer policies of the advanced economies. Mimicking the lockdown and transfer policies of the advanced economy leads the emerging market economy to experience a 1.4 percentage point higher decline in GDP, suggesting that little emerging market policymakers could have done differently to avoid high output losses.

Table 7 further investigates the extent to which policy could have mitigated outcomes in emerging market economies by displaying the model-predicted GDP losses and mortality for the emerging market and low-income economies if they implemented the transfer or lockdown policies of advanced economies. Looking at Panel (a), it is clear that large GDP losses in emerging markets were unavoidable. Implementing the advanced economy's less restrictive lockdown policies reduces GDP losses by only 0.7 percent and implementing larger transfers actually increases GDP losses by encouraging more workers to stay home.

In contrast to GDP losses, the model predicts that mortality in emerging market economies could have been substantially reduced through policy. While less stringent lockdowns, unsurprisingly, result in a slight increase in mortality, increasing the size of transfers to the level seen in the advanced economy substantially reduces mortality from 159 people per 100,000 to 88. This substantial reduction results from the fact that larger transfers make up for lost incomes and allow the most vulnerable social sector workers, who make up a substantial share of the population in emerging market economies, to avoid going to the workplace.

While the impact of policy differences in low-income countries move outcomes in similar directions, the overall quantitative contribution of these changes is small. The stringency of lockdowns in low-income and advanced economies were relatively similar, and so account for only a small part of the cross-country variation. Differences in transfer programs were much more substantial, but still only have modest effects on output losses and mortality. These outcomes are consistent with the notion that the relatively better macroeconomic outcomes experienced by low-income countries during the pandemic were largely the result of pre-existing



favorable demographics and high shares of nonsocial sector employment, rather than particular policy choices.

Finally, while we do not model optimal policy decisions, it seems reasonable to suggest that the lower transfers in emerging market economies were not an intentional choice by local policymakers but rather were an outcome of the limited fiscal capacity and high borrowing costs faced by many governments. Interpreted through this lens, the model's policy counterfactuals suggest that the ability of governments in emerging markets to borrow and fund emergency transfers was an important determinant of their overall mortality outcomes. Likewise, this result suggests that expansions in international emergency financial assistance during the pandemic, including debt relief and lending programs such as the IMF's Rapid Credit Facility (RCF) and Rapid Financing Instrument (RFI), contributed meaningfully to reducing mortality globally and particularly so in emerging market and lower income countries.

5 Empirical Correlates of GDP Declines During the Pandemic

In this section, we explore the empirical correlates of changes in GDP per capita from 2019 to 2020, focusing on the same variables emphasized in the model. We make no claim at uncovering causal patterns in this section. Instead, we assess the extent to which correlations between aggregate income changes during the pandemic and a country's demographic, economic, and policy characteristics are consistent with the model's predictions and quantitative exercises.

We begin with the basic relationship between declines in GDP per capita and pre-pandemic level of GDP per capita. The first column of Table 8 shows that this relationship is U-shaped, as we argued earlier. Both the level and quadratic coefficients on GDP per capita in 2019 are statistically significant at the five-percent level, with the former negative and latter positive. The second column includes controls for the agricultural employment share. The variable exhibits a significant positive correlation with changes in GDP, holding constant differences in national income, means that countries with larger percentages of their workforce in agriculture also experienced smaller declines in national income, all else equal. Interesting, the coefficients on GDP per capita and its square are now statistically indistinguishable from zero, with the former switching signs. The third column includes median age as a control which exhibits no significant correlation, somewhat puzzlingly. The fourth column controls for the stringency of lockdowns, which is positive and statistically significant. The fifth column adds controls for the generosity of economic support programs during the pandemic, which turns out to be statistically insignificant.

Column six of Table 8 adds all the covariates at once. This specification shows that agriculture's employment share remains a strong positive correlate of GDP changes, while lockdown stringency remains a strong negative correlate. Median age and the economic support index continue to be insignificant. Collectively, the inclusion of these controls eliminates the statistical significance of the original U-shape pattern in GDP per capita, and substantially reduce the magnitude of the original correlations. We take this as suggestive evidence that these variables are important



Table 8 Correlates of GDP per Capita Change from 2019 to 2020

Independent variables	Dependent variable: GDP per capita change from 2019 to 2020					
	(1)	(2)	(3)	(4)	(5)	(6)
GDP per capita in 2019	- 0.10** (0.046)	0.037 (0.068)	- 0.17* (0.094)	- 0.076* (0.044)	- 0.11 (0.068)	- 0.052 (0.11)
GDP per capita in 2019 ²	0.0014** (0.00066)	0.00021 (0.00071)	0.0020* (0.0010)	0.0011* (0.00063)	0.0014* (0.00080)	0.00084 (0.0011)
Agriculture emp. share		0.076*** (0.027)				0.062**
Median age			0.083 (0.079)			0.074
Lockdown stringency				- 0.13*** (0.043)		- 0.13** (0.053)
Economic support					0.0042 (0.036)	0.024 (0.038)
Constant	- 4.21 *** (0.60)	- 8.03*** (1.66)	- 5.67*** (1.48)	2.38 (2.07)	- 4.29*** (1.09)	- 2.97 (3.34)
Observations	144	144	144	140	140	140
R ²	0.031	0.071	0.037	0.129	0.030	0.163

Robust standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$ 

empirical determinants of macroeconomic performance across the world income distribution, at least thus far, during the pandemic.

6 Conclusion

The macroeconomic impact of the COVID-19 pandemic was most severe in emerging market economies, which represent the middle of the world income distribution. This paper provides a quantitative economic theory to explain why these economies fared so poorly compared to both poorer and wealthier nations. Our model is motivated by key economic and demographic differences across the world income distribution, including variation in lockdown policies, public insurance, demographics, healthcare capacity, and the sectoral composition of employment.

Our quantitative model does well in predicting the greater output declines and higher mortality rates in emerging market economies, as in the data. The model also quantitatively predicts the more modest output losses and fatalities in low-income countries, albeit to a greater extent than what is observed in the data. Among the factors we consider, the size of public transfer programs, age demographics, and the sectoral composition of employment are the most quantitatively important. Low levels of public financial assistance and a high share of jobs which require social interaction explains most of the greater GDP losses and higher fatalities in emerging markets. Low-income countries also suffered from low levels of public transfers, but the negative consequences were largely blunted by their substantially younger populations, whom are naturally more resistant to illness, and large agricultural employment share, which provide a resilient source of income during lockdowns and while socially distancing. Quantitatively, the results suggest that cross-country differences are mostly driven by variation in public transfer programs and factors outside the short-term control of government officials. The outsized role of public transfer programs in explaining cross-country differences highlights the importance of constraints which may limit the ability of governments to enact and sustain large scale social insurance programs during emergencies. A valuable avenue for future research is to better identify the sources of these policy differences and what impact they had on macroeconomic outcomes throughout the pandemic.

Overall, our findings suggest that much of the variation in aggregate outcomes across country income groups during the pandemic can be attributed to a small set of economic characteristics and broad policy choices. However, the model is stylized in many ways and does not attempt to analyze the many more granular policy choices that surely mattered for the first year of the pandemic. Absent from this study are policy decisions regarding school closings (e.g., Fuchs-Schündeln et al. 2020), mask use (e.g., Abaluck et al. 2021; Karaivanov et al. 2021), testing and tracing policies (e.g., Berger et al. 2020), and vaccine provision (e.g., Arellano et al. 2021). Future research could also fruitfully assess the quantitative importance of other policy choices for cross-country macroeconomic performance during the pandemic.

One salient cross-country feature missing from our analysis is informality; low-income and emerging market economies have much higher fractions of the population engaged in informal work than advanced economies do. Informality may be



important for two reasons. First, informal workers in the social sector may be able to avoid lockdown policies due to being outside of the reach of government enforcement, reducing the effectiveness of lockdowns. Second, informal workers may be more difficult to reach with government transfer programs due to not being registered with social security. However, data from Latin American suggest that these concerns may be quantitatively small. Acevedo et al. (2021) document that both the formal and informal sector experience similar losses in jobs, suggesting that informal work did not serve as a means through which workers shirked lockdowns, and Busso et al. (2021) find that governments created many new transfer programs that increased the coverage of social insurance, particularly for those in the lowest income quintile, and helped cover informal workers.

To the extent that informal workers are less likely or unable to receive government transfers, our model will underpredict fatalities in emerging market economies relative to low-income and advanced economies. While low-income countries have the highest proportion of informal workers, the vast majority of these workers are engaged in nonsocial work due to living in rural agricultural areas and thus do not need transfers as they are able to maintain their income. Emerging market economies possess a much higher fraction of informal workers employed in the social sector. The inability to receive transfers means that these workers will be much less likely to choose to reduce their income and protect themselves from the virus, leading to higher contagion and higher spread. Alon et al. (2020) perform a thorough analysis of the effect of informality on COVID-19 outcomes for countries of varying income levels.

Another key limitation of our analysis is that it relies on a large exogenous time-varying component of the infection rate in order to match the observed path of excess deaths in the USA. In reality, however, much of the time variation in infection probabilities is likely due public policy choices that are not modeled here. These include policies that increase the prevalence of mask wearing, the development of better treatments for the infected, the rate of vaccination, or general knowledge about how COVID-19 can and cannot be transmitted. Future research should more explicitly consider the role these factors play in determining cross-country differences in the pandemic's consequences.

Appendix

Appendix A: Figures

See Figs. 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27.



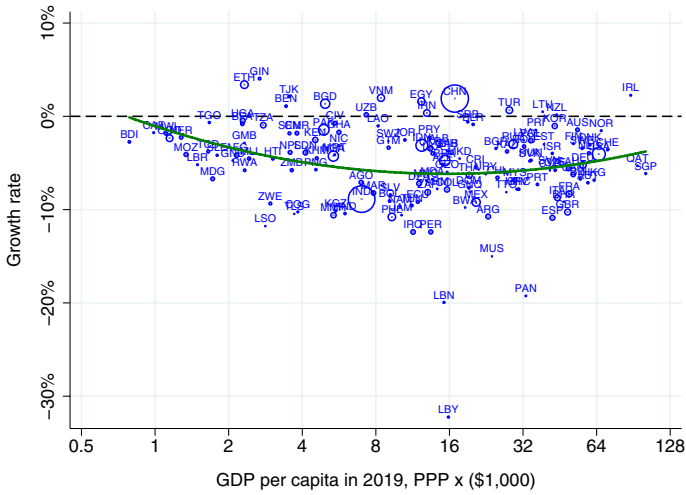


Fig. 12 GDP per capita Growth from 2019 to 2020. Notes: GDP per capita data come from the World Bank World Development Indicators. GDP per capita is expressed at PPP and is taken from the Penn World Table 9.1 (Feenstra et al. 2015)

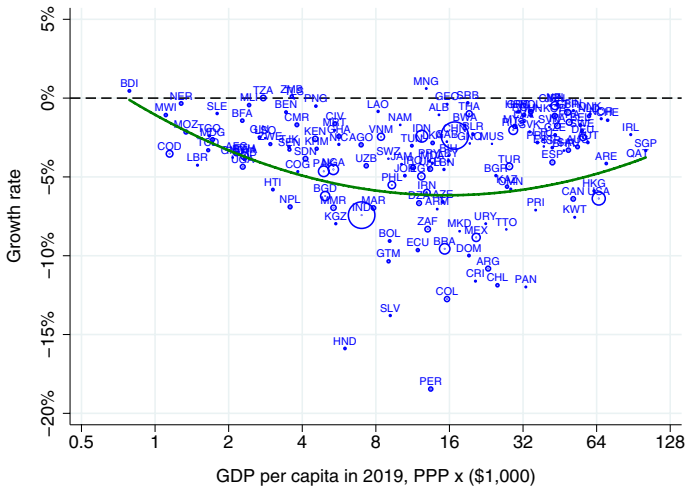


Fig. 13 Employment Growth from 2019 to 2020. Notes: Employment data come from the ILO Statistical Database. GDP per capita is expressed at PPP and is taken from the Penn World Table 9.1 (Feenstra et al. 2015)



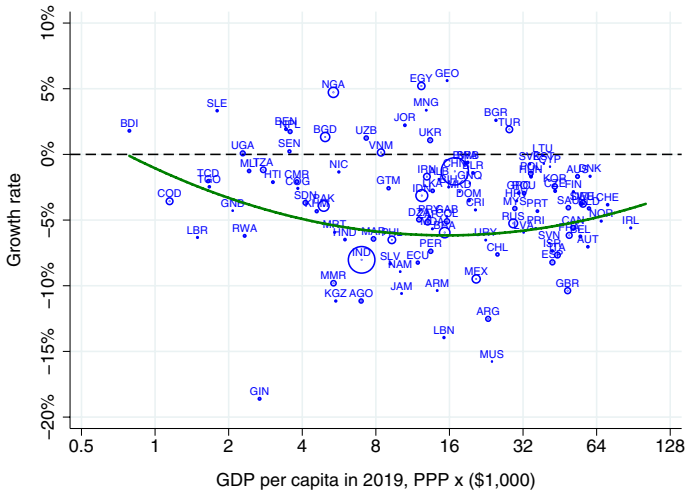


Fig. 14 Consumption-per capita Growth from 2019 to 2020. Notes: Consumption data come from the World Bank World Development Indicators. GDP per capita is expressed at PPP and is taken from the Penn World Table 9.1 (Feenstra et al. 2015)

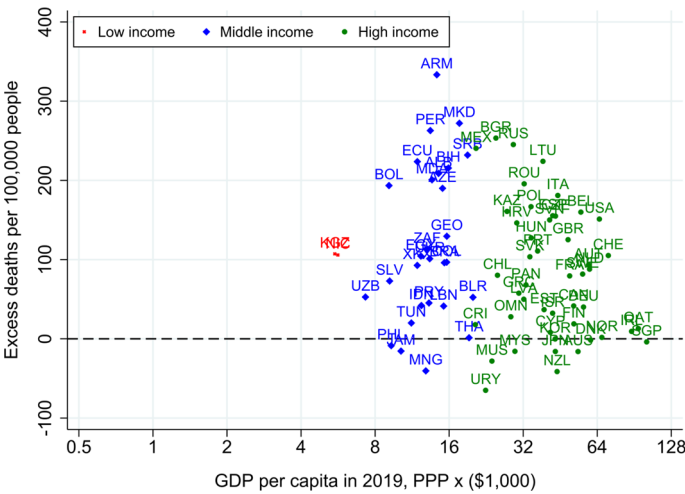


Fig. 15 Excess Deaths Estimated by *The Economist*. Note: Data sourced from *The Economist* excess mortality tracker



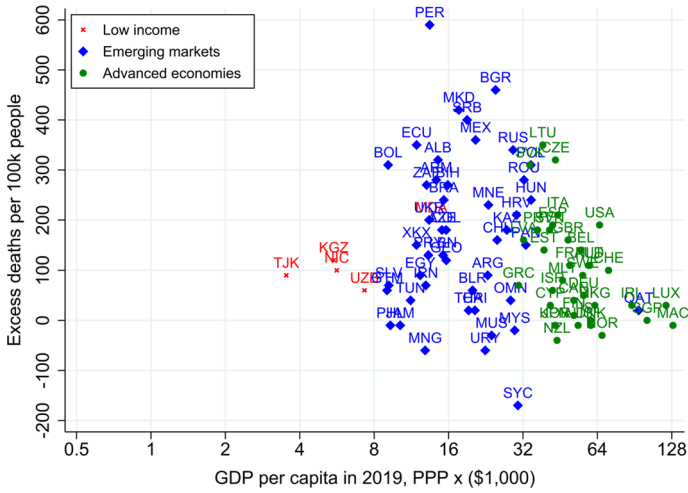


Fig. 16 Excess Deaths Estimated by Karlinsky & Kobak (2021). Note: Data sourced from Karlinsky & Kobak (2021)'s World Mortality Database

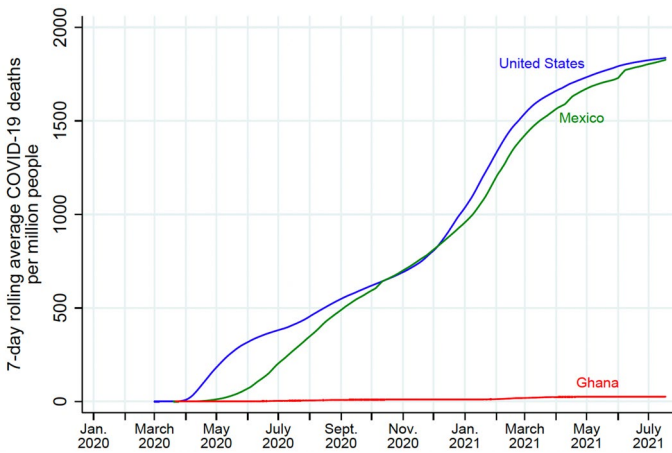


Fig. 17 Official COVID-19 Deaths in the USA, Mexico and Ghana. Note: This figure plots cumulative official deaths from COVID-19, according to Our World in Data, in the three focus countries: the USA, Mexico and Ghana



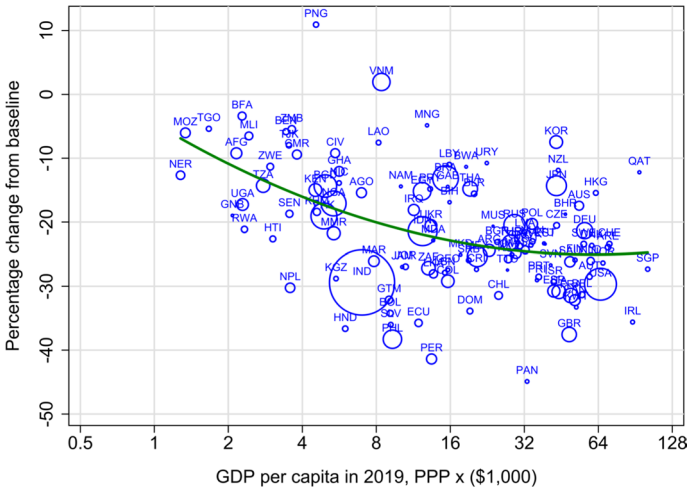


Fig. 20 Changes in Workplace Mobility in 2020. Note: This figure plots the average percent change in visits and time spent at workplaces from baseline in 2020 against GDP per capita in 2019. The baseline is the median value, for the corresponding day of the week, during the 5-week period Jan 3-Feb 6, 2020. GDP per capita is expressed at PPP and taken from Penn World Table 9.1 (Feenstra et al., 2015). Percent change in visits and time spent at home and workplace in 2020 comes from the Google COVID-19 Community Mobility Reports

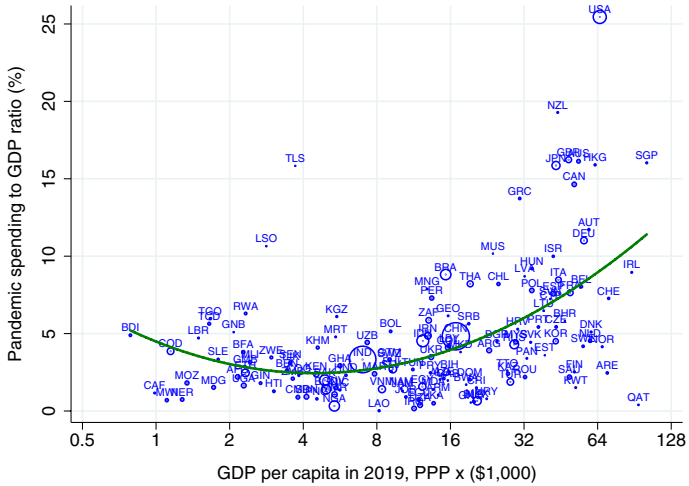


Fig. 21 Pandemic Spending as Share of GDP. Notes: Data on pandemic spending come from the IMF Fiscal Monitor Database. GDP per capita is expressed at PPP and taken from Penn World Table 9.1 (Feenstra et al. 2015)



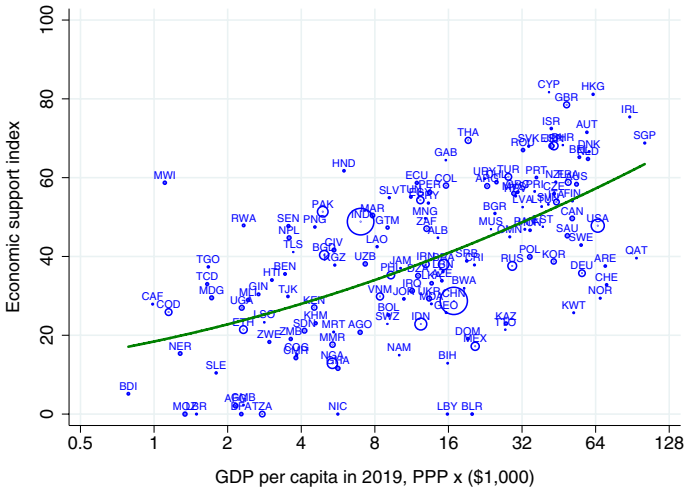


Fig. 22 Economic Support Index. Note: Oxford Coronavirus Government Response Tracker’s *Economic Support Index*

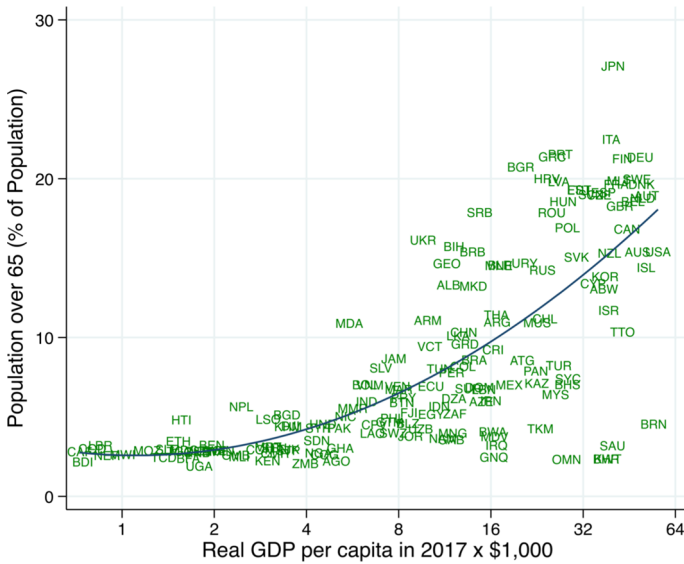


Fig. 23 Fraction of the Population Older than Age 65. Notes: This figure plots the proportion of population ages over 65 and above as a percentage of total population across 162 countries. GDP per capita is from Penn World Table 9.1 (Feenstra et al. 2015). Population data is World Bank staff estimates using the World Bank’s total population and age/sex distributions of the United Nations Population Division’s World Population Prospects: 2019 Revision



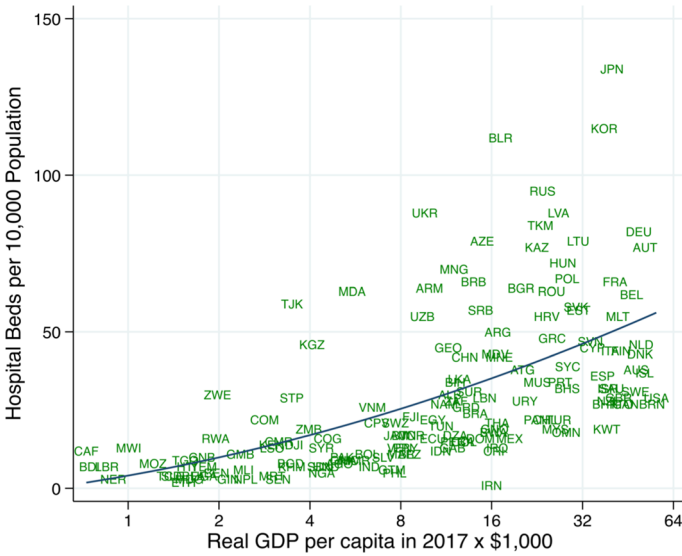


Fig. 24 Hospital Beds per 10,000 People. Note: This figure plots the number of hospital beds available per 10,000 inhabitants in 153 countries. GDP per capita is at PPP and taken from the Penn World Table 9.1 (Feenstra et al. 2015). The hospital bed data are from the World Health Organization’s Global Health Observatory

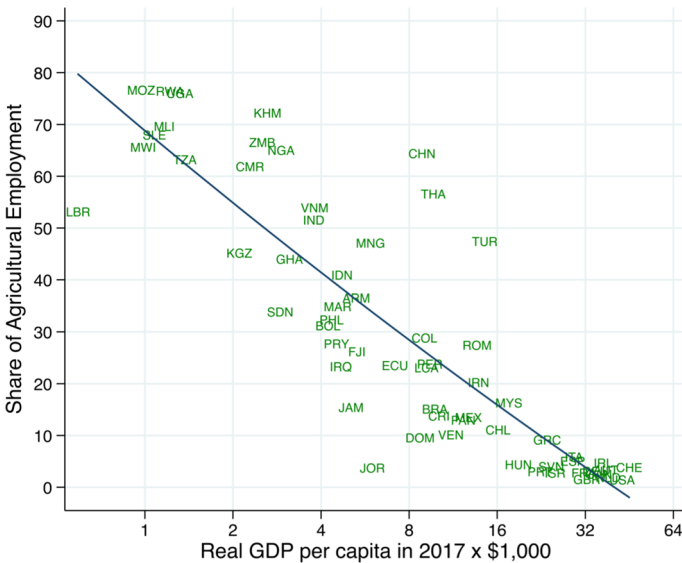


Fig. 25 Size of the Agricultural Sector. Notes: Agriculture employment data are taken from the IPUMS database. GDP per capita is expressed at PPP and is taken from the Penn World Table 9.1 (Feenstra et al. 2015)



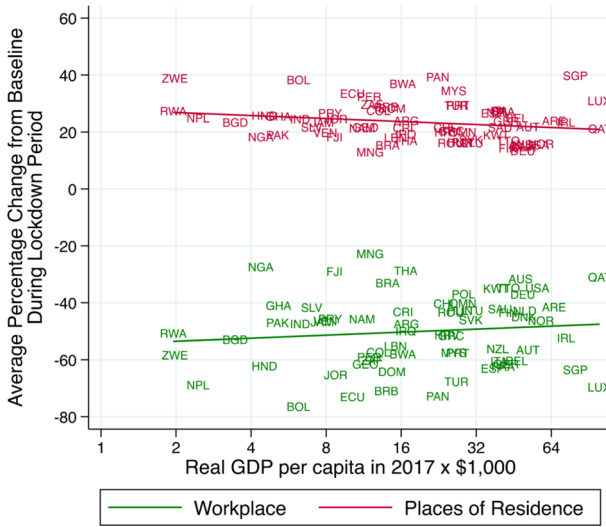


Fig. 26 Changes in Mobility Across Countries During Lockdown Periods. Notes: This figure plots the average percentage changes of the mobility metric in the 'Places of Residence' and 'Workplace' categories in the Google Community Mobility Report (Aktay et al. 2020), during the lockdown periods for the 65 countries which had implemented or are implementing lockdown. GDP per capita is from Penn World Table 9.1 (Feenstra et al. 2015). The average across all 65 countries is 23.44 percent. The slope of the fitted line is 1.52, with p value of 0.354 for the 'Workplace' category. For the 'Places of Residence' category, the slope of the fitted line is -1.52, with p value of 0.083

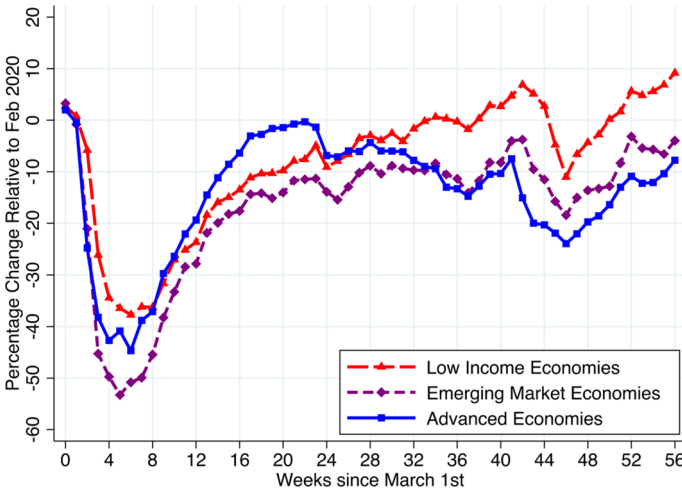


Fig. 27 Changes in Consumption-Related Mobility Across Countries. Notes: This figure plots the weekly weighted averaged percentage changes of the mobility metric in the 'Grocery and Pharmacy' and 'Retail and Recreation' categories in the Google Community Mobility Report (Aktay et al. 2020), during the lockdown periods for the low-income, emerging market, and advanced economies (total 115 countries). Log GDP per capita for each country was used as a weight in pooling countries within each group



Appendix B: Tables

See Tables 9, 10.

Table 9 ICU Bed Availability Across Countries

Country	ICU beds per 100,000 population	Per capita healthcare cost
USA	20.0–31.7	\$7,164
Canada	13.5	\$3,867
Denmark	6.7–8.9	\$3,814
Australia	8.0–8.9	\$3,365
South Africa	8.9	\$843
Sweden	5.8–8.7	\$3,622
Spain	8.2–9.7	\$2,941
Japan	7.9	\$2,817
UK	3.5–7.4	\$3,222
New Zealand	4.8–5.5	\$2,655
China	2.8–4.6	\$265
Trinidad and Tobago	2.1	\$1,237
Sri Lanka	1.6	\$187
Zambia	0	\$80

Source: Table 1 in Prin and Wunsch (2012). Healthcare cost includes all public and private expenditures

Table 10 Internally Calibrated Parameters and Model Fit

	Data	Model	Parameters	Description
Advanced Economies GDP Decline, '19–'20	– 4.60%	– 4.70%	$A(P)$	Pandemic TFP
US Employment Decline, '19–'20	– 6.40%	– 5.89%	ϕ_s	Productivity of remote work, social sector
Fraction Remote Workers pre COVID	8.20%	8.14%	σ_g	Variance of remote work taste shock



Appendix C: Robustness of Results

See Table 11.

In this section, we briefly check the robustness of our results to other parameters that we imagine could vary between Advanced and Emerging Market (EM) Economies. We focus on five additional model features that may vary and discuss each one in turn.

The first parameter we imagine might vary across advanced and EM economies is the discount factor of the old. In our model, this discount factor embeds the notion that individuals over the age of 65 have a lower expected lifespan than individuals under the age of 65 and thus carry a lower discount factor. Because life expectancy is lower in EE economies, it is intuitive that the "gap" between the discount factor of the young and the old should be larger. Quantitatively, we discipline this variation by noting that individuals at age 65 have 20 percent lower life expectancy in EE economies (according to a UN Population Division note), so the gap between the young and old discount rates should be 20 larger. This results in the implied value for β_o of 0.9955.

We also imagine that working from home may not provide as much protection from infection in EM economies due to larger household sizes (i.e., more contacts at home) and participation in crowded markets. We refer to Alon et al. (2020) who use contact matrices constructed by Mossong et al. (2008) and measure that individuals in advanced economies make about 36 percent of their contacts at work while individuals in EM economies make about 35 percent at work. Thus, working from home reduces contacts by about 1 percent ($\frac{36.1-35.8}{36.1}$) less in EM economies. Consequently, we inflate the parameter governing (relative) infection risk while working from home by 1 percent to 0.606.

Finally, vaccine rollout was substantially delayed in EM economies relative to advanced. We use vaccination data from Our World in Data (OWID). In particular, OWID reports the time path of vaccinations for countries grouped into "High income", "Upper middle income", and "Lower middle income". We consider the "High income" series to correspond to advanced economies and the average of the "Upper middle income" and "Lower middle income" series to correspond to EM

Table 11 Calibration of Economic Parameters

Param. Change	Description	GDP decline (%)	Mortality (Per 100k)	Source
	Baseline	- 6.3	159	
$\beta_o \rightarrow 0.9955$	Decrease Discount Factor for Old	- 6.3	159	UN Population Division
$\xi \rightarrow 0.606$	Higher Infection Prob. when WFH	- 6.3	172	Alon et al. (2020)
	Path of Vaccinations Reduced by 25%	- 6.3	158	Our World in Data
$r^F \rightarrow 0.0003$	Reduced Return to Savings	- 6.3	158	
$\phi_S \rightarrow 0.5$	Higher Penalty of Working Remotely	- 8.0	161	



economies. From this, we see that EM economies tend to have roughly 25 percent fewer vaccinations at any given point in time, which we feed into the model.

We also may be concerned that EM economies are more borrowing constrained and have more hand-to-mouth households than advanced economies. We capture this variation by reducing the interest rate faced by these economies, which reduces savings and leads more binding borrowing constraints. We also might be concerned that infrastructure for remote work is less robust in EM economies, resulting in social-sector workers earning a larger penalty from choosing to work remotely. We capture this variation by reducing the fraction of income that social sector workers keep when choosing to work from home. Lacking good data for both of these types of cross-country variation, we simply decrease r_F and ϕ_S by the arbitrary amounts of 50 percent and 20 percent respectively to explore the robustness of the model conclusions to these parameters.

Encouragingly, very few of these parameter changes have a substantial impact on model-predicted outcomes for EM economies. The two largest impacts are the increase in infection probability when working from home leading to slightly more deaths and the higher penalty of working remotely leading to slightly more GDP loss. Both of these results are intuitive as these parameters directly govern these outcomes essentially by construction.

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