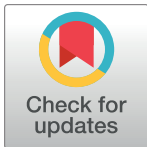RESEARCH ARTICLE

The impact of access to financial services on mitigating COVID-19 mortality globally

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Abstract

The COVID-19 pandemic has disproportionately affected different social and demographic groups, deepening the negative health implications of social and economic inequalities and highlighting the importance of social determinants of health. Despite a deep literature on pandemic-related disparities, specifically regarding social determinants and health outcomes, the influence of the accessibility of financial services on health outcomes during COVID-19 remains largely unexplored. Modeling (pre-omicron) COVID-19 mortality across 142 nations, we assess the impact of national-level usage and access to formal financial services. Two financial access indexes constructed through principal component analysis capture (1) usage of and access to formal financial tools and (2) reliance on alternative and informal financial tools. On average, nations with higher pre-pandemic use of and access to formal financial services had substantially lower population mortality risk from COVID-19, controlling for key population health, demographic, and socioeconomic covariates. The scale of effect is similar in magnitude—but opposite in direction—to major risk factors identified in previous literature, such as lung cancer, hypertension, and income inequality. Findings suggest that financial services deserve greater attention both in the public health literature related to COVID-19 and more broadly in policy discussions about fostering better public health overall.

Introduction

The COVID-19 pandemic has both highlighted the importance of social determinants of health and exacerbated the negative health implications of social and economic inequalities. There is broad literature and evidence that inequalities in income, access to resources, and other measures of household financial security affect household members' health [1, 2]. Specific to the pandemic, two systematic reviews of the burgeoning literature on the social determinants related to COVID-19 health outcomes, one early in the pandemic [3] and one more recently by the World Health Organization [4]—more than 200 articles and reports are included in the latter alone—revealed "glaring inequities" among population groups; main contributing factors include poverty, lack of household resources, affordability of prevention

measures, and limited access to various health and social services. Despite the hundreds of such studies related to the pandemic, and the obvious importance of, e.g., ability to pay, affordability, and payment options for accessing health services, none addressed access to broader arrays of financial services beyond formal insurance as a determinant of health outcomes from COVID-19. Yet access to savings, credit, money transfer services, and the like can also serve to buffer risks [5]. The preliminary evidence presented in the sections that follow suggests this may be a major gap in the literature.

Before COVID-19 hit, many developing economies had seen expansions in financial access such as banking deposit and credit services, digital payment systems, and other inclusive fintech innovations. For decades, advocates for global-scale investments in inclusive financial services have championed the role that improved access to financial services plays in helping families in developing economies, particularly those reliant on income from informal work, buffer the risks to their livelihoods and health they face from highly variable and unstable income flows [6–11]. Job losses and economic turmoil due to COVID-19 have exacerbated those risks to an unprecedented degree globally.

Yet it remains an open question whether investments in inclusive financial services and inclusive fintech have mattered for global health. Because health is such a complex socio-economic phenomenon, and financial access is only one (perhaps minor) element among many confounding factors, teasing out the health effects of expanding financial services has proven remarkably challenging. The unfortunately stark and broad natural experiment of COVID-19 might have strengthened the signal-to-noise ratio enough to present a unique opportunity to deepen understanding of the role of access to financial services in health outcomes.

Most of the literature to date linking COVID-19 and financial services has focused on how the pandemic has challenged the financial security of financial sector institutions (e.g., [12–14]), of businesses [15–17], and of households [18–20]. Similarly, the public health literature beyond COVID-19 has focused on how health problems can cause financial risk, including so-called distress financing, the phenomenon of lower-income households coping with health crises and health-related negative income shocks by relying on selling assets and over-indebtedness, in turn begetting further financial risk for the households [21–23]. Distress financing tends to be higher where insurance is thin and national systems lack universal healthcare.

But causality should run the other direction as well if financial security is beneficial to health. Advocates for inclusive finance might have hoped that financial access would have some impact on risk mitigation during the pandemic. Did it? If advocates have been correct, families, communities, and nations that had better financial access pre-COVID-19 should have been better able to weather the health storm in measurable ways during the pandemic. Somewhat surprisingly, there so far has been no global study exploring how the pandemic's effects correlate with financial access metrics and whether there is any evidence of risk mitigation.

The analysis that follows models COVID-19 mortality rates across 142 nations and finds that nations where residents had greater (pre-pandemic) access to an array of formal financial services had substantially lower population mortality risk during the pandemic. Indeed, the risk reduction is surprisingly large, similar in magnitude to but opposite in direction from the increased COVID-19 mortality risks associated with higher rates of lung cancer, hypertension, and greater income inequality.

Variables and data sources

Table 1 lists the dependent and control variables, details on the specific metrics used, and data sources; all are publicly available and measured at the national level. The dependent variable is

Table 1. Dependent and control variables, with sources.

Variables	Measures	Sources
COVID-19 death rate, through 9/30/21	ln(COVID-19 deaths per million population)	Accessed from Our World in Data, https://ourworldindata.org/covid-deaths; original source: COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University, https://github.com/CSSEGISandData/COVID-19 [44]
Demographic & Socioeconomic Control Variables		
Population aged 65 & older, 2019	% of population	United Nations, 2019 World Population Prospects, https://population.un.org/wpp/
Population aged 0–14, 2019	% of population	United Nations, 2019 World Population Prospects, https://population.un.org/wpp/
Population density, 2019	ln(population per sq. km)	United Nations, 2019 World Population Prospects, https://population.un.org/wpp/
Population in urban areas, 2018	% of population	United Nations, World Urbanization Prospects: the 2018 Revision, https://population.un.org/wup/
Per capita income, 2019	ln(per capita income, PPP adjusted, constant 2017 international $)	World Bank, World Development Indicators, https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD
Income inequality, 2019	Gini coefficient	Gapminder estimates, http://www.gapm.io/dgini
Population Health Control Variables		
Mortality from indoor air pollution, 2016	ln(mortality rate attributed to household & ambient air pollution, age-standardized, per 100,000 population)	World Bank, World Development Indicators, https://data.worldbank.org/indicator/SH.STA.AIRP.P5
Diabetes prevalence, 2019	ln(% of population ages 20–79 with type 1 or 2 diabetes, age-standardized)	World Bank, World Development Indicators, https://data.worldbank.org/indicator/SH.STA.DIAB.ZS
Lung cancer prevalence, 2018	ln(average lung cancer incidence rate, age-standardized per 100,000, male & female, all ages)	Accessed from https://canceratlas.cancer.org; original source: International Agency for Research on Cancer, Global Cancer Observatory: Cancer Today, https://gco.iarc.fr/today [45]
Body mass index, 2016	Mean body mass index, adults, age-standardized (kg/m^2)	World Health Organization, Global Health Observatory, https://apps.who.int/gho/data/view.main.CTRY12461
Raised blood pressure prevalence, 2015	% of population 18+ years, age-standardized, with systolic blood pressure ≥ 140 or diastolic blood pressure ≥ 90	World Health Organization, Global Health Observatory, https://www.who.int/data/gho/indicator-metadata-registry/imr-details/2386
Tuberculosis vaccine coverage, 1989–2018	Mean bacille Calmette-Guérin (BGC) immunization rate (%) among 1-year olds, 1989–2018	World Health Organization, Global Health Observatory, https://www.who.int/data/gho/data/indicators/indicator-details/GHO/bcg-immunization-coverage-among-1-year-olds-(-)
Health Infrastructure Control Variables		
Nurses & midwives, 2010–2019	ln(nursing & midwifery personnel per 10,000 population)	World Health Organization, Global Health Observatory, https://www.who.int/data/gho/indicator-metadata-registry/imr-details/5319. Used most recently available from 2010–2019.
Health services effective coverage, 2019	Universal healthcare (UHC) effective coverage index	Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2019, UHC Effective Coverage Index 1990–2019, doi: 10.6069/GT4K-3B35 [46]

https://doi.org/10.1371/journal.pgph.0001137.t001

(log-transformed) COVID-19 deaths per million population through the end of September 2021. This cutoff date was before the discovery and spread of the omicron variant. The independent variables listed in Table 1 aim to capture and control for factors known to contribute to variation across nations in COVID-19 mortality rates. All independent variables use the most recently available data predating the pandemic, i.e., 2019 or earlier. Variables with highly skewed distributions are natural log transformed. Two additional variables of main interest are financial services access indexes, constructed as discussed in the next section.

Population-level COVID-19 mortality risks are, by now, well understood in the medical literature to be related to a variety of population-level risk factors. Though our main interest here is not these previously studied population health and socioeconomic variables, we include some key national-level public health risk characteristics as control variables. These control variables were selected based on previous evidence in the literature as covariates with COVID-19 mortality, including population health and respiratory issues (levels of hypertension, lung

cancer, tuberculosis, diabetes, obesity, and air pollution); healthcare system availability and effectiveness; and socio-economic characteristics, including age distribution, urbanization, population density, and socioeconomic inequalities (e.g., [24–43]). To protect, temporally, against bias from reverse causality, all independent variables included in our main models (Tables 5, 6, and S4 Table) reflect national conditions in 2019 or earlier, prior to the arrival of COVID-19. (In S5 Table we do explore the addition of June 2021 COVID-19 vaccination rates and availability, three months before the mortality variable; main conclusions are unaffected).

In addition, we also screened for data availability. Much of the statistical modeling in the national-level literature suffers from limited data availability across nations, restricting sample size. Aiming for the broadest and most representative set of countries, we selected publicly available variables at the national level that had no more than five nations missing from the 142 nations for which financial inclusion variables and COVID-19 mortality rates were also available. S1 Table shows descriptive statistics for all variables in Table 1, and S3 Table is the correlation matrix.

Financial access variables methodology

To assess the extent to which access to financial services has contributed to mitigating COVID-19 risks, we develop financial inclusion indices at the national level using metrics from the World Bank's Global Findex Database [47]. The Global Findex includes multiple variables measuring the degree to which the population of each country is engaged in the use of various financial services and activities (as percentage of population). The data are collected through national surveys of more than 150,000 adults from 144 countries, of which 142 also had COVID-19 mortality data available.

We construct our financial access indexes from principal component analysis (PCA) on 20 metrics drawn from the Global Findex Database 2017 panel, the most recent available pre-pandemic. The 2017 panel includes indicators on the access and use of both formal and informal financial services as well as the use of various financial technologies. As described in Table 2, with descriptive statistics in S2 Table, several metrics relate to access to and usage of traditional formal financial tools, such as having any sort of financial institution account, borrowing from and saving in financial institutions, making transactions through financial institutions, and owning debit or credit cards. Other variables measure the use of digital financial services such as making transactions through mobile phones or payments via the internet. We also incorporate several variables indicative of access to financial security tools such as the availability of emergency funds, loans from financial institutions, borrowing for health purposes, and saving for old age. Additional variables measure the use of informal or distress finance, e.g., relying on friends and family for borrowing or for emergencies, or selling assets for emergency funding.

To reduce the dimensionality of our exploration of whether countries with greater access to financial services have better success mitigating COVID-19 risks while retaining most of the variability of the underlying metrics, we apply PCA. Our PCA incorporates all 20 variables in Table 2, from the Global Findex Database, to create indices of financial access at the national level. As shown in Table 3, the two principal components with the highest eigenvalues together account for nearly three-quarters (72%) of the total variance among the 20 variables. We use these top two to construct our two financial access indexes.

Table 4 shows how the top components correlate with each original variable. The first component correlates positively and relatively evenly across most of the formalized financial tools including both traditional tools (e.g., savings, loans, cards, and other services provided by financial institutions) and using the internet, and it correlates negatively with informal and

Table 2. Global Findex variables used to construct financial access indices (% age 15+).

Metrics capturing access to traditional formal financial tools	
Financial institution account	Respondents who report having an account (by themselves or together with someone else) at a bank or another type of financial institution
Borrowed from a financial institution or credit card	Respondents who borrowed any money from a bank or another type of financial institution, or using a credit card, in the past 12 months
Saved at a financial institution	Respondents who report saving or setting aside any money at a bank or another type of financial institution in the past 12 months
Debit card ownership	Respondents who report having a debit card
Credit card ownership	Respondents who report having a credit card
Received wages into a financial institution account	Respondents who received any money from an employer in the past 12 months in the form of a salary or wages for doing work directly into a financial institution account or into a card
Paid utility bills using a financial institution account	Respondents who personally made regular payments for water, electricity, or trash collection in the past 12 months directly from a financial institution account
Outstanding housing loan	Respondents who report having an outstanding loan (by themselves or with someone else) from a bank or another type of financial institution to purchase a home, an apartment, or land
Metrics capturing access to financial technologies (fintech)	
Used the internet to pay bills or to buy something online in the past year	Respondents who report using the internet to pay bills or buy something online in the past 12 months
Received wages through a mobile phone	Respondents who received any money from an employer in the past 12 months in the form of a salary or wages for doing work through a mobile phone
Paid utility bills using a mobile phone	Respondents who personally made regular payments for water, electricity, or trash collection in the past 12 months through a mobile phone
Made or received digital payments in the past year	Respondents who used mobile money, a debit or credit card, or a mobile phone to make a payment from an account, or used the internet to pay bills or to buy something online, in the past 12 months
Metrics capturing access to financial security tools	
Saved for old age	Respondents who saved or set aside any money in the past 12 months for old age
Borrowed for health or medical purposes	Respondents who borrowed any money for health or medical purposes in the past 12 months
Coming up with emergency funds possible	Respondents who, in case of an emergency, it is possible for them to come up with 1/20 of gross national income (GNI) per capita in local currency within the next month
Main source of emergency funds: savings	Among respondents reporting that in case of an emergency it is possible for them to come up with 1/20 of GNI per capita in local currency, the percentage who cite savings as their main source of this money
Main source of emergency funds: formal loans	Among respondents reporting that in case of an emergency it is possible for them to come up with 1/20 of GNI per capita in local currency, the percentage who cite borrowing from a bank, an employer, or a private lender as their main source of this money
Metrics capturing reliance on informal or distress financing	
Borrowed from family or friends	Respondents who borrowed any money from family, relatives, or friends in the past 12 months
Main source of emergency funds: family or friends	Among respondents reporting that in case of an emergency it is possible for them to come up with 1/20 of GNI per capita in local currency, the percentage who cite family, relatives, or friends as their main source of this money

(*Continued*)

Table 2. (Continued)

Main source of emergency funds: sale of assets	Among respondents reporting that in case of an emergency it is possible for them to come up with 1/20 of GNI per capita in local currency, the percentage who cited the sale of assets as their main source of this money

Note: Source data available here: https://www.worldbank.org/en/publication/globalfindex/Data.

https://doi.org/10.1371/journal.pgph.0001137.t002

distress finance, such as relying on family and friends and borrowing for health purposes or selling assets for emergency funds. Thus, we interpret the first component as an index of the extent to which a nation exhibits "Broad access to and use of formal financial tools." The higher the index, the more widespread and diverse are the formal financial tools in regular use in that country.

By contrast, the second index associates most closely with metrics related to alternative financial tools, such as mobile phone transactions and informal finance of borrowing from family and friends, and distress financing tools, such as selling assets for emergency uses and borrowing for health and medical needs. It is also negatively associated with the ability to raise emergency funds and access to family funding for emergencies, suggesting that high values of the second index associate, in part, with financial resilience challenges. We therefore interpret the second component as an index capturing a nation's tendency toward "Reliance on alternative, informal, and distress financial tools." Descriptive statistics on two financial tools indexes created from these two principal components are shown in S1 Table. The influence of these two index variables on COVID-19 mortality is our main interest in the econometric models that follow.

The correlation matrix in S3 Table shows these two financial tools access indexes' near zero correlation (r = -0.01) with each other, but high correlations with several economic, demographic, and healthcare infrastructure control variables. Chronbach's alpha tests of internal consistency on the covariance of these two indexes with each other (alpha = 0.02), with national income (0.52), with the two healthcare infrastructure variables (0.39), and among all five of these highly correlated variables together confirms (all alphas <0.6) they capture significantly different characteristics of national ecosystems. Moreover, despite the potential for noisy estimators from multicollinearity, our econometric modeling nevertheless finds statistically significant evidence for these financial tools access indexes—particularly robust for the first.

Table 3. Identification of principal components.

Component	Eigenvalue	Difference	Proportion of Variance	Cumulative Variance
Comp1	12.400	10.466	0.6200	0.6200
Comp2	1.935	0.630	0.0967	0.7168
Comp3	1.305	0.289	0.0653	0.7820
Comp4	1.016	0.196	0.0508	0.8329
Comp5	0.821	0.351	0.0410	0.8739
Comp6	0.469	0.067	0.0235	0.8974
Comp7	0.403	0.089	0.0201	0.9175
etc.	. . .	. . .	. . .	. . .
Comp19	0.024	0.001	0.0012	0.9989
Comp20	0.023	.	0.0011	1.0000

https://doi.org/10.1371/journal.pgph.0001137.t003

Table 4. Principal components' correlation with original Global Findex variables.

Variable	Comp1	Comp2	Comp3	Comp4
Finance institution account	0.259	-0.030	0.197	-0.027
Borrowed from a financial institution or credit card	0.261	0.009	-0.012	0.155
Saved at a financial institution	0.268	0.058	-0.137	-0.051
Debit card ownership	0.264	-0.008	0.153	-0.056
Credit card ownership	0.263	-0.017	-0.069	0.098
Received wages into financial institution	0.267	-0.012	0.130	-0.011
Paid utility bills using financial institution account	0.267	0.012	0.006	0.053
Outstanding housing loan	0.248	0.080	0.030	0.032
Used the internet for online transaction	0.272	0.066	0.032	-0.021
Received wages through mobile phone	0.061	0.535	0.232	-0.259
Paid utility bills through mobile phone	0.179	0.427	0.081	-0.125
Made or received digital payments	0.264	0.086	0.170	-0.035
Saved for old age	0.255	0.002	-0.190	-0.030
Borrowed for health or medical purposes	-0.193	0.312	0.003	0.023
Coming up with emergency funds: possible	0.194	-0.234	0.014	-0.167
Main source of emergency funds: savings	0.246	-0.020	-0.275	-0.142
Main source of emergency funds: formal loan	0.077	0.173	0.269	0.850
Borrowed from family or friends	-0.163	0.368	0.251	-0.237
Main source of emergency funds: family/friends	-0.134	-0.247	0.620	-0.055
Main source of emergency funds: sale of assets	-0.138	0.361	-0.419	0.202

Ethics statement

All data used in the study is publicly available secondary data, not collected by the authors. No permissions for data use were required. Protocols for data collection, ethics, and participants' rights protection vary by source organization, as listed in Table 1, all of which are widely known and internationally reputable. The main variables of interest, specifically the financial tools access indexes, were constructed from the World Bank's Global Findex, which is made up from national surveys done by Gallup as part of the Gallup World Poll [47]. Gallup World Poll uses nationally representative stratified random sampling and either face-to-face or random-digit-dialing telephone interviewing of residents aged 15 and older. Gender-matched interviewing occurs where cultural norms dictate. In select nations, Gallup excludes some regions for safety or unapproachability reasons.

Models and results

As the slight differences among variable observation counts in S1 Table indicate, ten nations lack values for one or several of the control variables, but the specific missing variables differed among nations. Because those ten nations did have data for most of our other variables, rather than lose them from the analysis, we opted for a linear model using full information maximum likelihood (FIML) estimation (following [48], which shows FIML estimates are similar to those from established missing variable imputation methods, e.g., [49–52]). Because COVID-19 patterns correlate geographically, we include World Bank region dummies, and robust standard errors are adjusted clustered by region. Our main results are shown in Table 5 (repeated as Model 1 in S4 Table), followed by a comparison OLS model in Table 6 without those ten nations that lacked full data (repeated as Model 2 in S4 Table), again with robust standard

Table 5. Full information maximum likelihood estimation.

STATA 17 Structural equation model	Number of observations n = 142					
Maximum Likelihood S.E.M. (missing values estimated)	Log-likelihood = -4838.003					
(Std. err. adjusted for 7 World Bank Region clusters)						
Country-level determinant	**Coef.**	**Robust Std. Err.**	**t**	**p>|t|**	**Signif. Level**	
Dependent Variable *ln (COVID-19-related deaths per 100K population, as of 9/30/2021)*						
Financial Tools Access Index Variables						**FINANCIAL ACCESS VARIABLES**
Broad access to & use of formal finance index	-0.299	0.059	-5.06	0.000	***	
Reliance on alternative, informal, & distress finance index	0.114	0.023	4.93	0.000	***	
Demographic & Socioeconomic Variables						**COUNTRY-LEVEL COVID-19 MORTALITY DETER-MINANTS from *BMJ* & similar public health literature**
Population aged 65 & older, 2019 (%)	0.000	0.042	-0.01	0.996		
Population aged 0 to 14, 2019 (%)	-0.040	0.014	-2.86	0.004	***	
ln(Population density per sq. mile, 2019)	-0.067	0.062	-1.08	0.279		
Population in urban areas, 2018 (%)	0.003	0.008	0.43	0.668		
ln(Per capita income, 2019)	0.476	0.224	2.12	0.034	**	
Income inequality, 2019 (Gini)	0.050	0.015	3.26	0.001	***	
Population Health Variables						
ln(Mortality from indoor air pollution per 100K, 2016)	0.060	0.395	0.15	0.880		
ln(Diabetes prevalence, %, 2019)	-0.415	0.220	-1.89	0.059	*	
ln(Lung cancer prevalence per 100K, 2018)	0.650	0.274	2.37	0.018	**	
Mean body mass index, 2016 (kg/m^2)	-0.035	0.043	-0.81	0.419		
Raised blood pressure prevalence, 2015 (%)	0.091	0.059	1.55	0.122		
Tuberculosis vaccine coverage, 1989–2018 (%)	-0.003	0.002	-1.42	0.156		
Health Infrastructure Variables						
ln(Nurses & midwives per 10K, 2010–2019)	0.199	0.167	1.19	0.233		
Health services effective coverage (UHC index), 2019	0.042	0.009	4.56	0.000	***	
World Bank Region Dummy Variables						*REGION EFFECTS*
East Asia & Pacific	-2.912	0.416	-7.01	0.000	***	
Europe & Central Asia	-0.921	0.265	-3.48	0.001	***	
South Asia	-0.302	0.278	-1.09	0.278		
Middle East & North Africa	-0.580	0.171	-3.39	0.001	***	
Sub-Saharan Africa	-1.841	0.298	-6.18	0.000	***	
constant	-3.821	2.889	-1.32	0.186		
Equation-level goodness of fit	Variance fitted	Variance predicted	Variance residual	R-squared	mc	mc^2
Dependent Variable						

(Continued)

Table 5. (Continued)

ln(Covid-related deaths per 100K, as of 9/30/2021)	3.474	2.572	0.902	0.7404	0.8605	0.7404

Note: two-tailed significance levels

***0.01

**0.05

*0.10.

mc = correlation between dependent variable and its prediction.

mc^2 is the Bentler-Raykov squared multiple correlation coefficient.

https://doi.org/10.1371/journal.pgph.0001137.t005

errors adjusted clustered by region, as a robustness check. Either model explains more than 72% of the variation in COVID-19 mortality rates across the 142 nations.

The first financial access index, capturing access to formal financial services, is statistically significantly related to COVID-19 mortality rates (p < .001), controlling for demographic, socioeconomic, population health and health infrastructure variables, and region. In Table 5, the -0.299 coefficient suggests that (pre-omicron) COVID-19 mortality rises 29.9% for a one-unit reduction in the (pre-COVID-19) access to formal finance index. The standard deviation of the index is 3.521, implying that, on average, nations with one standard deviation lower access to formal financial services had COVID-19 mortality rates more than double (0.299*3.521 = 105%) nations with average financial tools access, conditional on the other COVID-19 mortality covariates. The alternative coefficient estimate (0.316) from Table 6 is also statistically significant (p = .008) and very similar in scale, again suggesting more than doubling the mortality rate (111%).

As additional validity checks on the stability of estimates of our main financial access index variables of interest, S4 Table expands the number of alternative model specifications, showing models with only various subsets of the independent variables. Models 1 and 2 repeat Tables 5 and 6. Model 3 removes the region dummies. Model 4 uses only the two financial tools indexes. Because financial system strength is significantly correlated with national income, Model 5 adds only a single other variable, (ln) per capita income, to the two financial indexes. Model 6 adds only the other demographic and socioeconomic variables. Model 7 includes only the health infrastructure variables with the financial indexes. Model 8 adds population health variables. Model 9 aims for parsimony by removing from Model 2, post OLS, any variable with p>0.4. (Not shown, but the variables included in Model 9 are the same as those identified by a different technique, LASSO regression, except the LASSO-suggested model includes population density, which when added has essentially no substantive effect on other significant coefficients.) Finally, Model 10 includes the same variables as Model 9 but employs the FIML estimation method (as used in Model 1) to enable including the ten nations missing one or more specific variables.

To test the internal validity of model specification, a Ramsey RESET test and a LINK test are conducted after each model (except the FIML models) to test functional form and omitted variable problems. Wald tests on variables added beyond the two variables in Model 5 (financial indexes and income only) are also shown. The Ramsey, Link, and Wald test results appear in the bottom rows of S4 Table. The only statistically significant evidence of problems arises in the Models (4, 5, and 7) that omit all or most control variables, supporting the addition of variables such as those included our preferred model. The Wald tests suggest each added set of variables, added sequentially to other sets, is jointly significant. A Wald test also confirms the

Table 6. OLS regression using only nations with complete information.

STATA 17 Linear regression	Number of observations n = 132					
(heteroscedasticity robust, clustered standard errors)	R-squared = 0.7288					
(Std. err. adjusted for World Bank Region clusters)	Root MSE = 1.0438					
Country-level determinant	**Coef.**	**Robust Std. Err.**	**t**	**p>|t|**	**Signif. Level**	
Dependent Variable ln(COVID-19-related deaths per 100K population (as of 9/30/2021)						
Financial Tools Access Index Variables						**FINANCIAL ACCESS VARIABLES**
Broad access to & use of formal finance index	-0.316	0.081	-3.88	0.008	***	
Reliance on alternative, informal, & distress finance index	0.071	0.048	1.49	0.186		
Demographic & Socioeconomic Variables						**COUNTRY-LEVEL COVID-19 MORTALITY DETER-MINANTS from** *BMJ* **& similar public health literature**
Population aged 65 & older, 2019 (%)	0.004	0.046	0.09	0.935		
Population aged 0 to 14, 2019 (%)	-0.046	0.022	-2.07	0.084	*	
ln(Population density per sq. mile, 2019)	-0.045	0.069	-0.66	0.535		
Population in urban areas, 2018 (%)	0.002	0.010	0.21	0.840		
ln(Per capita income, 2019)	0.497	0.283	1.75	0.130		
Income inequality, 2019 (Gini)	0.058	0.010	6.05	0.001	***	
Population Health Variables						
ln(Mortality from indoor air pollution per 100K, 2016)	-0.005	0.411	-0.01	0.990		
ln(Diabetes prevalence, %, 2019)	-0.341	0.145	-2.35	0.057	*	
ln(Lung cancer prevalence per 100K, 2018)	0.666	0.313	2.13	0.077	*	
Mean body mass index, 2016 (kg/m^2)	-0.037	0.045	-0.81	0.447		
Raised blood pressure prevalence, 2015 (%)	0.084	0.070	1.20	0.275		
Tuberculosis vaccine coverage, 1989–2018 (%)	-0.005	0.001	-3.71	0.010	***	
Health Infrastructure Variables						
ln(Nurses & midwives per 10K, 2010–2019)	0.218	0.181	1.20	0.276		
Health services effective coverage (UHC index), 2019	0.038	0.009	4.05	0.007	***	
World Bank Region Dummy Variables						**REGION EFFECTS**
East Asia & Pacific	-2.722	0.413	-6.60	0.001	***	
Europe & Central Asia	-0.898	0.343	-2.62	0.040	**	
South Asia	-0.292	0.257	-1.13	0.301		
Middle East & North Africa	-0.516	0.195	-2.64	0.038	**	
Sub-Saharan Africa	-1.471	0.581	-2.53	0.045	**	
constant	-3.701	2.658	-1.39	0.213		

Note: two-tailed significance levels

***0.01

**0.05

*0.10.

https://doi.org/10.1371/journal.pgph.0001137.t006

variables removed from Model 2 for the parsimony Model 9 (post-OLS set of insignificant (p<0.4)) are not collectively significant.

S4 Table shows that the estimated size of the relationship between COVID-19 mortality rate—i.e., an approximate doubling per standard deviation reduction in the index of access to formal financial services—is robust to alternative sets of control variables, except in Model 4, which only includes the two financial tools indexes. Compared to Model 4, the addition in Model 5 of a single additional covariate that is significantly positively correlated with the depth of financial systems, per capita income, switches the sign of the coefficient on the first financial index. A similar effect can be seen in Model 7, which adds only the two health infrastructure variables, both also strongly positively correlated with national wealth. In other words, access to formal financial services becomes significantly negatively associated with COVID-19 mortality once any variables also related to national wealth are controlled for.

By contrast, the results for the second financial services index, reliance on alternative, informal, and distress financing, are weaker in scale and statistically less robust. In Table 5, a nation's pre-COVID-19 tendency to rely on alternative, informal, and distress financial tools is positively associated with higher COVID-19 mortality and statistically significant (p < .001). According to this model, mitigating COVID-19 impacts apparently was more challenging where financial emergency coping mechanisms rely on informal options and distress financing—an intuitively appealing result. However, compared to the formal finance index, the strength of the association is weaker. A one standard deviation increase in the alternative, informal, and distress finance index is associated with a 15.9% ($1.391^*.114$) increase in mortality. In the OLS version, Table 6, which includes data from fewer nations, the second index, though still positively related to COVID-19 mortality, falls to statistical insignificance (p = 0.186). Moreover, as S4 Table shows, coefficient estimates and significance for this second index are sensitive to which control variables are included.

While the control variables—drawn from the medical and public health literatures—are not our central interest, we now turn to those population health, demographic, and socioeconomic variables. Youthful populations are associated with statistically significantly lower mortality, as are more-equal income distributions. Consistent with existing literature (e.g., [53–56]), nations with higher degrees of income inequality have statistically significantly higher COVID-19 mortality rates. A one-unit increase in national Gini coefficient raises expected COVID-19 mortality rate by about 5%–6%, depending on the model. Nations with income inequality one standard deviation (7.79) above the average level would have roughly 40%–50% higher mortality rates.

Given that COVID-19 attacks the respiratory-system [35, 36, 43], it is unsurprising that population respiratory health appears important too. Higher national pre-COVID-19 lung cancer prevalence is a statistically significant COVID-19 mortality risk factor in models with regional dummies. As shown in Fig 1B, a one-unit increase (approximately the standard deviation, 1.08) from the mean ln(lung cancer prevalence) relates to a two-thirds greater COVID-19 mortality, conditional on the other independent variables. So too, higher pre-COVID-19 childhood tuberculosis vaccination rates are negatively correlated with COVID-19 mortality (though the latter is not statistically significant in Models 1 and 8).

We also find that nations with higher per capita incomes had statistically significantly higher mortality rates, even after controlling for characteristics associated with wealth, like aging and obesity, that might be problematic for richer nations. Though curious, this finding is consistent with most of the COVID-19 literature. For example, Goldberg and Reed [28] found, after controlling for several demographic, public health, policy response, weather, and mobility variables, that for a 1% increase in per capita GDP, COVID-19 mortality rose by 0.9%. Our results suggest a smaller relation, roughly half that, but still positive. Reasons for this
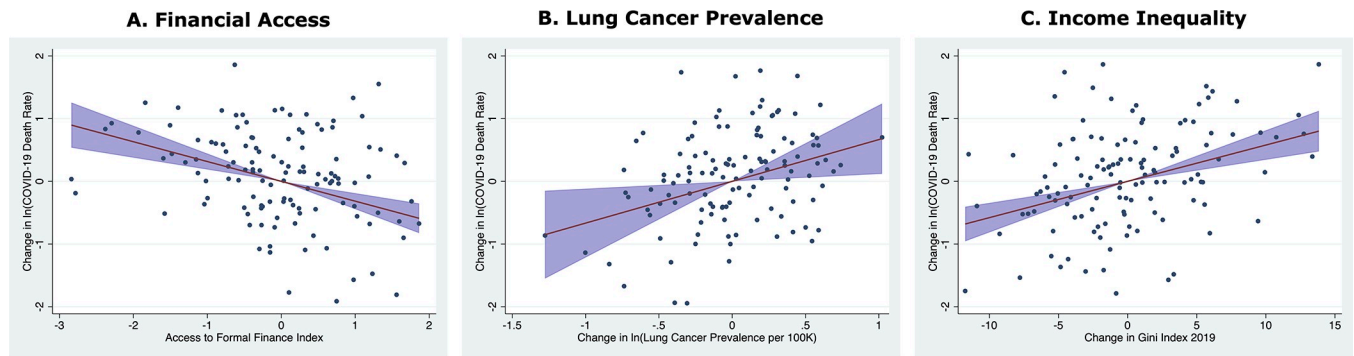
Fig 1. Comparing conditional partial correlation of COVID-19 mortality with financial access, lung cancer, and income inequality. (A) Conditional partial correlation of national COVID-19 mortality with pre-COVID-19 Index of access to formal finance; 95% confidence interval shaded. (B) Similar, with pre-COVID-19 ln(average lung cancer incidence rate, age-standardized per 100,000, male & female, all ages). (C) Similar, with pre-COVID Gini index of income inequality.

counterintuitive yet widely duplicated result are not well understood and have been discussed at length elsewhere (e.g., [28, 37–39, 56]).

Though not tested or of central interest here, numerous speculations—with often conflicting empirical results—exist in that literature about why wealthier nations, which also tend to be those with deeper financial services, have had substantially higher average levels of COVID-19 infection and mortality. Possible explanations include, for example: measurement issues such as less-robust public health data reporting resulting in undercounting by lower-income nations, or political and cultural differences in reporting transparency; political economic differences in policy responses; socio-economic differences like greater population mobility in wealthier nations either before or after lockdowns, very high population densities in the very largest urban centers in wealthier nations, previous experience in lower-income nations with handling and/or accumulated immunities from similar viral (e.g., SARS) outbreaks. or more-concentrated systems of elder care; and even seasonal differences in northern and southern hemispheres; or a host of other potential reasons. Clarifying what drives the counterintuitive wealth-COVID-19 correlation has so far been frustratingly difficult and remains a work in process and beyond the scope of this article.

Similarly counterintuitive, nations with more effective healthcare systems, as measured by the universal healthcare effective coverage index, have significantly higher COVID-19 mortality. The size of the relationship in our models is similar to that of lung cancer relation: a one standard deviation increase in the UHC index goes with an approximate two-thirds increase in mortality. Greater population shares of nurses and midwifery personnel are also positively related to mortality, however not statistically significantly in most models. The coefficients on diabetes hint at another puzzle. In models with regional dummies, diabetes prevalence associates negatively with COVID-19 mortality—not the direction we would expect based on the medical literature [41, 42]. However, the statistical significance is marginal ($p>.05$) except in Model 9. Indoor air pollution, body mass index, and raised blood pressure prevalence are not statistically related to mortality in most models.

An attempt to explore the effective healthcare system puzzle a bit, specifically whether the interaction between deeper financial systems and stronger healthcare systems might help untangle it, is shown in S1 and S2 Figs. The figures show the results of an OLS (robust, region clustered) model like Model 2 but including an interaction effect between the two (continuous) indexes of the formal financial tools access and health services effective coverage. Because of the interaction term, the marginal effects cannot be interpreted directly from the coefficients

(not shown) of the regression model. Rather, the figures show the average marginal effect on the predicted (ln) COVID-19 mortality rate of each of the two variables at various levels of the second variable, together with 95% confidence intervals. As S1 Fig shows, the marginal effect of the formal financial tools index suggests higher financial access reduces mortality, and increasingly so at higher levels of health care effectiveness; the predicted effects are generally statistically significantly, except at the lowest levels of the heath system index. S2 Fig then shows the average marginal effects of the health services effectiveness index at different levels of the financial access index. Unfortunately, the healthcare system puzzle remains. At low levels of financial access, higher healthcare system effectiveness is still statistically significantly positively associated with higher COVID mortality. The effect remains positive, though not significant, at higher levels of financial access. In short, on average in nations with the most effective healthcare systems, COVID-19 related mortality is higher and the mitigating effect of better access to financial tools is larger.

Finally, although the independent variables included in Models 1–10 reflect national conditions in 2019 or earlier, prior to the arrival of COVID-19, in S5 Table we do explore adding measures from June 2021 on COVID-19 vaccination rates and availability, which are clearly important for mitigating COVID mortality risk. Model 11 adds COVID-19 vaccination rate as a share of the total population by June, 30, 2021 [57]. Model 12 adds COVID-19 vaccine availability, measured as full doses acquired by the nation as of June 25, 2021 divided by total population [58]. Note the vaccine availability data in Model 12 is only available for 77 of the 142 nations. In all models except the limited sample Model 12, COVID-19 mortality statistically significantly declines with higher vaccination rates. Vaccine availability itself is not statistically related to mortality. In any event, the main conclusions on the financial tools access index variables are unaffected in any of the models including COVID-19 vaccine data. Neither does inclusion of vaccine data help clear up the puzzles of the signs of the GDP and health system effectiveness variables.

Discussion and conclusions

In summary, we find that greater pre-pandemic national levels of use and access to formal financial services are related to substantially lower death rates from (pre-omicron) COVID-19. The result suggests that financial services deserve substantially greater attention both in the public health literature related to COVID-19 and more broadly in policy discussions about fostering better public health overall. Robust financial services like savings, insurance, credit, payment systems, and the like are clearly potentially useful tools for households paying for food, housing, medicines, and health services and dealing with medical emergencies. Yet despite the extensive literature linking household financial security and health and the obvious potential link to COVID-19 outcomes, we are unaware of any other study exploring how COVID-19 mortality relates to financial systems.

To help assess the relative importance of the financial access variable, Fig 1A, based on the model in Table 5, shows the partial correlation of COVID-19 mortality with pre-COVID-19 levels of access to formal financial services conditional on the other independent variables in Table 5, with 95% confidence interval. The strength of the association in Fig 1A of COVID-19 mortality with pre-COVID-19 levels of access to formal financial services is similar in scale but opposite in direction to the estimated relations with pre-COVID-19 lung cancer rates (Fig 1B) and with income inequality (Fig 1C)—both of which are among the most important determinants of COVID-19 mortality in the medical and public health literatures. Many dozens (perhaps hundreds) of pandemic-related studies have now looked at each of those variables; financial services have been essentially ignored. Considering that the scale of the relationship

to population-level COVID-19 mortality rivals that of lung cancer, this appears to be a major exploratory blind spot.

Though the GDP-COVID-19 puzzle is not our central interest, our finding that deeper formal financial systems appear associated with better risk mitigation if anything deepens the perplexity. It is puzzling too that not only the income variable but also both health infrastructure variables relate positively to COVID-19 mortality. All three behave oppositely to our formal financial access metric, despite the clear relationship between national wealth and the depths of both financial systems and health systems. Some analysts have speculated the positive association of national income and COVID-19 might be an artifact of nations with deeper healthcare systems better tracking health statistics [39]. Yet controlling for the healthcare infrastructure here does not solve the GDP riddle. Regardless, the jury is still out on why rich countries have suffered more. It is remarkably counterintuitive that that pattern is replicated in both income and healthcare infrastructure.

Untangling the complex socio-economic and socio-structural determinants of health inequalities remains a major challenge. The role of financial tools in health should feature centrally in that inquiry.

Supporting information

S1 Table. Descriptive statistics for model variables.
(DOCX)

S2 Table. Summary descriptive statistics, Global Findex variables.
(DOCX)

S3 Table. Correlation matrix.
(DOCX)

S4 Table. Alternative model specifications.
(DOCX)

S5 Table. Models including COVID-19 vaccination variables.
(DOCX)

S1 Fig. Average conditional marginal effects on (ln) national COVID-19 mortality rate of pre-COVID-19 index of access to formal finance at various levels of the health system effective coverage (UHC) index; with 95% confidence intervals.
(TIFF)

S2 Fig. Average conditional marginal effects on (ln) national COVID-19 mortality rate of health system effective coverage (UHC) index at various levels of the pre-COVID-19 index of access to formal finance; with 95% confidence intervals.
(TIFF)

Acknowledgments

structuring assistance and two anonymous reviewers for helpful suggestions for improving the modeling and discussion.

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