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Abstract

Over the last year the world experienced the COVID-19 pandemic coupled with unprecedented policy responses. In this paper we examine the determinants of COVID-19 infections and fatalities in a cross-country analysis. We find that countries with greater income, less dense and greater elderly populations, fewer hospital beds, and more freedom experienced greater fatalities, and that travel restrictions and use of hydroxychloroquine reduced deaths. However, we find little evidence that lockdowns reduced fatalities, and though use of PCR testing resulted in more recorded infections, it was unassociated with fatalities.

JEL-Codes: O100, O200, Q540.

Keywords: pandemic, Covid-19, fatalities.

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1. Introduction

The COVID-19 pandemic emerged in late 2019 spreading across the globe, but countries differed greatly in terms of infections, fatalities, and policy responses. Variability in infections and fatalities offers an opportunity for exploration---why have some countries had relatively low rates of infections and fatalities whereas others experienced substantially greater infections and fatalities? Socio-economic, political characteristics, and pandemic policy responses are also diverse. Some countries imposed nationwide travel restrictions and mandatory lockdowns whereas others did not. Developed countries relied heavily on the PCR testing to determine infection rates, whereas generally less developed counties did not. Some countries encouraged hydroxychloroquine (HCQ) use, which if administered early is effective and safe (and inexpensive), whereas other countries discouraged and even prevented its use. Do these policy differences explain any of the variability across countries in infections and fatalities? Controlling for the underlying socio-economic, political, and geographic factors, this paper examines the degree to which these policy responses helped to save lives.

As the pandemic unfolded, we learned that the elderly and those with underlying health conditions are far more vulnerable, whereas younger healthy people are resilient. In the United States (U.S.) the survival rate for those 70 years older is 94.6% but is 99.997% for those aged 19 and under (CDC, 2021). Our evaluation of the determinants of COVID-19 infections and fatalities follows a line of research on disaster vulnerability that has shown that developed countries tend to be safer from disaster shocks because they are able to devote greater resources to safety. (Kahn, 2005, Toya and Skidmore, 2007). Our analysis of the COVID-19 pandemic contributes to this research by examining how socio-economic, political, geographic, and policy-related factors play a role in determining infections and fatalities.

While we are most interested in evaluating policies, it is also important to understand and control for the role other factors play in determining a county's vulnerability. For example, both income and degree of income inequality (Helliwell et al., 2021) are potentially important; those with limited resources may not have access essential healthcare services. Demographic factors are also important; as noted above the elderly are most vulnerable to the disease, and population density may also play a role in disease spread. Controlling for geography such degree of isolation may also be important as some countries such as island-states may be protected. Our primary interest, however, is in evaluating the different government policies implemented in response to the outbreak. Many countries restricted travel and imposed lockdowns of varying degrees, some imposing mandatory nationwide lockdowns, restricting economic and social activity deemed to be non-essential. Some countries made HCQ accessible as many health scientists understood that it was an effective treatment for coronavirus, whereas other countries prevented the use of HCQ.[1]

2. Empirical Analysis

COVID-19 infection and fatality data come from the World Health Organization (WHO) (https://covid19.who.int/table). We merge these data with socio-economic, political, geographic, and policy information, which are available from several sources as shown in Appendix Table A *(World Bank Indicators,* https://c19hcq.com/, https://www.kayak.com/travel-restrictions, https://www.bbc.com/news/world-52103747, https://freedomhouse.org/report/freedom-world, https://en.wikipedia.org/wiki/COVID-19_pandemic_by_country_and_territory#Timeline_of_first_confirmed_case_by_country*)*. The country is the unit of analysis, where we examine recorded COVID-19 infections per 10 million population and fatalities per one hundred thousand population for 144 to 159 countries, depending on data availability. To reduce concerns about endogeneity, the independent variables measure status before April 2020 so that they can be interpreted as predetermined. For example, travel restrictions are more likely to be adopted in places where COVID infections are growing. To reduce concerns about potential

[1] See https://c19hcq.com/ for a real-time database and meta-analysis of 280 HCQ studies of which 208 are peer reviewed. These studies show that early treatment with HCQ consistently has positive effects. In the U.S., HCQ was discouraged and even prohibited, even though the U.S. National Institute of Allergy and Infectious Diseases (NIAID) published an article in 2005 (Vincent et al.,2005) in its Virology Journal, which showed that HCQ was an effective treatment for coronavirus. Dr. Fauci was head of the NIAID at the time. The lead author (Vincent) and several other coauthors were employed by the U.S. Center for Disease Control and Prevention when the study was published.

endogeneity, the explanatory variables measure status prior to April 2020. Further, policies adopted later are less likely to have been implemented on time to affect COVID-19 infections and fatalities during the period of analysis (December 8, 2019 – April 1, 2021). For example, several countries began to administer Ivermectin and Remdesivir in late 2020, but the adoption dates were too late to observe effects in our timeframe of analysis.

To evaluate the role of travel restrictions, HCQ use, and lockdowns in reducing fatalities, we control for socio-economic, political, and geographic factors (real GDP per capita, Gini coefficient of income inequality, population density, proportion of population aged 65 or older, number of hospital beds, degree of freedom, and island and OECD country indicator variables). We expect countries with lower income, greater income inequality[2], fewer hospital beds, higher population density and proportion of elderly, and more freedom to have more infections and fatalities. Controlling for these factors, we test the hypotheses that PCR testing, travel restrictions, mandatory and recommended lockdowns, and HCQ use reduce infections and fatalities. These are prominent alternative policies that have been used differentially across countries. To illustrate, HCQ is used in African countries for the treatment of Malaria and thus the medication was known to be safe and was widely available. In contrast, North American and European countries discouraged and even prevented HCQ use. Appendix Table B provides summary statistics for all variables and Appendix Table C provides a list of countries included in the evaluation.

We estimate regressions to determine the relationship between the policy variables with controls and COVID-19 infections and fatalities in a robust regression estimation. The regressions are characterized by the following equations:

$$\text{Infections}_i = \beta_m(\text{Controls}_{ji}) + \beta_n(\text{Policies}_{ki}) + e_i$$

$$\text{Deaths}_i = \beta_m(\text{Controls}_{ji}) + \beta_n(\text{Policies}_{ki}) + e_i$$

[2] Davies (2021) finds that COVID-19 deaths were greater in countries with greater income inequality.

where infections and fatalities are the total number of COVID-19 infections per ten million population and deaths per one hundred thousand population in country i between December 8, 2019 and April 1, 2021, respectively. The vector $Policy_{ki}$ includes PCR testing, HCQ use, travel restrictions (complete and partial), and lockdowns (mandatory national, mandatory local, recommended national, recommended local), and $Controls_{ji}$ represents a vector of j control variables that determine infections and fatalities (GDP per capita, Gini coefficient of income inequality, number of hospital beds, freedom, population density, elderly population, island country indicator, and OECD country indicator).

Table 1 presents six infection regressions and Table 2 present six fatality regressions. Consider first Table 1. The R^2 ranges from 0.589 to 0.661, signifying that the regressions capture a high proportion of the variation in infections across countries. The control variables show that countries with higher income, fewer beds, more freedom, less dense and older populations had higher rates of infection, and that OECD and more isolated island countries had lower rates of infection. It is surprising that countries with higher income and with less dense populations were affected more severely because epidemics are more likely in highly populated lower income countries where access to clean water and sanitation is a challenge. Several of the policy variables are also significant. Countries with recommended national and local lockdowns and mandatory local lockdowns experienced fewer infections, but travel restrictions did not reduce infections. Also note that PCR testing is positive and significant.

Turning to the fatality estimates in Table 2, the regressions again capture a significant portion of the cross-country variation in fatalities. As with infections, countries with higher income, fewer beds, more freedom, and less dense and more elderly populations experienced more fatalities. OECD and island countries experienced fewer fatalities. Turning to the policy variables, countries with travel restrictions experienced fewer fatalities. Of the four lockdown variables, only recommended lockdowns significantly reduced fatalities. However, only one country was in this lockdown category; thus, it appears that relative to no lockdown countries, lockdowns generally did not reduce fatalities. In contrast to the positive and significant coefficient on PCR test in the infection regressions, this variable was statistically insignificant in the fatality regressions: This inconsistency may be due to the high rate of

PCR test false positives.[3] Finally, HCQ use significantly reduced fatalities where the magnitude of the effect is substantial. According to the coefficient estimate on HCQ in column 6, if the U.S. had made HCQ widely available, fatalities would have been reduced from about 515,000 to 427,000.

3. Conclusions

This paper offers a cross-country analysis of the determinants of COVID-19 infections and fatalities. Focusing on the policy variables, we find that greater use of PCR testing resulted in more recorded infections but was unassociated with fatalities. Countries that closed travel also experienced fewer fatalities. Of the different types of lockdown policies, recommended local lockdowns were most effective in reducing fatalities; mandatory lockdowns were ineffective. Last, HCQ use is perhaps the most effective low-cost policy option for reducing fatalities.[4] This short-run analysis does not fully capture longer-run impacts, nor does it capture the secondary effects of travel restrictions and lockdown policies such as the negative economic impacts and associated "deaths of despair." Nevertheless, our analysis provides useful guidance to policymakers in the design and implementation of future pandemic policy responses.

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[3] Mandavilli (2021) offers a discussion of PCR test false positives, referring to studies indicating that up to 90% of PCR tests generate false positives where "infected" individuals are neither sick nor contagious. See also Wernike et al. (2020).

[4] Ivermectin and vitamin D are also recognized effective treatments for COVID-19. See Real-time Database and Meta Analysis of 541 COVID-19 Studies, https://c19early.com/.

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Table 1
Determinants of COVID-19 Infections (December 8, 2019 - April 1, 2021)

Dependent variable: Total confirmed cases per 10 million population of April 1, 2021

	1	2	3	4	5	6
Log GDP per capita	0.104	0.105	0.113	0.079	0.105	0.093
	(5.523)	(5.667)	(6.086)	(3.478)	(5.567)	(4.078)
Aged 65 and above	0.033	0.033	0.029	0.034	0.033	0.030
	(4.429)	(4.425)	(4.181)	(4.592)	(4.617)	(4.505)
Beds per 1000 people	-0.023	-0.023	-0.024	-0.022	-0.023	-0.022
	(-1.870)	(-1.904)	(-2.009)	(-1.930)	(-2.142)	(-2.127)
Population density	-0.034	-0.034	-0.028	-0.048	-0.023	-0.032
	(-2.092)	(-2.073)	(-1.827)	(-3.188)	(-1.529)	(-2.080)
Gini	-0.002	-0.003	-0.004	-0.001	-0.002	-0.002
	(-1.135)	(-1.185)	(-1.784)	(-0.649)	(-0.970)	(-0.803)
Not free	-0.086	-0.083	-0.075	-0.084	-0.077	-0.061
	(-2.312)	(-2.157)	(-1.981)	(-2.267)	(-2.137)	(-1.652)
Island	-0.156	-0.161	-0.146	-0.160	-0.150	-0.135
	(-3.835)	(-3.983)	(-3.406)	(-3.613)	(-3.640)	(-3.008)
OECD	-0.351	-0.356	-0.341	-0.385	-0.352	-0.366
	(-3.888)	(-3.921)	(-3.960)	(-4.422)	(-4.119)	(-4.691)
HCQ		-0.020				-0.020
		(-0.532)				(-0.559)
Travel closed			-0.064			-0.059
			(-1.448)			(-1.317)
Travel partial			0.024			0.008
			(0.743)			(0.232)
PCR test				0.129		0.104
				(2.290)		(1.790)
Mandatory national lockdown					0.003	-0.016
					(0.059)	(-0.354)
Mandatory local lockdown					-0.089	-0.079
					(-2.287)	(-1.705)
Recommended national lockdown					-0.132	-0.130
					(-2.484)	(-2.405)
Recommended local lockdown					-0.310	-0.302
					(-7.748)	(-5.756)
Number of Countries	159	159	156	145	159	144
R^2	0.589	0.590	0.621	0.609	0.622	0.661

Notes: Numbers in parentheses are t-values.

Table 2
Determinants of COVID-19 Fatalities (December 8, 2019 - April 1, 2021)

Dependent variable: Total confirmed deaths per 100000 population of April 1, 2021

	1	2	3	4	5	6
Log GDP per capita	0.103	0.114	0.117	0.110	0.099	0.138
	(3.214)	(3.663)	(3.608)	(2.581)	(3.076)	(3.376)
Aged 65 and above	0.088	0.086	0.083	0.089	0.084	0.078
	(5.893)	(5.943)	(5.633)	(5.631)	(5.634)	(5.222)
Beds per 1000 people	-0.043	-0.045	-0.045	-0.050	-0.040	-0.048
	(-1.724)	(-1.929)	(-1.767)	(-1.947)	(-1.666)	(-2.149)
Population density	-0.081	-0.083	-0.068	-0.082	-0.073	-0.057
	(-3.968)	(-4.156)	(-3.293)	(-3.412)	(-2.956)	(-2.097)
Gini	0.005	0.004	0.003	0.004	0.006	0.002
	(1.121)	(0.930)	(0.629)	(0.774)	(1.325)	(0.522)
Not free	-0.228	-0.197	-0.186	-0.222	-0.207	-0.137
	(-3.154)	(-2.839)	(-2.446)	(-2.865)	(-2.984)	(-1.840)
Island	-0.369	-0.415	-0.332	-0.404	-0.343	-0.380
	(-4.136)	(-4.506)	(-3.317)	(-3.841)	(-3.734)	(-3.322)
OECD	-0.573	-0.613	-0.558	-0.602	-0.557	-0.613
	(-2.988)	(-3.224)	(-2.860)	(-3.067)	(-2.949)	(-3.144)
HCQ		-0.175				-0.173
		(-2.502)				(-2.412)
Travel closed			-0.202			-0.226
			(-1.971)			(-1.988)
Travel partial			-0.043			-0.027
			(-0.546)			(-0.307)
PCR test				0.012		-0.021
				(0.130)		(-0.208)
Mandatory national lockdown					0.139	0.166
					(1.806)	(2.090)
Mandatory local lockdown					-0.059	0.004
					(-0.826)	(0.053)
Recommended national lockdown					-0.043	-0.017
					(-0.374)	(-0.147)
Recommended local lockdown					-0.432	-0.365
					(-5.938)	(-3.774)
Number of Countries	159	159	156	145	159	144
R^2	0.577	0.593	0.584	0.561	0.600	0.608

Notes: Numbers in parentheses are t-values.

Appendix Table A: Definitions and Sources of Variables

Variables	Definition	Source
Deaths	Total confirmed deaths per 100000 population of April 1, 2021	WHO
Cases	Total confirmed cases per 10 million population of April 1, 2021	WHO
Log GDP per capita	Logarithm of real GDP per capita in 2010	WDI
Aged 65 and above	Population aged 65 and above of 2010 (% of total population)	WDI
Beds per 1000 people	Hospital beds per 1,000 people in 2015	WDI
Population density	Population density in 2010 (1000 people per sq. km of land area)	WDI
Gini	Gini index of income inequality	WDI
Not free	Dummy for not free country	FH
Island	Dummy for island country/area/territory	
OECD	Dummy for OECD country	
HCQ	Dummy for HCQ used widely	@CovidAnalysis
Travel closed	Dummy for travel only for citizens, residents returning home, or people in other special circumstances may enter the country.	KAYAK
Travel partial	Dummy for entrance into a country may depend on the traveler's citizenship, point of origin, or other specific regulations.	KAYAK
PCR test	The number of tests performed for the country/area/territory per 1 trillion people	WHO
Mandatory national lockdown	Dummy for nationwide mandatory lockdown on April 1, 2020	BBC, WIKI
Mandatory local lockdown	Dummy for mandatory local lockdown on April 1, 2020	BBC, WIKI
Recommended national lockdown	Dummy for recommended national lockdown on April 1, 2020	BBC, WIKI
Recommended local lockdown	Dummy for recommended local lockdown on April 1, 2020	BBC, WIKI

Sources:

WHO: World Health Organization https://covid19.who.int/table

WDI: World Bank Indicators https://databank.worldbank.org/reports.aspx?source=world-development-indicators#
FH: Freedom House https://freedomhouse.org/report/freedom-world

@CovidAnalysis: https://c19hcq.com/countries.html

KAYAK: https://www.kayak.com/travel-restrictions

BBC: https://www.bbc.com/news/world-52103747

WIKI: https://en.wikipedia.org/wiki/COVID-19_pandemic_by_country_and_territory#Timeline_of_first_confirmed_case_by_country

Appendix Table B: Summary of Statistics Variables

	Mean	Standard Deviation	Number of Observations
Deaths	0.503	0.622	159
Cases	0.267	0.308	159
Log GDP per capita	8.434	1.472	159
Aged 65 and above	7.924	5.432	159
Beds per 1000 people	2.840	2.351	159
Population density	0.176	0.594	159
Gini	37.98	7.899	159
Not free	0.239	0.428	159
Island	0.195	0.397	159
OECD	0.145	0.353	159
HCQ	0.340	0.475	159
Travel closed	0.192	0.395	156
Travel partial	0.571	0.497	156
PCR test	0.378	0.581	145
Mandatory national lockdown	0.440	0.498	159
Mandatory local lockdown	0.283	0.452	159
Recommended national lockdown	0.113	0.318	159
Recommended local lockdown	0.006	0.079	159

Appendix Table C: List of Countries Included in the Study

Afghanistan	Cote d'Ivoire	Iran, Islamic Rep.	Montenegro	Solomon Islands
Albania	Croatia	Iraq	Morocco	South Africa
Algeria	Cyprus	Ireland	Mozambique	Spain
Argentina	Czech Republic	Israel	Myanmar	Sri Lanka
Armenia	Denmark	Italy	Namibia	St. Lucia
Australia	Djibouti	Jamaica	Nepal	Suriname
Austria	Dominican Republic	Japan	Netherlands	Sweden
Azerbaijan	Ecuador	Jordan	New Zealand	Switzerland
Bangladesh	Egypt, Arab Rep.	Kazakhstan	Nicaragua	Tajikistan
Belarus	El Salvador	Kenya	Niger	Tanzania
Belgium	Estonia	Kiribati	North Macedonia	Thailand
Belize	Eswatini	Korea, Rep.	Norway	Timor-Leste
Benin	Ethiopia	Kyrgyz Republic	Pakistan	Togo
Bhutan	Fiji	Lao PDR	Panama	Tonga
Bolivia	Finland	Latvia	Paraguay	Trinidad and Tobago
Bosnia and Herzegovina	France	Lebanon	Peru	Tunisia
Botswana	Gabon	Lesotho	Philippines	Turkey
Brazil	Gambia, The	Liberia	Poland	Turkmenistan
Bulgaria	Georgia	Lithuania	Portugal	Uganda
Burkina Faso	Germany	Luxembourg	Qatar	Ukraine
Burundi	Ghana	Madagascar	Romania	United Arab Emirates
Cabo Verde	Greece	Malawi	Russian Federation	United Kingdom
Cambodia	Guatemala	Malaysia	Rwanda	United States
Cameroon	Guinea	Maldives	Samoa	Uruguay
Canada	Guinea-Bissau	Mali	Sao Tome and Principe	Uzbekistan
Central African Republic	Guyana	Malta	Senegal	Vanuatu
Chile	Haiti	Mauritania	Serbia	Venezuela, RB
China	Honduras	Mauritius	Seychelles	Vietnam
Colombia	Hungary	Mexico	Sierra Leone	Yemen, Rep.
Comoros	Iceland	Micronesia, Fed. Sts.	Singapore	Zambia
Congo, Dem. Rep.	India	Moldova	Slovak Republic	Zimbabwe
Costa Rica	Indonesia	Mongolia	Slovenia	