Causality and Dependence of COVID-19 Variables from Our World in Data

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Abstract

The existing literature on COVID-19 has been dominated by medical sciences as well as epidemiological studies related to different public health reasons or disease related issues. Using the data set of 8 variables of Roser et al. (2020) from Our World in Data we have tested several propositions from conventional wisdom by using Pearson's Product Moment Correlation, Panel Granger Causality test and Multivariate Bayesian VAR on 209 countries for 143 daily data during COVID19 outbreak in 2020 (31 December 2019-21 May 2020) in an unbalanced panel framework. It has been found that only a small fraction of new confirmed cases are being explained by new test conducted. Only a small fraction of new deaths due to COVID-19 is being explained by new confirmed cases. Stringency index neither

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contains contagion nor pacifies death rate or mortality. Even though bivariate analysis reveals some support to 'more test more death hypothesis' it has become weaker when we switch over to multivariate analysis. Urgent invention of a suitable vaccine is the only viable solution for fighting against this pandemic and save the humanity from this calamity.

Keywords: COVID-19, Corona Virus; Our World in Data; Granger Causality; Bayesian VAR; Dependence; Impulse Response Function; Variance Decomposition

JEL Classification: I1

Highlights

- COVID-19 variables are perceived to be interrelated.
- We use daily data for eight variables, 209 countries over a span of 143 days (31 December 2019-21 May 2020) from Our World in Data.
- We use Pearson's Product Moment Correlation, Panel Granger Causality, and Panel Bayesian Vector Auto Regression (VAR) method.
- Bivariate analysis finds some support to the conventional wisdom of 'more test more death and more cases'.

- From multivariate analysis only a small fraction of new_cases_per_million is being explained by total_tests_per_thousand.
- From multivariate analysis only a small fraction of new_deaths_per_million is being explained by new_cases_per_million.
- Stringency index is always self-determined. It neither contains contagion nor pacifies mortality.
- Urgent invention of a vaccine is the only solution to this pandemic and save the humanity from this calamity. It is hard to contain it by other actions if it does not die out automatically.

1. Introduction

In the recent outbreak of Covid-19, the world's death rate soared so high that some countries had to face challenges in burying the dead bodies. Over the last few months, the Covid-19 pandemic that has been derived from China's Wuhan province has spread and reached almost every corner of the earth like wildfire. So far, in 200 countries, with over 4.5 million infected cases and 0.3 million deaths, the virus was declared as a pandemic on March 11th 2020. Countries that suffered the most are The US, Russia, The UK, Spain, Italy, Brazil, France, Germany, Ecuador, etc.

Giuffrida and Tondo (2020) wrote that, in Italy coffins were lined up in churches and the bodies were sealed in rooms for days as the funeral services had to struggle to cope up with such large number of dead bodies. According to authors, the funeral companies received at least dozens of calls per hour, ran out of coffins and staffs. At a point, the military had to carry the scores of coffins in large trucks from Bergamo to cemeteries (Giuffrida & Tondo, 2020). Chandran and Harrisberg (2020), found that in New York, the rising death toll had caused a shortage of burial spaces in cemeteries. Hence, the authorities had to dig mass graves at burials in Potter's field on Hart Island to bury the dead bodies. The authors also wrote that, in Ecuador, authorities prepared an emergency burial ground on land donated by a local cemetery of Guayaquil to address the shortage of burial space. In South Africa, the soaring number of COVID-19 deaths has forced authorities to look for new burial grounds, as there is a severe shortage of land (Chandran & Harrisberg, 2020). .

The affected rates and the number of deaths due to Covid-19 are gradually increasing day by day, with no sign of stopping due to lack of vaccines. Even the most developed countries with advanced technologies and ample medical facilities were not spared from the impact of this virus. Although the virus has spread significantly worldwide, some countries have higher affected rates than others. Also, there are discrepancies over the data provided by different countries. For instance, the death rate in the US, UK and other developed countries is much higher than developing or least developing countries like Congo, Cuba, and Venezuela.

The confusion over varying death rates by countries can be addressed for various reasons. Countries that test the more significant number of its populations are also the countries where death rates are very high (Liton, 2020). Henriques (2020) wrote that, according to Dietrich Rothenbacher, the Director of the Institute of Epidemiology and Medical Biometry at the University of Ulm in Germany, the lack of systematic and widespread testing is one of the main reasons behind the international death rate discrepancies. He also argued that the current figures are not suitable enough to compare between countries, as there are concerns over the accuracy of the figures, according to the author. To get more accurate results, it is not only essential to test the symptomatic cases but the asymptomatic cases as well (Henriques, 2020). Wide range of testing will not only diminish the discrepancies over the figures of death rates, but it will also help countries to contain the virus effectively.

Internationally, there is also a concern about what counts as a COVID-19 death, this also has an impact on various death rates of many countries. According to Henriques (2020), in many countries, if a patient dies from some other disease but is found to have COVID-19 symptoms, his/her death will be considered as death from COVID-19. In the UK, Italy, Germany, a similar process is maintained to count their number of deaths. In Comparison, the author found that the US doctors maintain discretions while recording the number of fatalities as they are asked to keep a record whether a patient died from any other disease or COVID, before reporting to the 'Centers for Disease Control and Prevention'. However, there were cases where COVID-19 patients' death was recorded as under COVID-19 death rate, regardless of what the actual case of death was (Henriques, 2020). Harmon (2020) found that in many cases, the people who die at home in the US often go unreported. Recently, New York City has increased its death count, and officials announced that they would incorporate the number of people who were never tested positive for the COVID-19, but were presumed to have died of it (Harmon, 2020).

In some countries, the COVID-19 death rate is pretty low, and they could contain the virus effectively. Vietnam, for example, has successfully contained the virus despite sharing more than a thousand kilometer long border with China. It has reported 270 affected cases and zero COVID-19 deaths on April 30th, 2020 whereas, other countries in the world have reported more than 4 million active cases and more than 0.3 million deaths. Vietnam imposed stricter restrictions from the end of January to combat the virus. Its authority issued a 4-point guideline of 'on-site quarantine, on-site treatment, on-site facilities, and on-site human resources' with also the measures of 'Proactive prevention - Early detection - Timely quarantine - Distinct zoning - Thorough defeat - Effective treatment' have helped Vietnam to ensure a victory against COVID-19 virus (Embassy of the Socialist Republic of Vietnam, 2020). In New Zealand, a level 4 lockdown and a proper maintenance of social distancing for months, has seen 1469 cases and only 19 deaths so far (Anderson, 2020).

Before COVID-19, the world suffered from epidemic/pandemic diseases like MERS and SARS. SARS, also known as Severe Acute Respiratory Syndrome, was first reported in Guangdong province in Southern China, in November 2002 (Uras, 2020). According to the author the virus soon spread to 29 countries and was declared a pandemic. The virus affected around 8094 people and of which 774 died as 2014 reports suggest, and the symptoms of SARS include flue fever, malaise, myalgia, headache, diarrhea, and shivering (Uras 2020). In contrast, the author wrote that MERS, also known as Middle East Respiratory Syndrome, was first discovered in Saudi Arabia in 2012, and still is active in 27 countries. As of March 2020, 2,521 MERS cases was recorded and of which 886 died, and the symptoms of MERS include fever, cough and shortness of breath (Uras, 2020). However, the author noted that COVID-19 does not have any fixed symptoms. But in many cases, a COVID-19 patient may develop symptoms like fever, dry cough, tiredness, loss of smell, rash, diarrhea, and sore throat. While in some cases, the patients may not show any symptom at all in the beginning but once they reach the level of severity, they may face difficulty in breathing or shortness of breath, chest pain or pressure, loss of speech or movement. The virus is highly contagious, and it takes around 10-14 days for a patient positive with COVID-19, to exhibit any symptoms. Hence, the affected person may unknowingly spread the virus before developing the symptoms. However, it is possible to stop the virus from spreading any further by ensuring proper lockdown, social distancing, and a wide range of testing. This will not only help to contain the virus, but will reduce the death rates too.

Corona Virus epidemic, which is considered as the most catastrophic calamity of this century has outraced in Wuhan, China in the later part of December 2019 and transmitted to mighty countries like USA, UK, South Korea etc. In a word, it is hard to find a country, which is not directly or indirectly affected by it. Basically, the whole world is under lock down for the last one quarter due to this contagious disease. The disease has varying degrees of the outbreak and resulting mortality or death across different regions, sectors, countries and over time. The epidemic has affected our everyday life in such an extent that thousands of papers have been written on this topic during last one-quarter time from all the disciplines. Print and online newspapers are occupied with COVID19-rlated news all the time. Most of the Economics, Business, Science, Medicine, Public Health and other disciplines are conducting webinars, special issues on this virus and its short run and long-term effect on human being and this earth.

The death rate or mortality rate varies across countries and regions over time. The calamity has the inherent random nature. That's why it is hard to find a solid theoretical structure to examine the determinants of death rate due to COVID attack. Our World, an independent organization, has nicely compiled data of this outbreak on a daily basis, for 209 countries, for the last 143 days since its outbreak in December 2019 (Roser et al. 2020). They have nicely prepared a daily database of death rate, tests, etc.

The main objective of this study is to conduct an exploratory study on the causality and dependence of a selected set of eight variables compiled in the Our World in Data without going through any solid theoretical framework. Using some univariate, bivariate and multivariate process in a panel framework we would like to reveal some facts about the core COVID19 variables. If a country cannot conduct test on general population sufficiently it will be difficult to diagnose the disease and its resulting mortality as it is perceived from COVID19. People will die out of COVID19 but it might be included as regular death and the mortality due to COVID19 will turn out to be low. That means that lack of availability of testing may camouflage the mortality due to COVID19. The published death rate should be counted with caution because it does not always reflect the genuine outbreak in a country. To this end, the paper is organized as follows: Section 1 introduces the topic while Section 2 reviews existing literature on COVID19 which are relevant for this study, Section 3 presents the data and variables while Section 4 introduces bivariate and multivariate analysis. Section 5 concludes with some policy suggestions for Government and International Organizations.

2. Literature Review

The literature on determinants of death rate or mortality rate for COVID19 is most recent, and researchers have just started focusing on this issue. Sun, Qie, Liu, Ren and Xi (2020) have examined the fatality rate emanating from COVID19 vis-a-vis other deadly diseases of similar nature by using a Meta-analysis. In this study, the authors have searched PubMed, Cochrane Library, Embase and other databases and they have examined the clinical characteristics of COVID-19 infection and found that fever and cough are the most common symptoms in patients with 2019-nCoV infections, and the mortality rate of patients with 2019-nCoV infections are lower than that of SARS and MERS. In another study, it shows that COVID-19 has spread more rapidly than SARS and MERS. It happened due to increased globalization. Wuhan, China is the most extensive hub connecting North, South, East and West of China via railways and a major international airport. Various occasions of mass gatherings have enabled COVID-19 to penetrate throughout China, and eventually, globally (Peeri et al. 2020). For this study, the authors have used the Center for Disease Control and Prevention (CDC, USA) website, and reviewed a comprehensive PubMed literature. The authors extracted information regarding clinical signs and symptoms, treatment and diagnosis, protection methods, risk factors and transmission methods for Severe Acute Respiratory Syndrome (SARS), Middle East Respiratory Syndrome (MERS) and COVID-19.

In another study on the UK, USA, China, and South Korea Ferguson et al. (2020) found that mitigation and suppression could be aimed in reducing case numbers to low levels and maintaining that situation indefinitely. Otherwise, in the absence of any control measures or without any change in individual behavior, the authors would expect a rise in mortality to occur after approximately 3 months. The epidemic is predicted to be higher in the US than in the UK. This is due to the larger geographic integration of the US. The higher peak in mortality in UK is due to the older population and smaller size of the country compared with the US. The authors also showed in the context of both the countries that, suppression would minimally require a combination of social distancing of the entire population, home isolation and household quarantine of their family members. In this paper, the authors tried to simulate so-called public health measures aimed at reducing transmission of the virus. The authors have applied a micro simulation model to two countries: the UK (Great Britain specifically) and the US. Using data from several countries Oke and Heneghan (2020) found that case fatality rates differ significantly across countries due to the number of cases testing method, only those with severe diseases are preferable for testing, the delay between symptoms and deaths lead to underestimation, factors behind increase death rates (demographics, healthcare or coinfection) and how countries are defining death by coronavirus because dying with the disease is not same as dying from the disease.

Liu, Chen, Lin and Han (2020) examine the clinical reasons behind the death rate due to COVID19. The authors have compared the clinical characteristics of 56 elderly with Young and Middle-aged patients who were hospitalized in Hainan Provincial People's Hospital from January 15, 2020 to February 18, 2020. The result shows that the mortality of elderly patients with COVID-19 is higher than that of young and middle-aged patients and the elderly patients with COVID-19 are more likely to progress to severe disease. Wilder et al. (2020) conducted another study on China and Italy by using a stochastic, agent-based model for SARS-CoV2 spread. One of the important features of this model is the inclusion of population-specific demographic structure, such as the distribution of age, household structure, contact across age groups, and comorbidities. The author used this model on Hubei, China and Lombardy, Italy. Another study by Henriques (2020) on Italy, Germany, China, UK, Germany, South Korea, Iceland, Hong Kong, and the United States found that the reason behind discrepancies in death rates across the world is due to lack of widespread, systematic testing. To get an accurate figure, it is necessary to test not just the people who have the symptoms but also the people who do not show any signs of COVID-19.

Page (2020) conducted another study on UK, Italy, Germany, South Korea, Nigeria, China, and Spain and found that the difference between countries showing different death rates depends on how many older people are infected, along with factors like age, sex, and also the country's health care service. Some nations are not including mild or asymptomatic cases and only focusing on severely ill cases; for example, the UK is testing only severely sick people, but in Germany and South Korea the testing method is more comprehensive. Many experts also think that coronavirus causes not all death. The counting of death rates mainly depends on the country's testing method.

Sorci, Faivre and Morand (2020) have conducted a study on 118 countries for which at least 10 days had elapsed between the record of the 100th case and 4th April 2020. The findings of this study have shown no evidence of association between comorbidities and case fatality rate at the country level. Case fatality rate is negatively associated with the number of hospital beds per 1000 inhabitants and also report evidence suggesting an association between case fatality rate and the political regime. Overall, these results emphasize the role of socio-economic and political factors as 49 possible drivers of COVID-19 case fatality rate at the country level.

In another study Ward (2020) has shown that variation in sampling bias can create a lot of variation in the estimated Case-fatality ratio. The author has set many different hypotheses to explain the variations in estimated COVID-19 CFR across countries. The hypotheses are access to and the quality of health care; age and demographic condition of populations; methods for recording deaths; health of populations, and the magnitude of testing. The study considered only those countries, which have at least 5 deaths reported daily. The findings of this analysis have shown that Countries that have tested more, relative to the number of deaths, have much lower CFR estimates, and this is highly statistically significant across 60 countries and the findings also imply that many countries have substantially under-estimated cases. So, the author recommends all countries to do more testing urgently, including those with only mild or no symptoms, and this applies particularly to countries with lower tests/death ratios. Biswas (2020) using the case of India, opines that India's strict lockdown and predominant younger population can explain the lower fatality rate. The virus in India is less severe, and the hot temperature is instrumental in diminishing the contagion. According to this study, the lack of systematic testing explains India's lower fatality rate. Around 80% of deaths in India occur at home, and missing number of deaths can also be the reason behind the lower fatality rate.

Williamson et al. (2020) used Cohort study by using Cox-regression to generate age and sex adjusted hazard ratios and found that death from COVID-19 is strongly associated with being male, older age and deprivation, uncontrolled diabetes, severe asthma and various other prior medical conditions. Lusignan et al. (2020) have analyzed the RCGP Research and

Surveillance Centre primary care sentinel network's data for those patients who were tested for SARS-CoV-2 between Jan 28 and April 4, 2020. The authors have used multivariate logistic regression models with multiple imputations to identify risk factors for positive SARS-CoV-2 tests within this surveillance network. The authors have found that male is at the peak in testing positive for SARS-CoV-2 (18.4% of 1612 men and 13.3% of 2190 women). Adults were at more risk of testing positive for SARS-CoV-2 compared to children, and people aged 40–64 years are at the greatest. People living in urban areas versus rural areas and in more deprived areas were more likely to test positive. People with chronic kidney disease are more likely to test positive. Similar papers with similar opinions in different perspectives are also present (Hendrie 2020; Kretchmer 2020; Ma et al. 2020; Prompetchara, Ketloy and Palaga 2020; Sarkodie and Owusu 2020; Saxena 2020).

If we examine the existing literature, we see that a broad-based global study to examine the reasons for mortality variation across countries is missing in the literature. Most of the existing studies are country based or area based. We want to fill out this gap in the literature by conducting a rigorous panel study on eight COVID-19 related variables from Our World in Data.

3. Data and Variables

Our World in Data is the most dependable and longest longitudinal data on COVID19. The daily data on COVID19 has been taken from https://ourworldindata.org/coronavirus (Roser et al. 2020). The data starts from 31 December 2019 till today on daily basis. The eight variables used in our study as of 22 May 2020 are: total_cases_per_million, new_cases_per_million, total_deaths_per_million, new_deaths_per_million, total_tests_per_thousand, new_tests_per_thousand, new_tests_smoothed_per_thousand, and stringency_index. The Stringency Index has been formed by taking the composite of nine indicators. The indicators include travel bans, school closures, workplace closures etc. and the scores are arranged in such a way that highest scores represent the most stringent condition in a scale of 0 to 100 (Roser et al. 2020). One dimension is country and we have 209 countries and the time series ranges from 31 December 2019 to 21 May 2020 on a daily basis (7-days a week format) for 143 days maximum. This is an unbalanced panel in the sense that for some countries the data range is shorter depending on different inception date for COVID19 in that particular country.

Table 1. Name of Countries (209)

Afghanistan	Czech Republic	Kosovo	Romania
Albania	Democratic Republic of Congo	Kuwait	Russia
Algeria	Denmark	Kyrgyzstan	Rwanda
Andorra	Djibouti	Laos	Saint Kitts and Nevis

Angola	Dominica	Latvia	Saint Lucia
Anguilla	Dominican Republic	Lebanon	Saint Vincent and the Grenadines
Antigua and Barbuda	Ecuador	Lesotho	San Marino
Argentina	Egypt	Liberia	Sao Tome and Principe
Armenia	El Salvador	Libya	Saudi Arabia
Aruba	Equatorial Guinea	Liechtenstein	Senegal
Anguilla	Eritrea	Lithuania	Serbia
Australia	Estonia	Luxembourg	Seychelles
Austria	Ethiopia	Macedonia	Sierra Leone
Azerbaijan	Faeroe Islands	Madagascar	Singapore
Bahamas	Falkland Islands	Malawi	Sint Maarten (Dutch part)
Bahrain	Fiji	Malaysia	Slovakia
Bangladesh	Finland	Maldives	Slovenia
Barbados	France	Mali	Somalia
Belarus	French Polynesia	Malta	South Africa
Belgium	Gabon	Mauritania	South Korea
Belize	Gambia	Mauritius	South Sudan
Benin	Georgia	Mexico	Sri Lanka
Bermuda	Germany	Moldova	Sudan
Bhutan	Ghana	Monaco	Suriname
Bolivia	Gibraltar	Mongolia	Swaziland
Bonaire Sint Eustatius and Saba	Greece	Montenegro	Sweden
Bosnia and Herzegovina	Greenland	Montserrat	Switzerland

Botswana	Grenada	Morocco	Syria
Brazil	Guam	Mozambique	Taiwan
British Virgin Islands	Guatemala	Myanmar	Tajikistan
Brunei	Guernsey	Namibia	Tanzania
Bulgaria	Guinea	Nepal	Thailand
Burkina Faso	Guinea-Bissau	Netherlands	Timor
Burundi	Guyana	New Caledonia	Togo
Cambodia	Haiti	New Zealand	Trinidad and Tobago
Cameroon	Honduras	Nicaragua	Tunisia
Canada	Hungary	Niger	Turkey
Cape Verde	Iceland	Nigeria	Turks and Caicos Islands
Cayman Islands	India	Northern Mariana Islands	Uganda
Central African Republic	Indonesia	Norway	Ukraine
Chad	Iran	Oman	United Arab Emirates
Chile	Iraq	Pakistan	United Kingdom
China	Ireland	Palestine	United States
Colombia	Isle of Man	Panama	United States Virgin Islands
Comoros	Israel	Papua New Guinea	Uruguay
Congo	Italy	Paraguay	Uzbekistan
Costa Rica	Jamaica	Peru	Vatican
Cote d'Ivoire	Japan	Philippines	Venezuela
Croatia	Jersey	Poland	Vietnam
Cuba	Jordan	Portugal	Western Sahara

Curacao	Kazakhstan	Puerto Rico	Yemen
Cyprus	Kenya	Qatar	Zambia
			Zimbabwe

Source: Our World in Data

Now we conduct a panel descriptive statistic to reveal the nature of center and spread of our selected eight variables. We preferred to use per capita variables to make the data comparable across countries and using this kind of selection minimizes size effect.

Table 2. Panel Descriptive Statistics (8 variables, 210 Countries, and 143 Days: 2019-12-31 to 2020-05-21)

SL	Variables		Mean	Std. Deviation	Min	Max	Observations
01	total_cases_per_million	Overall	475.5128	1412.512	0	19329.37	N=18491
		Between		1052.78	.467	9561.55	n=210
		Within		989.7426	-7849.943	13971.33	T-bar=88.0524
02	new_cases_per_million	Overall	13.14679	64.05808	-265.189	4944.376	N=18491
		Between		24.3602	.0144355	218.1342	n=210
		Within		59.45404	-388.1644	4739.389	T-bar=88.0524
03	total_deaths_per_million	Overall	20.82581	89.82145	0	1208.085	N=18491
		Between		51.23515	0	468.1278	n=210
		Within		69.54957	-447.302	760.783	T-bar=88.0524
04	new_deaths_per_million	Overall	.5912648	3.653557	0	200.04	N=18491
		Between		1.282015	0	9.566029	n=210

		Within		3.393244	-8.974764	197.3519	T-bar=88.0524
05	total_tests_per_thousand	Overall	.385204	.6116208	0	7.285	N=4416
		Between		.469094	.0060714	2.497327	n=75
		Within		.4019685	-1.976123	5.636975	T-bar=58.88
06	new_tests_per_thousand	Overall	8679.989	26885.11	0	366278	N=5380
		Between		21802.61	181.0566	165650.1	n=85
		Within		151185.54	-15.2999.1	209307.9	T-bar=63.2941
07	new_tests_smoothed_per_thousand	Overall	.350842	.5233376	0	4.993	N=5380
		Between		.40621	.0039444	2.181632	n = 85
		Within		.3247309	-1.70479	3.16221	T-bar= 63.2941
08	stringency_index	Overall	55.15624	35.58702	0	100	N = 14464
		Between		20.49114	6.660362	97.23046	n = 163
		Within		29.4741	-32.81831	110.1197	T-bar=88.736

Source: Own calculation from Our World in data

The list of countries indicates that the data set covers most of the countries from all the continents. If we observe the data closely, we can say that within variations are substantially higher than the between variation for five out of nine COVID-19 related variables. That means that the data set is suitable for time series analysis and we can also conduct panel studies by using the data. Univariate panel descriptive statistics is not enough in revealing the answer to our research questions. To do so let us examine the bivariate nature of our data.

Table 3. Bivariate Correlation Coefficients (8 Variables)

	Total_cases_per_million	New_cases_per_million	Total_deaths_per_million	New_deaths_per_million	Total_tests_per_thousand	New_test_per_thousand	New_tests_smoothed_per_thousand	Stringency_index
Total_cases_per_million	1.0000							
New_cases_per_million	**0.6127**	1.0000						
Total_deaths_per_million	**0.5947**	0.2196	1.0000					
New_deaths_per_million	0.3956	0.3542	**0.6710**	1.0000				
Total_tests_per_thousand	**0.6083**	**0.4713**	0.2649	0.1600	1.0000			
New_tests_per_thousand	0.2745	0.2071	0.3026	0.2211	0.1784	1.0000		
New_test_smoothed_per_thousand	**0.6750**	**0.4853**	0.2923	0.1684	0.9125	0.1849	1.0000	
Stringency_index	0.0826	0.1115	0.0785	0.1120	0.0820	0.0512	0.0870	1.0000

Source: Own calculation from Our World in data. P values for the null of no correlation coefficient is always 0.00. That means the coefficients are significant at 1% level.

From the table it is clear that total cases per million is strongly associated with new cases per million, total deaths per million, total tests per thousand and new test smoothed per thousand. Smoothed data are useful for taking care of missing values for some countries. New cases are also highly correlated with total tests per thousand and new test smoothed per thousand. That means both the identified cases are highly associated with tests. Total deaths per million are highly correlated with new deaths per million which is also a reasonable finding. None of the eight COVID-19 variables have any linear association with Government Stringency Index which is an alarming finding and it requires further investigation of the issue because all the Governments except very few are heavily engaged in fighting against this deadly virus through undertaking some stringency measures. Now let us examine the Granger Causality test and see if we get something special from this framework.

Now let us switch over to bivariate Granger Causality and multivariate Bayesian VAR analysis.

4. Granger Causality and Bayesian VAR Result

We start with bivariate Granger Causality Test.

Table 4. Panel Granger Causality Test (Sample: 12/31/2019-05/21/2020: Countries: 212, Lags: 7)

SL	Null Hypothesis:	Obs	F-Statistic	Prob.	Direction of Causality
1	**NEW_DEATHS_PER_MILLION does not Granger Cause NEW_CASES_PER_MILLION***	16873	36.368	0.00	Two-way
	NEW_CASES_PER_MILLION does not Granger Cause NEW_DEATHS_PER_MILLION*		31.5617	0.00	
2	NEW_TESTS_PER_THOUSAND does not Granger Cause NEW_CASES_PER_MILLION***	4515	3.10095	0.00	One-way
	NEW_CASES_PER_MILLION does not Granger Cause NEW_TESTS_PER_THOUSAND		0.32931	0.94	Insignificant
3	STRINGENCY_INDEX does not Granger Cause NEW_CASES_PER_MILLION***	12903	4.0175	0.00	One-way
	NEW_CASES_PER_MILLION does not Granger Cause STRINGENCY_INDEX		0.97199	0.45	Insignificant
4	TOTAL_CASES_PER_MILLION does not Granger Cause NEW_CASES_PER_MILLION	16873	NA	NA	
	NEW_CASES_PER_MILLION does not Granger Cause TOTAL_CASES_PER_MILLION		NA	NA	
5	**TOTAL_DEATHS_PER_MILLION does not Granger Cause NEW_CASES_PER_MILLION***	16873	35.8659	0.00	Two-way
	NEW_CASES_PER_MILLION does not Granger Cause TOTAL_DEATHS_PER_MILLION*		29.6973	0.00	
6	**TOTAL_TESTS_PER_THOUSAND does not Granger Cause NEW_CASES_PER_MILLION***	3253	11.6697	0.00	Two-way
	NEW_CASES_PER_MILLION does not Granger Cause TOTAL_TESTS_PER_THOUSAND*		6.02095	0.00	
7	NEW_TESTS_PER_THOUSAND does not Granger Cause NEW_DEATHS_PER_MILLION*	4515	1.77454	0.09	One-way
	NEW_DEATHS_PER_MILLION does not Granger Cause NEW_TESTS_PER_THOUSAND		1.38797	0.21	Insignificant
8	NEW_TESTS_SMOOTHED_PER_THOUSAND does not Granger Cause NEW_DEATHS_PER_MILLION***	4515	2.83655	0.01	One-way
	NEW_DEATHS_PER_MILLION does not Granger Cause NEW_TESTS_SMOOTHED_PER_THOUSAND		1.41862	0.19	Insignificant

09	STRINGENCY_INDEX does not Granger Cause NEW_DEATHS_PER_MILLION***	12903	2.69297	0.01	One-way
	NEW_DEATHS_PER_MILLION does not Granger Cause STRINGENCY_INDEX		0.31702	0.95	Insignificant
10	**TOTAL_CASES_PER_MILLION does not Granger Cause NEW_DEATHS_PER_MILLION*** **	16873	26.1114	0.00	Two-way
	NEW_DEATHS_PER_MILLION does not Granger Cause TOTAL_CASES_PER_MILLION* **		37.5031	0.00	
11	TOTAL_DEATHS_PER_MILLION does not Granger Cause NEW_DEATHS_PER_MILLION	16873	NA	NA	
	NEW_DEATHS_PER_MILLION does not Granger Cause TOTAL_DEATHS_PER_MILLION		NA	NA	
12	**TOTAL_TESTS_PER_THOUSAND does not Granger Cause NEW_DEATHS_PER_MILLION*** **	3253	2.75863	0.01	Two-way
	NEW_DEATHS_PER_MILLION does not Granger Cause TOTAL_TESTS_PER_THOUSAND* **		5.25749	0.00	
13	**NEW_TESTS_SMOOTHED_PER_THOUSAND does not Granger Cause NEW_TESTS_PER_THOUSAND*** **	4779	3.71751	0.00	Two-way
	NEW_TESTS_PER_THOUSAND does not Granger Cause NEW_TESTS_SMOOTHED_PER_THOUSAND* **		4.54179	0.00	
14	STRINGENCY_INDEX does not Granger Cause NEW_TESTS_PER_THOUSAND	4288	0.43986	0.88	Insignificant
	NEW_TESTS_PER_THOUSAND does not Granger Cause STRINGENCY_INDEX		0.24442	0.97	Insignificant
15	TOTAL_CASES_PER_MILLION does not Granger Cause NEW_TESTS_PER_THOUSAND	4515	0.99161	0.44	Insignificant
	NEW_TESTS_PER_THOUSAND does not Granger Cause TOTAL_CASES_PER_MILLION**		2.1214	0.04	One-way
17	TOTAL_DEATHS_PER_MILLION does not Granger Cause NEW_TESTS_PER_THOUSAND***	4515	3.33272	0.00	One-way
	NEW_TESTS_PER_THOUSAND does not Granger Cause TOTAL_DEATHS_PER_MILLION		1.71077	0.10	Insignificant
16	TOTAL_TESTS_PER_THOUSAND does not Granger Cause NEW_TESTS_PER_THOUSAND***	3158	6.8101	0.00	One-way
	NEW_TESTS_PER_THOUSAND does not Granger Cause TOTAL_TESTS_PER_THOUSAND		1.46909	0.17	Insignificant

17	STRINGENCY_INDEX does not Granger Cause NEW_TESTS_SMOOTHED_PER_THOUSAND	4288	1.06008	0.39	Insignificant
	NEW_TESTS_SMOOTHED_PER_THOUSAND does not Granger Cause STRINGENCY_INDEX		1.61249	0.13	Insignificant
18	**TOTAL_CASES_PER_MILLION does not Granger Cause NEW_TESTS_SMOOTHED_PER_THOUSAND*****	4515	7.75034	0.00	Two-way
	NEW_TESTS_SMOOTHED_PER_THOUSAND does not Granger Cause TOTAL_CASES_PER_MILLION***		10.1843	0.00	
19	TOTAL_DEATHS_PER_MILLION does not Granger Cause NEW_TESTS_SMOOTHED_PER_THOUSAND*	4515	1.80537	0.08	Insignificant
	NEW_TESTS_SMOOTHED_PER_THOUSAND does not Granger Cause TOTAL_DEATHS_PER_MILLION*		1.85662	0.07	Insignificant
20	**TOTAL_TESTS_PER_THOUSAND does not Granger Cause NEW_TESTS_SMOOTHED_PER_THOUSAND*****	3158	211.976	0.00	Two-way
	NEW_TESTS_SMOOTHED_PER_THOUSAND does not Granger Cause TOTAL_TESTS_PER_THOUSAND***		17.731	0.00	
21	TOTAL_CASES_PER_MILLION does not Granger Cause STRINGENCY_INDEX*	12903	1.95132	0.06	One-way
	STRINGENCY_INDEX does not Granger Cause TOTAL_CASES_PER_MILLION***		3.15574	0.00	One-way
22	TOTAL_DEATHS_PER_MILLION does not Granger Cause STRINGENCY_INDEX	12903	0.76163	0.62	Insignificant
	STRINGENCY_INDEX does not Granger Cause TOTAL_DEATHS_PER_MILLION***		2.64811	0.01	One-way
23	TOTAL_TESTS_PER_THOUSAND does not Granger Cause STRINGENCY_INDEX*	3032	1.77083	0.09	One-way
	STRINGENCY_INDEX does not Granger Cause TOTAL_TESTS_PER_THOUSAND		0.3983	0.90	Insignificant
24	**TOTAL_DEATHS_PER_MILLION does not Granger Cause TOTAL_CASES_PER_MILLION*****	16873	40.5886	0.00	Two-way
	TOTAL_CASES_PER_MILLION does not Granger Cause TOTAL_DEATHS_PER_MILLION***		25.2455	0.00	
25	**TOTAL_TESTS_PER_THOUSAND does not Granger Cause TOTAL_CASES_PER_MILLION*****	3253	9.4111	0.00	Two-way
	TOTAL_CASES_PER_MILLION does not Granger Cause TOTAL_TESTS_PER_THOUSAND***		5.77891	0.00	

26	**TOTAL_TESTS_PER_THOUSAND does not Granger Cause TOTAL_DEATHS_PER_MILLION*** **	3253	2.85017	0.01	Two-way
	TOTAL_DEATHS_PER_MILLION does not Granger Cause TOTAL_TESTS_PER_THOUSAND* **		5.41994	0.00	

Source: Own calculation, ***, *** and * represent 1%, 5%, and 10% level of significance respectively.

We have found strong two-way causality in eleven cases, twelve one-way causality and sixteen insignificant F-ratios. Now, let us explain them to get an overall idea and compare them with our earlier results. If we observe the result closely, we can find a common pattern. New Tests Per Thousand is the most significant determinant of Total Deaths Per Million. This also supports some other studies that tests different propositions of lockdown and transmission in the context of COVID19 with fewer number of 69 countries (Ullah and Ajala 2020). Stringency has not been found as significant again in explaining cases or transmission. Therefore, the conventional wisdom regarding the fight against COVID-19 also face some challenges of lack of evidence in the world. Then the question that is appearing is whether the virus dies out automatically after killing some innocent people in the world and causing devastation in Economics, Society and Politics. Disaggregate analysis must be conducted seriously to reveal the truth.[5]

Both the bivariate correlation result and Granger Causality Test result call for multivariate analysis, which does not require any theoretical structure. This can be done with the help of Vector Auto Regression (VAR) after examining the panel unit root test for non-stationarity (Asna-ashary et al. 2020). We have conducted seven types of panel unit root tests with intercept and found that the null hypothesis of unit root is rejected in around 50% of the cases all the time against the alternative of stationarity.[6] That's why we have three candidates for conducting VAR: Standard VAR, VEC and Bayesian VAR. We can either go for VEC if we consider the series as non-stationary and cointegrated. But we have chosen an alternative path. We checked and found that most of the series are first different stationary. That's why we use Bayesian VAR, which does not suffer from over parameterization like standard VAR but used all the series in their first difference form to take care of their non-stationary nature. There are some arguments as well as counter arguments regarding the stationarity issues in the context of Bayesian VAR. VAR techniques are useful in the situations when we are not quite sure about our dependent and

[5] We have conducted the same Granger Causality Test with 1, 2,3,4,5 and 6 lags to see if the result changes and we find that the result with 7 lags also hold true with other lower level of lag selection

[6] The results of panel unit root test are not presented but they are available upon request.

independent variables in this kind of complex disease, which mostly behaves randomly. With eight variables and so many lags it is highly likely that we suffer from over parameterization. Bayesian VAR minimizes this problem by assigning prior probabilities to parameters by considering all the parameters as random as opposed to regular VAR, which is based on deterministic parameter assumptions.

Table 5. Bayesian VAR Estimates

Equations	(1) D(NEW_CASES_PER_MILLION)	(2) D(NEW_DEATHS_PER_MILLION)	(3) D(NEW_TESTS_PER_THOUSAND)	(4) D(NEW_TESTS_SMOOTHED_PER_THOUSAND)	(5) D(STRINGENCY_INDEX)	(6) D(TOTAL_CASES_PER_MILLION)	(7) D(TOTAL_DEATHS_PER_MILLION)	(8) D(TOTAL_TESTS_PER_THOUSAND)
D(NEW_CASES_PER_MILLION(-1))	**-0.424406**	0.002226	-1.059598	-5.01E-05	0.004695	**-0.424407**	0.002226	**-0.001278**
	(0.01586)	(0.00123)	(1.41898)	(4.7E-05)	(0.00369)	**(0.01586)**	(0.00123)	**(0.00027)**
	[-26.7646]	[1.81644]	[-0.74673]	[-1.05384]	[1.27192]	**[-26.7647]**	[1.81650]	**[-4.80186]**
D(NEW_DEATHS_PER_MILLION(-1))	0.253203	**-0.370146**	8.724563	-0.000689	0.006788	0.253199	**-0.370135**	0.001760
	(0.20437)	**(0.01580)**	(18.2919)	(0.00061)	(0.04758)	(0.20437)	**(0.01580)**	(0.00343)
	[1.23894]	**[-23.4225]**	[0.47696]	[-1.12458]	[0.14267]	[1.23892]	**[-23.4227]**	[0.51294]
D(NEW_TESTS_PER_THOUSAND(-1))	0.000202	1.48E-06	**0.405870**	**-2.06E-06**	-1.68E-05	0.000202	1.49E-06	-3.36E-06
	(0.00018)	(1.4E-05)	**(0.01644)**	**(5.5E-07)**	(4.3E-05)	(0.00018)	(1.4E-05)	(3.1E-06)
	[1.10217]	[0.10417]	**[24.6900]**	**[-3.73931]**	[-0.39289]	[1.10217]	[0.10480]	[-1.09109]
D(NEW_TESTS_SMOOTHED_PER_THOUSAND(-1))	**28.53307**	-0.027833	-611.6704	**0.565657**	1.651934	**28.53305**	-0.027886	**-1.273972**
	(5.13913)	(0.39728)	(460.324)	**(0.01541)**	(1.19739)	**(5.13912)**	(0.39727)	**(0.08631)**
	[5.55213]	[-0.07006]	[-1.32878]	**[36.7123]**	[1.37961]	**[5.55212]**	[-0.07019]	**[-14.7598]**
D(STRINGENCY_INDEX(-1))	-0.011494	0.000627	-0.810443	0.000231	**0.081605**	-0.011497	0.000625	0.000277
	(0.07018)	(0.00543)	(6.28338)	(0.00021)	**(0.01635)**	(0.07018)	(0.00543)	(0.00118)

	[-0.16377]	[0.11548]	[-0.12898]	[1.09932]	**[4.99161]**	[-0.16381]	[0.11516]	[0.23535]
D(TOTAL_CASES_PER_MILLION(-1))	**-0.023871**	**0.002177**	**1.747815**	**9.35E-05**	-0.002118	**0.976129**	**0.002177**	**0.000482**
	(0.00698)	**(0.00054)**	**(0.61987)**	**(2.1E-05)**	(0.00161)	**(0.00698)**	**(0.00054)**	**(0.00012)**
	[-3.41775]	**[4.03279]**	**[2.81963]**	**[4.49025]**	[-1.31461]	**[139.759]**	**[4.03272]**	**[4.13171]**
D(TOTAL_DEATHS_PER_MILLION(-1))	-0.103866	**-0.078667**	**32.84254**	3.23E-05	-0.037175	-0.103867	0.921336	-0.000775
	(0.10217)	**(0.00790)**	**(9.07225)**	(0.00030)	(0.02358)	(0.10217)	(0.00790)	(0.00171)
	[-1.01655]	**[-9.95897]**	**[3.62011]**	[0.10596]	[-1.57634]	[-1.01657]	[116.643]	[-0.45386]
D(TOTAL_TESTS_PER_THOUSAND(-1))	**-2.665489**	-0.050518	-166.5874	**-0.012848**	0.211415	**-2.665383**	-0.050456	**-0.167728**
	(1.00747)	(0.07788)	(90.4011)	**(0.00302)**	(0.23519)	**(1.00747)**	(0.07788)	**(0.01694)**
	[-2.64571]	[-0.64864]	[-1.84276]	**[-4.24949]**	[0.89893]	**[-2.64561]**	[-0.64786]	**[-9.89962]**
C	0.861383	0.053317	129.0612	0.002205	0.361033	0.861377	0.053313	0.009986
	(0.30580)	(0.02364)	(27.0584)	(0.00091)	(0.07032)	(0.30580)	(0.02364)	(0.00510)
	[2.81681]	[2.25542]	[4.76973]	[2.42338]	[5.13436]	[2.81679]	[2.25532]	[1.95942]
R-squared	0.212391	0.200136	0.180213	0.317306	0.011881	0.877155	0.833085	0.131034
Adj. R-squared	0.210473	0.198188	0.178217	0.315644	0.009476	0.876856	0.832679	0.128919
Sum sq. resides	757919.2	4528.365	5.92E+09	6.701852	39975.70	757918.6	4528.032	210.1407
S.E. equation	15.18720	1.173916	1342.331	0.045161	3.487902	15.18719	1.173873	0.252884
F-statistic	110.7651	102.7745	90.29454	190.9107	4.938948	2932.905	2050.087	61.93841
Mean dependent	0.367304	0.016172	319.3511	0.008354	0.323445	21.64448	1.050124	0.005965
S.D. dependent	17.09206	1.310994	1480.748	0.054591	3.504546	43.27843	2.869760	0.270952

Source: Own calculation from Our World in Data

Sample (adjusted): 1/10/2020 5/20/2020

Included observations: 3295 after adjustments

Prior type: Litterman/Minnesota

Initial residual covariance: Full VAR

Hyper-parameters: Mu: 0, L1: 0.1, L2: 0.99, L3: 1

Standard errors in ( ) & t-statistics in [ ]

In the multivariate Bayesian VAR framework, we find that the result is mixed. D(New tests smoothed per thousand) (-1) has a strong positive impact on transmission of D(new of cases per million) (Equation 1) and D(TOTAL_CASES_PER_MILLION(-1)) significantly affect the number D(new_deaths_per_million) (Equation 2). D(New tests smoothed per thousand) (-1) also strongly affects D(Total_Deaths_Per_Million) (Equation 7). Stringency has no significant impact either on transmission of cases or death rates. That means the impact of testing is clear even in a multivariate set-up. However, it is not quite clear why stringency is not bringing out any good outcome. We have taken first difference of variables before including them into VAR to tackle the apparent non-staionarity that we found in Panel Unit Root Test. Now let us introduce some Impulse Response Analysis (IRA) to test the impact of innovation on different responses.

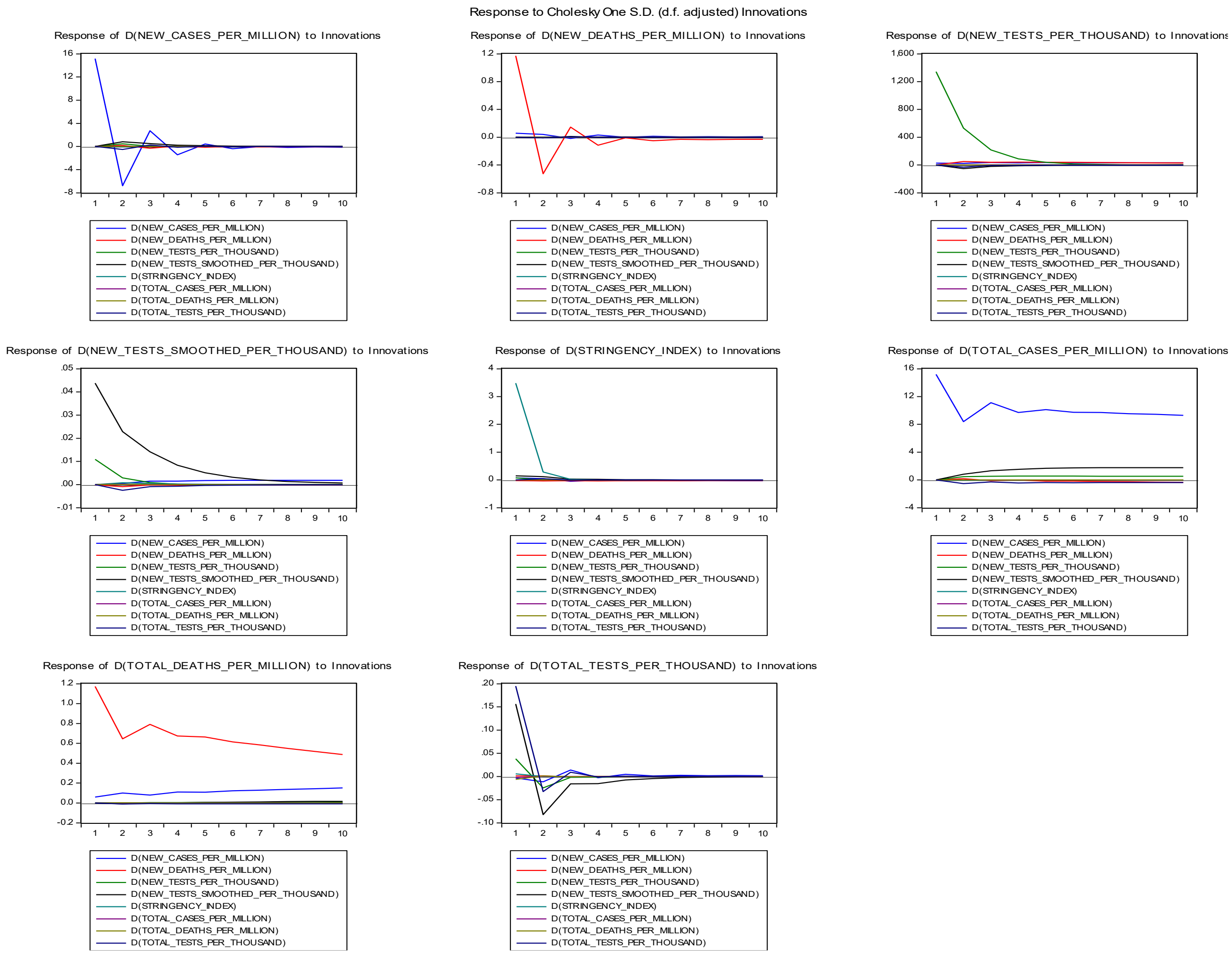

Figure 3. Impulse Response Functions

From IRA we find that D(New_Cases_Per_Million) and D(New_Deaths_Per_Million) satisfy the stable shocks in the sense that innovations lead to steady state very fast within 3rd lags. That indicates that new transmission and new deaths can be contained by taking appropriate Government action but not in the form of existing stringency measures which have not been found as very effective.

Now let us conduct some variance decomposition analysis in the context of Bayesian VAR to visualize the relative strength of each variable in determining other variables in the system as a percent of contribution out of 100%

Table 8. Variance Decomposition of Bayesian VAR (Stacked Graphs)

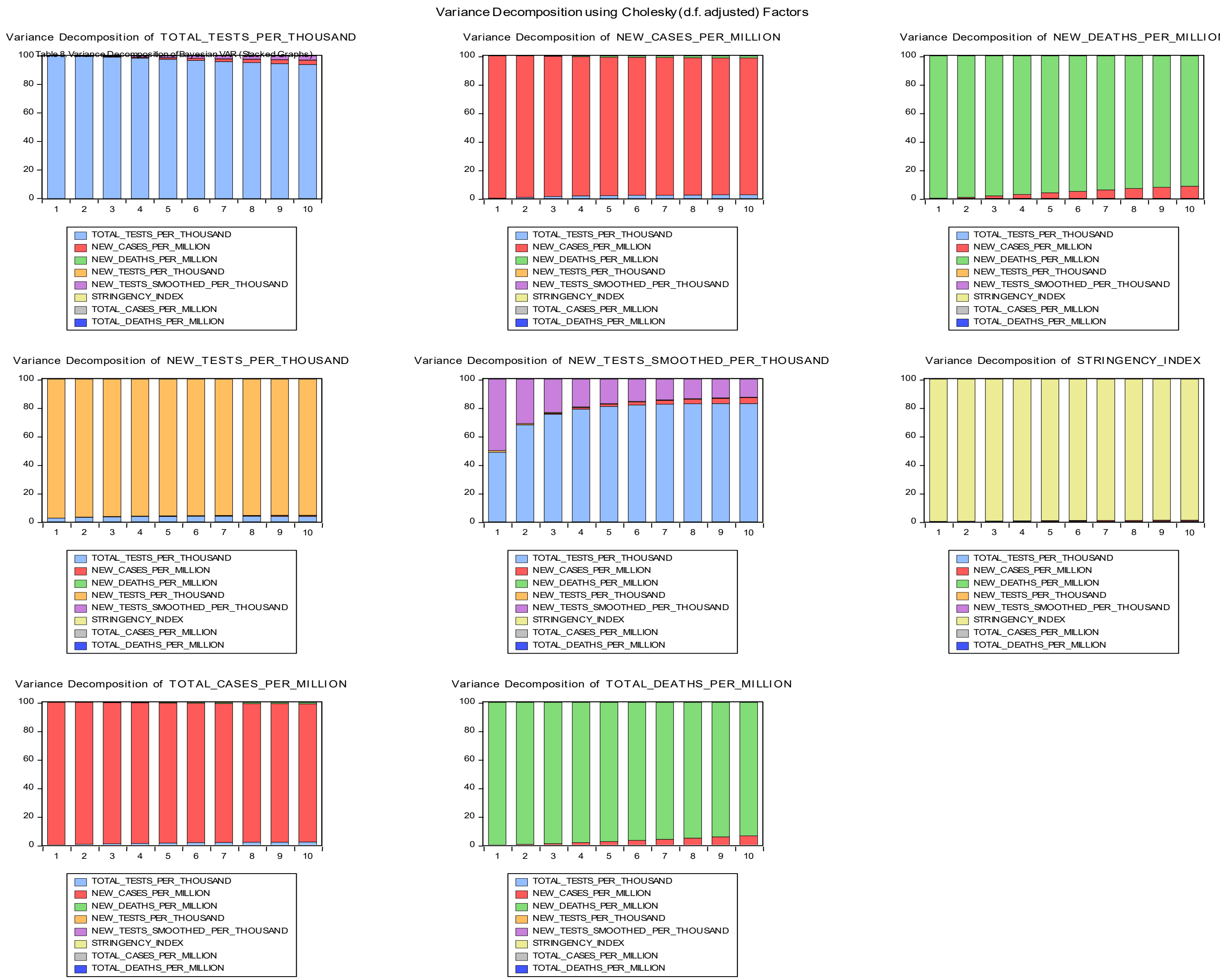

Figure 4. Variance Decomposition of Bayesian VAR for Selected 8 Variables (Stacked Graphs)

We have found the following stylized facts from the Variance Decomposition analysis:

- Only a small fraction of new cases per million is being explained by total tests per thousand.
- Only a small fraction of new_deaths_per_million is being explained by new_cases_per_million.
- That means that after controlling for all period effects of all the eight indicators new_tests_smoothed has some meager impact on news cases_per_million or transmission of COVID-19.
- Stringency is neither instrumental in determining mortality nor transmission of COVID-19 for 209 countries in a panel of 143 days during the virus pandemic.

Estimated VAR equation rather gives us better support to the conventional wisdom whereas IRA and variance decomposition do not reveal a stronger support to existing perceptions about COVID-19.

5. Conclusion and Policy Suggestion

COVID-19 death rate or fatality rate is a hot topic of research for all the major disciplines in the first quarter of 2020 in the wake of pandemic, which has far-reaching effect on society, economy, and politics of this globe. Researchers and policy makers are actively involved in finding out ways to contain the spread of this deadly virus. Countries with sufficient amount of surplus resources can afford increasing number of tests extensively to detect persons who are being confirmed as COVID-19 patients. That's why many countries are emphasizing on diverting resources in this direction so that they can detect COVID-19 patients and isolate them and find a way to help them recover from this disease quickly. World Health Organization, Johns Hopkins University, and European center for Disease Control publish data on COVID-19 on a daily basis. Our World in Data, an independent non-profit organization compiles a comprehensive data set by drawing data from all the sources and adding socio-economic variables with it for 209 countries in a panel framework where the daily data of eight variables are used in this study ranging from December 31, 2019 to May 21, 2020. This paper makes an attempt to examine the causality and dependence among eight variables from Our World in Data by using correlation analysis, Granger Causality Test and Bayesian VAR in panel framework and find that the conventional wisdom has been supported strongly in bivariate set up. The support gets weaker when we switch over to multivariate VAR analysis. Therefore, to reveal the real picture of COVID-19 and its widespread coverage we must concentrate more on tests and isolate the patients through physical distance in such a way that future infection can be contained. We should not be self-content by seeing the low death figures which might have been concealed due to our inability to test sufficiently. Home containment is necessary for containment of transmission of this virus but is not sufficient. We may actively seek medications and find out the right vaccine for it like what we did in the past for other diseases like cholera, smallpox, chicken pox or Spanish flu etc. It is hard to find the right mix of components in stringency, which is to be determined by each country separately considering its unique socio-economic structure. Economic capability is the prime determinant of many stringency. Many Government in the world cannot be that stringent even though they want to and it has the cost of increased death rate or transmission.

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