The impacts of COVID-19 measures on global environment and fertility rate: double coincidence

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Abstract

The study aims to examine the effects of coronavirus disease-2019 (COVID-19) measures on global environment and fertility rate by using the data of 1980 to 2019. The results show that communicable diseases including COVID-19 measures decrease carbon emissions and increase the chances of fertility rates in an account of city-wide lockdown. The knowledge spillover substantially decreases carbon emissions, while high energy demand increases carbon emissions. Poverty incidence increases fertility rate in the short-run; however, in the long-run, the result only supported with vulnerable employment and food prices that lead to increase fertility rates worldwide. The study concludes that besides some high negative externalities associated with COVID-19 pandemic in the form of increasing death tolls and rising healthcare costs, the global world should have to know how to direct high mass carbon emissions and population growth through acceptance of preventive measures, which would be helpful to contain coronavirus pandemic at a global scale.

Keywords COVID-19 · Carbon emissions · Fertility rate · Knowledge spillover · Energy demand · World aggregated data

Introduction

In a recent wave, when the novel coronavirus spreading all across the globe, the global unified policies have been prepared to minimize human and economic sufferings to reduce susceptible coronavirus cases and economic crisis (Hiscott et al. 2020). The social sustainability plan also encouraging for sustained long-term growth (Awan et al. 2020a). The COVID-19 measures on environmental changes are although positive in the short-run; however, it is likelihood to exacerbate it in the long-run when economic activities began after pandemic control (Zambrano-

Monserrate et al. 2020; Lu et al. 2020). Biomedical waste generation, soil, and water pollution increased many times with increase coronavirus disease. The safe disposal of biomedical waste and environmental resources are important for patients' safety and medical treatment (Ranjan et al. 2020; Zambrano-Monserrate et al. 2020). Mitra et al. (2020) considered a case study of Indian state Kolkata and evaluated the intercity carbon emission level before and after COVID-19 pandemic and found the significant variations between the two periods. During a pandemic, the closures of business activities in a city substantially decrease carbon emissions level in a city.

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Although the effect is temporary, however during a pandemic, the residents of Indian state inhale fresh air. Liu et al. (2020) considered a mainland of China economy as a reference study and evaluated the air quality index during from January to March 2020, and found significant variations of air quality level amid in February and March compared with January 2020 during COVID-19 pandemic. The fear of the spread of coronavirus pandemic restrains all economic activities that affect people's daily life through the lockdown. The quarantine policies have been implemented in order to control coronavirus pandemic countrywide; on the other side, the air quality index improved during the period because of closures of non-essential industries and travel and transportation restrictions to manage physical distancing. The study emphasized the need to devise more strategic economic and environmental policies to control coronavirus pandemic through smart lockdown that ultimately affect air quality index of the country. Chakraborty and Maity (2020) described the environmental situation of the world economy during coronavirus pandemic and argued that every nation of the world strive hard to decrease and controlled coronavirus pandemic through different strategies, including closures of non-essential industries that led to decrease the strain on the natural environment through less industrial waste; further due to complete restrictions on travel and transportation, road vehicles almost produce zero GHG emissions. The less energy demand in industries and lower fossil fuel combustion further decreases pollution strain from the environment that greatly recovered ecosystem. The pandemic, where it has some negative social and economic effects, has however some positive effects in the form of clean air and pollution-free environment across countries. Thus, the need for sustainable economic policies is desirable to contained coronavirus pandemic for long-term growth. Aletta and Osborn (2020) confined their findings on human health and environment during COVID-19 measures and found that environmental stressors are largely responsible to decrease community health, while during a pandemic, the environmental stressors become insensitive due to nationwide lockdown, which led to improving community health that earlier suffered from high carbon emissions. Thus, the positive health outcomes pertaining to low environmental emissions improve the quality of life of the peoples that help to improve human immunity to resist the virus. Sanità di Toppi et al. (2020) postulated the positive correlation between airborne particulate matter and novel coronavirus, as it could be possible while coronavirus spread in the air for some time; it remains active from some hours to several days that can be possible to adsorb in the atmospheric particulate matter that carries virus into the human stream. Sheykhi (2020) discussed the possible consequences of coronavirus pandemic all across the globe and argued that coronavirus pandemic may increase social disorder among the imprisoned peoples in home isolation due to lockdown, while many of them would likely to escape out due to fear of coronavirus to migrate to other countries, where they feel somehow secure and may able

to earn for living. The poor countries have low adaptability and less rehabilitation state; thus, it would become more chances the people migrate from their countries to the more developed country to escape out of the virus. Finally, the child labor could be emerged due to low opportunity of work for the adults' employment. The sociological dimensions of pandemic need to be reassessed to overcome the negative externalities emerged from the pandemic across countries. Selby and Kagawa (2020) concluded that the last year 2019 was declared for climate emergency that affected every 10th person on the planet, while in the late December and early January 2020, the year was declared by coronavirus emergency that is more disastrous with any other emergency led by the world in the preceding years. The need for quick precautionary measures and unified global healthcare policy would be helpful to reduce the vulnerability of coronavirus pandemic across the globe. Jones et al. (2020) discussed the multifaceted challenges that faced rural Australia in a given time, which includes the health impact of bushfires and coronavirus pandemic. Both are associated with a high risk of respiratory problems, while bushfires caused negative healthcare effects due to toxic smokes spread across it while coronavirus transmitted from close contacts between the community members. The rural communities already suffered from lack of basic amenities, comorbidities, and aging population, which turned into high mental disorders. The need to resolve both the issues are timely with sustainable policies. Lippi et al. (2020) considered a case study of Italy and found a significant variation between COVID-19 registered cases and environmental pollution. The greater need of preventive measures is required in a way to mitigate environmental pollution and controlled coronavirus pandemic in a country.

The above-stated discussion leads to the following research objectives of the study, i.e.,

- (i). To analyze the impacts of COVID-19 measures in improving air quality level and fertility rates at a global scale;
- (ii). To examine the role of knowledge spillovers, energy demand, and population density on environmental pollution across countries; and
- (iii). To determine the effects of food production, food prices, vulnerable employment, and poverty headcount on fertility rates at a global scale.

These stated objectives have been achieved by using time series cointegration technique in order to get parameter estimates for robust policy inferences.

Data and methodology

The study used the following COVID-19 measures that resulting impact on global environment and fertility rates.

Environmental pollution It is well documented that environmental pollution exceeds its level due to massive industrialization that makes the world warmer and it leads to negative health outcomes. The global unified measures for controlling COVID-19 pandemic somehow reduce high mass carbon emissions due to nationwide lockdowns in businesses and industries (Gautam 2020). The global pandemic started from late December 2019, and in the very early stages it has been identified that it is a transmitted disease that spread through close contacts, thus the globalized world manically decided to closures all economic activities including businesses and industries. The impacts of COVID-19 measures seem good enough to confine this pandemic on the cost of economic activities; however, human health is important from all, and it seems a good decisive policy to escape out from the virus. The closure of economic and business activities reduces the stock of carbon emissions, and the world is breathing in a fresh air that improves humans' immunity against the viruses and humans get to feel healthy and strong. Thus, the given study transformed carbon emission data in a way to analyze the impacts of COVID-19 measures on environmental quality by assuming a quarter of the carbon (denoted by CO₂ measured as a metric tons per capita) emission reduces because of confined measures of this pandemic.

Fertility rate The different family planning measures were adopted by the developed and developing countries in order to reduce total fertility rate, which somehow achieved by improving through women's education. It is very early to say that the COVID-19 measures increase fertility rate, as we observed that the male/female partners were over occupied in their job affairs and was busy in making money that given less time to think to increase their family size. Thus, because of nationwide lockdown and business closures, the family inside resumed in their homes and have a good time to spend together, which have a high likelihood to plan their family to wish by some new baby entrant in the family circle. The study transformed a data of fertility rate (denoted by FRATE measured as births per woman) by assuming a quarter-time increases the probability to think for a new baby in their family.

Knowledge spillover The knowledge spillover (denoted by KSO) is considered the best strategy to confined COVID-19 pandemic through knowledge diffusion among the masses by increasing education expenditures. There is a high need to know about the prevention measures against coronavirus pandemic, which is the only way to escape out of the virus. The international agencies and nationwide strategies have been made in this regard, and using social media, print media, and other social networking sites to spread the awareness campaigns to restrain the pandemic. The study used data of education expenditures measured by the percentage of GNI to assess knowledge spillover across the globe.

Energy demand Energy demand is considered one of the vital components of economic growth to perform economic functions through balancing energy supply and demand. The high consumption of electric power in households and business enterprises increases their demand enormously, which leads to serious environmental concerns. The COVID-19 measures further escalate the energy demand in the healthcare sector especially to regulate their healthcare issues. The study used electric power consumption (denoted by EPC measured as kilowatt hour per capita) in carbon emissions modeling to analyze its environmental effects that are pertaining to COVID-19 measures across the globe.

Economic crisis After the global financial crisis, the world economy faced new challenges pertaining to COVID-19 measures that have been converted into an economic crisis because of nationwide closures of economic activities. The significant dropdown in the world GDP is evident in a given scenario, which attempts to be financed by initiating some global packages. The study used the data of GDP per capita to assess economic crisis (denoted by ECR measured as constant 2010 US\$) because of COVID-19 measures across the globe.

Population density The high concern of the globalized world on population compactness is the provision of a transmission channel of spreading coronavirus pandemic. The high population density has a dual effect on the economy; i.e., it deteriorates the environment through sanitation issues, while due to close contacts between the populations, the transmitted diseases easily find a carrier to grow. The study used the data of population density (denoted by PDEN measured as people per square kilometer of land area) to assess its impact on carbon emissions under COVID-19 measures.

Food consumption The COVID-19 measures increase the demand for foodstuffs, as there are many reasons, which is not limited by the following; i.e., pandemic increases the stress level among the residents that may increase the intensity of food consumption; mass panic in community members regarding food shortages lead to increase in food storage for consumption; and leisure persons could get more food demand to remains busy in a day. Thus, the study used food production index (denoted by FPI) to assess the dietary habits of the population during remains reside in their homes in isolation.

Changes in food prices The COVID-19 measures create haphazard situations in many of the world counterparts that turned into increasing the storage of food for consumption, which leads to an increase in food prices across countries. The study used the consumer price index as a substitute for measuring changes in food prices (denoted by FPRICE, measured as %) under fertility model.

Vulnerable employment The family-owned businesses largely influenced with COVID-19 measures that turned into vulnerable employment. This is a likelihood that its effect will turned into increasing family size. The study used data of vulnerable employment (denoted by VEMP measured as % of total employment) in fertility modeling.

Poverty incidence Beside other sufferings attached by COVID-19 measures, the foremost impacts of COVID-19 measures are increasing the global poverty risk. The poor income group is largely not found an escape from pandemic due to low healthcare spending, lack of knowledge, inadequate basic sanitation facilities, low income, etc.; it is all lead to increasing poor sufferings across the globe. Further, poverty leads to increase more fertility rate as they remain available at their homes and they have less income and inadequate knowledge about contraceptives. The data of poverty headcount (denoted by POVHCR, measured as %) are used in this regard to assess its role in increasing fertility rate across countries.

Communicable diseases (including COVID-19) The transmitted diseases are highly infectious, and they lead to death worldwide (Contini and Costabile 2020). The COVID-19 is a deadly infectious disease that transmitted from one person to another through close contacts, touching, sneezing, talking, etc., while its remedial measures include physical distancing, avoid massive gatherings, used hand sanitizers, preventive masks, and self-quarantine. The study used data of “causes of death by communicable diseases” (denoted by COMMDIS, measures as % of total deaths), and its effect is discussed under the light of coronavirus pandemic across countries.

The data of the following variables have been borrowed from the World Bank (2020) database. The aggregate measures of world data are used for a period of 1980–2019. The stated discussion comes to form the following equations for empirical analysis, i.e.,

Model I: COVID-19 measures and carbon emissions

$$CO_2 = \beta_0 + \beta_1 COMDIS + \beta_2 KSO + \beta_3 EPC + \beta_4 ECR + \beta_5 PDEN + \varepsilon \quad (1)$$

Model II: COVID-19 measures and fertility rates

$$FR = \beta_0 + \beta_1 COMDIS + \beta_2 FPI + \beta_3 FPRICE + \beta_4 VEMP + \beta_5 POVHCR + \varepsilon \quad (2)$$

where CO_2 shows carbon emissions, COMDIS shows communicable diseases, KSO shows knowledge spillover, EPC

shows electric power consumption, ECR shows economic crisis, PDEN shows population density, FR shows fertility rate, FPI shows food production index, FINF shows food inflation, VEMP shows vulnerable employments, and POVHCR shows poverty headcount ratio.

The stated research objectives required substantial empirical investigation worldwide; thus, the study employed time series cointegration technique, i.e., ARDL-Bounds testing approach, which gives short- and long-run parameter estimates that are helpful for making sound policies (Pesaran et al. 2001). Fig. 1 shows the flow chart to bring more clarity in understanding the research methodology of the study.

Figure 1 shows the methodological flow chart, as it started from performing unit root test and if the order of integration of the variables are mixed than the estimation procedure is going to adopt ARDL-Bounds cointegration technique, followed by innovation accounting matrix, while if the variables are integrated at either order 1 or order 0, than the estimation procedure is using for either Johansen cointegration technique or simple ordinary least square (OLS) regression respectively, followed by Granger causality test.

Results and discussion

The descriptive statistics is presented in supplementary Table S1 for ready reference. Table 1 shows the unit root estimates and found that carbon emissions, communicable diseases, economic growth, electric power consumption, food production index, and poverty headcount ratio are first differenced stationary, as at level, these variables are not fall in the critical zone of 5% level of significance; however, by taking their first differences, the variables become significant; hence, the order of integration of the stated variables is one, i.e., $I(1)$ variables. The remaining variables, including fertility rate, food prices, knowledge spillover, and vulnerable employment are level stationary, as these variables are fall in the critical zone of 5% level of significance; hence, the order of integration is zero, i.e., $I(0)$ variables. The unit root estimates show the mixture of order of integration of the candidate variables; thus, it is highly likely to used such a time series cointegration technique that included both the $I(1)$ and $I(0)$ variables and examined the cointegration process between the stated variables. The ARDL-Bounds testing approach served the stated purpose and provides a good rationale to used this technique to handle both the $I(1)$ and $I(0)$ variables to form short- and long-run parameter estimates in a given time period.

Before proceeding to ARDL-Bounds testing approach for parameter estimates, the study evaluated cointegration test by using different regressors as the response variable at different lag length and imposed restrictions to verify alternative hypothesis against the null hypothesis of no cointegration by

Fig. 1 Research methodology flow chart

Wald F statistics. The estimates of ARDL cointegration test are presented in supplementary Table S2 for ready reference. Table 2 shows the ARDL-Bounds testing estimates for carbon emission model (Model I) for ready reference.

The results show that in the short-run and long-run, communicable diseases have a negative relationship with carbon emissions with an elasticity estimates of -0.146 , $p < 0.000$ (short-run estimates) and -0.108 , $p < 0.000$ (long-run estimates). The result implies that COVID-19 measures largely support air quality index at a global scale. The role of initial knowledge spillover in mitigating carbon emissions is evident in the given data set in the short-run; however, in the long-run, the relationship becomes averted and shows a direct relationship between the two stated factors under COVID-19 measures. It seems true that knowledge spillover substantially important to reduce the intensity of coronavirus pandemic through social media awareness campaigns and word-of-

mouth that further support to the global carbon emission reduction in the short-run, while in the long-run, knowledge transfer unfavorably causes air pollution among the countries. The direct relationship found between electric power consumption and carbon emissions, on one hand, while on the other energy crisis led to cause more carbon pollution during coronavirus pandemic. The results imply the upsurge of electric power consumption during coronavirus pandemic in healthcare and household sector, while going down economic and business activities led to increasing financial crunch cause of serious environmental destruction across the globe (Awan et al. 2020b). The overall results conclude that during COVID-19 measures, the closures of non-essential industries and businesses substantially reduce carbon emissions that tend to improve global air quality index. The number of existing studies supports the given result in the different economic and environmental settings, for instance, Sharma et al. (2020),

Table 1 Estimates of unit root test

Variables	Level		First difference	
	Constant	Constant + Trend	Constant	Constant + Trend
CO2	−0.534 (0.873)	−1.807 (0.681)	−4.481 (0.001)	−4.332 (0.007)
FR	−5.205 (0.000)	−1.307 (0.851)	−1.440 (0.551)	−5.048 (0.001)
COMDIS	−0.402 (0.898)	−2.401 (0.373)	−6.337 (0.000)	−6.306 (0.000)
ECR	1.395 (0.998)	−2.403 (0.372)	−4.819 (0.000)	−4.392 (0.001)
EPC	−0.723 (0.828)	−1.881 (0.645)	−5.637 (0.000)	−5.619 (0.000)
FPI	−0.397 (0.899)	−1.130 (0.910)	−4.572 (0.000)	−4.505 (0.004)
FPRICE	−2.440 (0.136)	−3.454 (0.058)	−5.902 (0.000)	−5.894 (0.000)
KSO	−2.699 (0.083)	−3.626 (0.041)	−5.774 (0.000)	−5.418 (0.000)
PDEN	−1.882 (0.336)	−0.199 (0.990)	−0.506 (0.879)	−0.770 (0.959)
POVHCR ^a	0.947 (0.995)	−1.424 (0.837)	−6.439 (0.000)	−7.136 (0.000)
VEMP	−3.364 (0.019)	−1.778 (0.695)	−2.030 (0.273)	−2.493 (0.325)

^a Phillips Perron unit root estimates. Small bracket shows probability values

Table 2 ARDL-Bounds testing estimates for model I

Variables	Coefficient	Std. error	<i>t</i> statistic	Prob.
$\Delta \ln(\text{CO}_2)_{t-1}$	0.134	0.106	1.261	0.231
$\Delta \ln(\text{CO}_2)_{t-2}$	0.585	0.115	5.065	0.000
$\Delta \ln(\text{CO}_2)_{t-3}$	0.504	0.130	3.873	0.002
$\Delta \ln(\text{COMDIS})_t$	−0.146	0.030	−4.800	0.000
$\Delta \ln(\text{COMDIS})_{t-1}$	0.025	0.026	0.958	0.356
$\Delta \ln(\text{KSO})_t$	−0.012	0.030	−0.406	0.691
$\Delta \ln(\text{KSO})_{t-1}$	−0.196	0.039	−4.984	0.000
$\Delta \ln(\text{KSO})_{t-2}$	−0.085	0.033	−2.582	0.024
$\Delta \ln(\text{KSO})_{t-3}$	−0.096	0.032	−2.985	0.011
$\Delta \ln(\text{EPC})_t$	0.199	0.056	3.510	0.004
$\Delta \ln(\text{ECR})_t$	0.323	0.113	2.861	0.014
$\Delta \ln(\text{ECR})_{t-1}$	−0.069	0.197	−0.354	0.729
$\Delta \ln(\text{ECR})_{t-2}$	−0.016	0.189	−0.086	0.932
$\Delta \ln(\text{ECR})_{t-3}$	−0.802	0.184	−4.349	0.000
$\Delta \ln(\text{PDEN})_t$	0.628	0.590	1.063	0.308
$\Delta \ln(\text{PDEN})_{t-1}$	−15.419	8.464	−1.821	0.093
$\Delta \ln(\text{PDEN})_{t-2}$	34.830	8.847	3.936	0.002
$\Delta \ln(\text{PDEN})_{t-3}$	−11.568	4.492	−2.575	0.024
CointEq_{t-1}	−1.070	0.127	−8.397	0.000
Long-run coefficients				
$\ln(\text{COMDIS})_t$	−0.108	0.023	−4.590	0.000
$\ln(\text{KSO})_t$	0.459	0.051	8.872	0.000
$\ln(\text{EPC})_t$	0.186	0.048	3.874	0.002
$\ln(\text{ECR})_t$	1.201	0.081	14.794	0.000
$\ln(\text{PDEN})_t$	−0.808	0.122	−6.594	0.000
<i>C</i>	−8.277	0.524	−15.792	0.000
Diagnostic tests				
Wald <i>F</i> statistics	9.327*	J.B Test	1.529	Prob. value: 0.465
Breusch–Godfrey serial correlation LM test			1.165	Prob. value: 0.303
Heteroskedasticity test: Breusch–Pagan–Godfrey			0.659	Prob. value: 0.811
Ramsey RESET test: <i>t</i> statistics			1.566	Prob. value: 0.145

$\ln(\text{CO}_2)$ is the dependent variable. The asterisk indicates 99% significance level

Fareed et al. (2020), and Bherwani et al. (2020). These studies largely supported the co-movement of coronavirus pandemic and environmental sustainability that is attained through COVID-19 measures, including countrywide lockdown and strict quarantine measures. These measures substantially improve the air quality index in the form of reduction of global carbon emissions. Despite its importance in environmental benefits, the substantial reduction of economic production decreases energy demand that positively affects on co-movement of COVID-19 measures and clean air. Although this impact is visible in the short-run, however in the forthcoming days when the nation goes for smart lockdown and allows industries to become operational, the effect of environmental benefits would go down, due to increasing global energy demand. The need for sustainable long-term policies would largely support the health and wealth of the nations.

The few more support for knowledge spillover during coronavirus pandemic exhibits by the earlier studies, for instance, Almutairi et al. (2015), Zhou et al. (2020), and Geldsetzer (2020). These studies exclusively discussed the role of knowledge spillover in the health sector by assessing through general survey, telehealth survey, and social media penetration for health communication across the globe. The variance decomposition analysis (VDA) for Model I is presented in supplementary Fig. S1 for ready reference. Table 3 shows the ARDL-Bounds test estimates for fertility model (Model II).

The results show that in the short-run, communicable diseases increase fertility rate with an estimated elasticity value of 0.018, $p < 0.090$. The result implies that COVID-19 measures seem increases the decision of newborn baby in the family circle, as closures of industrial and business allow work at home activities during coronavirus pandemic, which give

Table 3 ARDL-Bounds testing estimates: Model II

Variables	Coefficient	Std. error	<i>t</i> statistic	Prob.
$\Delta \ln(\text{FR})_{t-1}$	0.583	0.188	3.094	0.007
$\Delta \ln(\text{FR})_{t-2}$	0.770	0.260	2.957	0.010
$\Delta \ln(\text{COMDIS})_t$	0.018	0.009	1.907	0.077
$\Delta \ln(\text{COMDIS})_{t-1}$	0.017	0.014	1.183	0.256
$\Delta \ln(\text{COMDIS})_{t-2}$	-0.014	0.009	-1.558	0.141
$\Delta \ln(\text{FPI})_t$	-0.079	0.042	-1.856	0.084
$\Delta \ln(\text{FPI})_{t-1}$	-0.024	0.030	-0.820	0.425
$\Delta \ln(\text{FPI})_{t-2}$	-0.013	0.031	-0.437	0.668
$\Delta \ln(\text{FPRICE})_t$	0.0007	0.001	0.483	0.636
$\Delta \ln(\text{FPRICE})_{t-1}$	-0.0065	0.001	-3.414	0.004
$\Delta \ln(\text{FPRICE})_{t-2}$	-0.003	0.001	-1.878	0.081
$\Delta \ln(\text{VEMP})_t$	-0.769	0.221	-3.468	0.003
$\Delta \ln(\text{VEMP})_{t-1}$	-0.026	0.369	-0.070	0.944
$\Delta \ln(\text{VEMP})_{t-2}$	0.234	0.216	1.082	0.297
$\Delta \ln(\text{POVHCR})_t$	0.122	0.035	3.491	0.003
$\Delta \ln(\text{POVHCR})_{t-1}$	0.047	0.032	1.446	0.170
$\Delta \ln(\text{POVHCR})_{t-2}$	0.139	0.027	5.146	0.000
CointEq _{<i>t-1</i>}	-0.117	0.053	-2.212	0.044
Long-run coefficients				
$\ln(\text{COMDIS})_t$	-0.243457	0.138314	-1.760178	0.1002
$\ln(\text{FPI})_t$	-0.349750	0.092775	-3.769899	0.0021
$\ln(\text{FPRICE})_t$	0.114237	0.050166	2.277183	0.0390
$\ln(\text{VEMP})_t$	1.494382	0.244641	6.108473	0.0000
$\ln(\text{POVHCR})_t$	-0.614636	0.211730	-2.902929	0.0116
Diagnostic tests				
Wald <i>F</i> statistics	5.375*	J.B Test	0.182	Prob. value:0.912
Heteroskedasticity test: Breusch–Pagan–Godfrey			0.188	Prob. value: 0.999
Ramsey RESET test: <i>t</i> statistic			0.645	Prob. value: 0.529

Dependent variable is $\ln(\text{FR})$. The asterisk indicates 99% significance level

more likely to increase the fertility rate at global scale. The few other factors affect fertility rate decisions in a given circumstance, including food production, food prices, vulnerable employment, and poverty headcount. These factors have a differential impact on the global fertility rate; i.e., food production decreases fertility rate in the short-run while increases in the long-run, lagged food prices decrease fertility rate in the short-run while increases in the long-run, vulnerable employment increases fertility rate in the long-run, and poverty headcount increases fertility rate in the short-run, while it decreases in the long-run. The number of previous studies shows that COVID-19 equally threatened to the pregnant women and affected in different trimesters, for instance, Schwartz (2020), Breslin et al. (2020), and Zhang et al. (2020). These studies emphasized the need of special care of woman in pregnancy and give some preventive measures to minimize case fatality ratio. The literature is widely available on poverty incidence and fertility rates across developed and developing countries;

for instance, Schoumaker (2004) confirmed the stated relationship is selecting 25 countries of Sub-Saharan Africa, Mohanty and Ram (2011) found in India, Odwe (2015) confirmed this relationship in Kenya, and Wietzke (2020) found this relationship in a large panel of 140 countries. These studies largely confined their findings under different socio-economic factors. The fertility rate subject to price changes is largely discussed in the previous studies in different economic setting; i.e., Yi and Zhang (2010) shows a negative relationship between the stated factors in the context of Hong Kong, Adsera and Menendez (2011) concluded that fertility rate decreases during economic downhill in 18 countries case study, He (2018) confirmed this relationship in 12 advanced countries Under Schumpeterian growth model, and Iwasaki and Kumo (2020) argued that continued economic growth, favorable labor market conditions, ease of doing local businesses, improved education and social infrastructure, and moderate prices tend to increase fertility rate while large

migration flow, high incidence of poverty, and environmental associated health risks decrease the fertility rate in Russia, etc. These studies confirmed that under isolation in two factors could not yield robust inferences, while it is affiliated with a different facet of socio-economic and environmental factors that affect the decision of childbearing across countries. The VDA for Model II is presented in supplementary Fig. S2 for ready reference.

Conclusions and policy implications

The study examined the impacts of COVID-19 measures on environment and fertility rate by using the world aggregated data of the last 4 decades from 1980 to 2019. The results of the study supported the model-related assumptions and variations therein; for instance, the results confirmed that COVID-19 measures substantially decrease carbon emissions due to nationwide industry lockdown, while knowledge spillover helpful to minimize the spread of coronavirus pandemic through word-of-mouth campaigns. Further, the novel coronavirus leads to increase global depression via decreasing country's per capita income growth rate. The higher energy demand and population compactness lead to increase carbon emissions across countries. The chances of increasing fertility rates during COVID-19 are well evident in the study; finally, the vulnerable employment and poverty headcount ratio likely to increase fertility rates across countries. The results overall conclude that communicable diseases including COVID-19 measures substantially decrease carbon emissions and increase fertility rate due to citywide lockdown.

The impacts of COVID-19 measures are largely supported to restrain the susceptible cases of coronavirus, which further improving environmental quality and increasing the likelihood of fertility rates across countries. We should have to learn the lesson from the pandemic that decreases massive carbon emissions through closures of non-essential industrial productions. There is a high need to identify and culminate non-essential industries and rely on imports rather than imports substitute, which ultimately would release less carbon emissions in the atmosphere. Further, the need for green waste recycling units (Klemeš et al. 2020), sustainable supply and production (Sarkis et al. 2020), efficient carbon pricing (Burke and Bowen 2020), and sanitized practices (Bagnera and Steinberg 2020) is deemed desirable to support sustainable environmental agenda across the globe. The food shortage challenges are enormous that is associated with food production and its prices, which need careful monitoring and strategic policies to limit population growth through family planning during the pandemic and its aftershocks (Riley et al. 2020; Reshadat et al. 2018). The knowledge spillover for healthcare measures can be used as a strategic tool to widen preventive measures against coronavirus pandemic and its

transmission source through social media campaigns and print media. The factual-based statements and strong conviction to reduce coronavirus pandemic give strategic wisdom to support healthcare infrastructure. The need for electronic networking along with social networking is highly desirable to reduce susceptible coronavirus cases and mortality rates (Chan et al. 2020). The surge of electric power demand in the healthcare sector is deemed desirable that need efficient planning to provide free flow of electric supply and balanced energy demand and supply gap by utilizing other renewable energy sources. It would be helpful to mitigate negative environmental concerns while it uplifts economic activities to reduce pandemic intensity across the globe (Hosseini 2020).

The financial market is largely affected due to closures of industries and businesses in prevention to reduce coronavirus pandemic. Although every government is subsidized financial sector by certain expansionary reforms, however, the global financial index shows negative growth trends, which leads to cause a novel global depression. The easy access to credit, loan installments, simple scheduling to return the loan, charging low-interest rate, low bank discount rate, credit creation facility, and open market operations are few of the exemplary instruments to support economic activities. The need for mobilizing financial resources into overlooked sectors, including cottage industry in few economies, SMEs, marine fisheries, steel sector, mineral resources, and water and sanitation issues, are the few examples that can be strengthened during pandemic (Baker et al. 2020). COVID-19 measures improve air quality index and likelihood to increase fertility rate during a pandemic. The work at home, closures of industries and businesses, and leisure time may increase family size across the globe. The population control strategies could be provoked side-by-side during a pandemic, as it could be increases cause of long stay at home to both partners, who may result in a high fertility rate (Bahamondes and Makuch 2020). Further, the COVID-19 measures increase global poverty risk and vulnerable employment; thus, it also is the cause of high fertility rate. The provision of job opportunities, social safety networking, emergency relief packages for lower-income group, online training programs, and proper counseling may reduce poverty incidence and fertility rate across countries (Anser et al. 2020).

These policies would largely support to reduce coronavirus cases and mortality rate, while COVID-19 measures provide food-for-thoughts to the policymakers and government officials to make the policies more people-centric, environmentally friendly, and socially inclusive across the globe.

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