Environmental Science and Pollution Research (2020) 27:15901–15911
https://doi.org/10.1007/s11356-020-08167-8

RESEARCH ARTICLE

Environmental degradation and population health outcomes: a global panel data analysis

Muhammad Tariq Majeed[1] **· Ilhan Ozturk**[2,3,4]

Received: 8 January 2020 / Accepted: 19 February 2020 / Published online: 25 February 2020

Abstract
This study investigates the relationship between environmental degradation and population health using a global panel data of 180 countries from 1990 to 2016. The empirical analysis is conducted using fixed-effects approach based on Hausman test. Moreover, two-stage least squares (2SLS) and system-generalized method of moments (SGMM) are used to deal with the endogenous nature of environmental degradation. The indicators of life expectancy and infant mortality are used to measure population health, whereas environmental degradation is measured by CO_2 emissions. The empirical findings show that environmental degradation negatively influences population health outcomes. It implies that countries having a high level of environmental degradation experience low life expectancy and high infant mortality rates. Findings of the study suggest that health-related reforms need to be aligned with policies which ensure lower environmental degradation.

Keywords CO2 emissions · Environmental degradation · Infant mortality · Life expectancy · Climate change

JEL classifications Q53 · I10 · I15

Introduction

Climate change is generally considered to be one of the most severe global hazards to future population health and global development (Costello et al. 2009). Climate change has varied and significant effects on population health (Woodward et al. 2014). In 1988, heavy rains continued for 3 days in Central America and caused many infectious diseases such as cholera, malaria, and dengue fever (Epstein et al. 2005; Kovats and Hajat 2008).

The mechanisms through which climate change impacts health can be broadly categorized into direct, indirect, and delayed effects (Fig. 1). The direct or primary benefits include injuries and deaths produced by extreme weather events such as floods and cyclones. The indirect or secondary effects comprise infectious diseases caused by climate changes. The delayed or tertiary effects include disruption to health and social services which are produced over time (Butler and Harley 2010; McMichael 2013).

There are a number of ways through which environmental degradation can influence population health. Climate change affects health through creating adverse variations in food production (Rosenzweig et al. 2011; Chandio et al. 2019; Chandio et al. 2020), increasing concentration of outdoor air pollutants (Bernard et al. 2001; Knowlton et al. 2004; Haines and Patz 2004; Ozturk 2015; Azam et al. 2019); creating thermal stress (Martens 1998); creating extreme events (Knutson et al. 1998; Ikeda et al. 2005); causing waterborne diseases (Casman et al. 2001; Charron et al. 2004); and spreading diseases such as dengue fever (Hales et al. 2002), malaria (Loevinsohn 1994; Tanser et al. 2003), aeroallergens (Beggs 2004), and other diseases (Reiter 1998; Patz et al. 2005).

Responsible editor: Nicholas Apergis

✉ Ilhan Ozturk
ilhanozturk@cag.edu.tr

Muhammad Tariq Majeed
tariq@qau.edu.pk

1 School of Economics, Quaid-i-Azam University, Islamabad, Pakistan
2 Faculty of Economics and Administrative Sciences, Cag University, Mersin, Turkey
3 Department of Medical Research, China Medical University Hospital, China Medical University, Taichung, Taiwan
4 Department of Finance, Asia University, 500, Lioufeng Rd., Wufeng, Taichung 41354, Taiwan

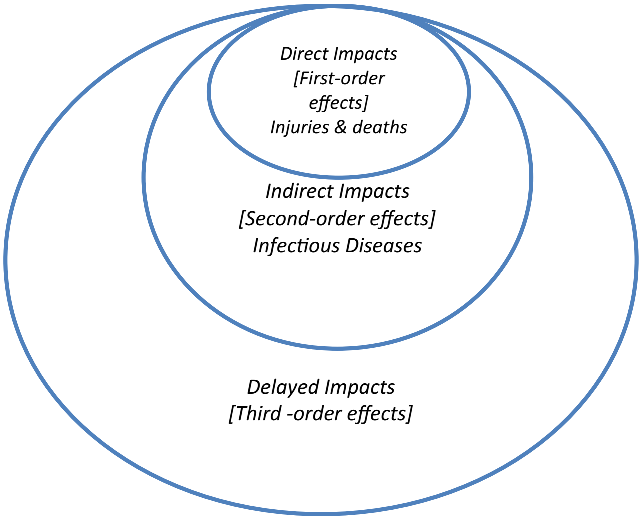

Fig. 1 The impacts of climate change on health. Source: Author's analysis

The extant literature on environment and health is based on qualitative studies. Some studies provide country-specific evidence which cannot be generalized for the rest of the world. This study extends the literature on environment and health by providing empirical evidence using a large panel data set of 180 countries for the period of 1990–2016.

This study addresses the following questions: (1) Does environmental degradation generate poor health outcomes? (2) Is the relationship of the environment with health outcomes is sensitive to different control variables? This study is the first of its kind that provides an empirical analysis of climate degradation and health using global panel data set. The potential issue of endogeneity is also resolved using instrumental techniques of estimation.

The remaining study is organized as follows: the next section provides the review of the related literature. Methodological discussion and data sources are provided in "Methodology and data." The results are interpreted in "Empirical results." Finally, conclusion and policy implications are provided in "Conclusion."

Literature review

Over the last five decades, human activities such as burning of fossil fuels have substantially released carbon dioxide and other greenhouse gasses, which trapped extra heat in the atmosphere, leading to climate change. As a result, global warming is increasing, glaciers are melting, sea levels are rising, and events related to extreme weather are becoming more frequent.

Climate change also has an effect on human health. Global warming may have some positive effects on human health such as fewer winter deaths in temperate climates and high food production in certain areas. However, overwhelming effects of climate change on human health are negative through degrading the quality of air, food, and drinking water.

Furthermore, climate change is fostering the frequency, intensity, and duration of heat waves, which adversely affect human health (Fig. 2). The World Health Organization states that during 2030 to 2050, climate change is projected to cause about 250,000 added deaths per year, from malaria, malnutrition, diarrhea, and heat stress. According to the World Health Organization (2016), 7,000,000 deaths have been caused by air pollution.

The literature has examined various short-run and long-run health problems related to climate change. The studies provide the evidence that extreme waves of heat and cold increase mortality rates (Lee et al. 2006; Deschenes and Moretti 2009; Gosling et al. 2009; Deschenes and Greenstone 2009; Barreca 2012; Li et al. 2013; Gasparrini et al. 2015).

Ecosystem variability generates floods and droughts that influence psychological and societal well-being as a consequence of insecurities related to livelihoods, food, and housing. Comrie (2007) asserts that extreme climate changes are likely to increase the risk of water-borne viruses as a result of increasing water temperature and flooding. The higher temperature increases ground-level pollution, including airway inflammation, breathing problems, and also reduces resistance to infections.

Chemical reactions and volatile organic compounds that formulate ozone are highly sensitive to climate change (Sillman and Samson 1995; Constable et al. 1999; Aw and Kleeman 2003; Seinfeld and Pandis 2016). Ozone concentration has negative effects on health by causing diseases such as asthma and lung cancer (Lippmann 1989; Dockery and Pope 1994; Thurston and Ito 1999; Apergis et al. 2020). Bell et al. (2007) analyze the effects of climate change on human health through changes in ozone concentrations. They use the sample of 50 Eastern US cities for five representative summers (1993–1997 and 2053–2057). Their analysis confirms the negative health consequences of climate change. Their study showed that high ozone levels increased total mortality from 0.11% to 0.27%.

Haines et al. (2006) argue that climate change influences health outcomes through several pathways, including heat waves, droughts and floods, vector-borne diseases, malnutrition, and risk of disasters. Extreme heat waves, droughts, and floods have an immediate effect on mortality. Climate change influences provision of goods and services which are

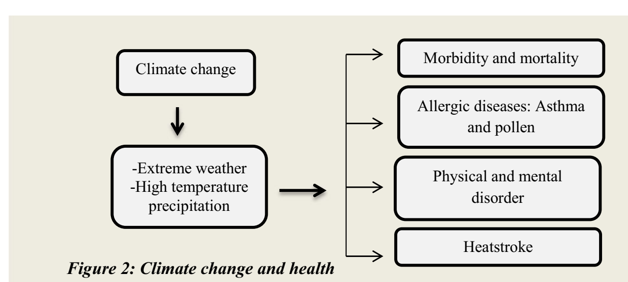

Fig. 2 Climate change and health

necessary for human health. Besides, droughts, flooding, and environmental degradation may lead to displacement and ecological refugees.

Campbell-Lendrum and Corvalan (2007) compile evidence of adverse health effects of climate change on urban population. They argue that heat waves in cities are exacerbated by the urban "heat-island" effect. Furthermore, global trends towards higher and increasingly variable temperatures as a result of climate change are increasing the frequency of heat waves. These waves have significant adverse effects on human health. For example, over 35,000 people died within 2 weeks in 2003 in Europe. Similarly, they provide evidence on climate change and health nexus for urban population through the channels of floods, storms, communicable diseases, and air pollution.

Using the database of health conditions at birth and historical global temperatures, Molina and Saldarriaga (2016) investigated the impact of temperature variability on infant's health in Andean Region. Their findings show that one standard deviation inclines in mean temperature reduces birth weight by 20 g. They attribute such changes to limited access to healthcare facilities and food insecurity during pregnancy. Temperature changes negatively affect food yield and stock that can affect maternal diet and infant health. Furthermore, extreme weather conditions can distort road infrastructure, thereby isolating people and limiting their access to health care facilities.

Ngo and Horton (2016) explore the influence of climate change on birth weight for New York City (Manhattan) from 1985 to 2010. Their analysis indicated that extreme heat negatively influenced birth weight during pregnancy. In particular, they asserted that those teenage mothers who work outdoor are more vulnerable to climate change.

The links of climate change with population health have received considerable attention in the recent years. The studies have focused on the diverse dimensions of this issue but empirical focus is largely ignored. Moreover, the extant literature in this field largely focused on case studies or country-specific evidence which cannot be generalized globally. This study, therefore, focuses on a global sample of 180 countries and provides empirical evidence of the relationship between environment and health.

Methodology and data

Methodology

This study follows health production function given by Grossman (1972). It links the relationship between health inputs and individual's health output. Grossman (1972) suggests that the health production depends on individual's behavior, medical facilities, and health constraints. The health production function can be described as follows:

$$H = f\ (HI) \tag{1}$$

where H refers to health output of an individual and HI represents inputs required for individual's health. Health inputs are factors that contribute to population health status. This model examines health outcome at micro level. Since this study examines health production at macro level, the model is converted to macro level by expressed health inputs in per capita form. Health inputs are broadly structured into three types of factors that are economic, social, and environmental factors (Fayissa and Gutema 2005).

$$H = f\ (E, S, N) \tag{2}$$

Where, E, S, and N refer to vectors of economic, social, and environmental indicators, respectively. Each vector incorporates diverse variables but empirical studies have used different indicators because of the data and other research limitations.

The vector of economic factors comprises economic growth and health facilities. The vector of social factors is limited to education and urbanization and finally vector of environmental factors comprises carbon dioxide emissions.

$$H = f\ (Economic\ Growth, health\ facilities, Edu, CO2E) \tag{3}$$

This study primarily focused on the relationship of health with environmental degradation. To assess the strength of this relationship, some other control variables are introduced one by one. These factors include clean water, better sanitation facilities, public health expenditures, food index, and age dependency ratio. Health outcomes are measured using two broader proxies, life expectancy and infant mortality. To measure environmental degradation, we have used CO_2 emissions. The empirical relationships between health inputs and health output can be specified as follows

$$lnH_{it} = \beta_{it} + \beta_2 lnY_{it} + \beta_3 lnHF_{it} + \beta_4 lnEDU_{it} + \beta_5 lnC02E_{it} + \beta_6 lnZ_{it} + \varepsilon_{it} \tag{4}$$

where = Countries 1, 2, 3 …180, t = time period 1990 to 2016, ln is natural logarithm, H is health status measured by "life expectancy at birth, total (years)," and "infant mortality per 1000," Y is "GDP per capita (constant 2005 US$)," HF represents "health facilities (physicians)," EDU refers to "education (gross enrollment ratio, secondary, both sexes (%))," CO_2 represents "carbon dioxide emissions (metric tons per capita)," and Z is a vector of other control variables. Empirical analysis is conducted using Pooled Ordinary Least Squares (OLS), Fixed Effects, Random Effects and System Generalized Method of Moments (SGMM).

Table 1 Pooled OLS result of environmental degradation and health

Variables	(1)	(2)	(3)	(4)	(5)	(6)
GDP per capita	0.0339***	0.0312***	0.0274***	0.0281***	0.0338***	0.0322***
	(0.00277)	(0.00380)	(0.00269)	(0.00274)	(0.00280)	(0.00266)
Education	0.0913***	0.0936***	0.0686***	0.0775***	0.0851***	0.0800***
	(0.00861)	(0.0104)	(0.00898)	(0.00940)	(0.00899)	(0.00856)
Physicians	0.0352***	0.0359***	0.0345***	0.0265***	0.0367***	0.0310***
	(0.00440)	(0.00498)	(0.00432)	(0.00440)	(0.00446)	(0.00428)
Urbanization	0.00343*	0.00432**	0.00500**	0.00550***	0.00364*	0.00489**
	(0.00192)	(0.00211)	(0.00194)	(0.00202)	(0.00196)	(0.00219)
CO_2 emissions	− 0.0116***	− 0.0129**	− 0.0148***	− 0.0168***	− 0.0108**	− 0.0185***
	(0.00441)	(0.00546)	(0.00453)	(0.00453)	(0.00449)	(0.00480)
Health spend		0.00186				
		(0.00133)				
Water			0.00200***			
			(0.000331)			
Sanitation				0.00143***		
				(0.000260)		
Food					0.000296**	
					(0.000129)	
Age dep.						− 0.00167***
						(0.000288)
Constant	3.574***	3.580***	3.549***	3.573***	3.571***	3.742***
	(0.0419)	(0.0514)	(0.0430)	(0.0405)	(0.0421)	(0.0458)
Observations	719	570	707	698	712	710
R-squared	0.773	0.775	0.789	0.788	0.774	0.785
Hat-square	(0.08)	(0.76)	(0.73)	(0.20)	(0.04)	(0.05)
Mean VIF	4.24	4.21	4.32	4.65	3.82	4.39
Breusch-Pagan	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Robust standard errors are in parentheses (*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$)

Data description

This study uses a panel data set of 180 countries from 1990 to 2016. The description of variables used and their sources are given as follows.

Health outcomes

Health outcomes are measured using two broad measures namely life expectancy and infant mortality. The indicator of life expectancy represents "life expectancy at birth, total (years)" and the indicator of infant mortality refers to "mortality rate, infant (per 1000 live births)." Both variables are extracted from World Bank (2016).

Environmental degradation

The focus variable is environmental degradation which is measured using the data series of "CO_2 emissions (metric tons per capita)." The data is extracted from World Bank (2016). The increasing levels of carbon in the atmosphere threaten human health. The expected impact of CO_2 emissions on life expectancy is negative and positive, respectively.

Control variables

Economic growth It is an important indicator of population health outcomes. Economic growth improves income of individuals and they can afford better diet, housing, education, and health facilities that lead to better health outcomes (Fayissa and Gutema 2005; Majeed and Gilani 2017). Economic growth is measured using "GDP per capita (constant 2005 US$)" data from World Bank (2016). The expected effect of economic growth on life expectancy and infant mortality is positive and negative, respectively.

Health care facilities Health facilities are important for better health outcomes. The supply of physicians measured as

Table 2 Fixed-effects result of environmental degradation and health

Variables	(1)	(2)	(3)	(4)	(5)	(6)
GDP per capita	0.0831***	0.0708***	0.0719***	0.0699***	0.0676***	0.0786***
	(0.00857)	(0.00765)	(0.00874)	(0.00916)	(0.00880)	(0.00922)
Education	0.106***	0.0996***	0.0739***	0.0904***	0.0806***	0.103***
	(0.00770)	(0.00721)	(0.00945)	(0.00832)	(0.00874)	(0.00816)
Physicians	− 0.000724	− 0.00746	− 0.00360	− 0.00327	− 0.00317	− 0.00149
	(0.00629)	(0.00563)	(0.00620)	(0.00630)	(0.00614)	(0.00641)
Urbanization	0.00790***	0.00342**	0.00826***	0.00939***	0.00716***	0.00804***
	(0.00196)	(0.00169)	(0.00192)	(0.00198)	(0.00192)	(0.00198)
CO_2 emissions	− 0.0238***	− 0.0163**	− 0.0236***	− 0.0255***	− 0.0212***	− 0.0236***
	(0.00781)	(0.00753)	(0.00769)	(0.00788)	(0.00766)	(0.00788)
Health spend		0.00641***				
		(0.00191)				
Water			0.00247***			
			(0.000450)			
Sanitation				0.00200***		
				(0.000429)		
Food					0.000588***	
					(0.000101)	
Age dep.						− 0.000380
						(0.000290)
Hausman test	47.20	66.02	47.20	39.81	39.58	45.63
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	3.102***	3.210***	3.116***	3.130***	3.276***	3.176***
	(0.0657)	(0.0569)	(0.0645)	(0.0662)	(0.0709)	(0.0863)
Observations	719	570	707	698	712	710
R-squared	0.482	0.603	0.508	0.498	0.512	0.483
Number of id	180	175	177	176	178	176

Standard errors in parentheses (***$p < 0.01$, **$p < 0.05$, *$p < 0.1$)

"physicians (per 1000 people)" is used in life expectancy model while immunization measured as "Immunization, measles (% of children ages 12–23 months)" is used in infant mortality model. A high number of physicians per 100 people indicate that access to health services and facilities is better because more people can avail treatment and medical attention. Likewise, if more children are immunized against measles, then chances of their survival will incline (Gupta et al. 2002). The expected impact of physicians and immunization on life expectancy and infant mortality is positive and negative, respectively. The data for these both indicators is extracted from World Bank (2016).

Education The importance of education for better health is well documented in the literature (Khan and Majeed 2018). Educated people can have better health-related information and can avoid risky behavior. Female education is also important for the better health of child and family. This study uses total education measured as "School enrollment, secondary (% gross)" in life expectancy model while female education measured as "Females School enrollment, secondary (% gross)" in infant mortality model. The expected effect of education on life expectancy and infant mortality is positive and negative, respectively. The data for both variables is extracted from World Bank (2016).

Urbanization Urbanization can have positive impact on health by providing easy access to health facilities (Gupta et al. 2002). In contrast, urbanization can have negative effect on health by increasing crowdedness that leads to social deprivation (Rogers and Wofford 1989). Urbanization variable is measured by "Urban population growth (annual %)" and is collected from World Bank (2016).

Sensitivity analysis Other than these control variables, some other important indicators of health are used for sensitivity analysis. These indicators include public health expenditures, clean water, better sanitation, food index, and age dependency ratio.

Public health expenditures The rise in public health expenditures can have better health outcomes by providing health facilities and improving health awareness (Gupta et al. 2002).

Improved water Safe drinking water is an important source of good health. Improved water variable is measured by "improved water source (% of population with access)" and is collected from World Bank (2016).

Improved sanitation Similarly, improved sanitation also has constructive impact on health. Improved sanitation variable is measured by "improved sanitation facilities (% of population

Table 3 Random effects result of environmental degradation and health

Variables	(1)	(2)	(3)	(4)	(5)	(6)
GDP per capita	0.0831***	0.0708***	0.0719***	0.0699***	0.0676***	0.0786***
	(0.00857)	(0.00765)	(0.00874)	(0.00916)	(0.00880)	(0.00922)
Education	0.106***	0.0996***	0.0739***	0.0904***	0.0806***	0.103***
	(0.00770)	(0.00721)	(0.00945)	(0.00832)	(0.00874)	(0.00816)
Physicians	− 0.000724	− 0.00746	− 0.00360	− 0.00327	− 0.00317	− 0.00149
	(0.00629)	(0.00563)	(0.00620)	(0.00630)	(0.00614)	(0.00641)
Urbanization	0.00790***	0.00342**	0.00826***	0.00939***	0.00716***	0.00804***
	(0.00196)	(0.00169)	(0.00192)	(0.00198)	(0.00192)	(0.00198)
CO2 emissions	− 0.0238***	− 0.0163**	− 0.0236***	− 0.0255***	− 0.0212***	− 0.0236***
	(0.00781)	(0.00753)	(0.00769)	(0.00788)	(0.00766)	(0.00788)
Health spend		0.00641***				
		(0.00191)				
Water			0.00247***			
			(0.000450)			
Sanitation				0.00200***		
				(0.000429)		
Food					0.000588***	
					(0.000101)	
Age dep.						− 0.000380
						(0.000290)
Constant	3.102***	3.210***	3.116***	3.130***	3.276***	3.176***
	(0.0657)	(0.0569)	(0.0645)	(0.0662)	(0.0709)	(0.0863)
Observations	719	570	707	698	712	710
R-squared	0.482	0.603	0.508	0.498	0.512	0.483
Number of id	180	175	177	176	178	176

Standard errors in parentheses (***$p < 0.01$, **$p < 0.05$, *$p < 0.1$)

with access)" and is collected from World Bank (2016). "Improved sanitation facilities are likely to ensure hygienic separation of human excreta from human contact. Poor management of excreta is linked to transmission of diseases such as cholera, diarrhea, dysentery, hepatitis A, typhoid and polio, and also contributes to malnutrition."

Food production index Improved food intake has constructive impact on health. "Food production index covers food crops that are considered edible and that contain nutrients. Coffee and tea are excluded because, although edible, they have no nutritive value."

Age dependency ratio It can have negative effects on health because health problems increase at older age. High dependency ratio indicates low working population ratio, which negatively affects savings of individuals and they cannot afford better food, shelter, sanitation, and health facilities.

Empirical results

Table 1 reports empirical results estimated using OLS. Column 1 indicates that environmental degradation has negative effect on health. This effect is statistically significant at 1% level of significance. To assess the robustness of health effect of environmental degradation, some additional health determinants are controlled one by one. These additional controls comprise public health spending, clean water, better sanitation, food index, and age dependency ratio. The negative health effect of environmental degradation remains consistently negative and significant in all models of population health production. The coefficient on health also remains consistent in its size and impact implying that 1% increase in carbon emissions lead to 0.01% decrease in life expectancy.

The effect of economic growth, education, physician, and urbanization is positive and statically significant implying that 1% increase in economic growth, education, physician, and urbanization improves health by 0.03%, 0.09%, 0.04%, and 0.003, respectively.

Table 1 also reports post-estimation tests in the last four rows. The link test confirms correct specification of the model because *p* values of hat square are larger than 0.05. The VIF test shows that the problem of the multicollinearity is not detected because mean VIF is not exceeding ten. The Breusch-Pagan test indicates that problem of heteroscedasticity is present in the selected model (*p* value is less than 5). To overcome this problem, robust regression analysis is used.

Since OLS results can be biased in the presence of country-specific time invariant effects, the model is re-estimated using fixed-effects method of estimation. The results of fixed effects are reported in Table 2. Column 1 shows that coefficient of CO_2

Table 4 System GMM result of environmental degradation and health

Variables	(1)	(2)	(3)	(4)	(5)	(6)
Life expectancy (t − 1)	0.765***	0.750***	0.757***	0.697***	0.787***	0.685***
	(0.0545)	(0.137)	(0.0581)	(0.0463)	(0.0518)	(0.0463)
GDP per capita	0.0150*	− 0.00422	0.0148*	0.00999	0.0150**	0.00800
	(0.00770)	(0.0108)	(0.00815)	(0.00694)	(0.00688)	(0.00647)
Education	0.0555***	0.0459*	0.0502**	0.0480***	0.0437**	0.0190
	(0.0137)	(0.0286)	(0.0216)	(0.0146)	(0.0222)	(0.0178)
Physician	0.0227**	0.0500***	0.0226**	0.00257	0.0254***	0.0230***
	(0.00892)	(0.0152)	(0.0100)	(0.0129)	(0.00821)	(0.00771)
Urbanization	0.0165***	0.0345***	0.0162***	0.0127***	0.0168***	0.0148***
	(0.00385)	(0.00910)	(0.00411)	(0.00398)	(0.00362)	(0.00355)
CO_2 emission	− 0.0264***	− 0.0319***	− 0.0272***	− 0.0302***	− 0.0264***	− 0.0214***
	(0.00784)	(0.0112)	(0.00838)	(0.00877)	(0.00808)	(0.00772)
Health spend		0.0204***				
		(0.00724)				
Water			0.000368			
			(0.000705)			
Sanitation				0.00171***		
				(0.000597)		
Food					0.000108	
					(0.000234)	
Age dep.						− 0.00186***
						(0.000514)
Constant	0.645***	0.803*	0.672***	0.888***	0.592***	1.311***
	(0.197)	(0.460)	(0.210)	(0.171)	(0.191)	(0.172)
Number of id	178	172	175	174	176	174
Number of instruments	28	21	28	28	28	28
AR1 (Pr > z)	0.49	0.19	0.47	0.56	0.53	0.70
AR2 (Pr > z)	0.97	0.91	0.96	0.88	0.91	0.38
Hansen test (HT)	0.192	0.11	0.18	0.17	0.07	0.05
GMM instruments for levels	0.39	0.67	0.45	0.48	0.20	0.12
HT excluding group difference	0.13	0.03	0.09	0.07	0.07	0.06
GMM instruments for lags	0.38	0.88	0.61	0.20	0.06	0.06
HT excluding group difference	0.18	0.08	0.17	0.16	0.07	0.03
Observations	571	556	563	559	566	565

Standard errors in parentheses (***$p < 0.01$, **$p < 0.05$, *$p < 0.1$)

emissions is negative and statistically significant at 1% level of significance implying that 1% incline in CO_2 emissions per capita improves life expectancy by 0.02%. Fixed-effects results reveal that the marginal impact of environmental degradation on health is double implying that OLS underestimated the health effect of environmental degradation.

Control variables have expected signs. Economic growth, education, physicians, and urbanization have positive and significant effect on population health outcomes which is consistent with the theoretical expectations. When average income is high in a country, the residents of that country have more resources to afford better food, shelter, and health care facilities. Education exerts positive influence on health as educated people can avoid unhealthy diets and habits. Physicians have positive effect on health implying that availability and accessibility of physicians increase and health treatment becomes more common. Urbanization has positive impact on health. This fining is consistent with Gupta et al. (2002). CO_2 emissions also significantly lower infant mortality (see Tables 5, 6, and 7).

Random effects estimation method is also used to control the effect of country-specific random effect. The results are presented in Table 3. The results are similar to fixed-effects estimation method. Environmental degradation has negative effect on health outcomes. Control variables also have consistent results.

To address the potential problem of endogeneity, 2SLS is used. In the presence of heteroscedasticity in the data, however, 2SLS is not considered an appropriate technique. The alternative is SGMM technique because it deals with both endogeneity and heteroscedasticity. For SGMM, this study uses lag of dependent variable as independent variable and lags of endogenous variables as instruments. Table 4 presents the results based on SGMM. The focused variable CO_2 emissions carry negative and significant coefficient implying that environmental degradation causes adverse health outcomes.

Control variables also have consistent and stable effects on population health outcomes.

Conclusion

This study extends the extant literature on population health production by empirically analyzing the relationship between environmental degradation and population health outcomes. The theoretical model of Grossman (1972) is extended using environmental degradation as input to health including other socioeconomic factors. The sample of study covers 180 countries from 1990 to 2016. Empirical analysis is based on POLS, FE, RE, and SGMM estimation methods. The outcome variable (health) is measured using life expectancy and infant mortality while environmental degradation is measured using CO_2 emissions as focused independent variable.

Findings of the study confirm that high environmental degradation negatively contributes to population health outcomes by decreasing life expectancy and increasing infant mortality. Environmental degradation affects health through creating adverse variations in food production; increasing concentration of outdoor air pollutants; creating thermal stress; creating extreme events; causing waterborne diseases; and spreading diseases such as dengue fever, malaria, aeroallergens, and other diseases. These findings are not sensitive to control variables.

This study has certain limitations. First, health is measured using life expectancy whereas health diseases are not incorporated. Moreover, life expectancy is a measure of quantity of life while it does not consider quality of life. Second, CO_2 emissions also influence mental health while this study focuses only on physical health. The present study uses two broader measures of health because of the data limitations. fFuture research can focus on other measures of health. Findings of the study suggest that health polices need to be designed in a way that negative effects of environmental changes can be mitigated. Health care programs need to be aligned with polices which ensure lower environmental degradation.

Compliance with ethical standards

Ethical statement The manuscript has not been previously published, is not currently submitted for review to any other journal, and will not be submitted elsewhere before a decision is made by this journal.

Appendix

Table 5 Pooled OLS result of CO_2 and health (infant mortality)

Variables	(1)	(2)	(3)	(4)	(5)	(6)
GDP per capita	− 0.561***	− 0.516***	− 0.535***	− 0.523***	− 0.560***	− 0.549***
	(0.0186)	(0.0291)	(0.0201)	(0.0192)	(0.0187)	(0.0181)
Education of females	− 0.195***	− 0.199***	− 0.149***	− 0.141***	− 0.186***	− 0.120***
	(0.0394)	(0.0509)	(0.0382)	(0.0420)	(0.0416)	(0.0374)
Immunization	− 0.593***	− 0.572***	− 0.480***	− 0.457***	− 0.583***	− 0.496***
	(0.0892)	(0.110)	(0.0923)	(0.0856)	(0.0899)	(0.0818)
Urbanization	0.0699***	0.0544***	0.0639***	0.0529***	0.0693***	0.0564***
	(0.0104)	(0.0104)	(0.0102)	(0.00920)	(0.0103)	(0.00854)
CO_2 emission	0.135***	0.0991***	0.138***	0.180***	0.130***	0.208***
	(0.0227)	(0.0275)	(0.0224)	(0.0220)	(0.0236)	(0.0245)
Health spend		− 0.0451***				
		(0.0165)				
Water			− 0.00669***			
			(0.00209)			
Sanitation				− 0.00777***		
				(0.00115)		
Food					− 0.000721	
					(0.000703)	
Age dep.						0.0134***
						(0.00165)
Constant	10.75***	10.50***	10.43***	10.17***	10.73***	9.031***
	(0.403)	(0.521)	(0.399)	(0.406)	(0.405)	(0.414)
Observations	751	615	739	728	745	737
R-squared	0.853	0.856	0.857	0.864	0.853	0.870

Standard errors in parentheses (***$p < 0.01$, **$p < 0.05$, *$p < 0.1$)

Table 6 Fixed effects result of CO_2 and health (infant mortality)

Variables	(1)	(2)	(3)	(4)	(5)	(6)
GDP per capita	− 0.875***	− 0.883***	− 0.838***	− 0.801***	− 0.838***	− 0.774***
	(0.0399)	(0.0402)	(0.0415)	(0.0406)	(0.0412)	(0.0407)
Education of females	− 0.272***	− 0.221***	− 0.203***	− 0.212***	− 0.231***	− 0.198***
	(0.0335)	(0.0354)	(0.0402)	(0.0347)	(0.0372)	(0.0335)
Immunization	− 0.333***	− 0.101	− 0.293***	− 0.314***	− 0.323***	− 0.321***
	(0.0649)	(0.0631)	(0.0662)	(0.0627)	(0.0644)	(0.0619)
Urbanization	− 0.00820	− 0.0150*	− 0.00899	− 0.0159*	− 0.00692	− 0.0104
	(0.00880)	(0.00836)	(0.00880)	(0.00861)	(0.00872)	(0.00841)
CO_2 emission	0.310***	0.257***	0.301***	0.313***	0.292***	0.305***
	(0.0381)	(0.0398)	(0.0384)	(0.0375)	(0.0381)	(0.0369)
Health spend		−0.0561***				
		(0.00969)				
Water			− 0.00719***			
			(0.00222)			
Sanitation				− 0.00989***		
				(0.00191)		
Food					− 0.00105**	
					(0.000443)	
Age dep.						0.00918***
						(0.00127)
Constant	12.52***	11.58***	12.38***	12.29***	12.11***	10.75***
	(0.351)	(0.346)	(0.353)	(0.340)	(0.373)	(0.418)
Observations	751	615	739	728	745	737
R-squared	0.650	0.710	0.658	0.675	0.653	0.686
Number of id	176	176	174	173	175	172

Standard errors in parentheses (***$p < 0.01$, **$p < 0.05$, *$p < 0.1$)

Table 7 Random effects result of CO2 and health (infant mortality)

Variables	(1)	(2)	(3)	(4)	(5)	(6)
GDP per capita	− 0.698***	− 0.682***	− 0.656***	− 0.631***	− 0.684***	− 0.635***
	(0.0284)	(0.0303)	(0.0294)	(0.0289)	(0.0285)	(0.0276)
Education of females	− 0.287***	− 0.266***	− 0.207***	− 0.231***	− 0.239***	− 0.193***
	(0.0322)	(0.0342)	(0.0372)	(0.0322)	(0.0356)	(0.0320)
Immunization	− 0.406***	− 0.192***	− 0.349***	− 0.363***	− 0.389***	− 0.367***
	(0.0637)	(0.0636)	(0.0650)	(0.0617)	(0.0631)	(0.0602)
Urbanization	0.0126	− 0.000546	0.0104	0.000942	0.0136*	0.00733
	(0.00828)	(0.00807)	(0.00824)	(0.00814)	(0.00819)	(0.00784)
CO_2 emission	0.234***	0.203***	0.230***	0.277***	0.210***	0.250***
	(0.0275)	(0.0291)	(0.0276)	(0.0280)	(0.0282)	(0.0261)
Health spend		− 0.0516***				
		(0.00892)				
Water			− 0.00846***			
			(0.00190)			
Sanitation				− 0.00936***		
				(0.00138)		
Food					− 0.00122***	
					(0.000418)	
Age dep.						0.0114***
						(0.00119)
Constant	11.49***	10.55***	11.30***	11.18***	11.24***	9.685***
	(0.302)	(0.312)	(0.303)	(0.294)	(0.308)	(0.345)
Observations	751	615	739	728	745	737
Number of id	176	176	174	173	175	172

Standard errors in parentheses (***$p < 0.01$, **$p < 0.05$, *$p < 0.1$)

References

Apergis N, Bhattacharya M, Hadhri W (2020) Health care expenditure and environmental pollution: a cross-country comparison across different income groups. Environ Sci Pollut Res:1–15. https://doi.org/10.1007/s11356-019-07457-0

Aw J, Kleeman MJ (2003) Evaluating the first-order effect of intraannual temperature variability on urban air pollution. J Geophys Res-Atmos 108(D12):1–12

Azam M, Khan AQ, Ozturk I (2019) The effects of energy on investment, human health, environment and economic growth: empirical evidence from China. Environ Sci Pollut Res 26(11):10816–10825

Barreca AI (2012) Climate change, humidity, and mortality in the United States. J Environ Econ Manag 63(1):19–34

Beggs PJ (2004) Impacts of climate change on aeroallergens: past and future. Clin Exp Allergy 34(10):1507–1513

Bell ML, Goldberg R, Hogrefe C, Kinney PL, Knowlton K, Lynn B et al (2007) Climate change, ambient ozone, and health in 50 US cities. Clim Chang 82(1–2):61–76

Bernard SM, Samet JM, Grambsch A, Ebi KL, Romieu I (2001) The potential impacts of climate variability and change on air pollution-related health effects in the United States. Environ Health Perspect 109(2):199–209

Butler CD, Harley D (2010) Primary, secondary and tertiary effects of eco-climatic change: the medical response. Postgrad Med J 86(1014):230–234

Campbell-Lendrum D, Corvalán C (2007) Climate change and developing-country cities: implications for environmental health and equity. J Urban Health 84(1):109–117

Casman E, Fischhoff B, Small M, Dowlatabadi H, Rose J, Morgan MG (2001) Climate change and cryptosporidiosis: a qualitative analysis. Clim Chang 50(1–2):219–249

Chandio AA, Magsi H, Ozturk I (2019) Examining the effects of climate change on rice production: case study of Pakistan. Environ Sci Pollut Res:1–11. https://doi.org/10.1007/s11356-019-07486-9

Chandio AA, Ozturk I, Akram W, Ahmad F, Mirani AA (2020) Empirical analysis of climate change factors affecting cereal yield: evidence from Turkey. Environ Sci Pollut Res:1–14. https://doi.org/10.1007/s11356-020-07739-y

Charron DF, Thomas MK, Waltner-Toews D, Aramini JJ, Edge T, Kent RA et al (2004) Vulnerability of waterborne diseases to climate change in Canada: a review. J Toxic Environ Health A 67(20–22):1667–1677

Comrie A (2007) Climate change and human health. Geogr Compass 1(3):325–339

Constable J, Guenther A, Schimel DS, Monson RK (1999) Modelling changes in VOC emission in response to climate change in the continental United States. Glob Chang Biol 5(7):791–806

Costello A, Abbas M, Allen A, Ball S, Bell S, Bellamy R et al (2009) Managing the health effects of climate change: Lancet and University College London Institute for Global Health Commission. Lancet 373(9676):1693–1733

Deschenes O, Moretti E (2009) Extreme weather events, mortality, and migration. Rev Econ Stat 91(4):659–681
Deschênes O, Greenstone M, Guryan J (2009) Climate change and birth weight. Am Econ Rev 99(2):211–217
Dockery DW, Pope CA (1994) Acute respiratory effects of particulate air pollution. Annu Rev Public Health 15(1):107–132
Epstein PR (2005) Climate change and human health. N Engl J Med 353(14):1433–1436
Fayissa B, Gutema P (2005) Estimating a health production function for sub-Saharan Africa (SSA). Appl Econ 37(2):155–164
Gasparrini A, Guo Y, Hashizume M, Lavigne E, Zanobetti A, Schwartz J et al (2015) Mortality risk attributable to high and low ambient temperature: a multi country observational study. Lancet 386(9991):369–375
Grossman M (1972) On the concept of health capital and the demand for health. J Polit Econ 80(2):223–255
Gosling SN, Lowe JA, McGregor GR, Pelling M, Malamud BD (2009) Associations between elevated atmospheric temperature and human mortality: a critical review of the literature. Clim Chang 92(3–4): 299–341
Gupta S, Verhoeven M, Tiongson ER (2002) The effectiveness of government spending on education and health care in developing and transition economies. Eur J Polit Econ 18(4):717–738
Haines A, Patz JA (2004) Health effects of climate change. Jama 291(1): 99–103
Haines A, Kovats RS, Campbell-Lendrum D, Corvalán C (2006) Climate change and human health: impacts, vulnerability and public health. Public Health 120(7):585–596
Hales S, De Wet N, Maindonald J, Woodward A (2002) Potential effect of population and climate changes on global distribution of dengue fever: an empirical model. Lancet 360(9336):830–834
Ikeda T, Yoshitani J, Terakawa A (2005) Flood management under climatic variability and its future perspective in Japan. Water Sci Technol 51(5):133–140
Khan F, Majeed T (2018) Education levels and life expectancy of males and females: empirical evidence from Pakistan. J Arts Soc Sci 5(I): 96–114
Knowlton K, Rosenthal JE, Hogrefe C, Lynn B, Gaffin S, Goldberg R, Kinney PL (2004) Assessing ozone-related health impacts under a changing climate. Environ Health Perspect 112(15):1557–1563
Knutson TR, Tuleya RE, Kurihara Y (1998) Simulated increase of hurricane intensities in a CO2-warmed climate. Science 279(5353): 1018–1021
Kovats RS, Hajat S (2008) Heat stress and public health: a critical review. Annu Rev Public Health 29:41–55
Lee SJ, Steer PJ, Filippi V (2006) Seasonal patterns and preterm birth: a systematic review of the literature and an analysis in a London-based cohort. BJOG Int J Obstetr Gynecol 113(11):1280–1288
Li T, Horton RM, Kinney PL (2013) Projections of seasonal patterns in temperature-related deaths for Manhattan, New York. Nat Clim Chang 3(8):717–721
Lippmann M (1989) Health effects of ozone a critical review. Japca 39(5): 672–695
Loevinsohn ME (1994) Climatic warming and increased malaria incidence in Rwanda. Lancet 343(8899):714–718
Majeed MT, Gillani S (2017) State capacity and health outcomes: an empirical analysis. Pak J Commer Soc Sci 11(2):671–697
Martens WJ (1998) Climate change, thermal stress and mortality changes. Soc Sci Med 46(3):331–344
McMichael AJ (2013) Globalization, climate change, and human health. N Engl J Med 368(14):1335–1343
Molina, O., & Saldarriaga, V. (2016). The perils of climate change: in utero exposure to temperature variability and birth outcomes in the Andean Region
Ngo NS, Horton RM (2016) Climate change and fetal health: the impacts of exposure to extreme temperatures in New York City. Environ Res 144:158–164
Ozturk I (2015) Measuring the impact of energy consumption and air quality indicators on climate change: evidence from the panel of UNFCC classified countries. Environ Sci Pollut Res 22(20): 15459–15468
Patz JA, Campbell-Lendrum D, Holloway T, Foley JA (2005) Impact of regional climate change on human health. Nature 438(7066):310–317
Reiter P (1998) Global-warming and vector-borne disease in temperate regions and at high altitude. Lancet 351(9105):839–840
Rogers RG, Wofford S (1989) Life expectancy in less developed countries: socioeconomic development or public health? J Biosoc Sci 21(02):245–252
Rosenzweig C (2011) Responding to climate change in New York state: the climAID integrated assessment for effective climate change adaptation in New York state: final report. Academy of Sciences, New York
Seinfeld JH, Pandis SN (2016) Atmospheric chemistry and physics: from air pollution to climate change. John Wiley & Sons
Sillman S, Samson PJ (1995) Impact of temperature on oxidant photochemistry in urban, polluted rural and remote environments. J Geophys Res-Atmos 100(D6):11497–11508
Tanser FC, Sharp B, Le Sueur D (2003) Potential effect of climate change on malaria transmission in Africa. Lancet 362(9398):1792–1798
Thurston GD, Ito K (1999) Epidemiological studies of ozone exposure effects. Air Pollut Health 1:485–509
Woodward A, Smith KR, Campbell-Lendrum D, Chadee DD, Honda Y, Liu Q et al (2014) Climate change and health: on the latest IPCC report. Lancet 383(9924):1185–1189
World Bank (2016) World development indicators. World Bank, Washington, DC Available at http://data.worldbank.org/products/wdi
World Health Organization (2016) The World Health Report 2016: mental health: climate change and health. World Health Organization