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The influence of environment and Earnings on Prolonged existence and human fertility: A Deeper Dive into Asia's environmentally vulnerable nations

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ABSTRACT

This study inspects the impact of environmental deterioration and income on longevity and fertility in Asian countries, specifically the nations that are highly vulnerable to extreme weather. The study examines the data, covering two decades from 2000 to 2019. The empirical conclusions of the panel ARDL-PMG and the CS-ARDL econometric models indicate that environmental degradation leads to a decline in birth rate and life expectancy, while a rising income has a significant influence over longevity. However, increasing per capita income alone cannot solve the problem of population crisis in climatically susceptible countries. Therefore, the sample countries must prioritize climate action and formulate climate-resilient policies to add more years to the lives of their citizens. Similarly, for increasing childbirth the sample nations need to make peace with nature. The outcomes of this study are strong enough, as both the models support each other's findings, producing similar significant outcomes.

1. Introduction

For the last thirty years, rising global temperatures and toxic air contaminants have instigated climatic instability [1,2]. As a result, in the near past world has witnessed disastrous consequences. For example, Australia's bush fire from 2019 to 2020 [3] harmed 3 billion animals,[1] Siberia's wildfire of 2021 [4] was the world's biggest forest fire that has scorched more than 62,300 square miles,[2] forest fires in 2021 in Turkey [5] has burnt out agricultural lands and killed many cattle [6]. Heavy rain in 2021 in China caused a severe flood that cost more than 4 thousand deaths and left 14 million citizens homeless.[3] Moreover, the floods of 2010 and 2022 in Pakistan devastated the country's infrastructure and killed hundreds of citizens [7,8]. Rising sea levels [9], melting glaciers, unpredictable monsoons, tornadoes, and volcanic eruptions [10] are also among the aftermaths of environmental degradation.

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[1] https://www.worldwildlife.org/stories/3-billion-animals-harmed-by-australia-s-fires.
[2] https://www.washingtonpost.com/world/2021/08/11/siberia-fires-russia-climate/.
[3] https://www.scmp.com/topics/flooding-china.

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Despite the mentioned environmental disasters, health-related consequences of a degraded environment are also of great concern. But unfortunately, these have largely been ignored. Such consequences have a dual impact, as they directly affect the overall health conditions, as well as reduce the resourcefulness of individuals who suffer from poor health conditions [11]. Environmental degradation causes millions of deaths each year. In 2019 alone, air pollution caused 21 % of lungs related deaths, 17 % of deaths caused by brain damage, 15 % of the demises were associated with heart disease and lung cancer, triggered by the poor environment, 13 % of diabetes, 13 % of breathing contagions and 7 % of the newborn syndrome associated deaths were caused by a deteriorated environment [12,13]. Damaging reproductive health and declining life expectancy are also among the major health discrepancies, and environmental degradation causes [14–17]. The given facts reveal the damaging health influence of a degraded environment [18]. Terrifyingly, a poor environment contributes approx. 40 % (natural disasters related demises are included) of the mortality rate worldwide [19], nearly 12.6 million people die each year due to unhealthy environments which is 25 % of the total deaths worldwide [20].

Moreover, the lack of longevity leads to premature mortality, while insufficient fertility rates threaten the future of human existence on Earth. In both scenarios, countries worldwide are grappling with population crises. However, it's worth noting that in many countries, this problem has reached an alarming level, and in most, population crises are becoming increasingly apparent [21]. When it comes to addressing infertility, several governments provide financial incentives to encourage residents to marry at an appropriate age and have children [22,23]. Despite these efforts, the problem continues to persist. Another common policy approach is to promote healthcare facilities to enhance life expectancies [24,25] governments usually take. Nevertheless, the issues of decreasing longevity and fertility are pushing the world to the brink of a population crisis. This raises questions about the dynamics causing infertility and declining life expectancy, as well as the effectiveness of the existing measures many governments are taking to cope with the underlined health concerns [26–28]. Given that the current study endeavors to formulate the following research questions.

(1) Can financial incentives enhance life expectancy and address the infertility issue?
(2) What if a degraded environment is a major culprit behind health issues; declining longevity and fertility rates?

Explanation: Both of these questions raise genuine concerns regarding the potential causes and policy measures for the mentioned health issues. If environmental degradation is indeed a significant factor contributing to infertility and premature deaths, then it becomes imperative to reconsider the policy measures in place.

Hence, this study fills that gap and takes both of the existential health issues into account from the direction of income as well as environmental excellence. Thus the study uncovers the true underlying factors responsible for the lack of longevity and infertility in those Asian countries that have been consistently impacted by dangerous climatic occurrences over the last two decades. As such, this study sets the following attainable objectives.

(1) To analyze the impact of environmental degradation and per capita income on life expectancy.
(2) To examine the influence of environmental degradation and individual income on fertility rates.

A few existing works have discussed health concerns. For example, a study by X. Zhao, M. Jiang, and W. Zhang [29] reported that environmental degradation significantly increases mortality. Z. Wang, M. M. Asghar, S. A. H. Zaidi, and B. Wang [30] found that in Pakistan pollution increases health overheads. Likewise, Mujtaba et al. [31] found that poor environmental quality increases health expenditures. According to P. C. Speldewinde, A. Cook, P. Davies, and P. Weinstein [32], environmental degradation causes mental illness. Castro [33]. highlighted that vector-borne diseases are the consequence of environmental degradation. Skakkebæk et al. [34] found the negative impact of the environment on birth rates. Majeed et al. [17] discovered that longevity can be harmed by environmental degradation. In light of the raised research questions and set objectives of the study, we develop related hypotheses as follows.

Hypothesis 1a. Environmental degradation decreases life expectancy.

Hypothesis 1b. Environmental degradation increases population crises.

Hypothesis 2a. Per capita income increases life expectancy.

Hypothesis 2b. Per capita income doesn't resolve population crises.

2. Literature review

The current study presents a literature review that focuses on the rare aspects of the subject matter. The literature review is organized under the following subheadings.

i) Causes of Environmental Degradation: This section aims to shed light on the anthropogenic activities that could harm the environment. This subheading provides a foundation for understanding the harmful impact of environmental degradation on health which is the subject matter of our study.
ii) Impact of a Degraded Environment and Income on Health: This section explores the effects of a deteriorated environment and income on health.

This structure of the literature review section is designed to enhance clarity and ensure that the study can easily be followed.

2.1. Causes of environmental degradation

Increasing output and per capita income can activate factors contributing to environmental degradation, such as carbon emissions [35–38], ecological footprints [39–41], rising temperatures, and unpredictable rainfall patterns. Countries often produce more output to increase individuals' income. Because economic growth empowers citizens to meet their basic needs [40,42,43]. However, to achieve economic growth, nations often rely on increased industrial production, leading to the overexploitation of natural capital, and overuse of energy and financial resources [44–46]. Consequently, natural settings are compromised [47–49]. Numerous studies [45,48,50–55] have revealed that energy-induced economic growth not only causes carbon emissions but also overexploits the natural capital in some countries. Whereas, a few studies [50,55,56] denied that claim, while testing energy-induced monetary development's influence over the environment in different nations by using changed statistical methods. Moreover, the increasing national output in countries through cross-border investments, trade, and liberalized trade can harm the climate but the extent of the impact depends on the specific countries in question [50,57]. Some researchers have warned that offering loans on easy terms to boost economic growth could intensify air pollution, thereby worsening the environment [53,54,57–62]. On the other hand, if countries provide credit on soft terms for environment-friendly projects, it can lead to improved environmental quality [51,53]. The underlined studies suggest that economic growth and an increase in per capita income through energy use, trade, investments, and easy access to finances can lead to environmental degradation [52,57,63,64]. Moreover, the overexploitation of natural and financial resources for economic expansion is also among the major culprits behind the worsening environment [14,65]. Since ancient times, the utilization of renewable and non-renewable earthly possessions has been considered a key device aimed at prosperity. However it started degrading the environment after the Industrial Revolution when countries around the world started using whatever was accessible beneath or above the Earth to pursue economic growth [43,47,57]. Hence, it is concluded that ecological excellence is compromised when countries start growing monetarily by overexploiting natural capital, fossil fuel energy resources, and monetary sources [45,58,61,66]. Resultantly, a substandard environment puts communities at risk of getting illnesses and costs countries with heavy healthcare expenditures [67,68]. Therefore, it is established that fiscal progress is among the major causes of environmental degradation [56,59,62,65].

2.2. Impact of a degraded environment and income on health

Recently, it has been witnessed that a polluted environment is not only responsible for desertification, depleting the ozone layer, melting glaciers, and causing acid rains and floods [69] (UNISDR,[4] 2009, p. 14), but has a damaging influence on human healthiness [18] as well. As a result of the poor environment, the likelihood of physical and mental unhealthiness among the population is increasing globally [14,70]. As per the American CDC report,[5] environmental troubles have led to an increase in the frequency of non-accidental premature deaths. In this context, the changing weather patterns cause environmentally sensitive health distress [71]. There are distinct ways by which a degraded environment influences negatively on individuals' health. Environmental degradation through several contaminants causes mental distress [32,72]. It provides a nurturing atmosphere for vector-borne illnesses [33,73]. As well as declines in the quality of persons' sperm thus dropping the birth rate [34,74,75]. A degraded environment also causes fatness and cancer by altering chromosomes [76]. Moreover, an unhealthy environment kills more than 10 million individuals each year.[6] It also facilitates human and animal interaction subsequently causing 75 % of zoonotic diseases in the recent past the world countries have faced a deadly disease called Covid-19 [77,78].

Studies by Abadi., 2023; Schuga et al., 2023; Gaskins et al., 2021 and Majeed et al., 2020 [15,17,69,79] have exposed the negative impacts of a polluted environment on individuals' overall health. A study by Mohanty et al., 2023 [80] has reported that over 150,000 villagers and workers of the Jajpur district in India are experiencing health problems due to the toxicity of chromium ions which have polluted the soil and water of the Sukinda Valley. Environmental degradation is among the chief origins of cancer-linked life losses in Italy [81]. A 180 countries study from 1990 to 2016, showed that environmental degradation lowers longevity and raises infant mortality [17]. A conducted research by Azam et al., 2023 [24] revealed that carbon emissions harmed life expectancy from 1975 to 2020 in Pakistan. In Africa, hazardous emissions impacted overall human health severely [82]. Air pollutants can cause a malfunctioning reproductive system in masses [18]. From the studies mentioned above, it is clear that various sources of environmental degradation can upset different dimensions of human health. For example, plastic littering in the seas can damage human health through chemical alterations [83]. Heavy metal pollutants from irrigation can also damage health [84]. Additionally, both indoor and outdoor air pollutants have been shown to reduce longevity and increase respiratory diseases [85–87]. On the discussed grounds, it is sensed that environmental degradation causes severe health problems, as demonstrated by numerous studies conducted worldwide. Whereas, according to a study by Azam et al., 2023 [24] in Pakistan between 1975 and 2020, per capita income had a positive impact

[4] UNISDR Terminology on Disaster Risk Reduction (2009), published by United Nations International Strategy for Disaster Reduction, Geneva, Switzerland, page.14, https://www.undrr.org/publication/2009-unisdr-terminology-disaster-risk-reduction.

[5] https://www.cdc.gov/climateandhealth/effects/default.htm#:~:text=The%20health%20effects%20of%20these,and%20threats%20to%20mental%20health.

[6] https://www.who.int/news/item/15-03-2016-an-estimated-12-6-million-deaths-each-year-are-attributable-to-unhealthy-environments#:~:text=An%20estimated%2012.6%20million%20deaths%20each%20year%20are%20attributable%20to%20unhealthy%20environments,-15%20March%202016&text=An%20estimated%2012.6%20million%20people,to%20new%20estimates%20from%20WHO.

on health aspects such as longevity. Household income was significantly associated with long life in the United States of America and Norway [88,89]. A study across North American, European, Central & East Asian & Pacific regions from 2000 to 2016, resulted in a growing income decline in mortality. Furthermore, Chetty et al., 2016 [90] discovered that higher income levels during 2001–2014 are associated with higher life expectancy in the US. Various studies; Escosura., 2023; Niu et al., 2021; Lange et al., 2017 and Thoa et al., 2013 [91–94] have shown that fiscal development, which leads to a per capita rise, can positively influence overall human health. The existing literature has statistically proven the interconnectedness of environment, income, and health.

It has been observed that throughout the last thirty years, numerous studies have been conducted to identify the causes of environment-related health consequences. However, these studies have produced varying results depending on the countries' regional and development classification. As a result, the issue remains a subject of debate, particularly when considering the use of newly collected datasets from diverse regions. Moreover, some major aspects of human health such as fertility rate and longevity have received less attention in the countries this study has taken into consideration. Therefore, this study aims to explore two important yet overlooked health aspects namely life expectancy, and fertility in climatically vulnerable Asian countries. Moreover, this study considers a wide range of environmental degradation dynamics and frames a broader measure of environmental degradation by estimating the composite index by including total greenhouse gas emissions, precipitation, and temperature. The index is named, the environmental index (EIN). Based on the discussed literature and set objects, the theoretical model of the research is illustrated in Fig. 1.

3. Analytical methodology

The period for this study lengths twenty years, from 2000 to 2019, and is directed by data convenience. Since this study focuses on environmentally vulnerable Asian countries. Hence, the top ten ranked countries by the Global Climate Risk Index (GCRI)[7] for the years 2017, 2018, and 2019, as well as for the period from 2000 to 2019, have been selected (see Fig. 2 for the corresponding map). The GCRI ranks countries based on the degree to which they have been affected by extreme weather conditions and environmental hazards. Quantitative datasets of eight shortlisted countries are acquired from the World Development Indicators (2021), and Climate Change Knowledge Portal of the World Bank. Based on the identified research gap and set objectives of the study, the dependent variables are comprised of two health-related factors: life expectancy at birth (total years) and fertility rate (births per woman). This study includes independent variables; real GDP per capita and an environmental index (EIN) consisting of total greenhouse gases, temperature, and precipitation (*see* Table 1). Due to the diversity of data sources, thereby addressing the issue of heterogeneity before estimating the index, we apply the min-max normalization technique to environmental-related data, which transforms the data within an identical range from 0 to 1, as follows [95,96].

$$NR_{env} = \frac{OV_{env} - OV_{min_{env}}}{OV_{max_{env} - OV_{min_{env}}}}$$

Where, NR_{env} is the normalized value of environment-related attributes, OV_{env} shows the original value of environmental characteristics within each country, $OV_{min_{env}}$ refers to the smallest number of the original attribute, and $OV_{max_{env}}$ is for the maximum number.

The remaining variables are transformed into the same scale by taking their natural logarithm (ln).

3.1. Principal Component Analysis (PCA)

To estimate the environmental index (EIN) this study accepts Principal Component Analysis (PCA). The technique was first used by Pearson in 1901 [97], later on, it was applied by Hotelling in 1933 [98] for reducing the dimensionality of variables in sample space [99,100]. PCA originated from the singular value decomposition (SVD) method, which gives a hierarchical coordinated data-driven system (see Steve Brunton, an online lecture on the topic).[8] Therefore, PCA eliminates the variables that have a smaller contribution and generates principal components (PC_1 to PC_n). The Linear combination of variables in PC_1 is as follows;

$$\text{Principal Component}_{\text{one}} = b_1 Y_1 + b_2 Y_2 + \ldots + b_p Y_p$$

Usually, the 1st generated component has a higher percentage of variance, thus considered a best-fit component and can be used as the index value for combined features. PC-one is obtained by multiplying the data matrix with variable loadings as follows;

$$\text{Principal Component}_{\text{one}} = Y \times L$$

Where Y is the data matrix & L shows variable loadings.

3.2. Statistical tests

Analyzing cross-sectional dependencies among nations is one of the initial steps in the statistical examinations. Cross-sectional dependency refers to a potential interdependence among the nations, this may exist when sample countries have some shared features, resultantly influencing the monetary decisions of each other, hence the matter cannot be ignored [49,99,101]. For handling the

[7] Global Climate Risk Index 2020 & 2021 published by Germanwatch

[8] https://www.youtube.com/watch?v=fkf4IBRSeEc&t=608s.

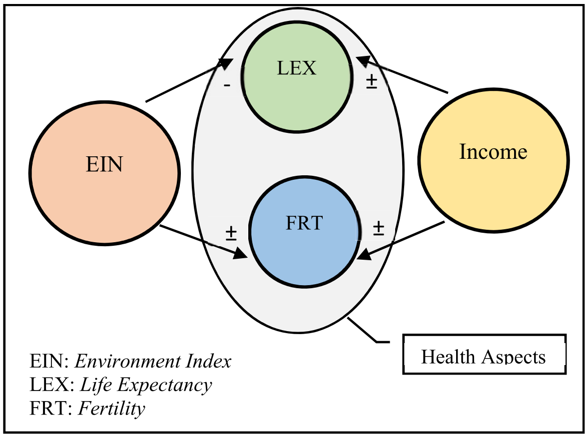

Fig. 1. Theoretical model.

Fig. 2. Environmentally vulnerable countries of Asia.
Source: Map created by authors with mapchart.net

Table 1
Varibale description and datasources

Variable	Measures	Symbol	Data Sources
Dependent Variables			
Longevity	Total life expectancy at birth in years.	lnLEX	WDI-2022
Fertility	Complete fertility rate as births per woman.	lnFRT	WDI-2023
Independent Variables			
Income	Real GDP per capita constant at 2015 USD	lnRGI	WDI-2022
Environment-Index	Total GHG releases are equal to kilotons of carbon dioxide.	EIN	WDI-2021
	The annual mean temperature in Celsius		CCKP
	Precipitation annual mean in millimeters observed by Climatic Research Unit.		

WDI: World Development Indicators. CCKP: Climate Change Knowledge Portal.

matter of correlation, this study adopts the CD test of Pesaran introduced in 2004 [102], which is calculated as Equation (1), given below [99,102–105].

$$CDp_{2004} = \sqrt{\frac{2y}{n(n-1)}}\left(\sum_{c=1}^{n-1}\sum_{j=c+1}^{n}\widehat{\rho}\,cj\right) \sim n(0,1) \tag{1}$$

Where, $\widehat{\rho}_{cj}$ shows the coefficient of pairwise correlation statistics between residuals, obtained through ADF regressions. $c = 1, 2, \ldots n$ is showing cross-section and $y = 1, 2, \ldots y$ is time element.

After handling interdependency issues in the data, this study proceeds to tackle the slope heterogeneity problems by employing the homogeneity test, which was introduced by Pesaran and Yamagata in 2008. This test has been previously used in studies such as; Pesaran., 2021, Qin et al., 2021 [103,106]. The delta (Δ_{SH}) and adjusted delta ($Adj\Delta_{SH}$) tests have standardized normal distributions and are asymptotically valid for testing slope homogeneity in panel datasets. Whether the slopes are homogeneous or heterogeneous, we can determine by applying the following Equations (2) and (3) [101,103,106–108].

$$\Delta_{SH} = \sqrt{n}\left(\frac{n^{-1}\,\widetilde{S}-k}{\sqrt{2k}}\right) \tag{2}$$

$$Adj\Delta_{SH} = \sqrt{n}\left(\frac{n^{-1}\,\widetilde{S}-E_{(\tilde{z}_{iT})}}{\sqrt{V(\widetilde{z}_{iT})}}\right) \tag{3}$$

H0. Cross-sectional slopes are homogenous

Ha. The slopes are heterogeneous

Where, Δ_{SH}& $Adj\Delta_{SH}$ indicate delta tilde and biased adjusted delta tilde respectively; n represents the cross-section dimensions, $\widetilde{S}$ is the measure of the Swamy test [109], k is for exogenous regressors, and in the biased-adjusted delta equation, $E_{(\tilde{z}_{iT})} = k$ and $V_{(\tilde{z}_{iT})} = \frac{2k(T-k-1)}{T+1}$, represent the mean and variance, respectively.

Afterward, the data is tested for unit root. The H_0 suggests the presence of unit roots in data, which is commonly accepted at the level [110]. Based on robustness, we apply the 2nd generation, cross-sectionally augmented IPS, i.e., the CIPS unit-root test of Pesaran., 2007 [111] as recommended by Li et al., 2021; Khan et al., 2020 and Le et al., 2020 [99,101,104]. The proposed test displays good asymptotic power and does not require an infinitely large sample size. This test improves the ADF regressions for each unit by incorporating cross-sectional means of lagged variables at 1st differences and levels, as demonstrated by Salman et al., 2019 [105]. The CADF statistic, which is used by Wang et al., 2019; Salman et al., 2019 and Pesaran., 2007 [49,105,111] is estimated as Equation (4) given below.

$$\Delta Y_{jp} = c_j + \beta_j Y_{j,p-1} + \gamma_j \overline{Y}_{p-1} + \sum_{A=0}^{q} \partial_{jA}\Delta\overline{Y}_{p-A} + \sum_{A=1}^{q}\theta_{jA}\Delta Y_{j,p-A} + E_{jp} \tag{4}$$

$$(j = 1 to n and p = 1 to p)$$

Where, c_j represents a deterministic term; $\overline{Y}$ shows an average of cross-sections; p is for a period, $\overline{Y}_{p-1}$ & $\Delta\overline{Y}_{p-A}$ are the cross-sectional means of units; & q is lag order. Once the CADF is formulated the CIPS is calculated by averaging the CADFj by using Equation (5) as follows [101].

$$CIPS(M,p) = \frac{1}{M}\sum_{j=1}^{M} T_j(M,p) \tag{5}$$

Where, $T_j(M,p)$ shows the number of jth observations and the corresponding p-ratio of β_i which is the constant of $Y_{i,p-1}$.

The null hypothesis for all $(i = 1, 2, \ldots N and t = 1, 2, \ldots T)$ is $H_0 : \beta_i \geq 0$.

The alternate hypothesis for all $(i = 1, 2, \ldots N and t = 1, 2, \ldots T)$ is $H_a : \beta_i < 0$.

The use of cointegration techniques helps in identifying the longer-period relationships between variables. For this purpose, Westerlund's cointegration test of 2007 [112] is employed in this study. This test is a composite of 4 normally dispersed statistics, including between groups (Gt), among groups (Ga), between panels (Pt), and among panels (Pa) statistics [42,101,105,112]. The test indicates H_0: no co-integration for ≥1 individual observation for Gt & Ga and all panel cross-sections; Pt & Pa [40]. Thus, H_0 suggests no co-integration while H_a proposes co-integration among variables [42]. The test uses an error correction model to detect co-integration. The group means (Gt, Ga) and panel statistics (Pt, Pa) are calculated by using the following Equations (6)–(9).

$$G_t = \sum_{i=1}^{N}\frac{\frac{\widehat{a}_i}{SE(\widehat{a}_i)}}{N} \tag{6}$$

$$G_a = \sum_{i=1}^{N} \frac{\frac{T\widehat{a}_i}{SE(1)}}{N} \tag{7}$$

$$P_t = \frac{\widehat{a}}{SE(\widehat{a})} \tag{8}$$

$$\text{and} P_a = T\widehat{a} \tag{9}$$

Where, conventional standard error of $\widehat{a}_i$ is $SE(\widehat{a}_i)$ and the parameter of error is calculated as $P_a = T\widehat{a}$ which shows the percentage-wise annual error rectification.

3.3. Econometric modelling

To examine the statistical influence of environmental deterioration and income on the health of citizens in countries that have been severely affected by weather events, the study employs the mathematical equations (a & b) as the basis for functional econometric models. These equations will undergo further processes [113].

$$\ln LEX = f(EIN, \ln RGI) \tag{a}$$

$$\ln FRT = f(EIN, \ln RGI) \tag{b}$$

Where, lnLEX: life expectancy, lnFRT: fertility, EIN: environmental index, and lnRGI: real GDP per capita income.

By following the raw mathematical equations (a & b), the general forms of the two econometric models are framed as follows [96, 114].

One $\ln LEX_{it} = \alpha_0 + \alpha_1 \ln LEX_{it-1} + \alpha_2 EIN_{it} + \alpha_3 \ln RGI_{it} + \gamma_i + \epsilon_{it}$.

Two $\ln FRT_{it} = \beta_0 + \beta_1 \ln FRT_{it-1} + \beta_2 EIN_{it} + \beta_3 \ln RGI_{it} + z_i + r_{it}$.

Where, γ_i, z_i, are country-related subscript characters, and i & t are representing country and time. While ϵ_{it}, r_{it}, are error terms of the equations.

In the models the dependent variables are lagged in the intervals, hence the one-period lag is taken into account [99,105,115]. Whereas, the theoretic explanations of symbols in the models are; i) if α_2, and α_3 are negative, it suggests that environmental degradation, and per capita income harm longevity. Whereas, the positive values indicate inversely, ii) the positive values of β_2, and β_3 are in favor of fertility, while the negative values are not.

3.4. Panel ARDL-PMG and CS-ARDL models

The Panel ARDL-PMG estimation model was first presented by Pesaran et al., 2001 [103], which can be employed to estimate the longer period association between dependent and independent variables. The model is applicable when the variables are stationary at either I(0), I(1), or a combination of both, as mentioned by Refs. [57,63]. The model allows for different lags to be used and the models for this study are calculated by using Equations (10) and (11) as estimated below [116].

$$\text{ARDL/PMG} \quad \text{Model One} \ln LEX_{1_{it}} = a_i \sum_{j=1}^{k} b_{2it} EIN_{it-j} + \sum_{j=0}^{k} b_{3it} \ln RGI_{it-j} + er_{1it} \tag{10}$$

$$\text{ARDL/PMG} \quad \text{Model Two} \ln FRT_{1_{it}} = ɐ_i \sum_{j=1}^{k} \vartheta_{2it} EIN_{it-j} + \sum_{j=0}^{k} \vartheta_{3it} \ln RGI_{it-j} + Ꝺ_{1it} \tag{11}$$

Where ln is the natural logarithm, a_i, $ɐ_i$, $Ꝏ_i$ & q_i represent intercepts, er_{1it}, $Ꝺ_{1it}$, $Ơ_{1it}$ & E_{1it} are error terms, $b_{2it}, b_{3it}, \vartheta_{2it}, \vartheta_{4it}$, are estimated parameters of relative proxies.

However, the PMG/ARDL model is a useful estimator for datasets with mixed order of integration, but it has been mentioned by Erülgen et al., 2020; Chudik et al., 2017; Chudik et al., 2015 and Wooldridge. 2002 [117–120] that the model is unable to handle cross-sectional dependency errors. Therefore, for robust results, along with the ARDL-PMG model we accept the cross-sectionally augmented autoregressive distributed lag (CS-ARDL) models as well [117,121]. For addressing C-D, unit-root, and heterogeneity issues, the CS-ARDL approach increases the lags of cross-sectional means in the Auto-Regressive Distributed Lag models [61,122,123]. The CS-ARDL model is estimated by transforming Equation (12) [44,122,124].

$$Q_{i,p} = \gamma_i + \sum_{l=0}^{D} \beta_{l,i} Q_{i,p-1} + \sum_{l=0}^{X} \delta_{l,i} M_{i,p-1} + E_{i,p} \quad (12)$$

Equation (12) is transformed into the CSARDL model, hence Equation (13) given below represents the model [118].

$$Q_{i,p} = \gamma_i + \sum_{l=0}^{D} \beta_{l,i} Q_{i,p-1} + \sum_{l=0}^{X} \delta_{l,i} M_{i,p-1} + \sum_{l=0}^{X} \mathscr{I}_{li} \overline{R}_{p-1} + E_{i,p} \quad (13)$$

Where, $\overline{R}_p = \overline{Q}_p$ and $\overline{M}_p$ which are cross-sectional means of all the covariates included in $\overline{R}_p$, x indicates the lag length, E_{ip} represents error terms and equals to $\tau_i T_p + \varnothing_{i,p}$ in which T_p are the unobserved common factor that causes cross-sectional dependence.

Lastly, the long-run estimation equation is framed as follows [61,124–126].

$$CSARDL_i = \frac{\sum_{I=0}^{X} \delta_{I,i}}{1 - \sum_{I=0}^{D} \beta_{I,i}}$$

4. Empirical results & discussions

4.1. Principal Component Analysis (PCA) results for environmental index

PCA results are visible in Table 2. In which the first principal component (PC_1) shows a greater eigenvalue than the second and third principal components, which is 1.28 (see Fig. 3 also). The eigenvalues are factors of scaling the principal components (PCs). The first PC explains 42.7 % of the variance, which is also higher than the variance explained by other PCs. Varimax rotation with Kaiser normalization is applied, and resultantly, the PC_1 influences precipitation, temperature, and total GHG emissions at the percentage of 3.4, 59.4, and 65.9, respectively, outcomes are depicted in Table 2 under "First Component's Score". The selection of the best-fit PC is based on its eigenvalue and percentage of variance. Since the first principal component possesses the highest eigenvalue and explains a higher ratio of the variance in sample space, than the other PCs, thus the PC-1 is used as an index for environmental degradation. Consequently, the remaining two PCs are skipped. Conclusively, the variables; total greenhouse gas emissions, temperature, and precipitation are replaced with the PC-one as it denotes a composite index of these features i.e., environmental index (EIN). The sampling competence (KMO) of the index is 0.44, and Bartlett's test is valid at a p-value of 0.00 with X^2 17.50.

4.2. Results of CD, SH, unit-root, and cointegration tests

The statistical outcomes of the cross-sectional dependency test of Pesaran 2004., Pesaran and Yamagata's [102,108] delta and adjusted delta tests for slope homogeneity, Pesaran's CIPS test for unit roots, and Westerlund's (2007) [112] test of co-integration are depicted in A, B, C, and D of Table 3, correspondingly. The outcomes of the CD testing rejected the null proposition which suggests that the data is cross-sectionally independent, at <1 %. According to Liu et al., 2018 [114], the degree of interdependence among cross-sections can be determined by using the C-D test. In this context, the outcomes are matching with the results of Yasmeen et al., 2018 [96], which suggest that the decision-making of one country can spill over and impact the decision-making of other countries of the panel. Δ_{SH} and AdjΔ_{SH} techniques suggest the exclusion of H_0 at less than 1 % of the significance for both of the models. The null hypothesis which suggests that slopes are not heterogeneous is rejected. Therefore, the outcomes of the study can be discussed at the country level. To prevent unreliable estimates of conventional unit root tests, we adopted Pesaran's 2nd generation CIPS test for examining the stationarity in panel datasets as suggested by Pesaran., 2021 [103]. The outcomes of this test in C of Table 3 present diversified integration orders, which means the null hypothesis is rejected at I(0) and I(I). The outcomes of the unit-root statistics direct us to accept Westerlund's test of co-integration [40,103]. The outcomes affirm the presence of longer-period relationships amongst variables. Based on the statistical outcomes of unit-root and cointegration techniques, we adopted the Panel MG/ARDL estimation model for long-run estimations as Ahmed et al., 2021 and Salahuddin et al., 2019 [57,63] adopted. Moreover, we apply the CS-ARDL model to acquire robust results.

4.3. Outcome of the panel ARDL-PMG and the CS-ARDL models

The outcomes of panel ARDL-PMG and the CS-ARDL equations are presented in Table 4. The panel autoregressive distributed lag (ARDL) technique consists of two equations. In the first equation, life expectancy is a dependent variable, whereas in its 2nd equation fertility rate is a dependent variable. The cross-sectional-autoregressive-distributed lag (CS-ARDL) also has life expectancy as a dependent variable in its first model and the fertility rate is a dependent variable in the second model. Whereas, in all the models, environmental degradation and per capita income are independent variables. Model one of the panel ARDL/PMG outcomes that one unit increase in environmental degradation declines the longevity in environmentally susceptible nations by 0.072 units. It means that an increasing temperature, intensifying hazardous gasses, and varying precipitation decline life expectancy in the countries. Whereas, per capita income can enhance the length of citizens' life in sample countries. Because per capita income has a 5.96 % positively significant influence on life expectancy with a one percent raise in per capita income. Since the increasing income causes

Table 2
PCA estimations of environmental features.

Principal Component	Eigenvalue	Percentage of Variance	Indicators	First Component's Score
One	1.28	42.71	Parcipitation	3.4 %
Two	1.06	35.34	Temperarure	59.4 %
Three	0.66	21.96	Total GHG	65.9
Kaiser-Meyer-Olkin		Bartlett's Test		
		Chi-Square	df.	Sig.
0.44		17.50	3	0.00

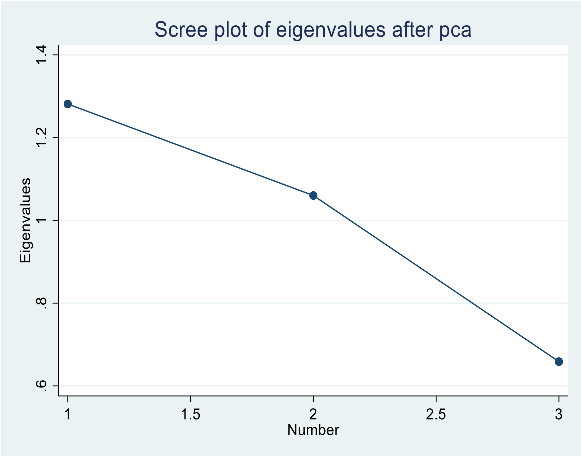

Fig. 3. Eigenvalue graph of PCs.

Table 3
Results of CD, SH, Unitroot, and Co-integration tests.

Variables			LEX		FRT	EIN		lnRGI
A. Pesaran (2004) CD test statistics								
t-Stats			22.014*		9.639*	8.411*		22.923*
The average absolute value of the off-diagonal			0.93		0.74	0.40		0.97
B. P & Y (2008) Delta $\widetilde{\Delta}$ and Adjusted Delta $\widetilde{\Delta}_{ADJ}$ statistics rowhead								
Models			$lnLEX = f(EIN, lnRGI)$			$lnFRT = f(EIN, lnRGI)$		
Statistics			$\widetilde{\Delta}$	$\widetilde{\Delta}_{ADJ}$		$\widetilde{\Delta}$	$\widetilde{\Delta}_{ADJ}$	
			14.699*	16.434*		16.963*	18.965*	
C. CIPS (2007) [Unit root test]								
Level			(2.440)**	(1.402)		(3.511)*	(2.194)	
1st Difference			.	(2.636)*		.	(2.784)*	
Decision			1(0)	1(1)		1(0)	1(1)	
D. Westerlund (2007) Co-integration test results [H0: No co-integration] rowhead								
Statistics	Value	z-Value	p-Value	Value		z-Value	p-Value	
G_t	(1.967)	0.208	0.583	(3.547)		(4.645)	0.000	
G_a	(6.970)	0.972	0.834	(0.315)		3.971	1.000	
P_t	(9.885)	(4.881)	0.000	(0.842)		3.877	1.000	
P_a	(17.822)	(6.048)	0.000	(1.130)		2.395	0.992	

Note: * & ** shows significance level at <1 % & <5 %, respectively. G_t & G_a are between and among groups, and P_t & P_a are between and among panels, respectively.

environmental degradation, therefore the underlined results may vary on the ground, until the increasing income stops harming the environment. Statistical outcomes of the CS-ARDL model one are consistent with ARDL's results, thus endorsing the strength of outcomes. Since the CS-ARDL can better deal with the basic econometric issues, model one represents that per capita income positively impacts 1.68 % on longevity in the countries. Conclusively, the ARDL and CS-ARDL models confirm that climatic deterioration has a harmful influence on life expectancy, whereas per capita income improves the longevity of inhabitants. Moreover, model two of ARDL affirms that environmental degradation declines the birth rate and causes population crises in climatically vulnerable countries. Mathematical outcomes reveal that if an environment is degraded by one percent, it negatively impacts on fertility rate by 0.022%. The CS-ARDL model two also discovers similar outcomes, which reveals that a one-unit deteriorated climate declines the birth rate by

Table 4
Long-run results of ARDL/PMG and CS-ARDL models.

Models	ARDL/PMG Models				CS-ARDL Models			
	Model 1. (2, 2, 2)		Model 2. (3, 1, 1)		Model 1.		Model 2.	
Dependent Variables	LEX		FRT		LEX		FRT	
	Coef.	P-Stat	Coef.	P-Stat	Coef.	P-Stat	Coef.	P-Stat
EIN	(0.00072)**	0.03	(0.02225)*	0.00	(0.00072)**	0.03	(0.00281)*	0.00
lnRGI	0.05964*	0.00	0.15784	0.30	0.01682***	0.07	0.18148	0.25
Trend	0.00173*	0.00	(0.00188)	0.40	.	.	.	.
MG^{Ψ}	.	.	.	.	(1.59695)*	0.00	(1.24369)*	0.00
N		144		136		152		152
S.E of Reg.		0.007		0.009		.		.
Sum Sq. Residual		0.005		0.008		0.100		0.570
Root MSE		0.006		0.007		0.000		0.010
Log-Likelihood		727.92		478.32		.		.
R^2 MG		.		.		0.890		0.400
CD Statistics		.		.		(1.40)		(2.11)

Note: *, ** & *** show important at p<1 %, p<5 % & p<10 %, respectively. Variables are lagged through Akaike-Information-Criterion (AIC). Ψ: Mean Group Adjusted-term.

0.002 units. Whereas, per capita income in both the models is insignificantly related to the fertility rate, which means that increasing income is even unable to help countries increase their population. The underlined findings of this study align with previous research by Rahman et al., 2022; Bernard et al., 2021; Wang et al., 2020 and Schramm et al., 2020 [127–130].

Moreover, infertility is a global dilemma, The World Economic Forum[9] reports that just in seven decades a fifty percent decline in the birth rate is observed. High-income nations are facing severe population crises, as reported by the IMF[10] that Japan, Korea, Singapore, and Chinese high-income regions including Taiwan, Shanghai, and Hong Kong recently observed the very lowest birth rates. Japanese PM Fumio Kishida[11] has warned the nation regarding the population crisis and he said must be resolved on a "now or never" basis. Based on the statistical outcomes, this study strongly encourages countries such as Bangladesh, India, Japan, Pakistan, Philippines, Sri Lanka, Thailand, and Vietnam to address the root causes of environmental degradation. This proactive approach is essential to prevent the current issue of infertility from potentially escalating into a full-blown population crisis. It is also crucial for ensuring the longevity of the population.

5. Conclusion

This study empirically analyzed the combined impact of environmental degradation and income on life expectancy and fertility rates in countries heavily affected by weather events in 2017, 2018, and 2019, covering the period from 2000 to 2019. The countries examined in this dataset are Bangladesh, India, Japan, Pakistan, Philippines, Sri Lanka, Thailand, and Vietnam. This study took life expectancy (in years) and fertility rate (births per woman) as the dependent variables for mathematical analysis. The independent variables included per capita real income and environmental degradation, which is represented by total greenhouse gas emissions, temperature, and precipitation. These three aspects of environmental degradation are combined into a composite index called the Environmental Index (EIN). To estimate the index value, the environmental features are standardized to the same scale using the min-max technique before applying Karl Pearson's Principal Component Analysis (PCA) technique. Natural logarithms are taken for other variables of interest. To ensure robust interpretations, this study implemented a series of statistical checkpoints to rigorously assess the variables of interest at different stages of the analysis. The analysis commenced by calculating the degree of interdependence among the variables, and applied Pesaran's CD test. Subsequently, Pesaran and Yamagata's test was conducted to assess the homogeneity of slopes among the variables. The datasets were then subjected to unit root tests to determine the order of integration. The CIPS unit root test was chosen for this purpose. The unit root test revealed mixed-order integration, which led to the selection of Westerlund's cointegration test from 2007 to confirm the existence of long-run cointegration among the variables. After establishing the presence of long-run cointegration, the study employed two long-run estimation models the Panel PMG/ARDL model developed by Pesaran et al., in 1999 [131] and the CS-ARDL model developed by Chudik et al., in 2015.

[118]. By following these rigorous statistical checkpoints, the study ensured the validity and robustness of its interpretations and findings throughout the analysis. In conclusion, this study revealed that environmental degradation significantly and negatively influences longevity and fertility in Bangladesh, India, Japan, Pakistan, Philippines, Sri Lanka, Thailand, and Vietnam.

The current study provides valuable insights into environmental health issues, shedding light on the fact that environmental degradation poses one of the most pressing threats to fertility and life expectancy. This threat remains pervasive, even in countries with robust per capita incomes, underscoring the inability of income alone to mitigate the detrimental impact of a degraded environment on

[9] https://www.weforum.org/agenda/2022/06/global-decline-of-fertility-rates-visualised/.
[10] https://www.imf.org/en/Publications/fandd/issues/2020/03/lessons-from-singapore-on-raising-fertility-rates-tan.
[11] https://edition.cnn.com/2023/01/23/asia/japan-kishida-birth-rate-population-intl-hnk/index.html.

the health of citizens, especially in nations susceptible to environmental challenges. These findings advocate for the integration of sustainable growth considerations into economic policy frameworks. In this context, the study emphasizes the critical need to focus on proactive methods capable of mitigating the root causes of environmental degradation, thereby averting the population crises, currently surfacing in many countries such as Japan. In this regard, the recent study presents compelling statistical evidence. By formulating and implementing strategies geared towards sustainable growth, countries facing climatic vulnerabilities can effectively address the issue of infertility and reduced life expectancy. Importantly, this study offers a comprehensive and practical framework for policymakers and practitioners, urging them to recognize environmental degradation as a significant and dynamic contributor to population crises. It advocates for a holistic approach that considers both economic and environmental factors. In addition to its practical implications, this study contributes significantly to the academic sphere. It provides the most up-to-date literature in the field of environmental health and underscores the critical importance of adopting an interdisciplinary approach in addressing the complex issue of existential threats posed by poor environmental conditions, specifically in the environmentally susceptible nations of Asia.

While the findings of this study are robust and highlight valuable insights, it is important to acknowledge some limitations. For instance, this study has a smaller sample size, including only eight countries. Additionally, the scope of this study focuses on just two aspects of citizens' health. However, environmental degradation could potentially impact numerous other health features as well. Furthermore, the analysis only incorporates per capita income, overlooking the potential influence of other monetary variables.

5.1. Future research directions

Based on the limitations of this study, future research should consider a larger sample size since environmental threats are global issues that cannot be confined to specific regions or countries. Moreover, numerous other health features need to be checked for more robust results. The skipped features of monetary variables in this study should be incorporated to examine the overall impacts of growth in the same countries to get more significant insights. Additionally, other variables that have a direct detrimental impact on human health should be examined, such as CO_2, heat waves, etc.

5.2. Policy suggestions

Our recommendations for environmentally vulnerable countries, namely Bangladesh, India, Japan, Pakistan, Philippines, Sri Lanka, Thailand, and Vietnam, are rooted in the findings of our study. Our research has unveiled the detrimental impact of environmental degradation on both longevity and birth rates. When it comes to longevity, we advise these countries to prioritize increasing per capita income. However, in the context of population crises, simply boosting income may not be sufficient. What is indeed effective is a concerted focus on climate action and climate resilience. As articulated by António Guterres[12] in 2020, the consequences of a degraded environment are the counter-attacks of nature and these burdens are endured by inhabitants of affected countries and regions in the shape of human, economic, agricultural, and infrastructural losses. Therefore, echoing Guterres' sentiments, we emphasize the urgent need to make peace with nature. The sample countries must enact environmentally friendly regulations, review and update existing ones, and consider implementing or raising taxes on hazardous emissions. Additionally, they should invest in cleaner technologies.

Originality

Authors confirm that this work is original and has not been published elsewhere, nor is it currently under consideration for publication elsewhere.

Ethical Approval

Not applicable because the study is conducted on publicly available data that was approved by all the authors.

Consent to publish

All authors have approved the manuscript and agree to publish it in Heliyon.

Data availability statement

The datasets used and analyzed in the current study are publicly available on the Climate Change Knowledge Portal and the World Development Indicators of the World Bank's official website. However, the authors can provide the data in a useful format upon request.

[12] The 9th Secretary-General of the United Nations.https://www.un.org/sg/en/content/sg/speeches/2020-12-02/address-columbia-university-the-state-of-the-planet.

Additional information

No additional information is available for this paper.

CRediT authorship contribution statement

Mansoor Ahmed Golo: Writing – review & editing, Writing – original draft, Software, Methodology, Formal analysis, Conceptualization. **Dongping Han:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Formal analysis, Conceptualization. **Muhammad Ibrar:** Writing – review & editing, Writing – original draft, Software, Methodology. **Muhammad Arshad Haroon:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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