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Article

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Linear and Threshold Effect of CO_2 Emissions, Economic Development, Clean Fuel and Technology on Health Expenditure in Central Asia

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ABSTRACT

The investigation is a pioneer in examining the joint impact of CO_2 emissions, economic development, access to clean fuel and technology, and threshold effect on health expenditure in Central Asia. For this purpose, the balanced panel dataset is built for 5 Central Asian countries, namely Uzbekistan, Kazakhstan, Kyrgyzstan, Tajikistan, and Turkmenistan, spanning 2000-2020 with annual data. The results of the Johansen cointegration test and error correction coefficients of vector error correction model and autoregressive distributed lag (ARDL) show a long-run association among the studied variables. Granger causality test shows the causal effect from independent variables to dependent variables, further validating model construction's relevance. According to the ARDL model findings, CO_2 emissions, economic development, access to clean fuel, and technology positively impact health expenditure. Threshold regression results reveal that the economic development stage (PGDP) should be between 2326.36 and 2345.87 USD to increase health expenditure that can rationally respond to environmental degradation. Policy actions like renewable energy transition and enhancing economic development levels are proposed.

Keywords: CO_2 Emissions, Economic Development, Clean Fuel and Technology, Central Asia, Autoregressive Distributed Lag, Vector Error Correction Model, Threshold

JEL Classification: Q51, O10, Q20, I10

1. INTRODUCTION

The expansion of intensive irrigation in the Aral Sea area in the early 1960s and the unreasonable and inefficient use of water prompted the emergence of important regions of secondary soil salinity and secondary solonchak, the origin of salt and salt product transportation. The Aral Sea crisis incorporates Uzbekistan, Kazakhstan and Turkmenistan, as well as indirectly influences Tajikistan and Kirgizstan. This catastrophe is considered one of the most drastic worldwide ecological disasters in modern age, outcoming in a human-caused sand and dust storms (SDS) source in Central Asia that releases more than 100 million tons of dust and toxic salts per annum. At present, this impacts 73 million inhabitants in Central Asia and poses a danger to the sustainable development of the territory, along with the healthcare and well-being, genetic illness and prospects of residing nearby (UNCCD Regional SDS Strategy, 2021). The ecological collapse of the Aral Sea area has caused the replacement of more than 100,000 inhabitants and influenced the health of more than 5 million humans all over Central Asia (UNCCD, 2021). According to the World Health Organization (WHO), the majority of countries with little spending on healthcare per capita were in Sub-Saharan Africa (Figure 1). Central Asian countries, specifically Uzbekistan, Kirgizstan and Tajikistan, were in the group 50-99 US$ per person, while Kazakhstan estimated to a greater degree in the 100-299 category. Remarkably, Turkmenistan took place in the 500-999 US$ category, and it held first status among Central Asia countries regarding healthcare expenditure per capita in 2019 (Figure 1).

Economic development is considered the secure way to grow health spending in emerging and developing countries (World Health Organization, 2018). Health expenditure per capita in developed countries was estimated to be higher than 4 times compared to the average gross domestic product (GDP) per capita in low-income countries. The average health expenditure per capita in the global economy was 1105 US$ in 2019; even so, there was a vast difference across income groups. In low-income regions, health spending per capita was 39 U.S$ per person, whereas in high-income countries, it was 3191 US$ per person. WHO roughly calculates that an extra 41 US$ per person is needed for healthcare expenditure in low- and middle-income countries to move forward on the way to the healthcare target of sustainable development goals (Stenberg et al., 2012; World Health Organization, 2021). According to the researchers, there was a bidirectional significant correlation between economic growth and healthcare expenditure in various developing countries (Gerdtham et al., 1992; Blomqvist and Carter, 1997; Baltagi and Moscone, 2010; Barkat, et al., 2019). Therefore, GDP growth directly influences the increased healthcare expenditure per capita in developing countries and Central Asia. Destruction of the environment and greenhouse gas excretion have become significant issues in academic and policy makers society (Saida and Kais, 2018; Cheikh et al., 2020), seeing that atmospheric contamination alone leads to untimely deaths of approximately 7 million people globally per annum (UNEP, 2020). The increased atmospheric pollution caused by human-induced emissions such as carbon dioxide gas influences healthcare expenditure per capita (Ahmad et al., 2021). Many economically developed and emerging countries undermine air quality and a clean environment in the interest of rapid production growth. Because of worsening atmosphere quality and environmental pollution, healthcare spending demand rises to make a healthy life feasible (Alimi et al., 2019).

The relationship linking energy and health is peculiarly apparent in homes in the formation of clean fuels and technologies in cooking. Access to clean and environment-friendly technologies in cooking is crucial to secure human beings healthcare from household air contamination because of the utilisation of stoves and fuels using polluting energy, namely biomass and coal. Today, worldwide, 2.4 billion population survive without having access to clean and eco-friendly fuels and technologies for cooking. Indoor air pollution, diffused from using polluting kitchen stoves and non-renewable energies, is a reason for some 3.2 million deaths every year. Specifically, women and children are in greater health, well-being and livelihood danger as they frequently work with food cooking and gathering fuel sources such as wood (World Health Organization, 2023).

The contribution of this paper to the existing literature is twofold: (1) The study firstly investigates the impact of environmental degradation on health outcomes in the case of Central Asia; (2) Secondly, the threshold values of economic development are identified, which allows increasing health expenditure concerning environmental degradation.

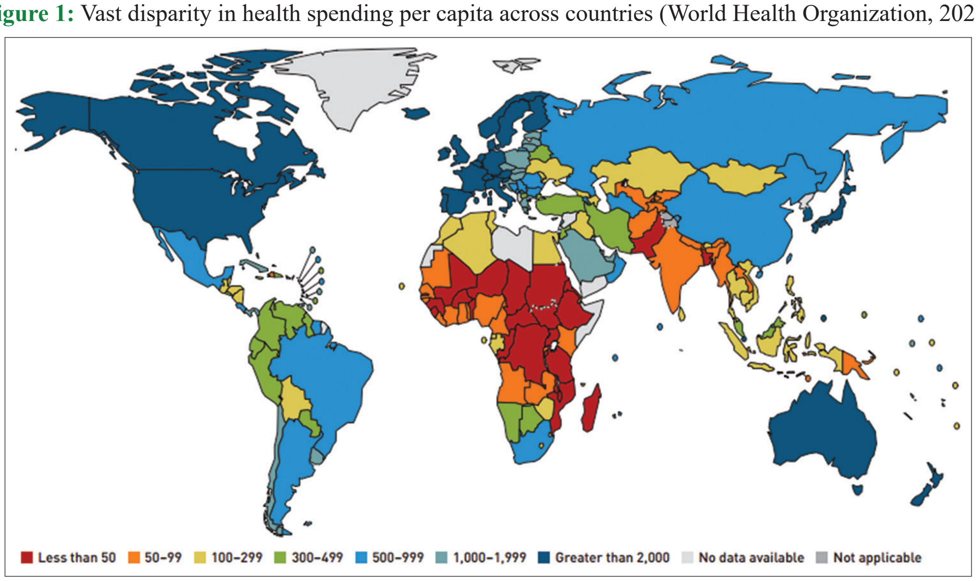
The rest of the study is structured as follows: Section 2 browses literature review and shows research contribution; Section 3 defines the data used in this work; Section 4 represents the methodology applied in the paper; Section 5 provides the empirical estimations; Section 6 concludes.

2. LITERATURE REVIEW

2.1. Health Expenditure and CO_2 Emissions

The studies addressing the association between environmental degradation and health outcomes have gained significant interest in academia. More specifically, Jerrett et al. (2003) assess the

Figure 1: Vast disparity in health spending per capita across countries (World Health Organization, 2021)



correlations between health expenditure and ecological factors by applying data from 49 territories of Canada Ontario. According to the results, healthcare spending per capita in the highly populated districts is more significant than in other regions. Increasing investment into better ecological quality standards prompts a reduction in healthcare spending. Narayan and Narayan (2008) scrutinised the influence of environmental quality on health care costs using the panel cointegration test in the eight organisation of economic cooperation and development (OECD) countries between 1980 and 1999. In the long run, it has been established that the emission from sulphur oxide has a statistically notable and affirmative influence on healthcare expenses. Yahaya et al. (2016) investigated the effect of environmental quality on per capita healthcare expenses, collecting data from 125 developing countries from 1995 to 2012 and applying the panel cointegration test. The results illustrate that the quality of the environment is one of the strong indicators that impact per capita health expenditures in emerging and developing countries.

Among the selected variables, environmental pollution from carbon dioxide is the main contributor to per capita healthcare cost growth. Apergis et al. (2018) examine the effect of carbon dioxide emissions on per-person health expenses, employing panel quantile regression and panel cointegration methods among the states of the U.S. over the period 1966-2009. The findings suggest that the impact of environmental emissions from carbon dioxide on health spending is more substantial in the states where expenditures on health are perceptibly high. The environmental emission (carbon dioxide) per population unit prompts to enlarge health expenditure at proportion contrasting from region to region. Moosa and Pham (2019) explore the relationship among CO_2 emissions, per capita health spending and per capita income, applying data from seven countries between 1995 and 2015 using the autoregressive distributed lag (ARDL) model. The results show that per capita health spending and CO_2 emissions have a positive relationship in low-income countries, while the association was negative in high-income countries. Assadzadeh et al. (2014) analysed the relationships between CO_2 emissions and health expenditure per capita using panel data for eight petroleum-exporting countries from 2000 to 2010. The results indicate that in the short term, CO_2 emissions have a positive and statistically significant impact on healthcare expenditure.

Furthermore, Raeissi et al. (2018) assess the association between CO_2 emissions on public and private healthcare expenditure by applying a time series methodology in an Iranian case from 1972 to 2014. Due to the findings, CO_2 emissions have a statistically significant and positive impact on healthcare spending. It is stated that the influence of CO_2 on healthcare expenditure per capita is considerably more critical over a long period than a short time. Zaidi and Saidi (2018) illustrate the positive and significant relationship between carbon dioxide emissions and healthcare spending. Saleem et al. (2022) examine the linkage among healthcare spending, carbon dioxide excretion and energy manufacture, using panel VAR and generalized method of moments (GMM) model for data from 38 OECD member countries between 2008 and 2018. The results show that CO_2 emissions and healthcare spending show a positive and bidirectional connection.

Hypothesis 1: There is a negative relationship between health expenditure and CO_2 emissions.

2.2. Health Expenditure and Economic Development

Many empirical works have investigated the impact of economic development on healthcare expenditures. Particularly, classic studies such as Newhouse (1977), Gerdtham and Jonsson (1992) and Hitiris and Posnett (1992) revealed that GDP influences strongly on health care spending in cross-selected OECD countries. Getzen (2000) indicates that healthcare expenditure is more a function of earnings over the preceding 5 years after the present time. That is, the country's economic growth successfully influences healthcare expenditure per capita following three to 5 years. Aboubacar and Xu (2017) explore the association between GDP growth and health expenditure in Sub-Saharan African countries from 1995 to 2014, employing a GMM estimator. The results show a statistically crucial and positive relationship between health expenditure and GDP growth. Khoshnevis Yazdi and Khanalizadeh (2017) reveal the influence of atmospheric pollution and GDP growth on healthcare expenditure in the case of eleven countries from the Middle East and North Africa region from 1995 to 2014, using the pedroni cointegration test. They corroborate that the region prompts toward increasing economic growth faces miserable environmental conditions that affect the standards of human health and well-being, which proceeds to increase health expenditure per capita. Zheng et al. (2010), employing the panel ordinary least square regression and error correction models for 31 selected Chinese regions, find that provinces economic growth and the quality of the environment positively influence health expenditure per capita. Kiymaz et al. (2006) researched the long-term connection between per capita health spending, GDP per capita and the increase in the residents of Turkey. They find that cointegration exists among all three variables, particularly the bivariate correlation between healthcare expenditure per capita and economic growth.

Consequently, the GDP growth of 10% would precipitate the increase of healthcare spending by 21.9% while controlling the growth of inhabitants in Turkey. İlgün (2022) utilises granger causality to analyse the relationship between economic growth per capita and health spending in 26 OECD countries from 1992 to 2014 years. The author identifies that among the selected countries, nine of them have unilateral relationships between GDP per capita and healthcare expenditure. In contrast, two states have bilateral relationships, whereas others do not correlate. Ke et al. (2011) empirically analysed the factors affecting healthcare spending in the case of 143 countries. They highlight that the growth of GDP brings enlarging healthcare expenditure per capita. Hosoya (2014) suggest that the development of GDP precipitates growth in healthcare spending in OECD countries. In contrast, Elmi and Sadeghi (2012) accentuate that the impact of economic growth is crucial for the increase of healthcare spending in 20 emerging countries.

Hypothesis 2: There is a positive relationship between health expenditure and economic development.

2.3. Health Expenditure and Access to Clean Fuel and Technology

It is becoming evident that access to clean fuels and technologies on healthcare spending plays a pivotal part in each individual's well-being and healthcare (Everard, 2019; Fukuda et al., 2019).

Several researchers such as Mensah and Adu (2015), Karimu et al. (2016), Olang et al. (2018), Karakara and Osabuohien (2020) and Alem et al. (2016) have concentrated on the factors of selecting household cooking power sources in emerging and developing countries with an exploration of clean and dirty cooking fuels. The main hindrance of these investigations is that they were unsuccessful in deliberating the correlation between energy selection and healthcare problems. Other studies, such as Baumgartner et al. (2011), Khan and Lohano (2018) and Ofori et al. (2018), make an effort to illustrate the influence of cooking fuels in families on individuals' well-being and healthcare with a particular focus on specific health condition. Moreover, Hou et al. (2022) investigate the causes of solid fuel use on health conditions in rural areas of China. A multinomial logistic regression model was applied in the research, conducted surveys and accumulated data from selected ten villages in the Northern part of China. The transformation from polluting energy to renewable and clean energy in rural areas prompts less indoor air pollution, which causes household health benefits. Luo et al. (2021) state that inside household pollution from fossil fuel use influenced significantly cognitive decrease among inhabitants in China. In addition to that, exposure to inside atmospheric pollution has been determined as a danger for various diseases, including lung cancer, asthma, chronic obstructive pulmonary and high blood pressure. Imelda (2000) highlights that access to clean fuel and cooking technology can considerably minimise infant mortality depending on a fuel-switch project in Indonesia. Furthermore, Liu et al. (2020) explore that unclean fuel consumers show high blood and depression symptoms in older people and also point out that elderly inhabitants using clean fuels have a higher potential to deal with daily activity.

Hypothesis 3: There is a positive relation between health expenditure and access to clean fuel and technology.

3. DATA

To empirically explore the relation among health expenditure, environmental degradation, economic development, access to clean fuel and technology, a panel dataset including five Central Asian countries, Uzbekistan, Kazakhstan, Kyrgyzstan, Tajikistan, and Turkmenistan, is developed over the period 2000-2020 using annual data. In the study, health expenditure, measured in USD per capita, is used as the dependent variable, whereas CO_2 emissions, measured in metric tons per capita, and economic development, measured in GDP per capita in USD. Access to clean fuels and technologies for cooking, measured in percentage of population, are used as independent variables. Data for GDP per capita and CO_2 emissions per capita are obtained from World Development Indicators[1], and the data on health expenditure per capita, access to clean fuels and technologies for cooking are downloaded from World Bank Data. Table 1 provides the definition and sources of the studied variables.

According to the descriptive statistics of the variables given in Table 2, the average health expenditure (HEALTH) was 142.14 USD per capita in Central Asian countries from 2000 to 2020. The mean value of CO_2 emissions (CO_2) per capita is 5.88 metric tons. 73.05% of the population have access to clean fuels and technologies (ACFT) for cooking on average. Per capita GDP (PGDP) is average counted as 3427.93 USD. Standard deviations of health expenditure (HEALTH) (131.35) and per capita GDP (PGDP) (3229.42) are huge, whereas the figures for CO_2 emissions (CO_2) (5.07) and access to clean fuels and technologies (ACFT) (19.31) are relatively higher. The skewness of health expenditure (HEALTH) and per capita GDP (PGDP) is positive, while the skewness of CO_2 emissions (CO_2) and access to clean fuels and technologies (ACFT) is nearly symmetric around its mean. The kurtosis of health expenditure (HEALTH), access to clean fuels and technologies (ACFT) and per capita GDP (PGDP) is almost mesokurtic, whereas the kurtosis of CO_2 emissions (CO_2) is platykurtic.

1 Accessed by Prof. Arusha Cooray, James Cook University, Australia, email: arusha.cooray@jcu.edu.au

Table 1: Definition and sources of the variables

Variable	Definition	Source
HEALTH	Health expenditure (per capita in current USD)	World Bank Data
CO_2	CO_2 emissions (metric tons per capita)	World Development Indicators
ACFT	Access to clean fuels and technologies for cooking (percentage of population)	World Bank Data
PGDP	Economic development (GDP per capita in USD)	World Development Indicators

GDP: Gross domestic product

Table 2: Descriptive statistics

	HEALTH	CO_2	ACFT	PGDP
Mean	142.14	5.88	73.05	3427.93
Median	79.33	4.38	73.30	2131.35
Maximum	488.62	15.34	99.90	11402.76
Minimum	5.91	0.32	20.80	430.34
SD	131.35	5.07	19.31	3229.42
Skewness	1.07	0.39	−0.47	1.12
Kurtosis	2.95	1.53	2.88	2.94
Jarque-Bera	20.27	12.11	4.05	22.11
P-value	0.00	0.00	0.13	0.00
Sample size (T×N)	105	105	105	105

SD: Standard deviation

4. METHODOLOGY

To examine the long-run association among CO_2 emissions (CO_2), access to clean fuels and technologies for cooking (ACFT), economic development (PGDP) and health expenditure (HEALTH) in Central Asia, panel vector error correction model (Sims, 1980) is employed. The general specification of the vector error correction model (VECM) model can be prescribed as the following:

$$HEALTH_{i} \quad c \quad c\sum_{p=1}^{n} HEALTH_{i\,t-p} \quad c\sum_{p=1}^{n} CO_{\,i\,t-p}$$
$$c_3\sum_{p=1}^{n}\Delta ACTF_{i,t-p} + c_4\sum_{p=1}^{n}\Delta PGDP_{i,t-p} +$$
$$\varnothing ECT_{i,t-1} + \theta_{i,t} \tag{1}$$

Where $Y_{i,t}$ is a country-specific vector of modelled variables, including, $HEALTH_{i,t}$, $CO_{2i,t}$, $ACTF_{i,t}$, $PGDP_{i,t}$, $\varepsilon_{i,t}$ The first difference operator is the model error and might be further detailed with the specification of unobserved heterogeneity. In addition, we introduce lag as 2, given the SIC criterion. Furthermore, we highlight that the short-term parameters Γ, the adjustment coefficients α, and the cointegrating equation coefficients β are constant across all subjects (countries) of our sample. Finally, we note that the term in parentheses, $\beta' Y_{i,t-1} = \mu_t$, is also called the cointegration residual or error correction term. We observe that, from an economic perspective, the parameters in the β' Vector are also defined as long-run multipliers. However, long-run multipliers can be estimated with one cointegrating relationship. If the number of cointegrating ranks is >1, panel ARDL might be used as a robustness check to estimate long-run coefficients.

The specification of the panel ARDL model (Pesaran and Smith, 1995; Pesaran et al., 1999) can be prescribed as the following:

$$\Delta HEALTH_{i,t} = c_0 + c_1\sum_{p=1}^{n}\Delta HEALTH_{i,t-p} + c_2\sum_{p=1}^{n}\Delta CO_{2i,t-p} + c_3\sum_{p=1}^{n}\Delta ACTF_{i,t-p} + c_4\sum_{p=1}^{n}\Delta PGDP_{i,t-p} + \varphi_1 HEALTH_{i,t-1} + \varphi_2 CO_{2i,t-1} + \varphi_3 ACTF_{i,t-1} + \varphi_4 PGDP_{i,t-1} + \theta_{i,t} \quad (2)$$

Where *HEALTH* is the dependent variable; CO_2, *ACFT* and *PGDP*are independent variables; *i* represents cross-sections, *t* represents period 2000-2020; ϵ is the model error and might be further detailed with the specification of unobserved heterogeneity; Δ is the first difference operator; n is the lag length; p denotes the lag order; c_0 is constant; c_1, c_2, c_3, c_4 are short-run coefficients and constant across all cross-sections; ϕ_1, ϕ_2, $\phi 3$, ϕ_4 are long-run dynamic multipliers and constant across all cross-sections.

To incorporate an error correction term, equation (2) can be rewritten as follows:

$$\Delta HEALTH_{i,t} = c_0 + c_1\sum_{p=1}^{n}\Delta HEALTH_{i,t-p} + c_2\sum_{p=1}^{n}\Delta CO_{2i,t-p} + c_3\sum_{p=1}^{n}\Delta ACTF_{i,t-p} + c_4\sum_{p=1}^{n}\Delta PGDP_{i,t-p} + \emptyset ECT_{i,t-1} + \theta_{i,t} \quad (3)$$

where, $ECT_{i,t-1} = (HEALTH_{i,t-1} - \emptyset_2 CO2_{i,t-1} - \emptyset_3 ACTF_{i,t-1} - \emptyset_4 PGDP_{i,t-1})$ is the error correction term; $\emptyset$ is the speed of adjustment of the model to the long-run equilibrium.

It should be noted that short-run coefficients are not of interest. We only stress the long-run coefficients and the coefficient of the cointegration equation (error correction term).

Even though CO_2 emissions (CO_2), access to clean fuels and technologies for cooking (ACFT), economic development (PGDP) directly impact on health expenditures (HEALTH), we assume that the effect of CO_2 emissions (CO_2) on health expenditures (HEALTH) varies depending on the level of economic development of Central Asian countries. Consequently, a panel threshold regression model (Wang, 2015) is also applied to estimate this relation. The panel threshold regression model divides the sample into sub-samples based on the different (lower and upper) regimes. The panel threshold regression model can be described by equation (4):

$$HEALTH_{i,t} = \beta_0 + \beta_1 CO2_{i,t} * I(PGDP_{i,t} \leq \gamma) + \beta_2 CO2_{i,t} * I(PGDP_{i,t}) > \gamma) + \beta_3 ACTF_{i,t} + \beta_4 PGDP_{i,t} + \mu_i + \varepsilon_{i,t} \quad (4)$$

Where I() denotes the indicator function. The threshold regression model explores the effect of CO_2 emissions (CO_2) on health expenditures (HEALTH) with the changes in economic development regimes (PGDP). β_0 is intercept, β_1, β_2, β_3 and β_4 are elasticity coefficients, μ_i is the individual effect, $\varepsilon_{i,t}$ is the disturbance.

In the empirical analysis, we will evaluate the existence of unit roots for the variables of interest and the occurrence of cointegration among them. Specifically, we consider the ADF – Fisher Chi-square (Maddala and Wu, 1999), and the P.P. – Fisher Chi-square (Choi, 2001) panel unit root tests to verify the presence of unit roots in our variables. We will also apply pairwise granger causality tests to strengthen the relevance of the impact of the independent variables on the dependent variable. Moreover, we employ the fisher (or combined Johansen) (Maddala and Wu, 1999) cointegration test.

5. EMPIRICAL SECTION

Table 3 represents tests for lag selection criterion where the tests such as the L.R. test statistic (L.R.), final prediction error (FPE), akaike information criterion (AIC), Schwarz information criterion (S.C.), and the Hannan–Quinan information (H.Q.) criterion are included. The L.R., FPE, AIC, and H.Q. criteria show 6 as an optimal lag length, whereas S.C. selects a lag length 2. We follow the S.C. criteria and set lag to 2 in all the estimations, including tests and models.

Both cointegration tests (Kao and Fisher) and models (VECM, ARDL) require the variables to be integrated at the first differences I (1). On this occasion, we run unit root tests to check the stationarity of the studied variables. The results are reported in Table 4.

Before model estimation, the causality is analysed between the variables in our panel by means of the Pairwise Granger causality test. The results are reported in Table 5. It should be noted that all independent variables have a causal effect on the dependent variable. This encourages the relevance of the studied variables in the model.

Figure 2: Impulse response functions impulse response function

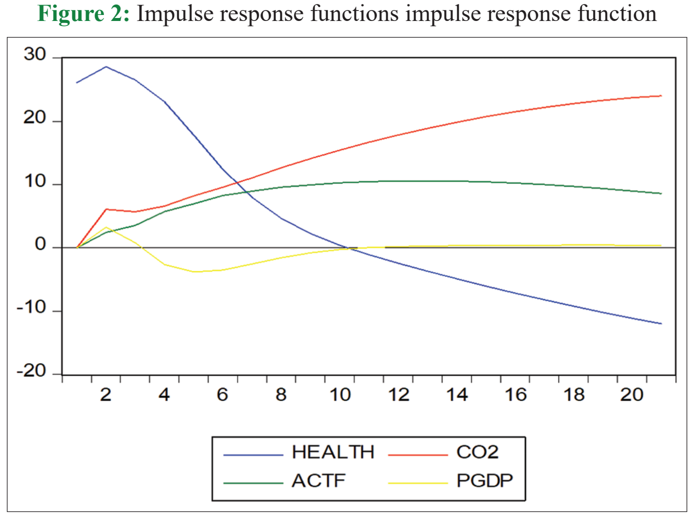


Table 3: The results of lag selection criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	−1552.304	NA	1.24e+13	41.50144	41.62504	41.55079
1	−969.2463	1088.374	3365832.	26.37990	26.99790	26.62666
2	−920.4841	85.82145	1410399.	25.50624	26.61864*	25.95041
3	−887.5368	54.47292	906140.2	25.05431	26.66111	25.69589
4	−872.9907	22.49803	958979.3	25.09308	27.19427	25.93207
5	−860.7820	17.58047	1092670.	25.19419	27.78977	26.23058
6	−815.9519	59.77347*	529557.7*	24.42538*	27.51537	25.65918*

*Represents the criterion selecting the lag order. L.R: Sequential modified L.R. statistic, FPE: Final prediction error, AIC: Akaike information criterion, S.C: Schwarz information criterion, HQ: Hanan-Quinn information criterion

Table 4: Unit root tests

Variables	ADF-Fisher Chi-square		PP-Fisher Chi-square		Integrated order
	Level	1st dif.	level	1st fid.	
HEALTH	0.85	0.00	0.90	0.00	I (1)
CO_2	0.73	0.00	0.29	0.00	I (1)
ACTF	0.00	0.03	0.00	0.00	I (1)
PGDP	0.41	0.02	0.02	0.04	I (1)

For the ADF and P.P. tests, the P-values are reported. Lags are set to 2, choosing the SIC criterion, including individual intercept. In the ADF and P.P. tests, the null hypothesis is the presence of a unit root. The null hypothesis is rejected when the P<0.05.

Table 5: Pairwise granger causality tests

Null Hypothesis	Level
CO_2 does not Granger cause HEALTH	0.00***
HEALTH does not Granger cause CO_2	0.03**
ACTF does not Granger cause HEALTH	0.02**
HEALTH does not Granger cause ACTF	0.59
PGDP does not Granger cause HEALTH	0.04**
HEALTH does not Granger cause PGDP	0.81
CO_2 does not Granger cause PGDP	0.00***
PGDP does not Granger cause CO_2	0.10
CO_2 does not Granger cause ACTF	0.20
ACTF does not Granger cause CO_2	0.35
ACTF does not Granger cause PGDP	0.21
PGDP does not Granger cause ACTF	0.77

The table reports the P-values for the Pairwise Granger causality test. Asterisks represent statistical significance *** and ** for 1% and 5%, respectively. The optimal lag has been selected as 2 using SIC

Before running VECM, we run the Fisher (or combined Johansen) cointegration test to identify a number of cointegration relationships (r). The VECM model is used if the cointegrating vectors are higher than 0 and less than the number of employed variables in the model (K), as follows:

$$0 < r < K.$$

The results are shown in Table 6.

According to Table 6, both trace and maximum eigenvalue tests show three cointegrating equations. More specifically, in our example (where $K = 4$), the application of VECM is appropriate since $r = 3$ because it satisfies the above condition $0 < r < K$ (i.e. $0 < 3 < 4$). This allows us to proceed with estimating the panel VECM model by adding three cointegrating ranks. We report only the adjustment coefficients. They are given in Table 7.

Table 6: Johansen fisher panel cointegration test

Hypothesised No. of CE (s)	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from max-eigen test)	Prob.
None	217.1	0.00***	165.7	0.00***
At most 1	102.5	0.00***	56.38	0.00***
At most 2	64.90	0.00***	53.12	0.00***
At most 3	33.48	0.00***	33.48	0.00***

The table shows the trace and maximum eigenvalue tests of Johansen Fisher for panel cointegration and their P values. The null hypothesis is associated with the cointegration ranks (i.e., the number of cointegrating relations) reported over the rows of column 1. Asterisks represent statistical significance, *** at 1% level and * at 10% level. We set the lag to 2 using SIC

According to the adjustment coefficients of the VECM model represented in Table 7, the adjustment coefficient of health expenditures (HEALTH), CO_2 emissions (CO_2) and economic development (PGDP) are statistically significant in cointegration equation 1. The adjustment coefficient of access to clean fuels and technologies for cooking (ACFT) in rural areas is statistically significant in cointegration equation 3. Since the adjustment coefficients of the studied variables are significant at least once in different cointegration equations, we might postulate all used variables will adjust to equilibrium in the long-run after short-run disequilibrium.

The VECM approach validates the presence of the long-run relationship among the variables. However, the long-run coefficients cannot be obtained. On this occasion, we apply the panel ARDL model. The results are indicated in Table 8.

According to the ARDL model estimations reported in Table 8, in the long run, environmental degradation (CO_2) causes increased health expenditures (HEALTH) in the Central Asian region. Access to clean fuels and technologies for cooking (ACFT) in rural areas also positively impacts health expenditures (HEALTH). As a result of economic development (PGDP), health expenditures (HEALTH) rise in the long-run. Furthermore, the coefficient of error correction term is negative and statistically significant. This validates that health expenditures (HEALTH) will reach equilibrium in the long-run after short-run disequilibrium, which has also been approved by the panel VECM approach.

To examine the response of health expenditure to the shocks in CO_2 emissions (CO_2), access to clean fuels and technologies for cooking (ACFT), economic development (PGDP), we plot impulse response function (IRF) (Figure 2) based on the residuals of the variables.

Table 7: The results of the VECM model – adjustment coefficients

Estimated Alphas (P-values)	Coefficients		
	Cointegration equation 1	Cointegration equation 2	Cointegration equation 3
HEALTH	−0.17*** (0.05)	0.00 (0.00)	0.97** (0.46)
CO_2	−0.00*** (0.00)	6.89 (3.70)	0.02** (0.01)
ACTF	0.00 (0.00)	−7.43*** (2.05)	−0.02*** (0.00)
PGDP	−0.64** (0.24)	−0.01 (0.00)	0.69 (2.28)

Standard errors are in parentheses. Asterisks represent statistical significance ***, ** for 1% and/or 5%, respectively

Table 8: The estimated coefficients by means of panel ARDL (1, 1, 1, 1) model

Dependent variable Health			
Long run			
Variables	Coefficient	Std. Error	P-value
CO_2	23.76	6.22	0.00***
ACTF	2.45	0.61	0.00***
PGDP	0.02	0.01	0.01**
ECT (−1)	−0.29	0.09	0.00***

Asterisks represent statistical significance *** and ** for 1% and 5%, respectively. The optimal lag has been selected as 2 using SIC

Due to the impulse response functions (Figure 2), the response of health expenditures to the shocks in CO_2 emissions (CO_2) and access to clean fuels and technologies for cooking (ACFT) corresponds to the model estimations (Table 8), which is positive. However, the response of health expenditures (HEALTH) to the shock in economic development (PGDP) is negative in the earlier periods. In contrast, it becomes positive in the later periods, contradicting the model estimation results (Table 8).

This incoherence leads us to assume that health expenditures (HEALTH) might vary according to the economic development (PGDP) stage. On this occasion, a panel threshold regression model is developed to overcome this problem and identify to what extent health expenditure (HEALTH) is influenced by the economic development (PGDP) level. In the threshold analysis, we determine CO_2 emissions (CO_2) as a regime-dependent variable—because CO_2 emissions (CO_2) vary due to the economic development (PGDP) regime. Moreover, access to clean fuels and technologies for cooking (ACFT) shows a positive relation with health expenditures (HEALTH) that its impact can be postulated as not highly-important.

Threshold regression model estimation needs to pass the threshold effect test to identify the number of thresholds. The threshold effect test outcomes are provided in Table 9. According to the results, it is clear that threshold regression should be run considering double threshold points since single and triple threshold tests show non-significant P-values.

Given this evidence, we estimate a threshold regression model with double threshold values, whose results are shown in Tables 10 and 11.

The results obtained from the panel threshold regression model given are in Table 11. Model 2 denotes the regression model which passed the double threshold effect test. Due to the results of Model 2, CO_2 emissions (CO_2) positively impact health expenditure (HEALTH) under all regimes. More specifically, one metric ton of CO_2 emissions (CO_2) causes an increase in per capita health expenditure (HEALTH) by 10.98 USD if economic development (PGDP) stage is below 2345.87 USD per capita (regime 1). The highest amount of per capita health expenditure (HEALTH), 25.88 USD per capita, is achieved by a rise of one metric ton CO_2 emissions (CO_2) when economic development (PGDP) stage is between 2326.36 and 2345.87 USD per capita (regime 2). Under regime 3, one metric ton of CO_2 emissions (CO_2) leads to a rise in per capita health expenditure (HEALTH) by 13.86 USD if the economic development (PGDP) stage is above 2968.11 USD per capita.

The impacts of access to clean fuels and technologies for cooking (ACFT) and economic development (PGDP) on health expenditure (HEALTH) are positive and significant as in the ARDL model estimation (Table 8).

Table 9: The results of the threshold effect test for single, double and triple threshold

Threshold	Test 1	Test 2	Test 3
Single	21.21	21.21	21.21
Double		36.80***	36.80***
Triple			13.27

P-values of F-statistic are reported. ***P<0.01

Table 10: The threshold values for the triple threshold model

Model	Threshold	Lower	Upper
Th-1	2326.36	2281.16	2345.87
Th-21	2345.87	2313.49	2354.59
Th-22	2968.11	2943.09	3047.30
Th-3	10539.04	10264.29	10758.52

Table 11: The results of the threshold regression model

Explanatory variable	Coefficient		
	Model 1 (single threshold)	Model 2 (double threshold)	Model 3 (triple threshold)
ACFT	1.03***	0.65**	0.63**
PGDP	0.03***	0.04***	0.05***
Regime-dependent variable			
CO_2			
Threshold regime 1	2.08	10.98***	8.90***
Threshold regime 2	12.23***	25.88***	23.12***
Threshold regime 3		13.86***	10.00***
Threshold regime 4			4.18
Constant	−120.21***	−138.13***	−138.65***
R-square	0.71	0.71	0.70
F-statistic	111.56***	135.34***	131.69***

**P<0.05, ***P<0.01

6. CONCLUSION

For the first time, this study examines the linear and threshold effect of CO_2 emissions, economic development, access to clean fuel and technologies for cooking on health expenditure in the Central Asian region. The results suggest that the health expenditure of the population in Central Asia increases concerning environmental degradation, validating theoretical linkage (Hypothesis 1). Admittedly, further environmental degradation causes more health problems, leading to increased health expenditure. Moreover, economic development positively impacts health expenditure, verifying theoretical association (Hypothesis 2). As the nation's wealth grows, the healthcare system also flourishes. Theoretical linkage (Hypothesis 3) is not justified for the relation between health expenditure and access to clean fuels and technologies for cooking. This might be because, in the Central Asian region, environmental degradation associated with CO_2 emissions is the main factor rather than access to clean fuels and technologies for cooking in determining health expenditure. In the joint effect of these variables, the role of access to clean fuels and technologies for cooking is not dominant.

The results also reveal that GDP per capita (PGDP) should be between 2326.36 and 2345.87 USD to achieve the highest level of health expenditure that rationally responds to environmental degradation. Moreover, this GDP per capita (PGDP) causes a well improved health care system. In Central Asia, per capita GDP (PGDP) does not reach that level in the case of Kyrgyz Republic and Tajikistan.

The Central Asian region will benefit significantly from the study's conclusions in terms of policy. Policymakers should prioritize tackling environmental deterioration, mainly caused by CO_2 emissions, as it is a significant factor in rising healthcare costs. Given this connection, authorities should emphasize encouraging the switch to renewable energy sources to reduce the harmful impacts of environmental deterioration on human health.

In light of this, policies should be modified to encourage economic growth that adheres to these criteria. Policymakers must understand the complex roles that many factors play in affecting health spending. Although the availability of clean fuels and modern cooking methods seems less impactful, governments shouldn't completely ignore these factors. Future research projects should also look into potential new variables to fully grasp how they affect health spending. By considering these policy ramifications, Central Asian nations can proactively address environmental issues, promote economic expansion, and maximize healthcare spending to manage the region's health challenges successfully.

To conclude, the policymakers of Central Asian countries must consider environmental degradation as the primary contributor to an increase in health expenditure. This leads policymakers to enhance the renewable energy transition. Moreover, policy implications must consider the estimated economic development stage (PGDP) in the threshold regression provided in the study because those levels of economic development allow increased health expenditure that can cope with health issues.

The limitation of this research might be overlooking other variables that might impact health expenditure. However, to avoid losing the degree of freedom, we propose their inclusion in future related works.

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