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Article

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Environmental Kuznets Curve for Extended Brics Economies: Do Women Governance and Water Stress Matter?

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ABSTRACT

Environmental Kuznets Curve (EKC) for extended BRICS is examined by considering different shapes such as liner, U-and N-shaped, and the impact of women's governance and water stress. To calculate cointegrating regressions, a Fully Modified Ordinary Least Squares (FMOLS) is applied, and the estimated long-term relations are included in a panel Vector Error Correction model. Moreover, Methods of Moments of Quantile Regression (MMQR) is run to robust the findings. The FMOLS results indicate the validation of the linear EKC association for extended BRICS compared to other relations, the U- and N-shaped. This is attributed to the reason that the extended BRICS nations are in the earlier stages of the EKC. It is observed that per capita gross domestic product increases CO2 emissions in the long term, whereas women's governance and water stress decrease CO2 emissions in the long term in extended BRICS. Furthermore, there exists a causal association between per capita GDP, women's governance, water stress, and CO2 emissions. MMQR results also validate the negative association between CO2 emissions, women governance and water stress across all the quantiles, 10%-90%.

Keywords: Extended BRICS, Environmental Kuznets Curve, Women Governance, Water Stress, VECM, MMQR
JEL Classifications: Q51, C53, Q25

1. INTRODUCTION

Currently, all countries across the globe are dedicated to pursuing the sustainable development goals set forth by the United Nations, including those about climate action (Goal 13), gender equality (Goal 5), and clean water and sanitation (Goal 6) (United Nations, 2015). This commitment extends to both the BRICS economies and the broader BRICS grouping. Nevertheless, there is a paucity of literature investigating the interrelations between the aforementioned factors. Nevertheless, it is of paramount importance to investigate the interrelations between CO2 emissions, women's governance, and water stress in the case of extended BRICS economies.

In more specific terms, the extended BRICS economies, which consist of China, India, South Africa, Brazil, Russia, Iran, the United Arab Emirates, Egypt and Ethiopia, demonstrate inequalities in gender. India, Iran, and Egypt are among the countries with the lowest gender gap statistics (Statista, 2023). Nevertheless, the involvement of women in political and economic life is essential to combat climate change. It is evident that gender differences in climate decision-making processes yield disparate outcomes. This arises from the reality that women generally demonstrate a higher level of awareness and attention regarding climate change than men (McCright, 2010; McCright and Dunlap, 2011). Gilligan (1982) and Beutel and Marini (1995) have suggested that females place a greater emphasis on values such as cooperation and carefulness, which are pertinent to climate change action. Similarly, the ramifications of climate change depend on gender. Seager et al. (2016) found that women's gendered caregiving and labor roles, as well as their social status, make them disproportionately vulnerable to the cost associated with climate change. Several research found that women have lower levels of overconfidence and a higher risk perception (Huang and Kisgen, 2013; Barber and Odean, 2001; Levi et al., 2014). This could indicate that Women are more resilient against feeling neglected by the environmental implications of their actions or overestimate their abilities to create appropriate solutions. Furthermore, women appear to behave more ethically than men. This is demonstrated by their tendency to regard problematic actions such as bribery, rule-breaking, and the abuse of private information (Franke et al., 1997). As a result, resolving environmental concerns requires the empowerment of women (Collins, 2019). There is little research in the academic literature attempting to look at the link among CO2 and women's role in governance. In further detail, Mavisakalyan and Tarverdi (2019) examine the impact of women's representation in national legislatures on climate change policy outcomes in a wide range of nations. According to the study, having more women in parliament is associated with less CO_2 emissions. Kuziboev et al. (2024) evaluated the impact of tax revenue, clean energy, and women's leadership on carbon dioxide emissions in 29 emerging Asian nations between 1996 and 2020. According to the study, women's governance reduces CO2 emissions by 15%. The existing literature indicates that women's governance decrease in carbon dioxide emissions.

Brazil and Russia will be the most resistant to water stress over the next three decades, as they possess the highest and second-highest quantities of renewable freshwater resources globally, respectively (Likhacheva, 2019). Nevertheless, other members of the BRICS, including China, Brazil, India, Russia, and South Africa, face water-related challenges. In more specific terms, Iran, the United Arab Emirates, and India are categorized as experiencing extremely high baseline water stress according to the Earth International Organization (Earth, 2023). Nevertheless, Water's ability to absorb carbon dioxide emissions makes it essential for mitigating climate change.

The category of water resource consumption has the greatest significant effects on CO2 absorption and emission (Zuo et al., 2023). Additionally, the accumulation of water accumulation in the environment directly reduces CO2 emissions. Santos e Silva et al. (2024) finds that higher rainfall leads to more CO2 absorption in Brazil. Anwer et al. (2024) results suggest that water allows CO2 solubility. It is acknowledged that theoretically, water may reduce CO2 emissions by absorbing it. However, it is acknowledged that the water is linked with CO2 emissions. Since, the process of supplying water necessitates energy, which in turn releases greenhouse gases that have adverse climate effects. As a result, water conservation provides environmental advantages by decreasing these emissions (Sowby and Capener, 2022). Biswas and Yek (2016) discovered that a groundwater treatment plant has a carbon footprint of 0.38 kg CO2 eq for the purpose of delivering water to households. As a result, it is possible to hypothesize that water scarcity increases emissions of carbon dioxide.

Numerous scholarly articles have utilized the Environmental Kuznets Curve Hypothesis (EKC) in relation to the BRICS nations. In their study, Pao and Tsai (2010) analyze the link between environmental degradation, energy usage and output in BRIC nations from 1971 to 2005, excluding Russia from 1990 to 2005. Their research suggests a U-shaped pattern in the environmental Kuznets curve. In their study, Dong et al. (2017) analyse the correlation among economic development, CO2 emissions per capita, and the usage of clean energy and natural gas for BRICS nations in the period of 1985 and 2016, analyzing this relationship in the environmental Kuznets curve (EKC) context. They utilize the augmented mean group (AMG) estimator to test the EKC hypothesis validity in the BRICS. In their study, Danish and Khan (2020) used dynamic ordinary least squares (DOLS) and fully modified ordinary least squares (FMOLS) long-run estimators to examine the link among natural resource rent, urbanization, real income, green energy usage, and ecological footprint in The BRICS economies. Their findings validate the Environmental Kuznets curve (EKC) in BRICS nations. In another study, Ummalla and Goyari (2020) examined the link among clean energy usage, economic growth and CO2 emissions in BRICS nations from 1992 to 2014. They specifically investigate the relationship within the environmental Kuznets curve (EKC) the framework. The work concluded that the EKC hypothesis holds true for the BRICS nations, with a reversed U-shaped pattern. In their research, Rafique et al. (2020) examine how foreign direct investment, technological innovation, and financial development affect the environment of BRICS economies. They analyze the time period spanning between 1990 and 2017, and use the Augmented Mean Group (AMG) estimator to draw their conclusions. There is evidence to validate a reversed U-shaped pattern of EKC. Leitao et al. (2021) examine the link between the EKC hypothesis and the complexity of economics. They analyze a panel of the BRICS members from 1990 to 2015. Various statistical techniques were used, including panel dynamic least squares, panel fully modified least squares, fixed effects, and panel quantile regression. The findings suggest the existence of an inverted U-shaped relationship.

Additionally, studies have been conducted that have not been able to provide the evidence for the justification of the EKC association in the BRICS nations. Hussain and Dogan (2021) explore the correlation between ecological footprints (EF) and environmental quality in BRICS economies. They examine the impact of environment-related technologies, energy usage, and institutional quality. This is accomplished within a framework defined by the environmental Kuznets curve (EKC) theory. The dataset covers the time frame from 1992 to 2016 and is used to analyze both long- and short-term connections. This is accomplished by utilizing the augmented mean group estimator, the common correlated effects mean group, and the cross-section augmented autoregressive distributive lag model. The findings fail to provide any support for the U-shaped EKC hypothesis. In contrast, the findings validate a correlation between GDP and the ecological footprint of carbon dioxide in a monotonically increasing manner, despite the existence of a statistically significant quadratic coefficient. Using an ecological footprint from 1980 to 2014, Dogan et al. (2020) investigate the validity of the EKC framework in the BRICS (China, Russia, Brazil, India, South Africa, and including Turkiye) nations. Based on the findings, GDP and ecological footprint have a negative linear relationship. Khan et al. (2020) employ STIRPAT model to examine EKC relationship in BRICS over the period of 1985-2014. They fail in validating EKC in the panel of BRICS even though their findings support the justification of EKC for some countries individually.

The literature review provided above gives a clear signal that there are research gaps. Firstly, there is no single paper that investigates the EKC hypothesis for extended BRICS economies. Secondly, women's governance and water stress factors have not been explored for BRICS and extended BRICS countries. The gaps in research motivate us to examine the EKC validity for extended BRICS economies with additional variables such as women's governance and water stress.

It is also crucial to demonstrate the rationale behind the complex link between water stress and women's governance factors within the EKC. In particular, the theoretical relationship between every variable used is necessary to justify cointegration, not the individual effects of independent variables on the dependent variable. In light of this, we provide a background for the justification of the impact of the studied variables on one another.

In more precise terms, academics and professionals have posited that enhanced water governance will ensue from the appointment of more women to decision-making roles. Anderson et al. (2013) posit that empowering women in community tends to facilitate the development of trust, the improvement of cooperative problem-solving and decision-making abilities, and the promotion of resilient water systems and communities. Similarly, Kevany and Huisingh (2013) and Shah (2002) posit that the inclusion of women's involvement in the community within the water industry has a positive influence on the efficient and sustainable use of water. Furthermore, Shah (2002) emphasizes the roles of women in cash flow management and the collection of water fees, as well as their status as a stronger agent of the water system. These literatures provide empirical evidence that there is an association from women's governance to water stress.

The phenomenon of water stress has an important effect on the women's involvement in governance activities within the water sector. This highlights the importance to the implementation of gender-inclusive policies and women participation in making decisions. The scarcity resulting from climate change and overuse presents a significant challenge for women, who play a pivotal role in water collection, domestic use, and household decision-making. In Ghane, the Kumasi metropolis, Buor (2004) identified significant factors affecting women's health when there is water scarcity. Similarly, Whittenbury (2012) highlighted that water stress has a detrimental impact on health conditions of women and well-being as well, including being stressed by work and experiencing stress-related symptoms such as depression. Seri (2023) reveals that water stress has a profound impact on women in communities, resulting in significant socio-economic consequences, including limitations on their daily activities and economic participation. However, the impact of water stress extends beyond the health and economic participation of women. It also has significant implications for women in governance. For instance, Figueiredo and Perkins (2013) found that water stress has a greater impact on women, increasing the difficulties they face in participating effectively in governance institutions.

In addition, scholarly research has been done to analyze the impact of women's leadership on the development of economy. It was recognized, on the one hand, women's role in achieving economic development is pivotal, on the other hand in attaining sustainable development as well, as outlined in the UN Agenda 21 from 1992. The agenda emphasized the importance of participation, equality, and empowerment of women as the cornerstones towards sustainability. The advancement of empowering women economically represents a catalyst for development that benefits not only women, but also the wider population, including women, and contributes to the reduction of poverty. Furthermore, it facilitates the acceleration of a nation's economic growth. Furthermore, improvements in the health of women can facilitate the demographic transition and result in sustainable economic growth (Bloom et al., 2020). Baskaran et al. (2018) demonstrated female politicians contribute more to economic growth in their constituencies than their male counterparts. Women are particularly adept at overseeing infrastructure projects, boosting non-farm employment, and are less prone to rent-seeking or criminal behavior while in office. Furthermore, Dahlum et al. (2022) proposed that women participation in politics could enhance economic growth by facilitating technological innovation. Furthermore, Mirziyoyeva and Salahodjaev (2023) demonstrated that women's representation in parliament and their involvement in decision-making processes enhance the surge in economy in Central Asia and Europe.

Although academic literature investigating the link from economic development to women's governance is limited, some theoretical justifications can be found in the field of academia. More specifically, economic growth can facilitate women's access to resources and education, thereby enabling them to assume an active role in government (Kabeer, 2005). Furthermore, in the short run, growth in economy raises labor outcomes of women. However, it has a reversed effect in the long term (Doğan and Akyüz, 2017).

The issue of water stress represents a significant challenge with far-reaching implications for economic development. As the world population is growing, water demand is increasing at rapid rate. Nevertheless, numerous regions are confronted with water scarcity as a consequence of a convergence of factors, including climate change, population growth, and suboptimal water management practices (Balasubramanya and Stifel, 2020; Bremere et al., 2021). The consequences of the scarcity of water on economic prosperity are numerous and far-reaching. Water is a fundamental resource

Table 1: Prescription of the studied variables

Variable	Description, unit	Sources	Online link
CO_2	CO_2 emissions (metric tons per capita)	World Bank Data	https://data.worldbank.org/indicator/EN.ATM.CO$_2$E.PC
PGDP	Gross domestic product per capita (current US$)	World Bank Data	https://data.worldbank.org/indicator/NY.GDP.PCAP.CD
WG	Women governance (Proportion of seats held by women in national parliaments (%))	World Bank Data	https://data.worldbank.org/indicator/SG.GEN.PARL.ZS
WS	Water stress (Level of water stress: freshwater withdrawal as % of available freshwater resources)	World Bank Data	https://data.worldbank.org/indicator/ER.H2O.FWST.ZS

Table 2: Descriptive statistics

	CO_2	PGDP	WG	WS
Mean	7.27	8845.46	14.77	289.82
Median	6.02	4422.94	11.00	62.36
Maximum	30.88	53708.00	50.00	1866.66
Minimum	0.04	110.46	0.00	0.56
Std. Dev.	7.10	11505.06	12.63	514.95
Skewness	1.32	2.01	0.95	1.89
Kurtosis	4.31	6.33	3.24	5.16
Jarque-Bera	101.89	318.62	43.67	222.36
Probability	0.00	0.00	0.00	0.00
Observations	280	280	280	280

for a number of crucial sectors, including agriculture, industry, and energy production. Consequently, when water resources are depleted or become contaminated, economic progress and advancement are impeded (Cai et al., 2020). As a sector of the economy, agriculture, which relies heavily on water for irrigation, is particularly affected by water stress influencing on economic growth and development. A reduction in the availability of water directly impairs crop yields, thereby exacerbating food insecurity and impeding income generation for farmers (FAO, 2022; Alrwis et al., 2021). The consequences of water scarcity extend beyond the agricultural domain. The adverse effects of water scarcity have been observed to ripple across diverse sectors, precipitating economic losses and hampering overall development trajectories (Zhou et al., 2017). The aforementioned arguments serve to justify the impact of water stress on economic development.

It is a well-established fact that economic growth increases in water usage across a range of sectors, including industry, agriculture, and domestic use (Hertel and Liu, 2019). In a research project conducted by Esen et al. (2020), they analyzed the effect of economic growth on water stress in nine European nations from 1995 to 2013. They utilized a panel threshold regression model to investigate this relationship. According to their research, when growth rates exceed a certain threshold, it leads to water stress surge. When growth is below this threshold, it has an insignificant impact on water stress. Additionally, the effect of economic development and international trade on water scarcity varies depending on whether the economies are developed or developing. Zhong et al. (2023) highlighted, importing food can help developed economies alleviate local water stress. However, this poses difficulties in the countries, particularly ones with low- and lower-middle-income, as it exacerbates water scarcity caused by international trade. In addition, the scarcity of water can significantly hinder economic growth (Roson and Damania, 2017). These studies show that economic development affects water stress.

Given the interrelationships between the variables, it may be appropriate to proceed with the estimation of cointegrating relations between them.

2. DATA AND METHODOLOGY

2.1. Data

The objective of the investigation is focused for empirical investigation of the connection between the level of water stress, gross domestic product, women governance, and carbon dioxide emissions. In order to reach the research aim, a panel dataset of the extended BRICS nations is constructed. The following countries were specifically examined during the period 1995-2022: Russia, China, India, Brazil, South Africa, Iran, the United Arab Emirates, Egypt, and Ethiopia. We employ (Table 1) CO_2 emissions, which are measured in metric tons per capita, as the reference variable in our analysis. The per capita GDP measured in current USD, the proportion of seats held by women in national parliaments (%) as a proxy of woman governance, and the level of water stress (freshwater withdrawal as a proportion of available freshwater resources) are variables that are relevant to emissions and are used to estimate the EKC.

CO2 emissions, gross domestic product per capita, the proportion of seats held by women in national parliaments, and the level of water stress were all sourced from the World Bank Data (Table 1).

The data on CO2 emissions, women's governance, and water stress are interpolated since there are missing values in the original data given the years.

Table 2 presented the descriptive statistics of the explored variables, indicate that the average CO2 emissions per capita in the extended BRICS nations between 1995 and 2022 was 7.27 metric tons. The average per capita GDP is calculated to be 8875.46 USD. The proportion of seats in the parliament occupied by women is, on average, 14.77%. The average level of water stress in the region is 289.82%. The standard deviations for the PGDP, WS are notably high, while those of CO2 and WG are relatively low. The data for CO2, PGDP, and WS are positively skewed, while WG shows normal skewness. The data for CO2, PGDP, and WS are leptokurtic, whereas WG is normal kurtosis. The p-values of the Jarque-Bera test indicate that variables under consideration are normally distributed.

2.2. Methodology

The validity of EKC hypothesis within the extended BRICS economies is examined in this study, with the inclusion of women's governance and water stress as additional variables in the condition of the long-term equilibrium. A Panel Vector Error Correction Model is being considered to estimate the long-run relation among variables which can be represented as:

$$\Delta Y_{i,t} = \alpha\left(\beta^{'} Y_{i,t-1}\right) + \Gamma \Delta Y_{i,t-1} + \varepsilon_{i,t} \quad (1)$$

The above formula presents the vector of endogenous panel variables, including $CO2_{i,t}$, $PGDP_{i,t}$, $WG_{i,t}$, $WS_{i,t}$, is denoted as $Y_{i,t}$. Δ is used as the operator for the first difference. The cointegration residual or error correction term is also known as β' $Y_{i,t-1}=\mu_t$ which is enclosed in parentheses. The long-run multipliers are represented by the parameters in the β` vector from an economic perspective. It is emphasized that Γ denoting the short-run coefficients, α representing the coefficients of the adjustment, and β showing the coefficients of the cointegrating equation are constant for all cross-sections (countries) in the sample. The model is estimated using a two-step method proposed by Sims (1980). The long-term parameters in the first phase, represented by the β vector, are analyzed using Dynamic OLS (or Fully Modified OLS as an alternative). In the second step, the stationarity of the cointegration residuals (evaluated based on the parameters from the first step) is utilized for the dynamic parameters and adjustment coefficients for the short term. These are run using standard least squares approaches. It is crucial to mention that a more flexible long-term equation can be specified by the use of a two-step approach.

The objective of the scientific analysis is to assess the stationarity among the variables under study and the prevalence of cointegration. Particularly, panel unit root tests implemented to determine if stationarity among variables exists or not. The Levin, Chin and Chu t*-test (Levin et al., 2002) is a test among others which is concentrated on evaluating the presences of a common unit root process. W-statistic and the ADF – Fisher Chi-square given in The Im, Pesaran, and Shin (Maddala and Wu, 1999) are tests for unit root.

Furthermore, the Fisher (or combined Johansen) test is used to look into whether the variables under analysis have a long-term relationship. Additionally, to evaluate the causality between the variables under the study, the Dumitrescu and Hurlin causality test (Dumitrescu and Hurlin, 2008) is implemented.

Based on the afore-mentioned considerations following theoretical framework and the literature, one can hypothesize that a single long-run relationship is possible, which is linked to the Empirical Kuznets Curve. As a result, if empirical evidence supports this hypothesis, the following long-run equation can be specified, which represents parameters for EKC that are constant to extended BRICS nations:

$$CO2_{i,t} = \delta_0 + \beta_2 GDP_{i,t} + \beta_3 WG_{i,t} + \beta_4 WS_{i,t} + \mu_{i,t} \quad (2)$$

An intercept is included in the vector β', to maintain coherence with the presence of a trend in the levels, in addition to the usual normalization with β_1=1. The error correction term represents the residual. A two-step procedure is followed for the estimation of the model, as mentioned earlier. Equation (2) is initially estimated to determine the cointegration relation. The interpretation of the obtained coefficients can be used to make a preliminary assessment of the EKC's existence for the BRICS extended nations. The adjustment coefficients and short-term dynamics are computed thereafter, providing further insights into the variable adjustment, following deviations from the EKC-implied equilibrium. In this instance, a Panel VECM model of equation (1) is used. The estimated error correction term is introduced as an explanatory (stationary) factor based on Sims (1980). The first differences estimate the following specifications.

$$\Delta Y_{i,t} = \alpha \hat{\mu}_{i,t-1} + \Gamma \Delta Y_{i,t-1} + \varepsilon_{i,t} \quad (3)$$

where the equation of CO_2 is read as

$$\Delta CO2_{i,t} = \alpha_1 \hat{\mu}_{i,t-1} + \gamma_{1,1} \Delta CO_{2,i,t-1} + \gamma_{1,2} \Delta \mathrm{P}GDP_{i,t-1} + \gamma_{1,3} \Delta WG_{i,t-1} + \gamma_{1,4} \Delta WS_{i,t-1} + \varepsilon_{1,i,t} \quad (4)$$

A similar structure is found in the other equations. The adjustment coefficients and the importance variables in the short-run dynamic model will be our main focus during this second phase. The findings of the causality test described before will be read with the full model results.

For robustness check, Methods of Moments of Quantile Regression is run. This method is robust to cope with heteroscedasticity and sample bias issues.

3. EMPIRICAL RESULTS

3.1. Main Results

We commence by examining the stationarity tests on the relevant variables, which are presented in Table 3. For CO2, PGDP, WG, and WS, the evidence is clear that all variables are stationary at the first differences. This is according to the t* statistic of Levin, Lin, and Chu (2002), the W-stat of Im, Pesaran, and Shin (2003), the ADF-Fisher-Chi-square, and the PP-Fisher-Chi-square.

For all unit root tests, the probability values are reported. Lags have been employed based on SIC (1), and only the individual intercept has been included). The null hypothesis means the presence of a unit root process whereas it is with the probability value <0.05.

We use the Fisher (combined Johansen) cointegration test to assess if cointegration is present, the findings confirm that the variables' integration order is one. Table 4 presents the results.

The findings of the two Johansen-type tests, trace, and max-eigen, show that there is cointegration between the variables. Therefore, we proceed with the Panel VECM model estimation.

The table shows the Fisher statistics and probabilities of the trace and maximum eigenvalue tests included in Johansen Fisher panel cointegration. The null hypothesis is the number of the cointegrating associations given in the rows of column 1. Asterisks represent statistical significance, *** at 1% level and ** at 5%

Table 3: The analysis performed with unit root tests

	CO_2		*PGDP*		*WG*		*WS*	
	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
Common unit root process								
t* statistics of Levin, Lin and Chu	0.08	0.00	1.00	0.00	0.82	0.00	0.00	0.00
Individual unit root process								
W-stat of Im, Pesaran and Shind	0.62	0.00	1.00	0.00	0.99	0.00	0.08	0.00
Chi-square of ADF- Chi-square Fisher	0.69	0.00	0.99	0.00	0.99	0.00	0.01	0.00
PP-Fisher	0.87	0.00	0.99	0.00	0.99	0.00	0.00	0.00

Table 4: The findings revealed by the means of Johansen Fisher Panel Cointegration test

Number of the cointegrating relations	Fisher Statistics (from trace test)	Prob.	Fisher Statistics (from max-eigen test)	P-value
None	80.31	0.00***	51.95	0.00***
At most 1	42.13	0.00***	34.78	0.01**
At most 2	21.74	0.24	18.97	0.39
At most 3	25.22	0.11	25.22	0.11

level. Lags are set relying on SIC (1).

Prior to estimating the model, Dumitrescu-Hurlin causality test is undertaken to investigate the causal linkages among the variables given in the panel. The test was conducted using the variables at the levels. The analysis's findings are listed in Table 5. Upon focusing on the level of causation between factors, it is observed that there is no causality from CO_2 to PGDP and from WG to PGDP. Nevertheless, in other instances, there exists a causal link among the variables under study. Moreover, the results indicate that there is causality from PGDP, WG, and WS to carbon dioxide emissions, that approve consistency with the Kuznets Curve for extended BRICS countries.

In Table 6, the estimated coefficients for the cointegrating equation (2) are shown for the linear, quadratic, and cubic scenarios of the influence of PGDP. The presence of a linear Environmental Kuznets Curve is confirmed by the estimations in column 1, which show evidence of a long-term link among the variables. This finding, which validates the linear Environmental Kuznets Curve (EKC), reinforced by Caporin et al. (2023), on whose study a linear EKC relation was validated for Central Asian nations. In particular, an increase in women's governance (WG) and water stress (WS) is associated with a decrease in carbon dioxide emissions over a long period.

Although the quadratic coefficient of PGDP is statistically significant in column 2, its value is so small that it cannot pose the reversed U-shaped association to turn. In column 3, the coefficients of the quadratic and cubic parameters do not show statistical significance neither at the 5% nor 1% levels. Moreover, the coefficient of water stress is also equal to zero, despite being statistically significant.

Given that the countries in question are developing economies, the validation of the linear EKC is consistent with economic intuition. This could occur if technological advancement does not keep pace with economic growth or if as an economy grows, environmentally

Table 5: Dumitrescu Hurlin panel causality tests

Causalities	P-value
$PGDP \rightarrow CO_2$	0.00***
$CO_2 \not\rightarrow PGDP$	0.12
$WG \rightarrow CO_2$	0.00***
$CO_2 \rightarrow WG$	0.01**
$WS \rightarrow CO_2$	0.00***
$CO_2 \rightarrow WS$	0.00***
$WG \not\rightarrow PGDP$	0.11
$PGDP \rightarrow WG$	0.00***
$WS \rightarrow PGDP$	0.00***
$PGDP \rightarrow WS$	0.00***
$WS \rightarrow WG$	0.01**
$WG \rightarrow WS$	0.00***

In the table, the probability valies of the Dumitrescu Hurlin panel causality test are represented. Asterisks represent statistical significance *** and ** for 1% and 5% levels, respectively. Lag has been set as 1 based on SIC

Table 6: The obtained estimates by the means of FMOLS, cointegrating regression

Variables	Explained variable=CO_2 emissions		
	Exploring linear association	Exploring EKC in U-shaped association	Exploring EKC in N-shaped association
WG	−0.05***	−0.03***	−0.04***
	(0.01)	(0.01)	(0.01)
WS	−0.01***	−0.00***	−0.00
	(0.00)	(0.00)	(0.00)
PGDP	0.12***	0.36***	0.81***
	(0.00)	(0.00)	(0.00)
$PGDP^2$		-7.93×10^{-6}***	-4.76×10^{-5}
		(0.00)	(0.00)
$PGDP^3$			5.70×10^{-10}***
			(0.00)

Standard errors are given in the parentheses. Asterisks represent statistical significance ***, **, and * for 1%, 5%, and 10% levels, respectively. PGDP is given in thousands

beneficial regulations are not put into practice (Shafik and Bandyopadhyay, 1992). Nevertheless, it is possible that an inverted U-shaped and/or N-shaped EKC may be observed in the case of developed economies. An inverted U-shaped relationship indicates that, in the initial phase, environmental deterioration is exacerbated by economic expansion. However, after reaching a specific threshold income, economic growth enables environmental restoration in the subsequent phase (Caporin et al., 2023). The observed inverted U-shaped curve in the first and second stages is consistent with the N-shaped EKC hypothesis. In the second phase, governments prioritize by lowering pollution levels which has a technological effect (Di Vita, 2008; Koilo, 2019; Porrini, 2016). In the third stage, nonetheless, there exist an impact of technical obsolescence, if technical advancement does not keep up, the environment and income deteriorate (Zhang, 2021). In more specific terms, Anser et al. (2020) identify a reverse U-shaped EKC connection for G-7 countries. Apergis et al. (2017) validate a reserved U-shaped EKC association in 10 US states, whereas Işık et al. (2022) justify a reversed U-shaped EKC hypothesis in 7 US states, and Atasoy (2017) verifies a reversed U-shaped association of EKS in 30 US states. Rafindadi (2016) validates a reversed U-shaped EKC validation for Japan.

After considering the preceding evidence, the VECM model in equation (3) is evaluated, solely for the linear case. The results of the VECM model, equation (3), are presented in Table 7, which shows the coefficients of the adjustment and the effect of the error correction term, or disequilibrium, on the first differences in the series.

Remarkably, the indications of the adjustment coefficients are consistent with predictions. It is evident that rising carbon emissions are a result of negative disequilibrium. Notably, this is in line with the estimates of the coefficients (Table 6) and the evidence provided by the cointegration equation (2). The identified adjustment mechanism suggests that emissions are a main variable responding to disequilibrium. Consequently, our approach identifies that the condition of long-run equilibrium exists, namely EKC in a linear curve. In summary, the empirical evidence supports the hypothesis that the EKC and the expanded list of variables considered with the inclusion of women's governance (WG) and water stress (WS) are causally related.

The empirical estimations are in accordance with the graphical evidence of the relationship among CO2 emissions and development level of economy, thereby validating the linear association (Figures 1-3).

Figures 1 and 2 demonstrate that in all extended BRICS countries, PGDP has a linear effect on environmental degradation. The primary rationale for this phenomenon can be postulated as the economic development levels of the extended BRICS economies are in the initial stages of the EKC. Consequently, the economic situation is not yet conducive to the advancement of technology. In more specific terms, the per capita GDP of Brazil and South Africa is strikingly similar, with figures of 8917.67 USD and 6766.48 USD, respectively, in 2022. A similar pattern is evident in Russia and China, with per capita GDPs of 15,270.7 USD and 12,720.2 USD, respectively. In Iran and Egypt, per capita GDP is nearly identical, with figures of 4669.57 USD and 4295.41 USD, respectively. The lowest per capita GDP is observed in India and Ethiopia, with values of 2410.89 USD and 1027.59 USD, respectively. The highest per capita GDP is observed in the United

Table 7: The adjustment coefficients obtained by estimating the VECM model

Estimated Alphas (P-values)	
CO_2	−0.12***
	(0.02)
PGDP	35.02
	(110.62)
WG	−0.31
	(0.18)
WS	2.04
	(1.27)

The parentheses contain standard errors. Asterisks represent statistical significance *** for 1% level

Figure 1: Illustration of PGDP-carbon dioxide emissions nexus for Russia, South Africa, Brazil, China, and Iran. The figure presents the correlation between the PGDP and the carbon dioxide emission. The nations are indicated by different colors

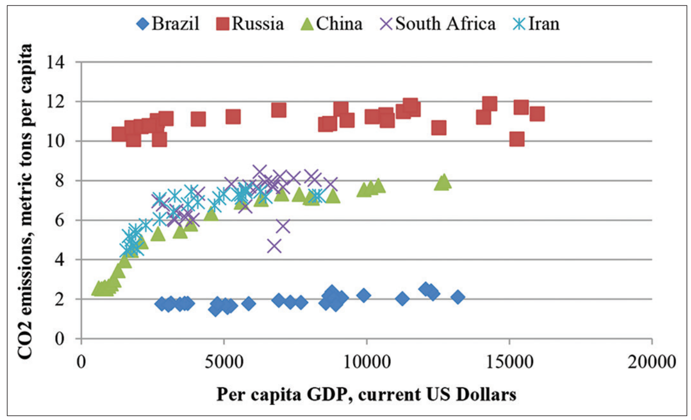

Figure 2: Illustration of PGDP-carbon dioxide emissions for India, Egypt, and Ethiopia. The figure presents a correlation between the PGDP (bottom axis) and the Carbon dioxide emission (left axis). The nations are indicated by different colors

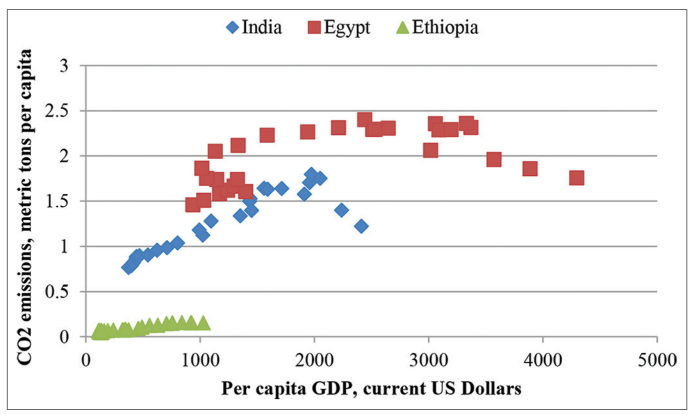

Figure 3: Illustration of PGDP-carbon dioxide emissions for the UAE. The figure presents a correlation between the PGDP (bottom axis) and the CO2 emission (left axis)

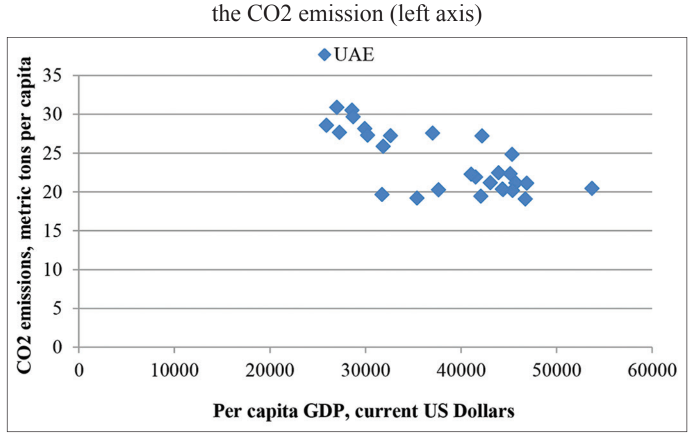

Table 8: The estimated results with MMQR

Variable			Quantiles								
	Location	Scale	10%	20%	30%	40%	50%	60%	70%	80%	90%
PGDP	0.00009	0.00002	0.0005	0.00006	0.00007	0.00008	0.00009	0.00001	0.00011	0.00011	0.00012
Std. err.	0.00003	0.00001	0.00006	0.00005	0.00004	0.00004	0.00003	0.00003	0.0003	0.00003	0.00003
Z-statistics	2.43	1.20	0.90	1.21	1.57	2.05	2.57	2.96	3.22	3.30	3.33
P-values	0.015	0.229	0.368	0.225	0.116	0.040	0.010	0.003	0.001	0.001	0.001
WG	−0.06559	−0.00326	−0.06034	−0.06172	−0.06303	−0.06452	−0.06604	−0.06726	−0.06846	−0.06918	−0.07021
SE	0.01434	0.00771	0.02220	0.01969	0.01753	0.01547	0.01399	0.01338	0.01338	0.01367	0.01442
Z-statistics	−4.57	−0.42	−2.72	−3.13	−3.59	−4.17	−4.72	−5.02	−5.11	−5.06	−4.87
P-values	0.000	0.672	0.007	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WS	−0.01395	0.00085	−0.01533	−0.01496	−0.01462	−0.01423	−0.01383	−0.01351	−0.01319	−0.01300	−0.01273
Std. err.	0.00272	0.00146	0.004	0.00373	0.00333	0.00294	0.00266	0.00254	0.00254	0.00259	0.00273
Z-statistics	−5.12	0.59	−3.64	−4.01	−4.39	−4.84	−5.20	−5.31	−5.19	−5.01	−4.65
P-values	0.000	0.558	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

*P<0.01, **P<0.05, and ***P<0.10

Arab Emirates (UAE), which was 53,708 USD in 2022.

3.2. Robustness Check

The study also applies Methods of Moments of Quantile Regression (MMQR) to examine the asymmetric impacts of women governance and water stress on carbon dioxide emissions. Since main results show the linear association between CO2 emissions and economic development, MMQR estimations also refer to women governance and water stress within linear relationship. The results are provided in Table 8.

The MMQR results suggest that women governance and water stress significantly and negatively effect on CO2 emissions across all the quantiles, 10%-90%, validating the findings of those obtained by FMOLS method. However, economic development has no impact on CO2 emissions in lower quantiles, 10%-30%.

The quantile results represent that women governance and water stress impact on CO2 emissions is not affected by sample bias and heteroscedasticity.

4. CONCLUSION

This research is an initial effort to apply EKC hypothesis to the extended BRICS economies, taking into account the influence of women's governance and water stress factors. These factors have not been examined in the case of BRICS even before the expansion. Nevertheless, the role of women's governance and water stress cannot be overlooked for the extended BRICS nations. In more specific terms, the organization comprises nations with disparate approaches to women's governance (gender equality) policy. Moreover, several of the countries that have recently joined the BRICS grouping are situated in regions that are relatively water-scarce. It must be acknowledged that these factors have an effect on environmental quality within the context of EKC theory. The results gained with the FMOLS and VECM analyses also justify the cointegration among the employed factors.

It can be demonstrated that U- and/or N-shaped curves are not validated in the case of extended BRICS economies. Although the EKC is not supported by the evidence, the studies indicate that the economies of the extended BRICS countries are a heterogeneous mix of countries at different income levels, which precludes the possibility of a turning point in the EKC. In particular, the technological development stage differs across the countries of interest. Consequently, economic development and other variables (women's governance and water stress) jointly reduce environmental pollution.

However, the findings show that women governance cannot be overlooked in coping with the reduction of environmental degradation in the BRICS economies. Consequently, the countries of the BRICS+ grouping, where the participation of women in parliament and other governance structures is relatively low, must strive to achieve gender equality and eliminate the obstacles that impede women's participation in governance.

Negative effect of water stress on carbon dioxide, showing that a surge in water stress is related to a reduction of environmental degradation. This result is not in accordance with the theoretical background. However, from an economic perspective, BRICS+ countries may invest in climate finance to cope with climate change. Consequently, the role of water stress may not be significant. Nevertheless, such an investment necessitates the availability of substantial capital, which is why it is of the utmost importance to implement water-saving technologies and to avoid any further deterioration of the water resource, which might ultimately lead to stress.

It should be noted that our research is not without limitations. To be more precise, there are omitted variables that might impact the EKC relation. Nevertheless, due to the limited sample size, it is necessary to restrict the scope of the estimations to the variables currently employed.

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