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Nexus between environmental sustainability, energy intensity and food security: evidence from emerging economies

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Received 28 May 2023
Revised 16 August 2023
4 October 2023
27 October 2023
Accepted 3 November 2023

Abstract

Purpose – Growing food insecurity is a leading cause of fatalities, particularly in developing nations like Sub-Saharan Africa and Southeast Asia. However, the rising energy consumption and carbon dioxide (CO2) emissions are mostly associated with food production. Balancing the trade-offs between energy intensity and food security remains a top priority for environmentalists. Despite the critical role of the environment in food security, there is a scarcity of substantial studies that explore the statistical connections among food security, CO2 emissions, energy intensity, foreign direct investment (FDI) and per capita income. Therefore, this study aims to provide more precise and consistent estimates of per capita CO2 emissions by considering the interplay of food security and energy intensity within the context of emerging economies.

Design/methodology/approach – To examine the long-term relationships between CO2 emissions, food security, energy efficiency, FDI and economic development in emerging economies, this study employs correlated panel-corrected standard error, regression with Newey–West standard error and regression with Driscoll–Kraay standard error models (XTSCC). The analysis utilizes data spanning from 1980 to 2018 and encompasses 32 emerging economies.

Findings – The study reveals that increasing food security in a developing economy has a substantial positive impact on both CO2 emissions and energy intensity. Each model, on average, demonstrates that a 1 percent improvement in food security results in a 32% increase in CO2 levels. Moreover, the data align with the Environmental Kuznets Curve (EKC) theory, as it indicates a positive correlation between gross domestic product (GDP) in developing nations and CO2 emissions. Finally, all experiments consistently demonstrate a robust correlation between the Food Security Index (FSI), energy intensity level (EIL) and exchange rate (EXR) in developing markets and CO2 emissions. This suggests that these factors significantly contribute to environmental performance in these countries.

Originality/value – This study introduces novelty by employing diverse techniques to uncover the mixed findings regarding the relationship between CO2 emissions and economic expansion. Additionally, it integrates energy intensity and food security into a new model. Moreover, the study contributes to the literature by advocating for a sustainable development goal (SDG)-oriented policy framework that considers all variables influencing economic growth.

Keywords Environmental sustainability, Energy intensity, Food security, Emerging economies

Paper type Research paper

JEL Classification — O44, Q15, Q56

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Journal of Business and Socio-economic Development
Vol. 5 No. 2, 2025
pp. 139-154
Emerald Publishing Limited
e-ISSN: 2635-1692
p-ISSN: 2635-1374
DOI 10.1108/JBSED-05-2023-0044

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1. Introduction

The global agenda for sustainable development has garnered significant attention regarding critical issues like energy and food security, as highlighted by environmental analysts such as Bekun (2022), Bilgili *et al.* (2020). Food insecurity, defined by the Food and Agriculture Organization as insufficient access to safe and nutritious food for a healthy life, has direct implications for malnutrition and indirect repercussions on the prevalence of chronic and infectious diseases (Bhutta *et al.*, 2017). The United Nations food and agricultural organization estimates the annual cost of malnutrition at USD 3.5tn, equivalent to 5% of global gross domestic product (GDP), emphasizing the economic impact of this issue Conway (2012). Malnutrition is linked to productivity loss and serves as an impediment to the economic growth of societies, particularly those dependent on agriculture (Thompson *et al.*, 2012).

The pursuit of economic growth shapes the developmental paths of countries, leading to a divergence of policy choices. Developed nations often focus on maintaining current development levels to enhance living standards, while developing countries prioritize achieving economic growth, sometimes at the expense of sustainable development. This sets up a traditional trade-off between growth and development for the latter. In contrast to industrialized nations, developing countries face challenges, particularly in areas like climate action, as highlighted in the latest sustainable development goals (SDG) progress report by Anwar *et al.* (2021a).

Emerging economies face significant health risks and environmental challenges associated with food production. A 2015 global study by the World Health Organization (WHO) reveals that around 600 million people in these economies suffered from food-related illnesses in 2010, resulting in 420,000 deaths, with Sub-Saharan Africa and Southeast Asia bearing the largest burden. Unsustainable use of nitrogen fertilizers, both inorganic and organic, is a major contributor, leading to surface and groundwater pollution with far-reaching consequences for local communities. This pollution, coupled with chemical use, not only jeopardizes human health but also hinders socioeconomic development by impeding the growth of a robust and safe food industry. Additionally, concentrated livestock populations pose challenges to regional air and water quality, especially in the absence of proper waste management. These practices, accompanied by increased energy intensity, contribute to heightened carbon dioxide (CO2) emissions and other environmental threats, as emphasized by researchers such as Lemaire *et al.* (2014) and Bekun *et al.* (2021).

Amid the recent global focus on agriculture and food security, many nations are implementing programs aimed at mitigating price shocks. However, some of these initiatives may compromise sustainability. The environmental impacts associated with food systems include contaminants, population disruption and resource depletion. Greenhouse gas (GHG) emissions, mainly from fossil fuel combustion in food production and distribution, contribute significantly to environmental degradation, impacting both climate change and water quality. Researchers such as Nesheim *et al.* (2015), Garnett (2011), Johnson *et al.* (2007), Escobar *et al.* (2009) and Pirog *et al.* (2001) have emphasized these concerns.

In light of this, this research aims to address the critical relationship between the environment, food security, energy intensity and CO2 emissions, especially considering the scarcity of recent studies integrating these factors in emerging economies. Focusing on 32 selected emerging world economies from 1990 to 2018, the study aims to provide a more accurate assessment of per capita CO2 emissions while accounting for food security and energy intensity. The research seeks to answer key questions, including the impact of agricultural output on carbon dioxide emissions, particularly within developing countries and the interconnected effects of energy use, population growth and economic development on CO2 emissions in these nations. The study recognizes the need to investigate the linkages between energy consumption, population dynamics, economic expansion, agricultural output and environmental degradation to gain insights into these complex relationships.

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In developing countries, where rapid industrialization is pursued as a means of achieving economic growth, agriculture remains a significant contributor to national revenue. Facing food crises, governments have adopted innovative approaches to ensure agricultural sustainability. However, the drive for increased agricultural output has, in some cases, led to adverse consequences, including deforestation and the displacement of natural habitats, causing environmental degradation. This study emphasizes the critical need for policymakers to closely examine agricultural activity patterns to mitigate the negative environmental impacts associated with these operations. Additionally, the research holds promise for informing the development of climate policies specifically tailored to the agricultural sector, as suggested by Ringler *et al.* (2011).

This assessment delves into the interconnections among environmental sustainability (CO2 emissions), energy intensity, food security, foreign direct investment (FDI) and GDP, focusing on emerging economies. To construct a robust analytical framework, this study addresses operational challenges in the dataset, considering cross-sectional dependency and panel heterogeneity, which are common in economies connected through economic and trade spillovers. This unique approach also encompasses the vital aspect of food security, employing methodologies beyond conventional techniques like "cross-sectional time-series feasible generalized least squares (FGLS) regression." By employing methods such as linear regression with correlated panels corrected standard errors (XTPCSE) and others, this paper addresses issues like cross-sectional heterogeneity, endogeneity and serial correlation. This methodological diversity enhances the analytical depth of the study, ensuring that the study's findings are robust and insightful (Xie *et al.*, 2020).

To attain optimal levels of food, energy and water security, policymakers must deepen their understanding of these interconnected issues and foster collaboration among ministries, communities, civil society and the corporate sector in policy creation and implementation. Successful strategies necessitate research that delves into the intricate connections between food, energy and water, emphasizing the imperative for an integrated approach to planning, investments and policy decisions. Failure to address these interdependencies may lead to heightened poverty and environmental degradation, ultimately hindering global food security. The research outcomes are intended to guide policy decisions to enhance agricultural and livestock yields and offer vital insights for developing nations striving for agricultural sustainability while minimizing the environmental impact of farming.

The other sections of the research include the literature review and hypothesis development section, the methodology section, the results and findings section and finally the conclusion section.

2. Literature review and hypothesis development

As previously mentioned, a complex interaction exists among energy intensity, food security and CO2 emissions. This interaction provides an opportunity to uncover strategies aimed at minimizing CO2 emissions for environmental sustainability. Several studies have examined the relationships between carbon emissions and various variables, including urbanization, income levels and the use of renewable energy sources, financial development and agriculture (Chien *et al.*, 2021; Jun *et al*, 2021). These factors have yielded diverse findings, with some suggesting a positive influence of emissions, while others indicating a detrimental role. The disparities in these results can be attributed mainly to variations in data sets, research methodologies, geographic regions, attributes and periods studied (Anwar *et al.*, 2021a). In this section, we will conduct a comprehensive review of the relevant literature and formulate hypotheses that are pertinent to our research objectives. The aim is to thoroughly explore the interaction between CO2, GDP, food security, environmental politics and energy intensity.

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2.1 CO2 and gross domestic product

Over the past two decades, extensive studies have consistently focused on the nexus between economic growth and energy usage, confirming a significant influence. Numerous researchers, including Antonakakis *et al.* (2017), Bekhet *et al.* (2017) and Alam *et al.* (2016) have made significant contributions to our understanding of this relationship. Notably, Riti *et al.* (2017) explored the relationship between economic expansion and CO2 emissions in China, basing their study on the "Environmental Kuznets Curve" (EKC) theory. Bildirici (2017a) examined the interrelationship among various energy factors, including biofuel consumption, CO2 emissions, militarization and economic growth in the United States, employing methods such as the panel autoregressive distributive lag model (ARDL) and Canonical Cointegration Regression. Zhang *et al.* (2017) argued for an indirect association between energy use and CO2 emissions in China, using an input-output model with data spanning from 2000 to 2010. These studies collectively contribute to our understanding of the intricate dynamics between economic growth and energy usage in different contexts.

Several studies have explored the intricate relationships among economic growth, energy use and environmental factors. Han *et al.* (2018), in their research focused on China, examined the impact of fossil fuel use, building materials and economic expansion on CO2 emissions, revealing a unidirectional relationship. Song *et al.* (2018) utilized an input-output model to assess how energy use influences GHG emissions in China, predicting a decline based on sector-specific policies. Zhao *et al.* (2017) employed the "Log mean Divisia index" (LMDI) approach to study the decoupling effect of economic development from CO2 production during 1992–2012. Alam *et al.* (2016) explored the influence of population growth on income, energy usage and CO2 emissions, noting higher emissions with increased income and energy use across sampled countries. Antonakakis *et al.* (2017) analyzed the dynamic relationships in the "output–energy–environment" nexus, confirming the bidirectional causality between energy use and economic growth from 1971 to 2011. These studies collectively provide diverse insights into the complex interplay between economic dynamics, energy utilization and environmental outcomes.

Bekhet *et al.* (2017) discovered a strong connection between energy usage, financial development, economic growth and CO2 emissions in their research. Mardani *et al.* (2019) focused on the Middle East, studying the influence of financial development on emissions in Saudi Arabia, Qatar, Bahrain and Oman from 1980 to 2011. They observed that in countries like Qatar and Saudi Arabia, economic growth led to higher CO2 emissions, while in Oman and Bahrain, financial development played a key role in reducing energy emissions. He *et al.* (2017) discovered associations among CO2 emissions, population, affluence and technology. They confirmed a U-shaped relationship between CO2 emissions and urbanization, with an increase in income contributing to higher emissions. These studies collectively provide valuable insights into the diverse dynamics of energy, finance and economic factors influencing CO2 emissions in different regions.

Research in the field of environmental economics has yielded somewhat inconclusive findings, with inconsistencies in results. Numerous contemporary studies indicate a positive and monotonic association between GDP elasticity and per capita CO2 emissions (Begum *et al.*, 2015; Jorgenson, 2014; Bekhet *et al.*, 2017; Kasman and Duman, 2015; Saboori and Sulaiman, 2013; Wang *et al.*, 2018). However, a smaller number of studies has suggested a negative elasticity, indicating a curbing of emissions per capita in the forms of N-shaped, U-shaped, or inverse U-shaped slopes concerning increases in GDP per capita (Ahmed *et al.*, 2017; Ajmi *et al.*, 2015; Alam *et al.*, 2016; Özokcu and Özdemir, 2017; Wang *et al.*, 2016b; Zoundi, 2017). Scholars have also recognized the impact of environmental issues on food security, acknowledging that environmental harm from food production, particularly in conventional agriculture, extends beyond deforestation or pollutant use. Crop harvesting processes can lead to significant depletion in nutrient value, energy and water from the soil (Cordell *et al.*, 2009; Godfray *et al.*, 2010).

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2.2 Environmental politics and food security

Despite the global and dispersed nature of CO2 effects, they manifest distant and indirect consequences on individual states, posing a threat to food security among nations. Efforts to reduce CO2 emissions from specific nations contribute to a decrease in the global stock, motivating voters and politicians to support climate policies. The literature in environmental politics underscores various factors influencing the adoption and implementation of environmental policies favoring CO2 reductions. This article reviews significant studies on regime type, energy intensity levels (EIL), food security and CO2 output in developing nations, aiming to evaluate the presented assertion.

H1. There is a relationship between the per capita CO2 emission and food security.

The global food sector can meet the world's food needs, but challenges related to access, cultural acceptability, affordability and nutritional adequacy persist (Johnston *et al.*, 2014). Sutton *et al.* (2013) and Bilgili *et al.* (2020) emphasizes the need to improve production quality and environmental sustainability, emphasizing challenges posed by climate change, population growth and the increased demand for animal-sourced foods. Intensive agriculture, population pressures, poverty, lifestyle changes and urbanization alter food consumption and production patterns, impacting the healthiness of human foods (Godfray and Garnett, 2014). The simultaneous loss of biodiversity and ecosystem degradation poses challenges to livelihoods, farming systems and health, necessitating a re-examination of food production systems and diets for sustainability.

Air pollution emerges as a prominent environmental issue negatively affecting agricultural production by causing a decline in productivity decline and distortion in market equilibrium. Toxicants such as sulfates, nitrates, heavy metals and dust accumulate along the food chain, posing threats to both animals and plants (Lobell and Gourdji, 2012; Watts *et al.*, 2015). Global warming resulting from consistent GHG emissions induces changes in species distributions and behaviors, leading to a decline in agricultural productivity. Health hazards from air pollution reduce employee productivity, indirectly threatening the food supply (Hanna and Oliva, 2015; Graff Zivin and Neidell, 2012). Air pollution adversely affects agricultural inputs in terms of quantity and quality, indirectly threatening food security. Emissions from transportation and agricultural inputs sectors, which have received limited research attention, contribute to an underestimation of agricultural vulnerability. The reduction in labor productivity and the impacts on outdoor activities have ripple effects on food supply, demand and market equilibrium. Currently, there is no systematic review that describes linkages between air pollution and food security comprehensively. Therefore, this review aims to emphasize the interlinkages between these two phenomena, identifying potential areas for reducing air pollution while ensuring food security.

In the context of environmental health and food security, existing studies suggest that the adoption of emission reduction policies supports sustainable economic development in food production. The high energy usage throughout the food system is identified as a constraint to achieving improved efficiency, particularly in developing economies. Furthermore, there is a notable lack of research on the energy performance of food processes, especially in developing economies. Concerns regarding energy price volatility and the long-term availability of fossil energy sources are highlighted. The nexus between food system productivity, energy use and resources remains under-researched, and this gap is accentuated by the inclusion of factors like globalization, urbanization and demographic factors all of which underscore the significance of energy usage in the food system amid ongoing concerns about food security.

According to Pelletier *et al.* (2011) and Sonnino *et al.* (2014), the energy consumption of the processing industry, particularly in activities such as cooling, freezing and cooking, significantly contributes to the overall energy consumption within the food system. When it

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comes to energy efficiency in crop production, the primary objective is to maximize the conversion of solar energy and other resources into valuable products. This involves the application of fertilizers, tillage, irrigation water and pesticides on limited arable land aiming to achieve maximum output while managing energy use effectively (Khanyile, 2018; Rhodes, 2014). Therefore, it is crucial to consider strategies for improving machinery efficiency and reducing energy consumption by integrating work processes on the farm.

H2. There is a relationship between the per capita CO_2 elasticity of GDP and energy intensity.

Energy intensity plays a crucial role in environmental studies as a key moderator for reducing CO2 emissions and combating climate change (Rogelj *et al.*, 2016; Shahbaz *et al.*, 2015). Policies aimed at lowering energy intensity are essential not only for environmental protection but also for safeguarding exhaustible fossil fuel resources, fostering economic growth (Bilgen, 2014) and mitigating environmental degradation (Wang *et al.*, 2016a).

Empirical studies on the relationship between energy use and CO2 emissions have been limited (Roca and Alcántara, 2001 Zhang *et al.*, 2016; Zhao *et al.*, 2017; Shahbaz *et al.*, 2015; Quito, del Río, Álvarez-García and Bekun, 2023). Zhang *et al.* (2016) discovered a strong positive correlation between carbon dioxide emissions and energy intensity in China, confirming the EKC hypothesis. Roca and Alcántara (2001) in Spain discovered that CO2 emissions in Spain and the agriculture sector are influenced by both GDP and energy intensity. Further studies by Zhang *et al.* (2016) in China and Shahbaz *et al.* (2013) in Portugal highlighted the impact of energy consumption intensity and financial development on carbon emission intensity. Hatzigeorgiou *et al.* (2011) explored the causal relationship between income, energy intensity and CO2 emissions in Greece, revealing a one-way causal relationship between energy intensity and economic growth.

Research on the effects of financial development and economic growth on CO2 emissions has been conducted in Brazil, China, Russia, the United States of America, India and Japan (Tamazian *et al.*, 2009). Tamazian and Rao (2010) found that institutions play a vital role in reducing CO2 emissions, and Al-mulali and Binti Che Sab (2012) explored the relationship between financial development, energy consumption, income and CO2 emissions in Sub-Saharan African nations.

To address discrepancies in academic perspectives, the current research examines the dynamic relationship between emissions, energy intensity, food security and economic development in 45 emerging economies from 1990 to 2017. To the best of our knowledge, this is the first multi-country research that integrates energy intensity, food security, CO2 emission and income in developing economies using the EKC paradigm.

2.3 Energy intensity and CO2 emission

The study investigates the evolution and assessment of energy and CO2 intensity within the framework of the decoupling concept, as suggested by United Nations Environment Programme. This analysis considers resource decoupling, focusing on managing resource depletion, such as energy usage per unit of economic activity and impact decoupling, aiming to expand economic output while reducing negative environmental consequences, specifically CO2 emissions. The distinction between absolute and relative decoupling is crucial as economies experience growth. Relative decoupling implies a slower growth rate of resources or environmental impact parameters compared to economic indicators like GDP growth. In contrast, absolute decoupling indicates a reduction in resource use or environmental impact despite economic growth. The study fills a gap in existing research by investigating the interconnectivity between energy intensity and the per capita CO2 elasticity of GDP, considering concerns about the suitability of analytical techniques for evaluating this relationship.

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H3. Energy intensity plays a significant in the per capita CO2 elasticity of GDP.

The study challenges the commonly held belief that reducing CO2 emissions is inherently tied to favorable economic outcomes for both developing and emerging countries. Existing literature on the relationship between economic growth and CO2 emissions falls into three categories: the first suggests economic growth leads to increased CO2 emissions due to higher energy demand; the second posits a bidirectional causal nexus between emissions and the economy, and the third proposes a neutrality hypothesis, denying causality between the two phenomena. The study emphasizes the necessity for effective energy conservation policies that facilitate CO2 reduction without compromising economic growth. The literature gap calls for a thorough investigation to identify key factors explaining the complex relationship between CO2 emissions, economic development, energy intensity and food security.

3. Data and methodology

By incorporating food security into the equation and using more robust methodologies such as linear regression with XTPCSE, regression with Newey–West standard errors (NEWEY) and regression with Driscoll–Kraay standard errors (XTSCC), this study distinguishes itself from others. The XTPCSE, NEWEY and XTSCC techniques, as proven by Xie *et al.* (2020) and Hoechle (2007), effectively address issues related to the cross-sectional heterogeneity, endogeneity and serial correlation, ensuring methodological complementarity aligning with the research's objectives.

3.1 Model specification

In assessing the relationship between environmental sustainability (CO2 emission), food security, energy intensity and FDI within emerging economies, this study incorporates food security into the model proposed by Zhang *et al.* (2016). Based on theoretical and empirical reviews, the interrelationships between these variables are presented in the functional form of [1] and in equation [2];

$$CO_2\,emission = (\mathrm{FSI, EIL, GDP, FDI, CPI, EXR, RIR}) \tag{1}$$

$$CO_2\,emission_{it} = \beta 0 + \beta 1\,\mathrm{FSI_{it}} + \beta 2\,\mathrm{EIL_{it}} + \beta 3\,\mathrm{FDI_{it}} + \beta 4\,\mathrm{CPI_{it}} + \beta 5\,\mathrm{EXR_{it}} + \beta 6\,\mathrm{RIRit} + \varepsilon_t \tag{2}$$

Here, the dependent variable is CO_2 Emissions, representing environmental sustainability in each country. FSI is the Food Security Index, EIL is Energy Intensity, FDI represents FDI as net inflows of investments acquiring a permanent management interest (10% or higher voting stock), CPI stands for Corruption Perception Index, EXR denotes the real exchange rate assessed using the "real effective exchange rate index" (2010 = 100) and RIR indicates the Real Interest Rate, or the lending interest rate adjusted for inflation using the GDP deflator (The World Bank, 2018). The parameters βi ($i = 0, 1, 2, 3$) symbolize the intercept and slope coefficients. The parameter εit measures the stochastic term, representing components that are not captured by the study model, also known as the "white-noise error term", characterized by a mean value of zero and constant variance and covariance. The variable t implies the time series, measured in years.

3.2 Data

Data from 32 emerging economies are utilized to investigate the relationships between food security, energy intensity, environmental sustainability, FDI and economic growth from 1990

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to 2018. Table 1 provides a detailed overview of the variables, their measurements and the data sources.

The study employs an econometric approach to address the heterogeneity problem overlooked by previous studies, ensuring a more unbiased conclusion. The choice between fixed and random effects in the static panel model is validated by the Hausman test, favoring a fixed effect model with $p \leq 0.015$. However, the study identifies the persistence of a heterogeneity problem, which is resolved through cross-sectional time-series FGLS regression (XTGLS). To enhance the robustness of our results, the study utilizes Pooled cross-sectional dependence test (XTPCSE), regression with Newey–West standard errors (NEWEY) and regression with Driscoll-Kraay standard errors (XTSCC). The PCSE estimator is applied for time-series, cross-sectional (TSCS) data, as recommended by Beck and Katz (1995), demonstrating its superiority in producing accurate coefficients and standard errors compared to FGLS, especially when T is close to N. In cases where T > N, the study highlights the potential efficiency loss of the PCSE estimator. The use of XTSCC, XTPCSE, or NEWEY helps obtain more accurate standard errors for estimated coefficients, addressing cross-sectional correlation, serial correlation and heteroscedasticity, ensuring the statistical analysis's robustness.

4. Findings and discussion

4.1 Preliminary findings

Table 2 presents a statistical summary of the entire series, assessing the relationship among EIL, food security and CO2 emissions in emerging countries. The table simultaneously

Table 1. Description of the variables and their sources

Variable	Measurement	Sources
CO2	CO2 emissions (kg per 2010 US$ of GDP)	WDI
FSI	Food Security Index	Global Food Security Index
EIL	The energy intensity level of primary energy	WDI
GDP	GDP per capita	WDI
EXR	Official exchange rate (LCU per US$, period average)	WDI
RIR	Real interest rate (%)	WDI
FDI	Foreign direct investment, net inflows (% of GDP)	WDI
CPI	Corruption perception index	Transparency International

Source(s): Authors' compilation

Table 2. Descriptive statistics

Variable		Mean	Std. Dev	Min	Max	Observations
GDP	Overall	7556.36	4853.00	910.77	26058.07	N = 192
CO2	Overall	0.62	0.36	0.07	2.06	N = 192
FSI	Overall	58.76	8.81	36.30	74.90	N = 186
EIL	Overall	4.76	2.09	2.09	13.52	N = 192
EXR	Overall	1228.40	4225.36	1.00	22370.09	N = 192
FDI	Overall	2.94	4.47	−10.66	55.49	N = 192
CPI	Overall	39.09	11.68	17.00	74.00	N = 192
RIR	Overall	4.69	8.00	−22.75	41.55	N = 156

Note(s): GDP = Gross domestic product, CO2s= carbon dioxide emissions, FSI= food security index, EIL = energy intensity level, FDI=foreign direct investment, EXR = exchange rate, CPI= corruption perception index, RIR=real interest rate
Source(s): Authors' calculation

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displays a summary for each series across countries (panel), over time (time series) and between cross-sectional dimensions. The mean value represents the average of all observations for each variable. In this study, various indicators are employed, including GDP, CO2 emissions, FSI, EIL, EXR, FDI, CPI and RIR. The mean values for these indicators in emerging economics are as follows: GDP = 7556.36, CO2 = 0.62, FSI = 58.76, EIL = 4.76, FDI = 1228.40, EXR = 2.94, CPI = 39.09 and RIR = 4.69. Additionally, the table provides information on the maximum and minimum values within each series, offering insights into the highest and lowest values and showing the range of values for each analytical variable.

4.2 Correlation analysis

Table 3 illustrates a positive correlation between CO2 and GDP, CO2 and EXR, as well as FDI and CO2. However, upon closer examination of the individual variable coefficients, all of which are below 0.5, it is evident that the strength of these connections is relatively moderate. On the other hand, the correlation coefficients for CO2 with FSI, CPI, FDI and RIR are all negative, as indicated by the sign of their respective coefficients (see Table 4).

Economic theories and research literature from various countries worldwide have recognized the relationship between EILs, food security and CO2 emissions. However, the findings presented in Table 3 reveal connections between the independent variables. Although there is a low correlation among the independent variables, confirming the absence of multicollinearity issues, these findings validate the variability within the chosen sample of developing countries.

Table 3. Pairwise correlation analysis

	GDP	CO2	FSI	EIL	EXR	FDI	CPI	RIR
GDP	1.00							
	(0.00)							
CO2	−0.37	1.00						
	(0.00)	(0.00)						
FSI	0.77	−0.15	1.00					
	(0.00)	(0.04)	(0.00)					
EIL	−0.17	0.75	−0.03	1.00				
	(0.02)	(0.00)	(0.71)	(0.00)				
EXR	−0.25	0.20	−0.19	0.01	1.00			
	(0.00)	(0.01)	(0.01)	(0.87)	(0.00)			
FDI	0.08	−0.09	0.17	−0.06	0.10	1		
	(0.25)	(0.23)	(0.02)	(0.37)	(0.17)	(0.00)		
CPI	0.41	−0.30	0.58	−0.25	−0.13	0.18	1.00	
	(0.00)	(0.00)	(0.00)	(0.00)	(0.07)	(0.01)	(0.00)	
RIR	−0.24	−0.16	0.01	−0.07	0.04	0.09	0.14	1.00
	(0.00)	(0.05)	(0.89)	(0.39)	(0.60)	(0.27)	(0.08)	(0.00)

Note(s): The correlation matrix is used to assess the strength and direction of the linear relationship between two or more variables. The correlation coefficient can range from −1 to +1, where −1 indicates a perfect negative correlation, +1 denotes a perfect positive correlation and 0 indicates no connection between variables
Source(s): Authors' calculation

Table 4. Cross-sectional dependency for panel static model

CD test	Critical value	Average absolute value
Friedman's test	4.43	0.69
Frees' test	8.06	0.69

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4.3 Cross-sectional dependency

Each cross-sectional unit in the study spans six years, resulting in a very short period. As a result, there is no need to test data stationarity. While cross-sectional dependency may exist, the cross-sectional dependence (CD) test indicates that there is no such dependency.

4.4 Long-run estimation

Table 5 presents the long-run impact of the independent variables (GDP, FSI, EIL, FDI, EXR, CPI and RIR) on energy intensity (CO2).

In Table 5, the coefficient of FSI is significant at the 1% level in XTGLS, XTSCC, XTPCSE and NEWEY estimates. These results suggest a positive relationship between FSI and CO2 in emerging countries. Specifically, a 1-unit improvement in emerging food security is associated with a 26% (XTGLS) and 32% (XTPCSE, NEWEY and XTSCC) increase in CO2 emission in emerging economies, consistent with prior studies (Rogelj *et al.*, 2016; Shahbaz *et al.*, 2015 as well that of Wang *et al.*, 2016a).

Additionally, the coefficients of EIL are significant at the 1% levels in XTGLS, XTSCC, XTPCSE and NEWEY estimations. These findings indicate a positive and statistically significant relationship between energy intensity and CO2 emissions in developing economies, demonstrating that an increase in energy intensity considerably adds to energy pollutants. To put it simply, a 1% increase in energy intensity is associated with a 0.66% increase in CO2 emissions. This finding aligns with the EKC hypothesis for emerging economies, corroborating research by Johnston *et al.* (2014), Godfray and Garnett (2014) as well as Pestel and Sommer (2017). In light of these results, we recommend reducing CO2 emissions by boosting the efficiency of environmental technologies. Furthermore, environmental protection ministries in emerging nations should strictly enforce existing environmental laws and regulations, promote the transition from fossil fuels to clean energy sources such as ethanol gas and encourage the use of eco-friendly vehicles like electric cars and motors.

CO2	XTGLS Coef	XTPCSE Coef	NEWEY Coef	XTSCC Coef
Constant	−0.01	−0.02	−0.02	−0.02
	(−0.03)	(−0.03)	(−0.05)	(−0.03)
FSI	0.26***	0.32***	0.32***	0.32***
	(0.05)	(0.11)	(0.13)	(0.08)
EIL	0.78***	0.66***	0.66***	0.66***
	(0.03)	(0.04)	(0.06)	(0.05)
GDP	−0.41***	−0.50***	−0.50***	−0.50***
	(−0.06)	(−0.13)	(−0.12)	(−0.1)
EXR	0.15***	0.14***	0.14***	0.14***
	(−0.03)	(−0.02)	(−0.04)	(−0.01)
RIR	−0.22***	−0.25***	−0.25***	−0.25***
	(0.02)	(0.05)	(0.05)	(0.02)
FDI	0.01	−0.04	−0.04	−0.04
	(−0.04)	(−0.05)	(−0.03)	(−0.03)
CPI	−0.11***	−0.04	−0.04	−0.04
	(−0.03)	(−0.03)	(−0.04)	(−0.02)

Note(s): XTGLS= Cross-sectional time-series FGLS regression, XTPCSE = Linear regression, correlated panels corrected standard errors, NEWEY=Regression with Newey–West standard errors and XTSCC= Regression with Driscoll-Kraay standard errors. Control variables are GDP, EXR, RIR, FDI and CPI
*** indicates $p \leq 0.01$, ** indicates $p \leq 0.05$ and * indicates $p \leq 0.10$ and figures in parentheses represent standard error
Source(s): Authors' calculation

Table 5. Coefficients of estimation results

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Similarly, the coefficient estimates of GDP are significant at the 1% level in all estimations. This implies that in emerging economies, GDP is negatively related to CO2 emission, as evidenced by XTGLS, XTPCSE, NEWEY and XTSCC estimators. This indicates that as the economy grows, CO2 emissions in emerging economies decline. According to the findings, a 1% increase in GDP corresponds to a remarkable 50% reduction in CO2 emissions in developing nations. Thus, an increase in energy may contribute to the growth process in emerging economies, according to research by Chaudhary and Bisai (2018), Bildirici (2017b), Zhang *et al.* (2017), Robaina-Alves *et al.* (2016) and Han *et al.* (2018). These results align with the Growth hypothesis, which posits a unidirectional causality between energy and economic growth. To manage the reduction of CO2 emissions without impeding economic development, energy conservation measures should be implemented. Understanding the relationship between CO2 emissions and economic development will facilitate the creation of sustainable energy policies and the responsible development of energy resources in economies.

Furthermore, the coefficients of EXR are significant at the 1% level in XTGLS, XTSCC, XTPCSE and NEWEY estimates. These findings indicate a positive relationship between EXR and CO2 emissions in emerging economies. Specifically, a 1% increase in EXR is associated with a 0.15, 0.14, 0.14 and 0.14% increase in CO2 emissions, respectively, supporting the idea that EXR contributes to higher energy pollutants. However, the coefficients of RIR are significant at the 1% level in the XTGLS, XTSCC, XTPCSE and NEWEY estimators. These results reveal a negative relationship between RIR and CO2 emissions in emerging economies. The results from XTGLS, XTPCSE, NEWEY and XTSCC estimators indicate that a 1% increase in RIR is associated with a 0.22, 0.25, 0.25 and 0.25% decrease in CO2 emissions, respectively, indicating that higher RIR levels contribute to reduced CO2 emission pollutants in these countries, consistent with previous studies (Bekhet *et al.*, 2017; Mardani *et al.*, 2019).

5. Conclusion and policy recommendation

This study investigates the long-term interconnections among energy, food security, energy intensity, CO2 emissions, FDI and economic growth in emerging economies from 1980 to 2018. To address potential issues related to heterogeneity problems and cross-sectional dependence, this study employs panel-corrected standard errors. Results reveal a positive and significant relationship between food security (FSI) and CO2 emissions within emerging markets. Energy intensity is positively linked to CO2 emissions, suggesting the need for policies to enhance food security and energy efficiency. The EKC theory is supported, indicating a negative correlation between GDP and CO2 emissions in rising economies. EXRs are positively associated with CO2 emissions, implying that EXR contributes to environmental performance in these countries. The corruption perception index (CPI) exhibits a negative relationship with CO2 emissions, suggesting the importance of anti-corruption measures in fostering improved GDP growth, energy efficiency and reduced CO2 emissions.

While this study offers valuable insights, it is essential to acknowledge several limitations. The reliance on data spanning from 1980 to 2018 may not fully capture recent developments, especially considering the abnormal year of the COVID-19 pandemic. Moreover, the presence of unobserved external factors and omitted variables may confound the identified relationships. The study's model, while robust, might not account for all potential econometric complexities, which could impact the results' robustness. In future research, considering institutional factors could enhance the model. Furthermore, this study contributes to understanding the agriculture-carbon dioxide emissions nexus. However, it fails to break down the agricultural production system into multiple indices to examine their influence or impact on CO2 emissions. This highlighted gap could inspire further research to explore and evaluate different mitigation strategies in terms of ecological efficacy and economic viability. Mitigation strategies entail

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guiding agricultural operations or activities toward more environmentally friendly methods. Moreover, treating all emerging economies as homogenous entities overlooks nuanced differences that could impact the outcomes. Further studies could consider conducting case studies to gain insights into how different contexts and characteristics impact the relationships under investigation. In addition, further research is needed to explore how the unique characteristics of each country affect their CO_2 emissions.

References

Ahmed, K., Rehman, M.U. and Ozturk, I. (2017), "What drives carbon dioxide emissions in the long run? Evidence from selected South Asian Countries", *Renewable and Sustainable Energy Reviews*, Vol. 70, pp. 1142-1153.

Ajmi, A.N., Hammoudeh, S., Nguyen, D.K. and Sato, J.R. (2015), "On the relationships between CO2 emissions, energy consumption, and income: the importance of time variation", *Energy Economics*, Vol. 49, pp. 629-638.

Al-Mulali, U. and Sab, C.N.B.C. (2012), "The impact of energy consumption and CO2 emission on the economic growth and financial development in the Sub Saharan African countries", *Energy*, Vol. 39 No. 1, pp. 180-186.

Alam, M.M., Murad, M.W., Noman, A.H.M. and Ozturk, I. (2016), "Relationships among carbon emissions, economic growth, energy consumption, and population growth: testing Environmental Kuznets Curve hypothesis for Brazil, China, India, and Indonesia", *Ecological Indicators*, Vol. 70, pp. 466-479.

Antonakakis, N., Chatziantoniou, I. and Filis, G. (2017), "Energy consumption, CO2 emissions, and economic growth: an ethical dilemma", *Renewable and Sustainable Energy Reviews*, Vol. 68, pp. 808-824, doi: 10.1016/j.rser.2016.09.105.

Anwar, A., Sinha, A., Sharif, A., Siddique, M., Irshad, S., Anwar, W. and Malik, S. (2021a), "The nexus between urbanization, renewable energy consumption, financial development, and CO2 emissions: evidence from selected Asian countries", *Environment, Development, and Sustainability*, Vol. 24, pp. 6556-6576, doi: 10.1007/s10668-021-01716-2.

Beck, N. and Katz, J.N. (1995), "What to do (and not to do) with time-series cross-section data", *American Political Science Review*, Vol. 89 No. 3, pp. 634-647.

Begum, R.A., Sohag, K., Abdullah, S.M.S. and Jaafar, M. (2015), "CO2 emissions, energy consumption, economic and population growth in Malaysia", *Renewable and Sustainable Energy Reviews*, Vol. 41, pp. 594-601.

Bekhet, H.A., Matar, A. and Yasmin, T. (2017), "CO2 emissions, energy consumption, economic growth, and financial development in GCC countries: dynamic simultaneous equation models", *Renewable and Sustainable Energy Reviews*, Vol. 70, pp. 117-132.

Bekun, F.V. (2022), "Mitigating emissions in India: accounting for the role of real income, renewable energy consumption, and energy investment", *International Journal of Energy Economics and Policy*, Vol. 12 No. 1, pp. 188-192.

Bekun, F.V., Gyamfi, B.A., Onifade, S.T. and Agboola, M.O. (2021), "Beyond the environmental Kuznets Curve in E7 economies: accounting for the combined impacts of institutional quality and renewables", *Journal of Cleaner Production*, Vol. 314, 127924.

Bhutta, Z.A., Berkley, J.A., Bandsma, R.H., Kerac, M., Trehan, I. and Briend, A. (2017), "Severe childhood malnutrition", *Nature Reviews Disease Primers*, Vol. 3 No. 1, pp. 1-18.

Bildirici, M.E. (2017a), "The effects of militarization on biofuel consumption and CO2 emission", *Journal of Cleaner Production*, Vol. 152, pp. 420-428, doi: 10.1016/j.jclepro.2017.03.103.

Bildirici, M. (2017b), "CO2 emissions and militarization in G7 countries: panel cointegration and trivariate causality approaches", *Environment and Development Economics*, Vol. 22 No. 6, pp. 771-791.

Downloaded from http://ftp.nowpublishers.com/jbsed/article-pdf/5/2/139/9661197/jbsed-05-2023-0044.pdf by guest on 23 June 2026

Bilgen, S. (2014), "Structure and environmental impact of global energy consumption", *Renewable and Sustainable Energy Reviews*, Vol. 38, pp. 890-902.

Bilgili, F., Koçak, E., Kuşkaya, S. and Bulut, Ü. (2020), "Estimation of the co-movements between biofuel production and food prices: a wavelet-based analysis", *Energy*, Vol. 213, 118777.

Chaudhary, R. and Bisai, S. (2018), "Factors influencing green purchase behavior of millennials in India", *Management of Environmental Quality: An International Journal*, Vol. 29 No. 5, pp. 798-812.

Chien, F., Anwar, A., Hsu, C.C., Sharif, A., Razzaq, A. and Sinha, A. (2021), "The role of information and communication technology in encountering environmental degradation: proposing an SDG framework for the BRICS countries", *Technology in Society*, Vol. 65, 101587.

Conway, G. (2012), *One Billion Hungry: Can We Feed the World?*, Cornell University Press, Ithaca, NY. doi: 10.7591/9780801466083.

Cordell, D., Drangert, J.-O. and White, S. (2009), "The story of phosphorus: global food security and food for thought", *Global Environmental Change*, Vol. 19 No. 2, pp. 292-305.

Escobar, J.C., Lora, E.S., Venturini, O.J., Yáñez, E.E., Castillo, E.F. and Almazan, O. (2009), "Biofuels: environment, technology and food security", *Renewable and Sustainable Energy Reviews*, Vol. 13 Nos 6-7, pp. 1275-1287.

Garnett, T. (2011), "Where are the best opportunities for reducing greenhouse gas emissions in the food system (including the food chain)?", *Food Policy*, Vol. 36, pp. S23-S32.

Godfray, H.C.J. and Garnett, T. (2014), "Food security and sustainable intensification", *Philosophical Transactions of the Royal Society B: Biological Sciences*, Vol. 369 No. 1639, 20120273.

Godfray, H.C.J., Beddington, J.R., Crute, I.R., Haddad, L., Lawrence, D., Muir, J.F., Pretty, J., Robinson, S., Thomas, S.M. and Toulmin, C. (2010), "Food security: the challenge of feeding 9 billion people", *Science*, Vol. 327 No. 5967, 812818.

Graff Zivin, J. and Neidell, M. (2012), "The impact of pollution on worker productivity", *American Economic Review*, Vol. 102 No. 7, pp. 3652-3673.

Han, H., Zhong, Z., Guo, Y., Xi, F. and Liu, S. (2018), "Coupling and decoupling effects of agricultural carbon emissions in China and their driving factors", *Environmental Science and Pollution Research*, Vol. 25, pp. 25280-25293.

Hanna, R. and Oliva, P. (2015), "The effect of pollution on labor supply: evidence from a natural experiment in Mexico City", *Journal of Public Economics*, Vol. 122, pp. 68-79.

Hatzigeorgiou, E., Polatidis, H. and Haralambopoulos, D. (2011), "CO2 emissions, GDP and energy intensity: a multivariate cointegration and causality analysis for Greece, 1977-2007", *Applied Energy*, Vol. 88 No. 4, pp. 1377-1385.

He, Z., Xu, S., Shen, W., Long, R. and Chen, H. (2017), "Impact of urbanization on energy related CO2 emission at different development levels: regional difference in China based on panel estimation", *Journal of Cleaner Production*, Vol. 140, pp. 1719-1730.

Hoechle, D. (2007), "Robust standard errors for panel regressions with cross-sectional dependence", *Stata Journal*, Vol. 7 No. 3, pp. 281-312, doi: 10.1177/1536867x0700700301.

Johnson, J.M.-F., Franzluebbers, A.J., Weyers, S.L. and Reicosky, D.C. (2007), "Agricultural opportunities to mitigate greenhouse gas emissions", *Environmental Pollution*, Vol. 150 No. 1, 107124.

Johnston, J.L., Fanzo, J.C. and Cogill, B. (2014), "Understanding sustainable diets: a descriptive analysis of the determinants and processes that influence diets and their impact on health, food security, and environmental sustainability", *Advances in Nutrition*, Vol. 5 No. 4, pp. 418-429.

Jorgenson, A.K. (2014), "Economic development and the carbon intensity of human well-being", *Nature Climate Change*, Vol. 4 No. 3, p. 186.

Jun, W., Mughal, N., Zhao, J., Shabbir, M.S., Niedbała, G., Jain, V. and Anwar, A. (2021), "Does globalization matter for environmental degradation? Nexus among energy consumption, economic growth, and carbon dioxide emission", *Energy Policy*, Vol. 153, 112230.

Downloaded from http://ftp.nowpublishers.com/jbsed/article-pdf/5/2/139/9661197/jbsed-05-2023-0044.pdf by guest on 23 June 2026

Kasman, A. and Duman, Y.S. (2015), "CO2 emissions, economic growth, energy consumption, trade and urbanization in new EU member and candidate countries: a panel data analysis", *Economic Modelling*, Vol. 44, pp. 97-103.

Khanyile, S. (2018), "*Urban-rural interactions for the diffusion of sustainability business model for food, energy, and water: a case study of Tshwane food and energy center (TFEC, Gauteng) and KwaSwayimane (KZN)*".

Lemaire, G., Franzluebbers, A., de Faccio Carvalho, P.C. and Dedieu, B. (2014), "Integrated crop–livestock systems: strategies to achieve synergy between agricultural production and environmental quality", *Agriculture, Ecosystems and Environment*, Vol. 190, pp. 4-8.

Lobell, D. and Gourdji, S. (2012), "The influence of climate change on global crop productivity", *Plant Physiology*, Vol. 160 No. 4, pp. 1686-1697, 208298.

Mardani, A., Streimikiene, D., Cavallaro, F., Loganathan, N. and Khoshnoudi, M. (2019), "Carbon dioxide (CO2) emissions and economic growth: a systematic review of two decades of research from 1995 to 2017", *Science of the Total Environment*, Vol. 649, pp. 31-49.

Nesheim, M.C., Oria, M., Yih, P.T., Resources, N. and Council, N.R. (2015), "Environmental effects of the US food system".

Özokcu, S. and Özdemir, Ö. (2017), "Economic growth, energy, and environmental Kuznets curve", *Renewable and Sustainable Energy Reviews*, Vol. 72, pp. 639-647.

Pelletier, N., Audsley, E., Brodt, S., Garnett, T., Henriksson, P., Kendall, A. and Troell, M. (2011), "Energy intensity of agriculture and food systems", *Annual Review of Environment and Resources*, Vol. 36, pp. 223-246.

Pestel, N. and Sommer, E. (2017), "Shifting taxes from labor to consumption: more employment and more inequality?", *Review of Income and Wealth*, Vol. 63 No. 3, pp. 542-563.

Pirog, R.S., Van Pelt, T., Enshayan, K. and Cook, E. (2001), "Food, fuel, and freeways: an Iowa perspective on how far food travels, fuel usage, and greenhouse gas emissions".

Quito, B., del Río, M.D.L.C., Álvarez-García, J. and Bekun, F.V. (2023), "Spatiotemporal influencing factors of energy efficiency in 43 European countries: a spatial econometric analysis", *Renewable and Sustainable Energy Reviews*, Vol. 182, pp. 113-340.

Rhodes, C.J. (2014), "Soil erosion, climate change, and global food security: challenges and strategies", *Science Progress*, Vol. 97 No. 2, pp. 97-153.

Ringler, C., Karelina, Z. and Pandya-Lorch, R. (2011), "Emerging country strategies for improving food security: linkages and trade-offs for water and energy security", *Bonn 2011 Conference: The Water, Energy, and Food Security Nexus*, Bonn.

Riti, J.S., Song, D., Shu, Y. and Kamah, M. (2017), "Decoupling CO2 emission and economic growth in China: is there consistency in estimation results in analyzing environmental Kuznets curve?", *Journal of Cleaner Production*, Vol. 166, pp. 1448-1461.

Robaina-Alves, M., Moutinho, V. and Costa, R. (2016), "Change in energy-related CO2 (carbon dioxide) emissions in Portuguese tourism: a decomposition analysis from 2000 to 2008", *Journal of Cleaner Production*, Vol. 111, pp. 520-528.

Roca, J. and Alcántara, V. (2001), "Energy intensity, CO2 emissions and the environmental Kuznets curve. The Spanish case", *Energy Policy*, Vol. 29 No. 7, pp. 553-556.

Rogelj, J., Den Elzen, M., Höhne, N., Fransen, T., Fekete, H., Winkler, H., Schaeffer, R., Sha, F., Riahi, K. and Meinshausen, M. (2016), "Paris Agreement climate proposals need a boost to keep warming well below 2 C", *Nature*, Vol. 534 No. 7609, p. 631.

Saboori, B. and Sulaiman, J. (2013), "CO2 emissions, energy consumption, and economic growth in Association of Southeast Asian Nations (ASEAN) countries: a cointegration approach", *Energy*, Vol. 55, pp. 813-822.

Shahbaz, M., Hye, Q.M.A., Tiwari, A.K. and Leitão, N.C. (2013), "Economic growth, energy consumption, financial development, international trade and CO2 emissions in Indonesia", *Renewable and Sustainable Energy Reviews*, Vol. 25, pp. 109-121.

Downloaded from http://ftp.nowpublishers.com/jbsed/article-pdf/5/2/139/9661197/jbsed-05-2023-0044.pdf by guest on 23 June 2026

Shahbaz, M., Solarin, S.A., Sbia, R. and Bibi, S. (2015), "Does energy intensity contribute to CO2 emissions? A trivariate analysis in selected African countries", *Ecological Indicators*, Vol. 50, 215224.

Song, J., Yang, W., Wang, S., Higano, Y. and Fang, K. (2018), "Exploring potential pathways towards fossil energy-related GHG emission peak prior to 2030 for China: an integrated input-output simulation model", *Journal of Cleaner Production*, Vol. 178, pp. 688-702.

Sonnino, R., Moragues Faus, A. and Maggio, A. (2014), "Sustainable food security: an emerging research and policy agenda", *International Journal of Sociology of Agriculture and Food*, Vol. 21 No. 1, pp. 173-188.

Sutton, M.A., Bleeker, A., Howard, C., Erisman, J., Abrol, Y., Bekunda, M. and Oenema, O. (2013), "*Our nutrient world. The challenge is to produce more food and energy with less pollution*".

Tamazian, A. and Rao, B.B. (2010), "Do economic, financial and institutional developments matter for environmental degradation? Evidence from transitional economies", *Energy Economics*, Vol. 32 No. 1, pp. 137-145.

Tamazian, A., Chousa, J.P. and Vadlamannati, K.C. (2009), "Does higher economic and financial development lead to environmental degradation: evidence from BRIC countries", *Energy Policy*, Vol. 37 No. 1, pp. 246-253.

The World Bank (2018), World Development Indicators Data Bank, The World Bank, available at: https://databank.worldbank.org/source/world-development-indicators

Thompson, B., Cohen, M.J. and Meerman, J. (2012), "World food insecurity and malnutrition: scope, trends, causes and consequences", in Thompson, B. and Cohen, M. (Eds), *The Impact of Climate Change and Bioenergy on Nutrition*, Springer, Dordrecht, pp. 21-41, doi: 10.1007/978-94-007-0110-6_3.

Wang, S., Fang, C. and Wang, Y. (2016b), "Spatiotemporal variations of energy-related CO2 emissions in China and its influencing factors: an empirical analysis based on provincial panel data", *Renewable and Sustainable Energy Reviews*, Vol. 55, pp. 505-515.

Wang, S., Li, G. and Fang, C. (2018), "Urbanization, economic growth, energy consumption, and CO2 emissions: empirical evidence from countries with different income levels", *Renewable and Sustainable Energy Reviews*, Vol. 81, pp. 2144-2159.

Wang, Q., Zeng, Y.-E. and Wu, B.-W. (2016a), "Exploring the relationship between urbanization, energy consumption, and CO2 emissions in different provinces of China", *Renewable and Sustainable Energy Reviews*, Vol. 54, pp. 1563-1579.

Watts, N., Adger, W.N., Agnolucci, P., Blackstock, J., Byass, P., Cai, W., Chaytor, S., Colbourn, T., Collins, M., Cooper, A. and Cox, P.M. (2015), "Health and climate change: policy responses to protect public health", *The Lancet*, Vol. 386 No. 10006, pp. 1861-1914.

Xie, L., Yan, H., Zhang, S. and Wei, C. (2020), "Does urbanization increase residential energy use? Evidence from the Chinese residential energy consumption survey 2012", *China Economic Review*, Vol. 59, 101374.

Zhang, W., Li, K., Zhou, D., Zhang, W. and Gao, H. (2016), "Decomposition of the intensity of energy-related CO2 emission in Chinese provinces using the LMDI method", *Energy Policy*, Vol. 92, pp. 369-381.

Zhang, Y.J., Bian, X.J., Tan, W. and Song, J. (2017), "The indirect energy consumption and CO2 emission caused by household consumption in China: an analysis based on the input–output method", *Journal of Cleaner Production*, Vol. 163, pp. 69-83.

Zhao, X., Zhang, X., Li, N., Shao, S. and Geng, Y. (2017), "Decoupling economic growth from carbon dioxide emissions in China: a sectoral factor decomposition analysis", *Journal of Cleaner Production*, Vol. 142, pp. 3500-3516.

Zoundi, Z. (2017), "CO2 emissions, renewable energy, and the Environmental Kuznets Curve, a panel cointegration approach", *Renewable and Sustainable Energy Reviews*, Vol. 72, pp. 1067-1075.

Downloaded from http://ftp.nowpublishers.com/jbsed/article-pdf/5/2/139/9661197/jbsed-05-2023-0044.pdf by guest on 23 June 2026

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Anwar, A., Siddique, M., Dogan, E. and Sharif, A. (2021b), "The moderating role of renewable and non-renewable energy in environment-income nexus for ASEAN countries: evidence from Method of Moments Quantile Regression", *Renewable Energy*, Vol. 164, pp. 956-967.

Guarnieri, M. and Balmes, J.R. (2014), "Outdoor air pollution and asthma", *The Lancet*, Vol. 383 No. 9928, pp. 1581-1592.

Hellegers, P., Zilberman, D., Steduto, P. and McCornick, P. (2008), "Interactions between water, energy, food, and environment: evolving perspectives and policy issues", *Water Policy*, Vol. 10 No. S1, pp. 1-10.

Kang, S., Hao, X., Du, T., Tong, L., Su, X., Lu, H., Li, X., Huo, Z., Li, S. and Ding, R. (2017), "Improving agricultural water productivity to ensure food security in China under changing environment: from research to practice", *Agricultural Water Management*, Vol. 179, pp. 5-17.

Lichter, A., Pestel, N. and Sommer, E. (2017), "Productivity effects of air pollution: evidence from professional soccer", *Labour Economics*, Vol. 48, pp. 54-66.

Pinstrup-Andersen, P. (2012), "The food system and its interaction with human health and nutrition", Edited by Shenggen Fan and Rajul Pandya-Lorch, 21.

Saboori, B., Sulaiman, J. and Mohd, S. (2012), "Economic growth and CO2 emissions in Malaysia: a cointegration analysis of the environmental Kuznets curve", *Energy Policy*, Vol. 51, pp. 184-191.

Sachs, C.E. (2018), *Gendered Fields: Rural Women, Agriculture, and Environment*, Routledge, New York.

Scialabba, N. and Hattam, C. (2002), *Organic Agriculture, Environment, and Food Security*, Food & Agriculture Org, Rome.

Shahbaz, M., Jam, F.A., Bibi, S. and Loganathan, N. (2016), "Multivariate Granger causality between CO2 emissions, energy intensity and economic growth in Portugal: evidence from cointegration and causality analysis", *Technological and Economic Development of Economy*, Vol. 22 No. 1, pp. 47-74.

West, P.C., Gerber, J.S., Engstrom, P.M., Mueller, N.D., Brauman, K.A., Carlson, K.M. and Ray, D.K. (2014), "Leverage points for improving global food security and the environment", *Science*, Vol. 345 No. 6194, pp. 325-328.

Westhoek, H., Lesschen, J.P., Rood, T., Wagner, S., De Marco, A., Murphy-Bokern, D. and Oenema, O. (2014), "Food choices, health, and environment: effects of cutting Europe's meat and dairy intake", *Global Environmental Change*, Vol. 26, pp. 196-205.

Wheeler, T. and Von Braun, J. (2013), "Climate change impacts on global food security", *Science*, Vol. 341 No. 6145, pp. 508-513.

Zilberman, D., Hochman, G., Rajagopal, D., Sexton, S. and Timilsina, G. (2012), "The impact of biofuels on commodity food prices: assessment of findings", *American Journal of Agricultural Economics*, Vol. 95 No. 2, pp. 275-281.

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