Energy 93 (2015) 999–1010

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Sustainability in the food-energy-water nexus: Evidence from BRICS (Brazil, the Russian Federation, India, China, and South Africa) countries

Ilhan Ozturk*

Faculty of Economics and Administrative Sciences, Cag University, 33800, Mersin, Turkey

ARTICLE INFO

Article history:
Received 11 June 2015
Received in revised form
1 August 2015
Accepted 22 September 2015
Available online xxx

Keywords:
Ecological indicators
Food index
Energy demand
Water resources
Environmental Kuznets curve
BRICS (Brazil, the Russian Federation, India, China, and South Africa) countries

ABSTRACT

This study explores the ecological indicators relevant to long-term sustainability by the food-energy-water nexus among BRICS (Brazil, the Russian Federation, India, China, and South Africa). The sustainability issue arises with the EKC (environmental Kuznets curve) hypothesis and biodiversity that require proper resource allocation to provide food security among the BRICS countries. This study then employs principal component analysis to construct a food security index comprising agricultural machinery, land under cereal production, and agricultural value added. Furthermore, it employs dynamic panel modeling in a GMM (generalized method of moments) system to obtain reliable parameter estimates. The results reveal that energy shortages and inadequate water resources impair the BRICS' food security. Economic growth amplifies energy demand and environmental degradation. Depletion of forests and natural resources encumbers economic prosperity, which is driven by rapid industrialization, high growth, domestic investment, improved water sources, and labor force participation. The EKC hypothesis tested across the BRICS countries, with the finding that an inverted U curve indeed does exist between carbon dioxide emissions and economic growth for Brazil, India, and South Africa, even if not for the entire panel of countries, is still a significant finding and provides motivation for new (and better) integrated economic-environmental policies.

1. Introduction

The food–energy–water nexus is considered one of the critical agenda for sustainable development globally. Rapid expansion in the population growth rate, inadequate agricultural reforms and short fall in the energy demand and supply put the burden on economic growth that required the optimum level of food, energy and water for balancing the natural flora of the world. Although the five BRICS (Brazil, the Russian Federation, India, China, and South Africa) countries—Brazil, the Russian Federation, India, China, and South Africa—have contributed to world economic growth, their lack of sustainable governance mechanisms raises doubts regarding their income convergence in the coming decades [1]. The transformation toward equitable sustainability calls for aligning food consumption by the world's growing population—i.e., assuring food security—with limits on the earth's natural resources and ecosystems. This transformation is notable among the BRICS countries. China and India, the world's most populous countries, are especially challenged to fulfill food requirements.

The BRICS countries have different income convergence strategies. China's economy is labor intensive and dependent on manufacturing exports, but its low domestic investment and consumption create a current account surplus. Russia, another export-oriented economy, relies heavily on its energy resources, and long-run policies to amplify manufacturing exports could create trade gains for the country. Aided by its policy of flexible exchange rates, India flourishes by importing capital goods. Brazil and South Africa face current account deficits. Brazil's imports are motivated by the desire to boost domestic demand, and South Africa relies on its natural resources and expanding manufacturing base to export more value-added products [2].

The food–energy–water nexus is a popular topic of debate in industry and academia, as indicated by increasing numbers of studies. Villamayor–Tomas et al. [3] examined the food–water–energy nexus under an institutional development framework. Middleton et al. [4] discussed its implications with

* Tel./fax: +90 324 6514800.
E-mail address: ilhanozturk@cag.edu.tr.

http://dx.doi.org/10.1016/j.energy.2015.09.104
0360-5442/

respect to environmental justice. Jalas and Juntunen [5] emphasized the role of energy consumption in household consumption. Salvati and Carlucci [6] stressed the role of agroforestry in sustainable development. Bazilian et al. [7] emphasized the need for integrated models that address the food–energy–water nexus globally.

Davidson et al. [8] considered Sub-Saharan Africa and examined economic development and climate change among the BRICS countries. Results confirm the development-climate nexus under the food and energy security system. Routhausen and Conway [9] traced greenhouse gas emissions from energy use in the water sector. Ringler et al. [10, p.617] concluded that "Water, land and energy resources are all crucial contributors to food security." Bogardi et al. [11] examined world water demand and the equitable allocation of water resources under a water governance framework. Global interconnectivity challenges policymakers to devise flexible water management policies. Khan and Hajra [12, p.130] argued that "Investments to boost water productivity and improve energy use efficiency in crop production are two pathways to reduce the environmental footprint."

Gheewala et al. [13] examined the relation between biomass energy and water resources to mitigate global greenhouse gas emissions. The use of fresh water for cultivating biomass is a concern for countries that facewater shortages. Therefore, biomass fuel potentially helps to address regional climate change. Examining water resources and energy consumption among MENA (Middle East and North African) countries, Siddiqi and Anadon [14] proposed an integrated assessment model that favors reusing water for agriculture rather than investing in energy intensification and desalination systems. Allouche [15] showed that food security associated with water shortages has affected global trade and raised food prices worldwide.

Hardy et al. [16] concluded that approximately 58% of Spain's energy demand is associated with the largest reservoirs of water that intensified irrigated agricultural land with energy demand. In addition, Spain's water sector supports biomass production, heightening the need for legislation to allocate water in the country's energy mix. Jobbins et al. [17] examined water resources, energy demand, and food security in Morocco and found that measures to reduce energy and water consumption fail because small farmers' adoption of drip irrigation is provisional. Therefore, the adoption of drip irrigation creates winners and losers.

The EKC (environmental Kuznets curve) hypothesis—a concept derived from the broader work of Kuznets [18]—has become a standard but contested feature in the literature of environmental policy. The hypothesizes asserts that pollution and environmental degradation increase during the early stages of economic growth but decline after a country attains some level of per capita income. These countries display an inverse U-shaped relation between measures of environmental degradation and per capita income. Fig. 1 illustrates the EKC showing different level of economic growth and environmental depletion. Different points on the curve reveal different level of environmental damage associated with a given income level. For instance, any position on the curve before "turning point" indicates that as income increases the pressure on the environment also increases leading to environmental depletion. Thus, "turning point" represents the threshold income level. Then after this threshold income level, the pressure on the environment is now getting reduced. This may be as a result of the fact that the people's willingness to pay for a clean environment has increased.

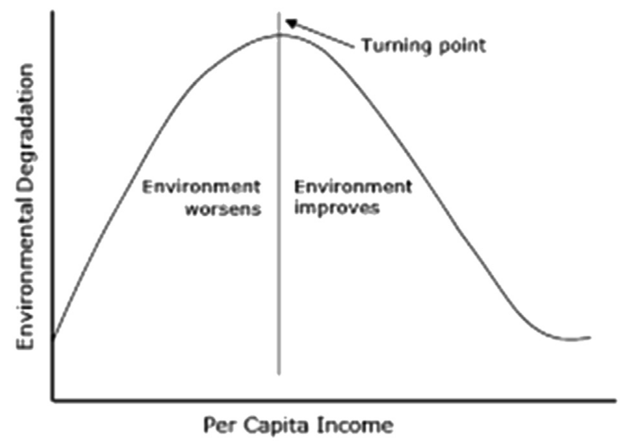

Fig. 1. Environmental Kuznets curve.

Many scholars have sought its existence in their countries. Examining cross-national panel data, Seldon and Song [19] found inverted U-shaped relationships among four air pollutants and per capita income among the BRICS countries. Torras and Boyce [20] examined economic growth, income inequality, and air pollution in low-income countries and found the EKC hypothesis confirmed by measures of air and water quality. Dinda's [21] comprehensive survey of the EKC hypothesis identified the phases of transformation from clean energy to polluting industrial development globally. Stern and Common [22] uncovered slight support for the hypothesis in sulfur emissions of high-income countries. Stern [23] recorded a history of the EKC hypothesis in developed and developing countries. López–Menéndez et al. [24] documented inverted U-shape relationships between carbon dioxide (CO_2) emissions and per capita income in countries that rely on renewable energy sources.

Pao and Tsai [25] confirmed the EKC hypothesis in their examination of economic growth, financial development, and environmental degradation in panel data for the BRIC (Brazil, Russian Federation, India, and China) countries during 1980–2007. Sebri and Bin–Salha [26] discovered a feedback loop between energy sources and economic growth in the BRICS countries during 1971–2010. Apergis and Ozturk [27] confirmed the hypothesis among the BRICS in a panel of 14 Asian countries during 1990–2011, although Al-Mulali et al. [28] found no confirmation in their study of Vietnam.

Salahuddin and Gow [29] examined the empirical relationship between economic growth, energy consumption, and carbon dioxide emissions, calculated the trend of decoupling effects, and finally analyzed the evolution of inequality in CO_2 emissions in the GCC (Gulf Cooperation Council) countries. Results indicate a positive and significant short-run and long-run associations between energy consumption and CO_2 emissions and between economic growth and energy consumption among the GCC countries. No significant relationship appears between economic growth and CO_2 emissions. Energy consumption and CO_2 emissions Granger cause each other, although a unidirectional causal link runs from economic growth to energy consumption. Divergences in the Gini index values contributed to differences in emissions inequality in the region. Inequality in CO_2 emissions significantly declined both in energy carriers and in economic sectors over time.

Al-Mulali and Ozturk [30] examined environmental degradation in 14 MENA countries during 1996–2012 via a panel model that used an ecological footprint to indicate environmental degradation. The Pedroni test revealed cointegration among the ecological footprint, energy consumption, urbanization, trade openness, industrial development, and political stability. Moreover, results obtained from fully modified ordinary least squares concluded that energy consumption, urbanization, trade openness, and industrial