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Energy consumption, carbon emissions and economic growth in Saudi Arabia: An aggregate and disaggregate analysis



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HIGHLIGHTS

- Carbon emissions increase with the increase in per capita income in Saudi Arabia.
- The income elasticity of CO₂ is negative for the gas consumption model.
- The income elasticity of CO₂ is positive for the oil consumption model.
- The results suggest that electricity is less polluting than oil and gas.

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ABSTRACT

The objective of this study is to examine the relationship among economic growth, carbon emissions and energy consumption at the aggregate and disaggregate levels. For the aggregate energy consumption model, we use total energy consumption per capita and CO₂ emissions per capita based on the total energy consumption. For the disaggregate analysis, we used oil, gas and electricity consumption models along with their respective CO₂ emissions. The long-term income elasticities of carbon emissions in three of the four models are positive and higher than their estimated short-term income elasticities. These results suggest that carbon emissions increase with the increase in per capita income which supports the belief that there is a monotonically increasing relationship between per capita carbon emissions and per capita income for the aggregate model and for the oil and electricity consumption models. The long- and short-term income elasticities of carbon emissions are negative for the gas consumption model. This result indicates that if the Saudi Arabian economy switched from oil to gas consumption, then an increase in per capita income would reduce carbon emissions. The results also suggest that electricity is less polluting than other sources of energy.

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1. Introduction

In recent years, environmental pollution, greenhouse gases and climate change have been among the most important environmental concerns worldwide. The ever-increasing levels of carbon dioxide (CO₂) and other greenhouse gases in the atmosphere are considered to be among the world's greatest environmental threats. Among the greenhouse gases, CO₂ plays a powerful role in enhancing the greenhouse effect and is responsible for greater than 60 percent of this effect (Ozturk and Acaravci, 2010). Energy production and consumption patterns, energy intensity, the price and availability of energy play an important role in CO₂ emissions development trends. Energy is considered an engine of industrial

development and economic growth; thus, it is believed that a country with high energy consumption also has a high living standard. However, high energy consumption also causes high carbon emissions, which adversely affect the environment. Thus, the effects of global warming and climate change on the world economy have been studied intensively by academics and practitioners. The empirical literature shows that the relationship between per capita income and environmental pollution follows an inverted U-shaped pattern, which is commonly known as the environmental Kuznets curve (EKC). According to the EKC hypothesis, at early stages of economic growth, degradation and pollution increases, but beyond some level of income per capita, the trend reverses, such that a high level of income leads to environmental improvement (Stern, 2004). There is a wide range of literature that has assessed the relationships among energy consumption, economic growth and carbon emissions. The empirical evidence suggests that there is a long-term relationship between pollution levels and economic growth; therefore, any constraint that is

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placed on energy consumption to aid in reducing emissions will have a negative effect on economic growth (Ozturk and Acaravci, 2010; Halicioglu, 2009; Chontanawat et al. 2008; Lise, 2006; Lee, 2005; Soytaş and Sari, 2003).

The United Nations has been seriously attempting to reduce the adverse effects of global warming and climate change through binding agreements, such as the Kyoto Protocol (Halicioglu, 2009). The Protocol was initially adopted on December 11, 1997, in Kyoto, Japan, and entered into force on February 16, 2005. As of September 2001, 191 countries had signed and ratified the protocol. The Kyoto Protocol is generally considered an important development toward a truly global emissions reduction regime that will stabilize greenhouse gas emissions and provide the essential architecture for any future international agreements on climate change. Therefore, promoting sustainable development and combating climate change have become integral aspects of energy planning, analysis and policy making in many countries of the world, including Saudi Arabia. The Saudi Arabian government has taken many important and constructive steps to preserve its natural resources. To achieve the lowest possible level of energy intensity, Saudi Arabia has actively participated in the global trend to preserve the environment through a combination of positive initiatives and environmental regulation. Saudi Arabia has revised its general environmental laws and the rules for their implementation to be consistent with Article 32 of the constitution with the following aims:

- “The State shall endeavor to preserve, protect and improve the environment and prevent its pollution.
- Protect public health from activities and acts that harm the environment.
- Conserve and develop natural resources.
- Include environmental planning as an integral part of overall development planning in all industrial, agricultural, architectural and other areas.
- Raise awareness of environmental issues and strengthen individual and collective feelings regarding the sole and collective responsibility for preserving and improving the environment and encouraging national voluntary efforts.
- Address various types of environmental violations and appropriate penalties for protecting the human health from pollution both at present and in the future”.

The Saudi Arabian economy is an oil-based economy and comprises energy-intensive sectors such as the industry, building and transport sectors. Therefore, total energy consumption is increasing rapidly in the country despite the measures and regulations that have been adopted. According to *Saudi Arabia's Energy Efficiency Report (January 2011)*, energy consumption is growing more rapidly than GDP in Saudi Arabia, and primary energy consumption per capita was 6.8 toe in 2009, which is four times higher than the world average. Total energy consumption is growing at an average rate of 5.8 percent per year since 1990, and the rate has tripled between 1990 and 2009. The final and primary energy intensities rose by 2.3 percent per year, on average, between 2000 and 2009, and CO₂ intensity has risen by 2 percent per year since 2000 (*Saudi Arabia's Energy Efficiency Report, 2011*).

The choice of Saudi Arabia for this study is motivated by the fact that Saudi Arabia has experienced a sharp increase in energy consumption and carbon emissions in recent years as a result of its strong economic and industrial growth. Historically high international oil prices and large domestic fuel subsidies also play an important role in the recent economic growth and high energy consumption in the country. Because of strong economic and industrial growth, the consumption of oil, gas and electricity

increased sharply during the 1980–2010 period. In 2010, Saudi Arabia's oil consumption was approximately 2.65 million barrels/day, which is 4.3 times the 1980 level. Electricity consumption reached 478 billion kWh, and gas consumption reached 3095.7 billion cubic feet in 2010, which are 9.7 and 9.3 times their 1980 levels, respectively (*U.S. Energy Information Administration, 2012*). According to *Boden et al. (2011)*, Saudi Arabia's share of carbon emissions worldwide in 2008 was at 14th place, or a 1.54 percent share of worldwide emissions, with 118 million metric tons of carbon emissions.

The steps that have been taken by the Saudi Arabian government to protect the environment by preserving energy resources have important implications for the sustainable development of the country. The literature suggests that any effective policy should consider the dynamic nature of the relationships among energy, the environment and growth and should have a long-term vision. Hence, understanding the intertemporal relationship among emissions, energy use and economic growth in an individual country is essential to generate effective policies (Soytaş and Sari, 2009). There is no country-level study for Saudi Arabia that focuses on aggregate and disaggregate analyses of energy consumption, carbon emission and growth. Therefore, one objective of this study is to investigate the existence of the EKC for Saudi Arabia for aggregate and disaggregate energy consumptions and carbon emission data. For the aggregate analysis, we use total energy consumption per capita and per capita CO₂ emissions from the total energy consumption. We disaggregate the total energy consumption into oil, gas and electricity consumption to examine the separate effect of each of these types of energy consumption on CO₂ emissions. Therefore, for the disaggregate analysis, we use oil, gas and electricity consumption along with their respective CO₂ emissions. The other objective of the study is to examine the long- and short-term causal relationships among economic growth, carbon emissions and energy consumption at the aggregate and disaggregate levels of energy consumption and carbon emissions to determine whether Saudi Arabia can achieve its objective of an environmental friendly atmosphere without compromising its sustainable economic growth pattern. This paper also addresses the collinearity and omitted variable bias problems in the estimation methodology. As *Stern (2004)* and *Narayan and Narayan (2010)* noted, most of the EKC literature is econometrically weak. Earlier studies model carbon emissions as a function of income augmented by income-squared and income-cubed type variables, which suffer from multicollinearity problems. A test of collinearity between income and income squared for Saudi Arabia has been conducted, and the correlation between income and income squared is determined to be 0.9999 for the 1980–2011 period. The previous studies (for example, *Narayan and Narayan, 2010; Alam et al., 2012*) relied on a bivariate analysis and thus suffered from an omitted variable bias problem.

The remainder of this study is organized as follows. *Section 2* discusses the empirical literature on the relationship among economic growth, carbon emissions and energy consumption. *Section 3* discusses the data and methodology used in the study. *Section 4* presents the empirical findings, and the conclusion and policy implications are included in *Section 5*.

2. Literature review

The literature on the relationship among economic growth, energy consumption and environmental pollution has three broad strands (*Zhang and Cheng, 2009*). The first strand of the literature focuses on environmental pollution and the economic growth nexus. This strand of the literature involves testing for the existence of an EKC, which states that in the early stages of economic growth,

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