Carbon emissions, energy consumption and economic growth: An aggregate and disaggregate analysis of the Indian economy

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HIGHLIGHTS

- Relationships among carbon emissions, energy consumption and economic growth are investigated.
- The EKC exists at aggregated and disaggregated levels for India.
- All energy resources have positive effects on carbon emissions.
- Gas energy consumption is less polluting than other energy sources in India.

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ABSTRACT

This study investigates the long and short run relationships among carbon emissions, energy consumption and economic growth in India at the aggregated and disaggregated levels during 1971–2014. The autoregressive distributed lag model is employed for the cointegration analyses and the vector error correction model is applied to determine the direction of causality between variables. Results show that a long run cointegration relationship exists and that the environmental Kuznets curve is validated at the aggregated and disaggregated levels. Furthermore, energy (total energy, gas, oil, electricity and coal) consumption has a positive relationship with carbon emissions and a feedback effect exists between economic growth and carbon emissions. Thus, energy-efficient technologies should be used in domestic production to mitigate carbon emissions at the aggregated and disaggregated levels. The present study provides policy makers with new directions in drafting comprehensive policies with lasting impacts on the economy, energy consumption and environment towards sustainable development.

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1. Introduction

Climate change is one of the most debated environmental issues worldwide. Economic development and globalization have contributed to raising the levels of CO_2 emissions and other greenhouse gases in the atmosphere. In the past few decades, climate change has become an issue of discussion among political leaders and experts. To date, CO_2 emissions have contributed more than 60% to the increase in the effect of greenhouse gases on the atmosphere (Ozturk and Acaravci, 2010).

Market liberalization and globalization play important roles in economic growth worldwide. Since the mid-twentieth century, world economies have rapidly grown owing to developments in research and technology, international investment, international market access, and transportation. The rising trend of economic activities in the world in the past few decades has reflected the considerable consumption of energy. Energy is the "oxygen" that gives life to economic activities. Developing countries have also been consuming energy in large amounts for sustainable economic development and better living standards. However, energy consumption is accompanied by pollutants that contribute to climate change (Alkhathlan and Javid, 2013).

Energy consumption and CO_2 emissions are continuously increasing in different countries, especially developing ones such as India, whose emerging economy and rapid economic development

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has caught the attention of the world. India is the fifth and seventh largest country in terms of energy consumption and energy production, respectively. The growth rate of India has been increasing constructively over the past couple of decades. Thus, the Indian government has adopted several energy policies to generate a sustainable energy supply that can meet the country's demand without any constraints in the future. Inevitably, rapid economic growth in the country also resulted in a large amount of carbon emissions, making India the third largest carbon emitter at a global level to date.

Masih and Masih (1996) noted that the Indian economy is dependent on energy, which is a major source of carbon emissions. The Indian government also has serious concerns about the sustainability of its economic growth and environment quality. In its 12thfive-year plan (2012–2017), the Indian government set a target of 9% GDP growth. Consequently, energy supply should be increased by 6.5% per year to fulfill this target. In 2009, the Indian government also committed to a 20–25% reduction of carbon emissions by 2020 as compared to 2005 (Boutabba, 2014). Today, India faces the daunting task of identifying a solution that could help achieve maximum economic growth with minimum CO_2 emissions. Therefore, the relationship among CO_2 emissions, energy consumption and economic growth in India should be understood from both aggregated and disaggregated perspectives for comprehensive policies on energy, economy and the environment.

Most of the studies on India examined the effect of a single energy source on total CO_2emissions, thereby failing to provide a clear picture for policy making. By contrast, in this study, all major energy sources of India are considered and their respective effects on CO_2 emissions are examined separately. India meets its overall energy demand by exploiting crude oil, petroleum products, coal, natural gas, electricity and other energy sources. These energy sources play an important role in meeting the increasing demand for energy in India; coal, oil and gas respectively account for 44%, 22%, and 7% of the total energy consumption in 2012. India is the third leading coal consumer, the fourth biggest oil consumer and eleventh largest gas consumer in the world. The infrastructure of electric power has increased significantly, but electricity supply remains insufficient to meet the demands of the country. In fact, the growth rate of electricity consumption is lower than the economic growth rate in the last decade. The electricity consumption per capita of India is the lowest in the world (EIA, 2014).

Numerous studies have considered the relationships among CO_2 emissions, energy consumption and economic growth at the aggregated level, resulting in mixed empirical findings (e.g., Alam et al., 2011; Ghosh, 2010; Jayanthakumaran et al., 2012; Vidyarthi, 2013). Considering the increasing impact of climate change, many researchers (e.g., Acaravci and Ozturk, 2010; Akbostanci et al., 2009; Boutabba, 2014; Managi and Jena, 2008; Pao and Tsai, 2010) have inspected the empirical relationships among CO_2 emissions, energy consumption and economic growth. Their results validated the existence of the environmental Kuznets curve (EKC), which defines the turning point of CO_2 emissions with respect to economic growth.

This study extends the literature by identifying the long and short run relationships that result from the disaggregation of CO_2 emissions, energy consumption (oil, gas, coal, and electricity) and economic growth. Some researchers argued that the relationships among carbon emissions, energy consumption and economic growth at the aggregated level may not provide a clear picture because different energy sources have different causality results on economic growth and carbon emissions (e.g., Wolde-Rufael, 2010; Yuan et al., 2008; Ziramba, 2009). Consequently, recent studies have focused on the relationships among carbon emissions, energy consumption and economic growth at the disaggregated level (e.g., Alkhathlan and Javid, 2013; Rahman et al., 2015; Saboori and Sulaiman, 2013; Shahbaz et al., 2015; Wolde-Rufael, 2010; Ziramba, 2015).

All above mentioned researches only studied single energy sources for India (e.g., Chandran Govindaraju and Tang, 2013; Tiwari et al., 2013; Shahbaz et al., 2015), and no one considered all major energy sources simultaneously for analysis. This is a big gap in literature on India and we fill this gap by analyzing the relationships among carbon emissions, energy consumption and economic growth at aggregated and disaggregated (coal, gas, oil and electricity) level with EKC hypothesis. Aggregate EKC analysis provides information about the relationship among energy consumption, economic growth and carbon emissions as a whole. But this information is not clear enough for policy making about future energy demand in terms of which energy source is the better substitute for environment protection. For this purpose we have conducted the disaggregated EKC analysis for each energy source separately. Disaggregated analysis examines the effect of each energy source on carbon emissions and economic growth in details and provides information about which energy source is the better substitute for future energy demand of India. We can also overcome the shortfalls of aggregated EKC analysis by applied disaggregated EKC analysis which provide us complete information about the relationships between economic growth and carbon emissions with respect to different energy sources (coal, gas, oil and electricity) usage separately. So, policy makers can compare and select the best energy source to meet the future increasing demand of energy of India and achieve Indian government's target of minimizing carbon emissions without compromising on economic growth at the same time.

Compared with previous studies, such as Alkhathlan and Javid (2013), our contributions are as follows: Firstly, we studied the issue of India, it is a very important country and a fast growing economy, and it is also the third largest carbon emitter in the world. This study has great importance for Indian policy maker. Secondly, we considered all major energy sources (coal, gas, oil, electricity) of India and checked their impact on their respected carbon emissions. Thirdly, we used a longer time series data during 1971–2014 for more reliable and efficient results. Fourthly, some previous studies used only ARDL approach to confirm cointegration among variables. We used both Johansen cointegration test and ARDL bond testing approaches for more reliable results. Lastly, some previous studies did not conduct EKC analysis due to high multicollinearity among independent variables. We overcame this problem by using a large sample size of time series data from 1971 to 2014 and conducted EKC analysis between carbon emission and economic growth in each energy consumption model.

The rest of the paper is presented as follows: Section 2 presents a brief review of the literature, the methodology and data sources employed in this study are described in Section 3, a discussion of the empirical analysis and results is provided in Section 4, and the concluding notes as well as policy recommendations are given in Section 5.

2. Literature review

Three main groups of researchers have examined the relationships among carbon emissions, energy consumption and economic growth in the literature (Zhang and Cheng, 2009). The first group concentrated on analyzing the existence of EKC, i.e., inverted U-shaped relationship between carbon emissions and economic growth. Kuznets (1955), the proponent of the Kuznets curve, described the relationship between economic growth and income inequality. The Kuznets curve was later transformed into economic growth and environment quality relationship and called environmental Kuznets curve. In the beginning, Grossman and