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Does natural gas consumption mitigate CO_2 emissions: Testing the environmental Kuznets curve hypothesis for 14 Asia-Pacific countries

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ABSTRACT

This study aims to investigate the nexus of per capita carbon dioxide (CO_2) emissions, per capita gross domestic product (GDP), and per capita natural gas consumption by examining the validity of the environmental Kuznets curve (EKC) hypothesis and analyzing the effectiveness of natural gas consumption for a panel of 14 Asia-Pacific countries for 1970–2016. To do so, a Granger causality framework covering panel unit root, cointegration, estimation, and causality tests allowing for cross-sectional dependence is employed. The main findings are: (i) The augmented mean group (AMG) estimates provide strong evidence in favor of the EKC hypothesis as the EKC holds in 13 of the 14 countries; the EKC exists independent of the individual country's per capita GDP; (ii) the turning points (TPs) lie between $1937.23 (Bangladesh) and $58,235.90 (Australia), while the turning years (TYs) are estimated to stay between 2019 (Australia) and 2048 (Bangladesh); per capita GDP positively and negatively affects the TPs and TYs, respectively; (iii) natural gas consumption has a significantly negative effect on CO_2 emissions; the significantly negative effect of natural gas consumption on CO_2 emissions is also independent of per capita GDP but, conversely, may be affected by the proportion of natural gas in the primary energy mix; and (iv) bidirectional causality runs between natural gas consumption and CO_2 emissions in both the short run and long run. Important policy implications are highlighted for Asia-Pacific countries' policymakers with respect to halting global warming and promoting growth in the natural gas industry.

1. Introduction

In the last few decades, the Asia-Pacific region has witnessed unparalleled economic development thanks to its rapid industrialization and urbanization. The gross domestic product (GDP) has increased more than 12-fold from 2047.6 billion US dollars (US$) in 1965 to 24,632.2 billion US$ in 2016, with an average annual growth rate of 4.9% [1]. Simultaneously, abundant energy fuels have been consumed in the Asia-Pacific region. According to statistics from BP (formerly British Petroleum), the total primary energy consumption in the Asia-Pacific region in 2016 amounted to 5580 million tonnes oil equivalent (Mtoe), accounting for approximately 42.0% of the planet's total consumption of energy [2]. However, the rapidly increasing economic level has triggered tremendous challenges related to environmental pressures in the Asia-Pacific region, in particular carbon dioxide (CO_2) emissions. Specifically, the CO_2 emissions in the Asia-Pacific region grew from about 1429.0 million tonnes (Mt) in 1965 to 16,100.5 Mt in 2016, almost a 12-fold increase [2].

Therefore, to mitigate the greenhouse effect, natural gas has emerged as an effective alternative to other fossil fuels (e.g., coal, oil) in many Asia-Pacific countries [3], as the combustion of coal and oil is the largest contributor to the Asia-Pacific region's CO_2 emissions [4,5]. The consumption of natural gas in the whole Asia-Pacific region has soared from 5.9 billion cubic meters (bcm) in 1965 to 722.5 bcm in 2016, an increase of nearly 123-fold, with an average annual growth rate of 9.7%. Furthermore, in 2016, the Asia-Pacific region as a whole

Abbreviations: ADF, Augmented Dickey Fuller; AMG, Augmented mean group; AR, Autoregressive; Bcm, Billion cubic meters; BP, British Petroleum; BRICS, Brazil, Russia, India, China, and South Africa; CADF, Cross-sectionally ADF; CD, Cross-section dependence; CIPS, Cross-sectionally augmented Im, Pesaran, and Shin; CO_2, Carbon dioxide; EKC, Environmental Kuznets curve; FMOLS, Fully modified OLS; GDP, Gross domestic product; IPS, Im, Pesaran, and Shin; LLC, Levin-Lin-Chu; LM, Lagrange multiplier; Mt, Million tons; Mtoe, Million tonnes oil equivalent; NG, Natural gas consumption; PP, Philips-Perron; TPs, Turning points; TYs, Turning years; US, United States; VAR, Vector autoregressive; VECM, Vector error correction model; VR, Variance-ratio

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contributes approximately 20.4% of the total world consumption of natural gas and has become the third largest global natural gas consumption region.

Given the above background, it is important to investigate the causal links among CO_2 emissions, economic growth, and natural gas consumption in the case of Asia-Pacific countries, which is particularly useful not only for combating global warming, but also for promoting growth in the Asia-Pacific countries' natural gas industry. However, based on a review of the literature to date, very few studies have investigated the causal relationship among CO_2 emissions, economic growth, and natural gas consumption in the context of Asia-Pacific countries. Moreover, the environmental Kuznets curve (EKC), first proposed by Kuznets in 1955, postulates that an inverted U-shaped relationship exists between environmental pollutants and economic growth. The EKC is particularly useful in investigating the energy-growth-pollutant nexus, particularly for developing countries that are currently striving to boost their economy. However, to our knowledge, very few empirical studies have examined the validity of the EKC hypothesis CO_2 emissions in the case of Asia-Pacific countries. In addition, the first-generation estimators usually adopted in prior studies on the energy-growth-pollutant nexus, such as fully modified ordinary least squares (FMOLS), ignore the cross-sectional dependence that may exist within the Asia-Pacific countries, which may create inconsistent estimates or result in misleading conclusions [6–8]. Conversely, the second-generation estimators, such as augmented mean group (AMG) estimator, can overcome this shortcoming; however, to the best of our knowledge, very few studies fall within the energy-growth-pollutant nexus by employing the second-generation estimators, especially for the Asia-Pacific region. To fill this knowledge gap, this study investigates the dynamic causal links among CO_2 emissions, economic growth, and natural gas consumption for a panel of 14 Asia-Pacific countries spanning 1970–2016, employing the most recent panel estimator which allows for cross-sectional dependence (i.e., the AMG estimator). In addition, this study also tests the validity of the EKC hypothesis for CO_2 emissions and identifies the turning points (TPs) and turning years (TYs) of each country and panel group, respectively.

This study contributes to the literature in the following three aspects. First, most existing studies ignore cross-sectional dependence, which might lead to biased and inconsistent estimates. Therefore, by employing the most recent panel estimator allowing for cross-sectional dependence, this study can provide a more robust analysis. Second, to our knowledge, this study is the first to examine the causal relationships among CO_2 emissions, economic growth, and natural gas consumption within the framework of EKC for the case of Asia-Pacific countries. Third, the TPs and TYs of each country and panel group are identified, which is particularly useful for each Asia-Pacific country's government not only in devising long- and short-run policies for tackling CO_2 emissions, but also in promoting growth in the natural gas industry.

The remainder of this paper is organized as follows. Section 2 reviews the related literature. Section 3 provides the methodology and data. Section 4 presents the empirical results. Section 5 contains further discussion. The ending section concludes this study and provides policy implications.

2. Literature review

The CO_2 emissions-economic growth-energy variety nexus has attracted the attention of a large number of researchers in different countries or areas in recent years; their findings are summarized in Table A1 of Appendix A. As shown in this table, numerous studies have employed a range of econometric approaches to investigate the role of various kinds of energy in affecting CO_2 emissions, such as Pereira and Pereira [9], Shahbaz et al. [10], and Squalli [11] for coal consumption, Lotfalipour et al. [12], Alkhathlan and Javid [13], and Lim et al. [14] for oil consumption, Apergis et al. [15], Saidi and Mbarek [16], and Ozturk [17] for nuclear energy consumption, and Bhattacharya et al. [18], Danish [19], and Dong et al. [20] for renewable energy consumption.

However, to the best of our knowledge, very few studies fall within the CO_2 emissions-economic growth-natural gas consumption nexus, especially for the Asia-Pacific region. For instance, Lotfalipour et al. [12] employ the Toda-Yamamoto Granger causality approach for 1967–2007 to detect unidirectional causality running from natural gas consumption to CO_2 emissions in Iran. Using the vector autoregressive (VAR) Granger causality approach, Pereira and Pereira [9] indicate that similar results are evident in Portugal. In addition, this study finds unidirectional causality running from natural gas consumption to economic growth. Recently, further study has been conducted on China's CO_2 emissions-economic growth-natural gas consumption nexus by Dong et al. [21], who employ FMOLS model and a data span from 1995 to 2014 to study the causal relationship between natural gas consumption and CO_2 emissions. This study finds unidirectional causality running from natural gas consumption to CO_2 emissions in the long run for China. The study also claims that the move away from other fossil fuels (e.g., coal, oil) to natural gas can reduce CO_2 emissions in China. Similarly, with respect to the United States (US), VAR Granger causality results obtained by Li and Su [22] confirm the presence of unidirectional causality running from natural gas consumption to CO_2 emissions. In addition, Alkhathlan and Javid [13], Saboori and Sulaiman [23], and Dong et al. [8] indicate the existence of a bidirectional causal relationship among CO_2 emissions, economic growth, and natural gas consumption in Saudi Arabia, Malaysia, and the BRICS countries (i.e., Brazil, Russia, India, China, and South Africa), respectively, employing similar vector error correction model (VECM) Granger causality techniques.

3. Methodology and data

3.1. Empirical model

To investigate the dynamic impact of natural gas consumption in CO_2 emissions and examine the validity of the EKC hypothesis, this study extends the common EKC model by adding natural gas consumption as a new explanatory variable by referring to the previous study of Dong et al. [21]. The empirical equation in the study is represented in a quadratic form, as follows:

$$CO_{2it} = f(GDP_{it}, GDP_{it}^2, NG_{it}) \quad (1)$$

where i indicates the country samples ($i = 1, 2\cdots14$); t indicates the time span (1965–2016); CO_{2it} represents the per capita CO_2 emissions of country i in year t; GDP_{it} represents the per capita GDP of country i in year t; and NG_{it} represents the per capita natural gas consumption of country i in year t. The estimation model is transformed to its logarithmic form and can be re-written as follows:

$$\ln CO_{2it} = \beta_0 + \beta_1 \ln GDP_{it} + \beta_2(\ln GDP_{it})^2 + \beta_3 \ln NG_{it} + \mu_{it} \quad (2)$$

where β_0 and μ_{it} are the intercept and the error term, respectively. The parameters β_1–β_3 denote the estimated coefficients. Following EKC insight, β_1 and β_2 are expected to be positive and negative, respectively. Following Dong et al. [3] and taking the case of per capita coal consumption and natural gas consumption as an example, the substitution effect and the change in the per capita CO_2 emissions can be explained as $\Delta CO_2 = 1.79^*\Delta Coal + 0.0006^*\Delta NG$, where $\Delta Coal$ denotes per capita coal consumption and will decrease and ΔNG denotes per capita natural gas consumption and will increase. Thus, the sign of ΔCO_2 will be negative, indicating that natural gas consumption can optimize for a cleaner energy consumption structure through the substitution away from other fossil fuels and, therefore, mitigate CO_2 emissions. Thus, β_3 is expected to be negative.