Science of the Total Environment 640–641 (2018) 293–302

Contents lists available at ScienceDirect

Science of the Total Environment

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

CO_2 emissions, natural gas and renewables, economic growth: Assessing the evidence from China

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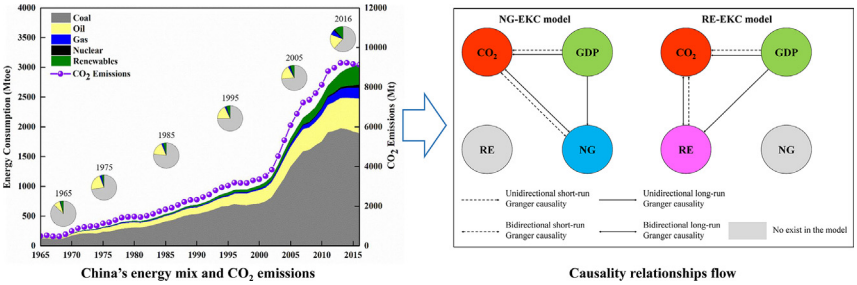
HIGHLIGHTS

- The energy-growth-pollutant nexus is investigated in China for 1965–2016.
- The study confirms the existence of the EKC for CO_2 emissions in China.
- Both natural gas and renewable energy consumption can mitigate CO_2 emissions.
- The mitigation effect of natural gas will be weakened over time.
- Renewable energy will become progressively more important.

GRAPHICAL ABSTRACT



China's energy mix and CO_2 emissions | Causality relationships flow

ARTICLE INFO

Article history:
Received 6 April 2018
Received in revised form 24 May 2018
Accepted 25 May 2018
Available online xxxx

Editor: J Jay Gan

Keywords:
CO_2 emissions
Natural gas and renewable energy consumption
Environmental Kuznets curve
ARDL
China

ABSTRACT

This study aims to test the environmental Kuznets curve (EKC) for carbon dioxide (CO_2) emissions in China by developing a new framework based on the suggestion of Narayan and Narayan (2010). The dynamic effect of natural gas and renewable energy consumption on CO_2 emissions is also analyzed. Considering the structural break observed in the sample, a series of econometric techniques allowing for structural breaks is utilized for the period 1965–2016. The empirical results confirm the existence of the EKC for CO_2 emissions in China. Furthermore, in both the long-run and the short-run, the beneficial effects of natural gas and renewables on CO_2 emission reduction are observable. In addition, the mitigation effect of natural gas on CO_2 emissions will be weakened over time, while renewables will become progressively more important. Finally, policy suggestions are highlighted not only for mitigating CO_2 emissions, but also for promoting growth in the natural gas and renewable energy industries.

Abbreviations: ADF, Augmented Dickey Fuller; AIC, Akaike information criterion; ARDL, autoregressive distributed lag; Bcm, billion cubic meters; BP, British Petroleum; BRICS, Brazil, Russia, India, China, and South Africa; CCR, canonical cointegration regression; CO_2, carbon dioxide; CSY, China Statistical Yearbook; CUSUM, cumulative sum; CUSUMSQ, cumulative sum of squares; DOLS, dynamic OLS; ECT, error correction term; EKC, environmental Kuznets curve; FMOLS, fully modified OLS; G7, Canada, France, Germany, Italy, Japan, the UK, and the US; GDP, gross domestic product; Mt, million tonnes; Mtoe, million tonnes oil equivalent; NDRC, National Development and Reform Commission; NG, natural gas; OECD, Organization for Economic Cooperation and Development; PP, Philips-Perron; RE, renewable energy; Toe, Tonnes oil equivalent; UK, United Kingdom; UREC, unrestricted error correction; US, United States; VECM, Vector error correction model; ZA, Zivot and Andrews.

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https://doi.org/10.1016/j.scitotenv.2018.05.322
0048-9697/

1. Introduction

As the world's largest energy consumer and carbon dioxide (CO_2) emitter, China is now facing several energy and environmental challenges (Dong et al., 2018; Dong and Zeng, 2018; Wang et al., 2016; Yang et al., 2017; Zhou et al., 2018). In fact, abundant fossil and non-fossil fuels have been consumed in China. In 2016, China's total primary energy consumption amounted to 3053 million tonnes oil equivalent (Mtoe) (Fig. 1), accounting for approximately 23% of the total world consumption of energy (Dong et al., 2017). One of the consequences of such huge energy consumption is rapidly increasing CO_2 emissions in China. According to statistics from BP (formerly British Petroleum) (BP, 2017), CO_2 emissions in China accounted for approximately 489 million tons (Mt) in 1965 and 9123 Mt. in 2016, an increase of almost 20 times (Fig. 1). With increasing CO_2 emissions and rising concerns over the related environmental and health consequences, China is moving to increase its consumption of natural gas and renewable energy (Dong et al., 2017; Zhao and Luo, 2017), as these two fuels tend to produce fewer CO_2 emissions than some dirty fossil fuels, such as coal and petroleum (Jaramillo et al., 2007). Specifically, as shown in Fig. 1, the consumption of natural gas in China has soared from 1.1 billion cubic meters (bcm) in 1965 to 210.3 bcm in 2016, nearly 190 times as much, with an average annual growth rate of 10.8%. Meanwhile, renewable energy consumption in China has increased by nearly 70 times, from 5.0 Mtoe in 1965 to 349.2 Mtoe in 2016 (Fig. 1); it is expected to increase by approximately 20% from 2016 to 2020, representing more than one-fourth of the total generation capacity, according to the 13th Five-Year Plan on renewable energy development released by the National Development and Reform Commission (NDRC) of China in 2016 (NDRC, 2016).

Along with the enormous demand for natural gas and renewable energy and the rapidly increasing CO_2 emission levels, a better understanding of the casual relationship among CO_2 emissions, economic growth, and natural gas and renewable energy consumption in China is particularly useful for the Chinese government not only in devising long- and short-run policies for tackling CO_2 emissions, but also in promoting growth in the natural gas and renewable energy industries (Dong et al., 2018). Also, the environmental Kuznets curve (EKC), first stated by Kuznets (1955), is particularly significant for investigating the energy-growth-pollutant nexus, particularly for developing countries that are currently striving to boost their economy (Sugiawan and Managi, 2016). However, the conventional EKC models could lead to the problems of either collinearity or multicollinearity as they contain both income and square of income as exogenous variables. The new method of testing the EKC hypothesis, proposed by Narayan and Narayan (2010), can overcome this shortcoming; however, to our knowledge, no empirical studies have used the Narayan and Narayan method to test the EKC hypothesis in China. Furthermore, the traditional unit root tests and estimators adopted in existing studies usually ignore the presence of structural breaks in a series, which may lead to errors in estimation and analysis. Given the above motivation, this study aims to explore the short- and long-run effects of natural gas and renewable energy consumption on CO_2 emissions with consideration of the structural breaks for the case of China, based on data spanning 1965 through 2016 due to data availability. Additionally, to avoid the problems of either collinearity or multicollinearity, a new framework for testing the EKC hypothesis that is based on the Narayan and Narayan method is provided.

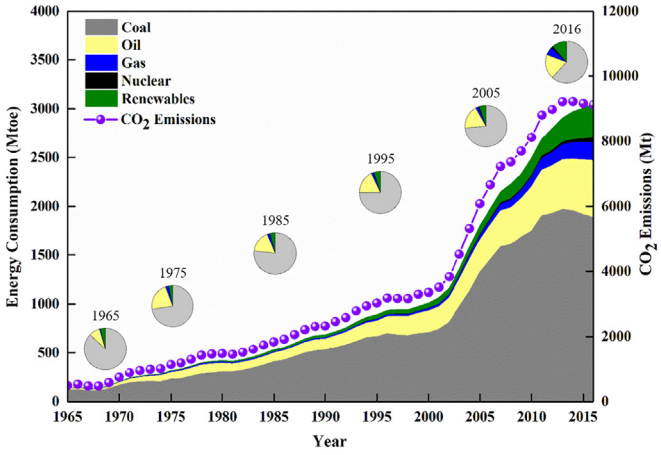

Fig. 1. China's energy mix and CO_2 emissions for1965–2016. *Data source*: BP (2017).

The contributions of this study with respect to other references mainly lie in the following aspects. First, based on the Narayan and Narayan method, this study provides a new framework to test the EKC hypothesis for CO_2 emissions in China; this could avoid the problems of either collinearity or multicollinearity, and also fill the academic gap in the existing EKC literature in China. Second, different from the traditional unit root tests and estimators that ignore the presence of structural breaks in a series, the unit root test and estimation technique in this study take into account structural breaks, doing which can provide a more robust analysis of the causal links among all the selected variables.

The remainder of this paper is organized as follows. Section 2 reviews the related literature. Section 3 describes the econometric methodology. Section 4 presents the empirical results and discusses their implications. Section 5 concludes the paper and provides policy implications.

2. Literature review

2.1. Emission, natural gas and renewables, and growth nexus studies

Along with the enormous demand for natural gas and the rapidly increasing CO_2 emission levels, the relationship among CO_2 emissions, economic growth, and natural gas consumption has been investigated in different countries and regions of the world in prior studies (see part A in Table A1), such as Alkhathlan and Javid (2013) for Saudi Arabia, Kum et al. (2012) for G7 countries (i.e., Canada, France, Germany, Italy, Japan, the United Kingdom (UK), and the United States (US)), Lotfalipour et al. (2010) for Iran, Rafiq and Salim (2009, 2011) for six Asian emerging countries, and Solarin and Shahbaz (2015) for Malaysia. On the other hand, the CO_2 emissions-economic growth-renewable energy consumption nexus has attracted the attention of a large number of researchers in different countries and areas in recent years in the previous studies (see part B in Table A1), such as Aïssa et al. (2014) for 11 African countries, Apergis and Payne (2010) for a panel of 20 Organization for Economic Co-operation and Development (OECD) countries, Bilgili (2012), Bilgili et al. (2016, 2017) for the US, Cherni and Jouini (2017) for Tunisia, Dong et al. (2017) for BRICS countries (i.e., Brazil, Russia, India, China, and South Africa), Fang (2011) for China, Ocal and Aslan (2013) for Turkey, Menegaki (2011) for 27 European countries, Shafiei and Salim (2014) for OECD countries, and Yildirim et al. (2012) for the US.

However, although China is the world's largest energy consumer and CO_2 emitter, very few studies deal with the dynamic causal relationship among CO_2 emissions, economic growth, and natural gas and renewable energy consumption for the case of China by analyzing the effectiveness of natural gas and renewable energy consumption. Also, the structural breaks in a series are usually ignored in previous studies, which may lead to errors in estimation and analysis.

2.2. Emission, growth, and the EKC nexus studies

The EKC, first stated by Kuznets (1955), has contributed to investigations of the relationship between economic development and environmental pollutants, such as the previous works of Alam et al. (2016),