Journal of Cleaner Production 162 (2017) 400–410

Contents lists available at ScienceDirect

Journal of Cleaner Production

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

Impact of natural gas consumption on CO_2 emissions: Panel data evidence from China's provinces

Kangyin Dong [a, b], Renjin Sun [a, *], Gal Hochman [b], Xiangang Zeng [b, c], Hui Li [a, d], Hongdian Jiang [a]

[a] School of Business Administration, China University of Petroleum-Beijing, Beijing 102249, China
[b] Department of Agricultural, Food and Resource Economics, Rutgers, The State University of New Jersey, NJ 08901, USA
[c] School of Environment and Natural Resources, Renmin University of China, Beijing 100872, China
[d] Energy Systems Research Center, The University of Texas at Arlington, Arlington, TX 76019, USA

ARTICLE INFO

Article history:
Received 16 January 2017
Received in revised form
25 April 2017
Accepted 11 June 2017
Available online 12 June 2017

Keywords:
CO_2 emissions
Natural gas consumption
Environmental Kuznets curve
China

ABSTRACT

This study utilizes 1995–2014 panel data of the 30 provinces in China to investigate the existence of the environmental Kuznets curve (EKC) for carbon dioxide (CO_2) emissions in China. The potential impact of natural gas consumption on CO_2 emissions is also analyzed. According to the panel fully modified ordinary least squares (FMOLS) and panel dynamic OLS (DOLS) estimation results, in the long run, an inverted U-shaped EKC link exists between per capita CO_2 emissions and per capita gross domestic product (GDP). In the panel FMOLS model and panel DOLS model, with 99,261 yuan and 59,159 yuan for per capita GDP, the EKC of China will reach its peak by around 2029 or 2019, respectively. Furthermore, natural gas consumption has a significant negative impact on CO_2 emissions, which indicates that, 1% increase in natural gas consumption for the panel FMOLS model and panel DOLS model will decrease CO_2 emissions by 0.033627% or 0.054914%, respectively. At the provincial level, provinces in which the EKC hypothesis holds are predominantly concentrated in central and eastern China, and the energy consumption structure (share of natural gas in total energy consumption) may affect the occurrence of a significant negative impact of natural gas consumption on CO_2 emissions. Another finding of this study is that both the existence of EKC and the occurrence of a positive/negative impact of natural gas consumption on CO_2 emissions are independent of the individual provincial per capita GDP.

1. Introduction

At present, most climate scientists insist that greenhouse gas (GHG) emissions, especially carbon dioxide (CO_2) emissions, play a crucial role in global warming (Wang et al., 2014, 2016). As the largest developing country, China's economy and energy consumption have entered a period of rapid and continuous expansion since implementation of the Reform and Opening-up policy in 1978 (Bai et al., 2014). According to statistics from BP (BP, 2016a) and the National Bureau of Statistics of China (NBS, 2015), energy consumption in China increased from 131 million tonnes oil equivalent (Mtoe) in 1965–3014 Mtoe in 2015, while its GDP rose from 172.0×10^8 yuan in 1965 to 67.7×10^{12} yuan in 2015, as shown in Fig. 1. Also, as the largest CO_2 emitter in the world, CO_2 emissions in China have increased rapidly in the past decades, from 475,973 kt in 1965 to 10,249,463 kt in 2013, with an average annual growth rate of 6.3% (World Bank, 2016). Currently, many scholars have claimed that rapidly increasing energy consumption and the coal-dominated energy consumption structure have posed tremendous challenges related to environmental pressures in China, such as CO_2 emissions (Kang et al., 2016; Wang et al., 2016). As a result, several national energy strategies have been implemented by the Chinese government for CO_2 emissions reduction, such as optimize the energy consumption structure (Dong et al., 2017). Recently, at the 2015 Paris Climate Change Conference, the Chinese government set a goal to peak CO_2 emissions by around 2030 and to reduce the emissions of CO_2 per unit of annual gross domestic product (GDP) by 60%–65% from the 2005 level.

China has huge reserves of natural gas resources, it has discovered 240 gas fields; remaining recoverable gas reserves are 4.6×10^{12} m^3 according to the analysis of BP in 2015, and it is expected to become the third largest natural gas producer by 2035,

* Corresponding author.
E-mail address: sunrenjin@cup.edu.cn (R. Sun).

http://dx.doi.org/10.1016/j.jclepro.2017.06.100
0959-6526/

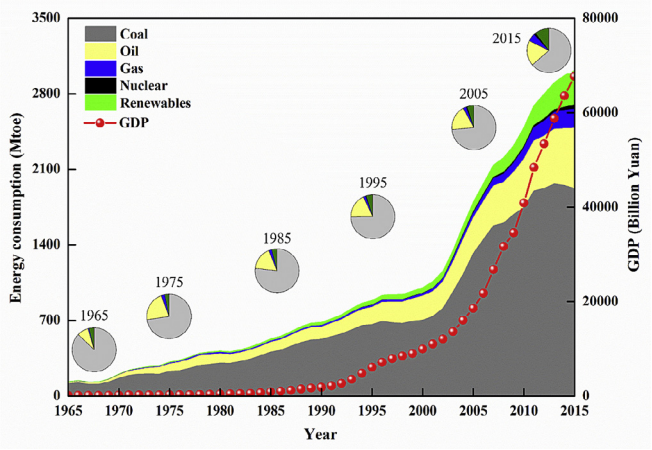

Fig. 1. Total energy consumption and GDP from 1965 to 2015 in China. Data source: BP Statistical Review of World Energy 2016, and NBS China Statistical Yearbook 2015.

according to BP's Energy Outlook 2035 (BP, 2016b). On the other hand, although natural gas combustion induces CO_2 emissions, it emits 50% less environmental pollution than other fossil fuels, such as coal and petroleum (Solarin and Shahbaz, 2015). To meet increased energy needs, modify the existing energy consumption structure, and deal with environmental problems, the Chinese government takes natural gas as an effective alternative to other fossil fuels (e.g., coal, petroleum), and has established a series of policies to promote development of the natural gas industry (Xiao et al., 2016). Natural gas consumption in China has soared since 1965, from 11.0×10^8 m^3 in 1965–1973.0×10^8 m^3 in 2015 (Fig. 1), with an average annual growth rate of 10.9%. According to statistics from BP, China will surpass Russia and become the second largest global gas consumer around 2020 (BP, 2016b). Along with managing the enormous demand for natural gas and the rapidly increasing CO_2 emissions, the questions critical to research in this field for China are as follows: Whether natural gas can be an effective alternative to other fossil fuels? How does natural gas consumption affect CO_2 emissions at the national and provincial levels? Is there an inverted U-shaped EKC link between CO_2 emissions and economic growth when considering natural gas consumption?

Although the prior studies have investigated the environmental Kuznets curve (EKC) connections among CO_2 emissions, economic growth, and energy consumption from various perspectives, to our knowledge, in this strand no studies have explored the dynamic relationship between natural gas consumption and CO_2 emissions in China. To fill in gaps left by previous researches, this study tests the validity of the EKC hypothesis and investigates the long-run relationship between CO_2 emissions and natural gas consumption at the provincial level, based on panel data of China's 30 provinces covering 1995–2014; which can shed some light on the dynamic link between natural gas consumption and CO_2 emissions in China, and would be very useful for policy makers to put forward specific policy measures to reduce CO_2 emissions.

In relation to previous research, this study has three main contributions. First, besides other common variables including economic, social and meteorological dimensions, this study specifically assumes natural gas consumption as a socioeconomic driver of CO_2 emissions to estimate its effect on CO_2 emissions in China; this could offer new evidence for developing specific policy to tackle CO_2 emissions. Second, the study employs both panel and individual estimators to investigate the casual relationship between natural gas consumption and CO_2 emissions in China. This empirical analysis of this study is particularly useful for Chinese government not only in devising national and provincial level plans for controlling CO_2 emissions, but also in promoting rapid development of the natural gas industry. Third, the linkage between CO_2 emissions and economic growth within the framework of natural gas consumption is investigated to support the EKC hypothesis, which can fill the academic gap in this field and is therefore one of the main contributions of this study.

The remainder of this paper is organized as follows. Section 2 reviews the related literature on the EKC hypothesis. Section 3 describes the methodology and sample data. Section 4 contains the empirical results, and Section 5 concludes the paper and discusses policy implications.

2. Literature review

The number of studies on the relationship between environmental pollutants and economic growth has increased rapidly since the EKC hypothesis was introduced by Kuznets in 1955. Kuznets postulated that an inverted U-shaped relationship exists between per capita environmental pollutants and income. That is, environmental quality deteriorates with economic development in the early period until reaching a certain level of income, called the inflexion point, and then improves. Since the 1990s, many studies have been conducted to examine the EKC hypothesis empirically. For example, Grossman and Krueger (1991) utilized the EKC to explore the environmental impacts of the North American Free Trade Agreement. In subsequent studies, the EKC has been widely applied as a significant tool for investigating the relationship between environmental pollutants and economic development. Since the turn of the millennium, CO_2 emissions have resulted in global warming and climate change and drawn wide attention from the international community. Consequently, many more scholars have utilized the EKC to investigate the relationship between CO_2 emissions and economic growth. However, the research into the CO_2 emissions-economic growth nexus has not reached consensus so for. Some scholars have found the traditional inverted U-shaped EKC link between CO_2 emissions and economic growth. For example, for 43 developing countries, Narayan and Narayan (2010) examined the EKC hypothesis based on the short- and long-run income elasticities and their findings supported the EKC hypothesis. Nasir and Rehman (2011) investigated the relationships among carbon emissions, income, energy consumption, and foreign trade in Pakistan for 1972–2008 and confirmed the existence of EKC for Pakistan. Saboori et al. (2012) investigated the causal relationship between economic growth and CO_2 emissions for Malaysia, covering the period 1980–2009, by utilizing the autoregressive distributed lag (ARDL) method and found an inverted U-shaped relationship between CO_2 emissions and GDP in both the short and long run, supporting the EKC hypothesis. Kanjilal and Ghosh (2013) revisited the cointegrating relationships among carbon emissions, energy use, economic activity, and trade openness for India for 1971–2008 by using threshold cointegration tests and the results supported the EKC hypothesis. Using a panel of 14 Asian countries, Apergis and Ozturk (2015) employed the general method of moments (GMM) to test the EKC hypothesis with annual data from 1990 to 2011 and found an inverted U-shaped association between emissions and per capita income, supporting the EKC hypothesis. Bilgili et al. (2016) employed a panel data set of 17 Organization for Economic Cooperation and Development (OECD) countries for 1977–2010 by launching panel fully modified ordinary least squares (FMOLS) and panel dynamic OLS (DOLS) estimations and the findings supported the EKC hypothesis for the panel.

Other scholars have not subscribed to the notion that the EKC always exists. For instance, Akbostancı et al. (2009), Musolesi et al.