Energy Policy 109 (2017) 650–658

Contents lists available at ScienceDirect

Energy Policy

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

Path analysis of factors impacting China's CO_2 emission intensity: Viewpoint on energy

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ARTICLE INFO

Keywords:
Emission intensity
Path analysis
China
Panel data

ABSTRACT

To explore the means of achieving carbon intensity targets in China, this study empirically discusses the key factors influencing the CO_2 emission intensity and the causal relationships among these factors based on a path analysis using panel data. Six factors are included in the analysis: gross domestic product (GDP) per capita (A), technology effect (TE), energy price (EP), industrial structure (IS), energy structure (ES) and foreign direct investment (FDI). The study period is divided into three stages: 1991–2002, 2003–2014 and 1991–2014. Improving T is the most significant way to decrease the emission intensity, followed by FDI. In each stage, the effects of A, EP, ES and FDI on the emission intensity mainly come from indirect contributions through TE and IS, and the effects of TE and IS arise primarily through direct contributions. Improving A promotes the development of TE in each stage and the adjustment of IS in 1991–2002 but increases the proportion of secondary industry in 2003–2014. A rising EP negatively affects TE in 2003–2014. Improving the FDI promotes the development of TE in each stage but is not conducive to the adjustment of IS in 2003–2014.

1. Introduction

Given the accelerated process of industrialization, the global energy demand is increasing, and thus, carbon dioxide-based greenhouse gas (GHG) emissions are also increasing year by year. This trend is leading to global climate change, and the ecological system is now under threat. Surrounding the issue of sharing GHG emission-reduction obligations, international negotiations have grown increasingly fierce. Being the largest developing country with a strong sense of responsibility, in recent years, China's efforts to develop its economy have been associated with a commitment to protect the global environment in a variety of ways. Before the climate change summit in Copenhagen, the Chinese government committed to decrease its carbon pollution by 40–45% relative to the 2005 level by 2020. To meet this goal, China will need to decrease its carbon intensity by 7% annually. This target plays an important role in combating climate change in China and will have a profound impact on the national economy in the next 10 years and beyond.

In the late 1970s, after the oil crisis, scholars focused on the CO_2 emission intensity. These researches mainly focused on developed countries, with relatively less attention paid to developing countries. Using the Divisia index decomposition approach, Shrestha and Timilsina (1996) analysed the evolution of CO_2 intensity in the electricity sectors of 12 selected Asian countries from 1980 to 1990 and showed that fuel intensity was mainly responsible for the changes in the CO_2 intensity of electricity generation in most countries during the study period. Nag and Parikh (2000) identified the major factors influencing carbon emissions at different levels of primary energy requirements and the final energy consumption in India using the Divisia decomposition technique by considering activity levels, structural changes, the energy intensity, fuel mix and fuel quality. They demonstrated that, beginning in the 1980s, instead of the energy intensity, the income effect became the major determinant of India's per capita emission increase, and that the coal quality also exerted a substantial influence. Sun (2000) analysed the difference in the CO_2 emission intensities of Finland and Sweden using a modified decomposition model. The main reason underlying the higher CO_2 emission intensity in Finland was its higher proportion of fossil fuels usage out of the total energy consumption. Sun (2003) described the CO_2 emission intensity as being derived from two properties, the natural property and the social property, which include decreasing the energy intensity and the development of energy and environmental policies, respectively. Bhattacharyya and Ussanarassamee (2004) identified factors affecting the industrial energy and CO_2 intensities using data from Thailand during 1981–2000 and the log-mean Divisia decomposition (LMDI) technique. The results indicated that, in four different phases,

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http://dx.doi.org/10.1016/j.enpol.2017.07.034
Received 15 February 2017; Received in revised form 8 June 2017; Accepted 15 July 2017
0301-4215/

the roles of the energy intensity, structural changes and fuel mix were important for the CO_2 emission intensity. They also considered the effects from the perspectives of sub-sectors. Ebohon and Ikeme (2005) analysed and compared the CO_2 emission intensities in oil-producing and non-producing sub-Saharan African countries in 1971–1998 using a refined Laspeyres decomposition model. Their factor analysis indicated that the changes in the CO_2 emission intensities were mostly due to the energy consumption intensity, the CO_2 emission coefficients of the utilized energy types, and the economic structure. Bhattacharyya and Matsumura (2010) identified the driving factors of GHG emissions in 15 European Union (EU) countries during 1990–2007 using the LMDI decomposition approach. Changes in the energy mix and a reduction in the energy intensity were mainly responsible for the emission reduction in the EU-15. Based on the LMDI decomposition method, González and Martínez (2012) analysed three factors—the energy intensity, CO_2 coefficient and structure—affecting the CO_2 emission intensity in Mexican industry from 1965 to 2010. They concluded that the energy intensity was the main driving factor of the decrease in CO_2 intensity; in contrast, the influence of the CO_2 coefficient was relatively weak, whereas the structural effect tended to result in an increasing trend. Pretis and Roser (2016) proposed socio-economic scenarios to distinguish countries' contributions to the global growth rates of fossil fuel CO_2 emissions. The results showed that the differences were driven by the high growth rates in Asia and Eastern Europe, particularly in Russia and China. Although the decomposition method is an important tool for exploring the determinants of the carbon intensity, its use is limited in terms of obtaining comprehensive results about each factor.

Some scholars have used methods such as the environmental Kuznets curve (EKC) and regression analysis to study the effects of the CO_2 intensity. Roberts and Grimes (1997) modified the EKC model to analyse the evolution and determinants of the CO_2 intensity across countries with different income levels. They found that the CO_2 intensity and gross domestic product (GDP) per capita have an inverted U-shaped relationship, indicating that the CO_2 intensity eventually decreases as an economy develops, even without any external reduction policies. Davidsdottir and Fisher (2011) assessed the relationship between the economic performance and carbon emission economic intensity using a panel analysis covering 48 US states from 1980 to 2000. The analysis results indicated that changes in either the aggregate energy efficiency or economic structure can, if correctly implemented, not only reduce the carbon emissions economic intensity but also enhance the economic performance. Additionally, the increased use of renewable energy does not have obvious inhibitory effects on the economic performance.

Studies on China's CO_2 emission intensity started relatively late. Before the commitment to the emission intensity reduction target, the question of how to realize energy intensity and related total emission control attracted substantial attention (Zhang, 2003; Wu et al., 2005, 2006; Wang et al., 2005). They provided base ideas for studies on the CO_2 emission intensity. Subsequently, the realization of the reduction commitment became another research topic. Using the adaptive weighting Divisia decomposition method, Fan et al. (2007) identified and quantified the key factors that led to a decline in China's primary energy-related carbon intensity during 1980–2003. The results showed that the reduction in the real energy intensity and the change in the primary energy mix were overwhelming contributors to the decline in the energy-related carbon intensity. Based on various input-output models, Chen et al. (2010) and Chen and Chen (2010) successively analysed the effect of the energy intensity and structure on the carbon emission intensity from the perspectives of both the overall economy and separate departments. Both Liu et al. (2011) and Cai et al. (2011) applied the input–output method and found that the huge consumption of high-carbon commodities in daily life is the main driving force of increased carbon emissions; therefore, implementing demand-side energy management and guiding people to take up a "low-energy consumption, low-carbon emission" lifestyle is necessary. Bai (2011) explored the relationship between the economic development and carbon intensity using both theoretical and empirical methods. The empirical results showed that the GDP per capita in China had a negative impact on the carbon intensity. Employing a regional disaggregation approach based on a series of principles, Zhou et al. (2014) demonstrated that energy structure (ES) adjustments, technical improvements and energy substitution are the three main approaches to reducing the carbon intensity.

In recent years, regression analysis has been widely used to study the factors affecting China's CO_2 emission intensity. Fang and Deng (2011) established an impact model to identify the key influencing factors of the carbon intensity from the regional perspective. Their article reported that increases in the primary energy consumption and coal share lead to an increase in the carbon intensity, and an increase in the productivity efficiency induces a decline in the carbon intensity. Using the environmental impact by regression on population, affluence and technology (IPAT) model combined with scenario analysis, Yue et al. (2013) analysed the optimal CO_2 reduction path for Jiangsu province. The results showed that the reduction target can be achieved by reducing the energy intensity and increasing the renewable energy share. Based on five types of panel data for 31 provinces, Tsai (2014) investigated the influencing factors of the carbon emission intensity. That study revealed that the energy intensity, economic growth, proportion of secondary industry, and fiscal expenditures are the main factors influencing the carbon intensity in various regions. Long et al. (2015) employed the modified IPAT model and performed a scenario analysis of the economic development, population size, energy intensity, and energy consumption structure to examine the carbon intensity in three regions of Jiangsu province from 2015 to 2020. The results showed that the key factors for carbon intensity reduction are the energy intensity and energy consumption structure. Though regression analysis, Wang et al. (2016) empirically studied the key factors influencing the carbon intensity in both China and eight economic regional levels. The results demonstrated that declines in the proportion of secondary industries decreased the carbon intensity.

In addition to the energy intensity, technological progress and ES, various other parameters have also been studied to explore the carbon intensity and its dependence on the energy price (EP) (Birol and Keppler, 2000; Stern, 2002; Fisher-Vanden et al., 2004). Through an in-depth simulation using path analysis, Ju et al. (2017) analysed the effect of the EP on China's economy and environment. They observed that energy price distortions benefit China's economic development but negatively affect the environment. Currently, the EP system in China is gradually shifting from a government pricing mechanism to a market price system. However, in the current EP system, which remains under government regulation, the overall EP level is low, even lower than the international level. An in-depth analysis of the effects of the EP on the carbon dioxide emission intensity and transmission mechanisms has important practical significance for the development of reasonable EP policies, promotion of technological upgrades and ES adjustments, steady healthy development of the economy, and effective reduction of CO_2 emissions.

As China becomes more deeply involved in the World Trade Organization (WTO), the impact of foreign direct investment (FDI) on the CO_2 emission intensity has attracted widespread scholarly attention. There are two distinct opinions on this topic. The results of Hübler (2009) and Chen et al. (2011) indicate that the continuous development of FDI had a significant positive effect on China's CO_2 emission intensity, enabling significant reductions, whereas Sha and Shi (2006) and Hu and Zhao (2010) argued that FDI exerted a negative or relatively weak impact on China's environment, suggesting that its development could not reduce the emission intensity.

Regression analysis is an important and widely used method to analyse the effects of various factors on China's CO_2 emission intensity. The level of economic development, energy intensity (technology effect