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The differences of carbon intensity reduction rate across 89 countries in recent three decades

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HIGHLIGHTS

- There is a significant CO_2 intensity convergence across the world.
- High GDP growth may accelerate CO_2 intensity decline, yet total emissions will grow dramatically.
- GDP per capita are negatively related to CO_2 intensity decline.
- The potential for carbon intensity reduction is becoming less with the economic development.
- The conclusions are robust to the possible impact factors such as initial year, and country grouping.

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ABSTRACT

In the recent decades, most countries' CO_2 intensity has decreased, but their decline rates are significantly different. Based on the data set of 89 countries from 1980 to 2008, this paper tries to quantitatively investigate the potential reasons for their differences, and discusses the possibility for developing countries to maintain a high carbon intensity reduction rate in the future as before. The econometric analysis implicate that (1) the decline rate of CO_2 intensity in countries with high initial carbon intensity will be higher, which means CO_2 intensity across the world has a significant convergence trend; and (2) keeping fast and steady economic growth can significantly help CO_2 intensity decline, yet total carbon dioxide emissions will grow dramatically. Therefore, with the two objectives of intensity reduction and total amount control, carbon abatement policies need to weigh one against another. The results are robust to the initial year selection and country classification.

1. Introduction

International communities are paying a lot of attention into climate change issues recently, alarmed by increasingly hot temperatures and rising sea levels. According to the IPCC Fourth Assessment Report [1], the average global temperature from 1995 to 2006 was the warmest since 1850, and the global average surface temperature has rose by 0.74 °C in a hundred years from 1906 to 2005. In particular, Asia's average surface temperature has even increased by more than 1 °C in the same period.

Global warming may pose threats to humankind, but due to a relatively weak economic foundation and the lagged technology compared to the developed countries, developing countries' ability to cope with climate change and disasters is relatively weak. For example, According to Stern Review on the Economics of Climate Change [2], if the average temperature increases by 2 °C, Africa's agricultural production will fall by 5–10%, at least 4–6 million people will suffer from malaria.

Considering the severe situation faced by developing countries and its appeal to CO_2 reduction, this paper quantitatively analyzes various factors influencing each country and region's CO_2 intensity change in recent 30 years. Analyzing each country's basic status quo and characteristics of CO_2 emissions, as well as the difference of carbon intensity change from the perspective of international comparison is valuable for further analysis of developing country's carbon emission trajectory and carbon reduction strategy in future.

Literature that addresses factors influencing CO_2 emissions can be roughly classified into three categories according to their perspectives or methods.

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The first category uses input–output method to analyze the sources or structures of carbon emissions from the perspective of industrial structure or demand structure, and calculates direct and indirect emissions based on the relations of different industrial sectors. Gay and Proops [3] studied the balance between different sources of power generation (fossil fuels and other sources) to reduce CO_2 emissions by a composition change of goods and services in final demand. Lin and Sun [4], Guo et al. [5] studied the influence of import and export scale and structure on China's carbon emissions. Zhang [6] analyzed the impact of economic development mode transformation on China's carbon intensity, and the results showed that, from 1987 to 2007, economic development mode had caused China's carbon emission intensity to decline by 66.02%. The advantage of input–output analysis is the detailed analysis of all departments with full consideration of the correlations of industries. However, there are drawbacks to this method as well. As the data of the input–output table is updated within a certain period (e.g. that of China is updated every 5 years), it is difficult to reflect the long-term historical evolution trend of carbon dioxide emissions. Moreover, different countries' input–output tables are based on different compilation methods and calibrations, which make it hard for the data to be applied to a cross-country analysis of carbon emission differences.

The second category employs index decomposition analysis from the angle of carbon emission accounting process to work out the impacts of changes of industrial structure and carbon intensity of different departments on carbon emissions. In recent years, a large number of studies on this category, such as Feng et al. [7], Zhang [8,9], Zha et al. [10], have been published. Index decomposition method decomposes CO_2 emissions into GDP per capita, energy intensity, energy consumption structure, population and other factors, and analyzes the relative importance and changing trend of each factor based on the decomposition. In applications, index decomposition methods are varied according to different decomposition formula and index, yet the results are similar. Nearly all studies have found that energy intensity and economic scale change are the primary driving factors of CO_2 emissions, while the influence of economic structure and energy consumption is less important. Akbostancı et al. [11] used Divisia Index method, and decomposed the changes of CO_2 emissions in manufacturing industry into five parts, and found that changes of the whole industrial activity and energy intensity were the main factors determining the changes in CO_2 emissions during 1995–2001 in Turkey's manufacturing industry. Index decomposition method is simple and clear, and the identities can be changed to a certain extent according to specific problem being examined. However, this method has some limitations, since it often takes endogenous factors into account, and many other factors are hard to be incorporated into the study, for example, the probable non-linear relation between the level of economic development and CO_2 emissions, the impact of technological advances and the influence of ownership etc. On the basis of index decomposition results, energy conservation and emission reduction policies may lead to implications of adopting administrative interference means and central-planning thinking, such as energetically adjusting industrial structure, reducing the proportion of carbon intensive industries, restricting or closing "high pollution" and "high energy consuming" enterprises.

The third category is the employment of larger sample or a longer historical period for econometric analysis. Glen and Hertwich's [12] study found that, 72% of Norway's CO_2 emissions were caused by its export. Ang [13] inspected China's influence factors based on macroeconomic time series data and found that CO_2 emissions were negatively correlated with R&D strength, technology transfer and absorption capacity, and positively related with income level, the amount of energy used and openness of trade. Chang [14] employed multivariate co-integration Granger causality test to study the relationship between energy consumption, CO_2 emissions and economic growth. It was found that blind pursuit of economic growth would increase energy consumption and CO_2 emissions, which would have bad effects on climate change. Hatzigeorgiou et al. [15], using cointegration tests and Granger-causality test based on a multivariate VEC Model, resulted that the decoupling of CO_2 emissions and economic growth seemed quite separate in Greece from 1977 to 2007.

The econometric analysis can not only overcome the input–output analysis limitations of data lag and different compilation methods, but also avoid administrative intervention conclusions drawn by index decomposition method to a great extent. In addition, the cross-sectional data analysis can avoid, to some extent, the sequence of non-stationary and spurious regression problem brought by time series analysis, and the conclusion of cross-sectional analysis is robust as well. Thus, in this paper, cross-sectional data econometric analysis is applied. In order to ensure the reliability of the results of cross-sectional analysis, the variable data is the average numbers of nearly three decades instead of 1 year, which is able to ensure that the conclusions are representative.

Most of the present studies focus on the analysis of CO_2 intensity or CO_2 emissions per capita, while in current policy practices, we pay more attention to the direction and speed of carbon intensity change. In addition, most of the current researches are based on a specific nation's carbon emissions with a lack of internationally comparative analysis. This paper employs the CO_2 emission data of 89 countries from 1980 to 2008, in a hope to seek out the influence factors of CO_2 emission intensity change differences of different countries.

2. Methodology and data sources

2.1. Methodology and variable selection

Affected by the economic development level, energy consumption structure and other factors, the changes of each country's CO_2 emission intensity are significantly differing. However, due to technological progress and economic structure adjustment, CO_2 emissions per unit of GDP in most countries and regions declined to some distinct extent. From 1980 to 2008, a general decline in CO_2 emissions per unit of GDP occurred in the developed countries, CO_2 intensity was decreased by 57.32% in the United Kingdom, and 28.63% in Italy. In contrast, the situation in developing countries is a little complicated. China had a sharp decline by 67.44% in CO_2 intensity. The data in South Africa and India decreased only a little, while Brazil increased by 5.45%. Main countries are shown in Fig. 1.

The dependent variable in our study is the annual decline rate of CO_2 emissions per unit of GDP (E) from 1980 to 2008. The independent variables are as follows:

(1) CO_2 emissions per unit of GDP (m_0) in the initial year (1980). For a certain country, the higher initial carbon emissions per unit of GDP, the larger reduction potential there is. Therefore, the coefficient of m_0 is expected to be positive.
(2) Energy consumption structure change (s). Coefficients of carbon emissions from different kinds of energy are not the same; the amount of CO_2 emissions from coal combustion is 1.6 times as that of natural gas, and 1.2 times as that of oil. The nuclear power, hydropower, wind power, and solar energy are clean energies, and do not directly emit CO_2. The impact of energy consumption structure change on carbon intensity change is significant, which has been found by Zhang [16]. In this paper, we use the average annual change of fossil energy's proportion in total energy