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Decomposing the influencing factors of industrial carbon emissions in China using the logarithmic mean divisia index method

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ABSTRACT

Decomposition analysis has been popular in the study on influencing factors of industrial carbon emissions(ICE). This paper analyzes the change of sectoral CO_2 emissions from the three main industries in China over the period 1980-2009 based on the logarithmic mean divisia index (LMDI) method. The research shows that economic activity effect is the main influence factor for ICE increase in China over the entire period, The decline in energy intensity and the adjustment of energy and change in the CO_2 emission coefficient are major determinants for reduction of ICE, with the former alone accounting for 85% of the reduction. However, the change of industrial structure exhibit positive effect to the CO_2 increase. The results indicate that China has made a significant contribution to reducing global CO_2 emissions by decreasing its energy intensity. Moreover, according to the situation of China, this paper analyzed the mechanism of CO_2 emission changes and puts forward the pressure-driven environment protection model.

KEYWORDS

CO_2 emissions;
LMDI;
Structural effect;
Efficiency effect.

INTRODUCTION

The increasing threat of global warming and climate change has been the major, world-wide, on-going concern in the last two decades. Amongst several environmental pollutants causing climate change, carbon dioxide (CO_2) is held responsible for 58.8% of the GHG, in a report of the World Bank (2007a). China is the world's second-largest source of CO_2 emissions behind the United States, it is necessary for China's energy and environmental policy makers to know fully changes and the driving forces governing CO_2 emission levels and their evolution.

The purpose of this study is to decompose the factors that give rise to CO_2 emissions. Chinese economy is divided into three aggregated sectors, namely agriculture, industry and services, and energy sources used by these sectors are aggregated into four groups: solid fuels, petroleum, natural gas and electricity. From related studies we can deduce that the output effect is the most important factor that affects CO_2 emission reductions. This paper will continue to provide a deeper understanding of the driving forces behind the evolution of energy-related CO_2 emissions between 1980 and 2009. A newly proposed factor decomposition method is used to quantify the relative contributions of selected driving forces to the variations in CO_2 emissions, thereby providing the relevant authorities with more advanced and concrete reference material in regard to policies to reduce CO_2 emissions.

LITERATURE REVIEW

With the advantages of sound theoretical foundation, high degree of adaptability, ease of use, and ease of understanding and result presentation[1], the application of decomposition analysis has increased since the late 1970s, and has been especially widely applied for investigating mechanisms influencing energy consumption and its environmental side effects. Sun[2] used a complete decomposition model to analysis energy consumption and CO_2 emissions of the OECD from 1960 to 1995. Subhes[3] analyzed the changes in industrial energy intensities and CO_2 intensities from use of energy in Thailand during 1981-2000, and then identified the factors affecting the two intensities using the LMDI technique. Lee and Oh[4] decomposed the changes of CO_2 emissions in APEC countries based on the LMDI approach, and found that the growth in per capita GDP and population are the two dominant contributors to the increase in CO_2 emissions. Wietze[5] analyzed the changes of CO_2 emissions by undertaking a complete decomposition analysis for Turkey over the period 1980-2003, and concluded that the biggest contributor to the rise in CO_2 emissions is the expansion of the economy. Diakoulaki and Mandaraka[6] explained the changes in industrial CO_2 emissions in 14EU countries for the period 1990-2003 based on the refined Laspeyres model. Using the LMDI approach, Subhes[7] analysed the reduction in greenhouse gas emissions in 15 countries of the European Union between 1990 and 2007 to find out the contribution of different countries.

Recently some effort has been paid to the factors for energy-saving and environment quality in China. Wang et al.[8] analyzed the change of aggregated CO_2 emissions in China based on the LMDI method and concluded that the total theoretical decrease of CO_2 emissions was 2466 Mt during 1957-2000. Wu et al.[9] investigated the evolution of energy-related CO_2 emissions from 1985-1999 in China and underlying driving forces based on time-series decomposition of the LMDI approach. Wu et al.[10] used the LMDI method to study CO_2 emissions from 1980 to 2002, and concluded that economic scale, fuel mix and energy intensity on the energy-demand side mainly drove the changes in China's CO_2 emissions, and the structure and efficiency changes on the energy-supply side played only a minor role before 1996. More, over the period 1996-2000, the acceleration of efficiency improvement in end-use and transformation sectors accounts for the decline in China's CO_2 emissions that were related to the total primary energy supply. Liu et al.[11] analyzed the change of industrial carbon emissions from 36 industrial sectors based on the LMDI approach, and concluded that the industrial activity and energy intensity were the overwhelming contributors to the change of China's industrial sectors' carbon emissions in the period 1998-2005. Fan et al.[12] employed the input-output approach to compute energy requirement and CO_2 emissions under each scenario in China, and showed that China's energy needs and related CO_2 emissions will grow exponentially even with many energy efficiency improvements. Guan et al.[13] assessed the driving forces of China's CO_2 emissions from 1980 to 2030 by combining structural decomposition and input-output analysis, and concluded that production-related CO_2 emissions will increase three times by 2030. Household consumption, capital investment and growth in exports will largely drive the increase in CO_2 emissions, relying on efficiency improvements alone will not stabilize China's future emissions. Zhang et al.[14] used the complete decomposition method to analyze the nature of the factors that influence the changes in energy-related CO_2 emissions and CO_2 emission intensity during the period 1991-2006, and find that energy intensity effect is confirmed as the dominant contributor to the decline in CO_2 emissions and CO_2 emission intensity. Zhang et al.[15] used the complete decomposition technique to identify the factors influencing the sectoral changes in CO_2 emissions in China for the period 1991-2006, and concluded that economic activity has the largest positive effect in CO_2 emission changes in all major economic sectors and China has achieved a considerable decrease in CO_2 emissions mainly due to the improved energy intensity.He et al.[16] identified the main features of CO_2 emissions from fossil energy combustion in China. Li et al.[17] appraised low carbon energy potential in China and identified low carbon energy development strategies.

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However, with respect to the total CO_2 emissions in China, those studies do not take the importance of sectoral dimension into account. This paper attempts to identify the factors influencing the change of industrial CO_2 emissions from the three main industries based on the LMDI method, determines the contribution of the factors which influence energy-related CO_2, and then analysis the mechanism of CO_2 emissions in China. To better investigate changing trends of the factor' relative contribution with time, the time period of statistical data from 1980 to 2009 used in this paper is divided into three equal time intervals (sub-periods), namely 1980-1992, 1992-2000, and 2000-2009. The variations are attributed to the factors of overall activity(activity effect), activity mix(structure effect), sectoral energy intensity(intensity effect), sectoral energy mix(energy-mix effect) and CO_2 emission factor(emission-factor effect).

METHODS

The following method is given by IPCC[18], total CO_2 emissions in the *i*th sector is estimated based energy consumption, carbon emission factors and the fraction of oxidized carbon by fuel as follows.

$$C_i^t = \sum_j C_{ij}^t = \sum_j E_{ij}^t \times EF_j \times (1 - CS_j^t) \times O_j \times M \qquad (1)$$

Where C_i^t is the total CO_2 emissions of the *i*th sector in year *t*, C_{ij}^t is the total CO_2 emissions of the *i*th sector based on fuel type *j* in year *t*, E_{ij}^t is the total energy consumption of the *i*th sector based on fuel type *j* in year *t*, EF_j is the carbon emissions factor of the *j*th fuel (*t*C/TJ), CS_j^t is the fraction of the *j*th fuel is not oxidized as raw materials in year *t*, O_j is the fraction of carbon oxidized based on fuel type *j*, *M* is the molecular weight ratio of carbon dioxide to carbon(44/12). In this study, the emission factors EF_j are assumed to be 25.8, 21.1 and 15.3 *t*C/TJ of energy used for coal, oil and natural gas, respectively, and the fractions of carbon oxidized O_j are taken as 0.90, 0.98 and 0.99 for coal, oil and natural gas, respectively, based on the IPCC.

Ang and Liu[19], and Ang[20] argued that the logarithmic mean Divisia index (LMDI) method should be preferred to other decomposition methods with the advantages of path independency, ability to handle zero values and consistency in aggregation. Therefore, we have adopted this method to analysis CO_2 emissions.

Changes in CO_2 emissions of the economy can be decomposed into changes in overall economic activity, activity mix, sectoral energy intensity, sectoral energy mix and CO_2 emission factor.

RESULTS

According to the economic development of China, The calculated results are tentatively presented over three periods, from 1980 to 1992, from 1993 to 2000 and from 2001 to 2009.

In this section, we apply the proposed models to explore the contributions of the various effects to the changes in China's energy consumption. Table1 shows the decomposition results. It indicates that during 1980-2009, China experienced spectacular economic growth, the increase of CO_2 emissions caused by economic activities was 9908.19 Mtons, accounts for +194.52% of CO_2 emission changes over the entire period of 1980-2009.

The central government's development policy and investment priorities were biased towards rapid industrialization before 2000, which increased not only the energy consumption of the whole economy, but also CO_2 emissions, during the sub-period of 1980-1992 and 1992-2000, the structural shifts increased CO_2 emissions 118.33 and 116.48 Mtons, accounts for 15.37% and 14.35% of CO_2 emission changes, respectively.

The energy intensity effect plays an important role in mitigation of CO_2 emissions. Our results also show that technological change plays the dominant role in decreasing CO_2 emissions, which is consistent with the conclusions of previous empirical studies. The improvement of energy efficiency decreased CO_2 emissions by 4351.85 Mtons, accounts for 85.43% of CO_2 emission decrease over the entire of 1980-2009. Due to improvements in energy efficiency, the accumulative theoretical decrease of CO_2 emissions during the sub-period of 1980-1992,1992-2000and 2000-2009 amounted to 1043.85 Mtons, 1063.17 Mtons and 1195.02 Mtons, respectively, and the theoretical decrease rate was 26.36%, 23.09% and 10.36%, respectively. This can be attributed to the encourage of efficient energy policies towards sustainability.

As a result of energy mix adjustment in industry and mostly contributed by clean electricity, the consumption share of electricity increased while in the same timeframe the electricity was mainly generated from coal-burning thermal power, which has a higher carbon emission coefficient value than any other type of fossil fuel. So the decrease of carbon emissions resulting from energy mix and the CO_2 emission coefficient is 397.49 Mtons and 268.55 Mtons during 1980-2009, respectively.

DISCUSSION

Based on the above research results, We will deeply analysis the mechanism of environment according to the situation of China. Environment quality's scale indexes are the decrease amount of CO_2, SO_2, solid offal and etc. In the mid industrialization in China, many corporations are indifferent to the idea of environment protection. The driver of environment protection comes from stress of the central and district governments, including compulsory policy and incentive policy. The compulsory policy provides impetus by administration and Law means to regulate the contamination standard. The incentive policy encourages environment protection by economic means such as collecting environment tax and contamination emission fee. In addition, publicizing environment-protecting knowledge promotes social willingness for environment protection as well.

TABLE 1 : Decomposition of the changes in CO_2 emissions in China (Milliontons)

Index	Decomposition of changes in CO_2 emissions					Real change	Theoretical decreaseΔC*	Rate of theoretical decrease (%)
	ΔC_{emf}	ΔC_{int}	ΔC_{str}	ΔC_{mix}	ΔC_{act}			
1980-1992	-136.05	-914.94	118.33	-111.19	1814.08	770.22.	-1043.85	26.36
	-17.66	-118.79	15.37	-14.44	235.53	100	-135.53%	
1992-2000	65.09	-1149.82	116.48	-94.91	1874.74	811.57	-1063.17	23.09
	8.02	-141.68	14.35	-11.69	231.01	100	-131.01%	
2000-2009	165.96	-1054.56	-155.43	-150.99	4605.37	3410.34	-1195.02	10.36
	4.86	-30.92	-4.56	-4.43	135.04	100	-35.04%	
1980-2009	-268.55	-4351.85	203.45	-397.49	9908.19	5093.74	-4814.45	29.77
	-5.27	-85.43	3.99	-7.80	194.52	100	-94.51%	

The central government establishes environment protection policy based on the environment improvement. Meanwhile, the industry and energy structure reaches optimization by its internal industry domino effect, region domino effect and energy domino effect, and finally improves environment quality and forms a benign closed loop system (see Figure 1).

Since the emissions mainly result from consumption of fossil fuels, reducing energy consumption seems to be the direct way of handling the problem. However, due to its negative impacts on economic development, reducing energy consumption may not be viable for China. In the future, the Chinese government should actively absorb successful international experiences and draw out feasible and operable policies and measures to encourage energy conservation and environment protection.

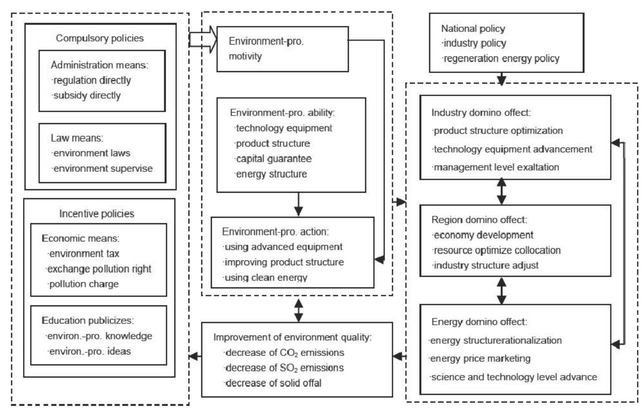

Figure 1 : The mechanism of pressure-driven environment protection model in China

Firstly, the mode of economic development can affect environment quality. The second sector appears to have the highest share of responsibility on the continuous rise of CO_2 emissions, the CO_2 emissions mainly come from the industrial sector and coal consumption, in the period of 1980-2009, the industrial CO_2 emission accounts for about 66.31-85.93% of total CO_2 emissions. If China's economic growth keeps relying on these resource and energy dependent industries, the future of China's economic growth is doomed. Hence China should jump through the mesh of heavy industrialization to a more efficiency-oriented and less resource-depleted development mode, so that more energy can be saved and a better environment can be reserved for the next generation.

Secondly, energy conservation is so far the most important mean to reduce CO_2 emissions, the composition of energy consumption in China is unbalanced in comparison with other countries. China's heavy reliance on coal will make it the largest emitter of CO_2 in the world. Furthermore, China's energy mix has not changed significantly. In the early 1980s, coal accounts for 71% of total energy consumption. It dropped to its lowest point of 66% in 2002, but by 2009, it had climbed back to 70%[21]. This situation has imposed a high cost on the economy in terms of environmental damage associated with excessive use of coal. The environmental impact associated with energy use attracted wide concern as a result of the new evidence leading to a heating debate regarding global climate changes[24]. Because other options like fuel switching and renewable resources have much less potential in the short and medium term. China is a country short of clean energy (such as oil, natural gas and hydro power and others), and nearly half of domestic oil consumption depends on import currently. Therefore, one effective long-term policy is to diversify energy supply with preference on renewable energy (hydro, biomass, wind, geothermal, solar, and tidal). In 2005, China firstly enacted the Renewable Energy Act to provide the legal base for the development of renewable energy and formulate its principle of R&D, industrialization, popularization & application and economic incentive for renewable energy exploitation and utilization. In 2007, the Medium and Long Term Development Plan for Renewable Energy stipulated a concrete goal that the ratio of renewable energy in total energy consumption should be no less than 10% in 2010 and 15% in 2020, while the renewable should account for no less than 30% of total power generation capacity in 2020. Additionally, there is potential for changes through additional production of nuclear energy and alternate energy sources in China and/or through policies to improve energy efficiency in the Chinese economy.

Thirdly, the central government should place tight limitations on the export of high energy-intensive products and the investment in the energy-intensive products. As a major exporter of energy-intensive products, China consumed much energy while emitted much GHG, such as CO_2. Increases in the ratio of exports to domestic demand of secondary energy exert an increasing impact on CO_2 emissions related to primary energy input for exports[10]. However, given China's high use of coal in electricity production and inefficient production systems relative to those nations exporting goods to China, this assumption largely overestimates the actual embodied CO_2 in China's imports.

Fourthly, Technological innovations and improvements are one of the most effective ways of reducing CO_2 emissions. As the leading emitter of CO_2, China will come under increasing pressure to assume more responsibility for its emissions. Some Chinese businesses are already willing to take actions. Increases in energy efficiency will also lead to changes in other emissions. Government-supported R&D, technical assistance, training, and information exchange continued to play an important role in China's energy efficiency improvement in 1990s. Introducing the CO_2 tax is an effective way to decrease emissions. Whenever feasible, energy conservation and reduction of output share of energy-intensive sectors are important strategies for reducing energy intensity.

Lastly, it is urgent to set up and complete an effective environment-protection management system, increase investment of environment-protection, and enact the environment-protection laws. In addition, promoting regulation measures and enhancing supervision of pollution emission can also guarantee the realization of environment-protection goals. At the same time, it is important to emphasize the critical role played by local governments in environment-protection. The central government has forbidden some low efficiency production, including shutting down inefficient generators in the electricity sector and terminating inefficient mining operations. In the future, the Chinese government must implement more economic incentive policies to enhance energy efficiency.

China plans to rehabilitate old plants with large and relatively efficient units. These initiatives could be expected to play a role in continued reductions in China's carbon intensity, thus reducing fuel consumption and improving the environment. With the growth of average labor productivity, which has a dominant positive effect on CO_2 emissions, is expected to recover in the near future due to reforms in the industrial sector[30].

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