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Article

Decomposition Analysis of Energy-Related Industrial CO_2 Emissions in China

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Abstract: Based on the logarithmic mean Divisia index (LMDI) approach, this paper presents a decomposition analysis of China's energy-related industrial CO_2 emissions from 1985 to 2007, as well as a comparative analysis of differential influences of various factors on six sectors. Via the decomposition, five categories of influencing factors are included: (1) *Per capita* GDP (*PCG*) was the largest positive driving factor for industrial CO_2 emissions growth for all sectors in China, with the largest cumulative contribution value; Population (*P*), economic structure (*YS*) and energy structure (*ES*) also played a positive driving role, but with weak contributions. As the only negative inhibiting factor, energy intensity (*EI*) significantly reduced the energy-related CO_2 emissions from industrial sectors. Meanwhile, CO_2 emissions reduction based on the efficiency of energy use still held a large space. (2) Various influencing factors imposed differential impacts on CO_2 emissions of six sectors.

Keywords: decomposition analysis; energy-related industrial CO_2 emissions; industrial discrepancy

1. Introduction

Intensive use of fossil fuels can be cited among the main reasons of the significant increase in anthropogenic greenhouse gases (GHG) that lead to climate change. The long term reduction of greenhouse gases (GHG's) and low-carbon development has long been identified by the Intergovernmental Panel on Climate Change (IPCC) as an appropriate response to climate change. At the end of 2009, the Chinese government put forward the intensity target that CO_2 emissions per GDP should be reduced by 40%–50% in 2020, which has been included in the long-term program for national economy and social development. In the 12th Five-Year Plan Outline, China planned to boost the value-added proportion of the GDP accounted for by the service sector by 4%, and to reduce energy consumption by 16% and carbon emissions by 17% per unit of GDP in 2015 [1]. However, controlling and mitigating energy-related carbon emissions require careful analysis of the factors that influence these emissions so that appropriate remedies can be developed.

Decomposition analysis is one of the most effective tools for investigating the mechanisms influencing energy consumption and its environmental side effects. In recent decades, index decomposition analysis (IDA) has been widely accepted as a decomposition methodologies based on the Laspeyres and the Divisia indices that are well known in the fields of economics and statistics [2]. One basic drawback of the conventional Laspeyres and Divisia index methods was the large residual term found in most applications, leaving a significant part of the examined changes unexplained [3]. However, this problem has been effectively solved through the improved variants [4,5].

The logarithmic mean Divisia index (LMDI) method has been identified as the preferred approach in energy use and CO_2 emission analyses under the umbrella of IDA [2,6,7], because of its robust theoretical foundations, strong adaptability to a range of situations, and ability to provide perfect decomposition; that is, no unexplained residual terms [8]. LMDI was first used in 1998 to study the factor decomposition for the CO_2 emissions of energy consumption from China's industrial sectors [9]. It has since broadened its scope to include analysis of energy supply and demand, energy-related emissions, material flow and dematerialization, monitoring of national energy efficiency trends and making cross-country comparisons of energy performance [10,11].

Recently, energy-related carbon emissions have been studied by adopting LMDI approach in different scale levels. At the global level, the driving forces for the changes of energy consumption and carbon emissions are decomposed in multiple scales [12–14]. On top of this, the secondary decomposition is further conducted for intensity factors of CO_2 emissions from sectors like manufacturing and transportation [15,16]. These studies generally considered different kinds of energy (such as coal, oil, natural gas, and electricity) and sectors (such as primary industry, secondary industry, and tertiary industry). Case studies at the national level include the research of main factors driving changes in CO_2 emissions of different time intervals in different countries, such as South Korea [17,18], Thailand [19], India [20], Brazil [21,22], Turkey [23], The United Kingdom [24], and Greece [25]. Studies on the cyclical fluctuation and driving forces of energy-related CO_2 emissions are also applied to China [26–35]. These studies considered a relatively small number (four or fewer) of types of energy, thereby decreasing the accuracy of the accounting. In addition, more detailed information about each sector's carbon emissions and the proportion of total emissions accounted for by each sector that could guide management planning was often not provided [33]; at an urban level, most of the literature focuses on a province/city [36–39], discussing the mechanism of main factors affecting regional CO_2 emissions, and coming up with alternative policies [40–42].

As can be seen, the index decomposition technique has good performances on identifying the magnitude of some predetermined driving factors of changes in observed indicators. It has been not only conducted at different scale levels, but also for studies on energy consumption and energy-related CO_2 emissions in a specific industry or sector. These studies estimated and evaluated observed indicators to examine the factors, structural, and technological changes at industry level [10,43–47]. Many scholars also suggested the use of IDA to specifically focus on China's industry and give a disaggregated sectoral decomposition often dealing with three or four sectors [34,48–51].

Since the industrial sector is a major consumer of energy in China, the total industrial CO_2 emissions absolutely represents a dominant share. Investigating the intrinsic driving factors of China's industrial CO_2 emissions growth in time series is necessary to understand the trends in energy use, to forecast future energy demand and carbon emissions and to measure the effectiveness of energy-related policies. This paper hereby offers a year-by-year decomposition analysis of the cumulative effects of influencing factors for China's energy-related industrial CO_2 emissions from 1985 to 2007 and compares differential influences of all factors on the cumulative effects of six sectors.

2. Data Set and Estimation

The time interval of data sample ranged from 1985 to 2007. The GDP for each sector were obtained from the China Statistical Yearbook [52–74], and the economic output and income data are adjusted according to the constant price of 1985, which serves as the reference period. According to the industrial structure specified in *China Statistical Yearbook*, we divided the national economy into six sectors: agriculture (farming, forestry, animal husbandry, fisheries, and water conservation), industry, construction, transport, storage, and postal services, urban and rural households and business (wholesale, retail, trade, hotel, and restaurants; and other tertiary sectors). According to the classification of industrial internal sectors in China Energy Statistical Yearbook, there are three major sectors, including mining, manufacturing and electric power, gas and water production and supply.

Energy consumption data were obtained from the China Energy Statistical Yearbook [75–84], including eight types of fossil fuels: coal (raw coal, cleaned coal, other washed coal, briquettes), crude oil, gasoline, kerosene, diesel oil, fuel oil, coke, and natural gas. Using the reference method provided in "*2006 IPCC Guidelines for National Greenhouse Gas Inventories*" [85], we have also estimated the amounts of CO_2 emission in China over the years based on the fossil fuel classification and sector classification. The carbon emissions coefficients for estimation of different energy resources are given in Table 1.

Table 1. The carbon emission coefficients of different energy resources. tce = ton of standard coal equivalent.

Energy Type	IPCC coefficients (kgC/GJ)	Adopted coefficients (tC/tce)
Coal	25.8	0.7552
Coke	29.2	0.8547
Crude Oil	20.0	0.5854
Gasoline	18.9	0.5913
Kerosene	19.6	0.5737
Diesel Oil	20.2	0.5913
Fuel Oil	21.1	0.6176
Natural Gas	15.3	0.4479

According to the estimation results, the energy-related industrial CO_2 emissions increased gradually with the rapid industrialization process and underwent different stages (Figure 1) from "steadily rising" of 1985–1996 to "stable with a decline" of 1997–2001, and then to "rapid growth" of 2002–2007. The fluctuation intensity significantly increased after 1996. In addition, the substantial differences of energy-related CO_2 emissions existed among different sectors in China. From 1985 to 2007, the total energy-related industrial CO_2 emissions absolutely represented a dominant share and always accounted for around 80%. Thus, it was the largest carbon emitter in China. The total CO_2 emissions of other sectors only accounted for around 20% of the total emission and gradually decreased.

As can be seen from the variables of CO_2 emissions in three major industrial internal sectors (Figure 2), from 1985 to 2007, manufacturing was the largest carbon emitter in China, accounting on average for 60% of total industrial CO_2 emissions, and dropping gradually from 1996; the next was electric power, gas and water production and supply, which accounted for 30% and maintained stable growth; mining was involved in the minimum CO_2 emissions, which accounted for 10%. In spite of the relatively low CO_2 emissions, the relative proportion still decreased slowly.

Figure 1. The total amount of energy-related CO_2 emissions in six different sectors.

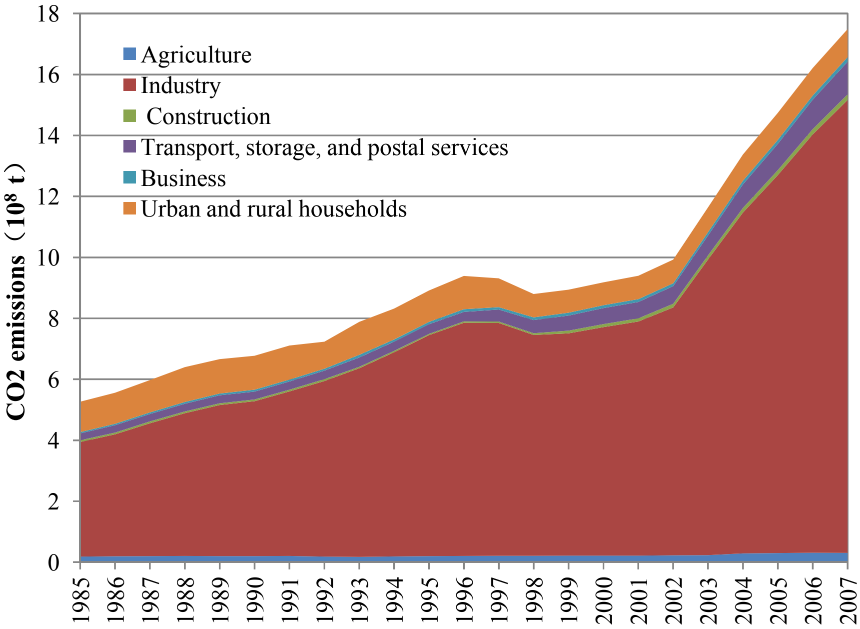
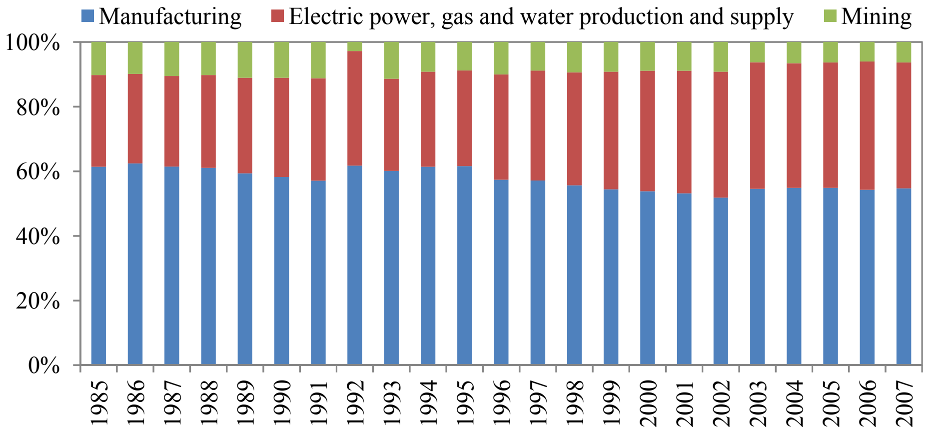
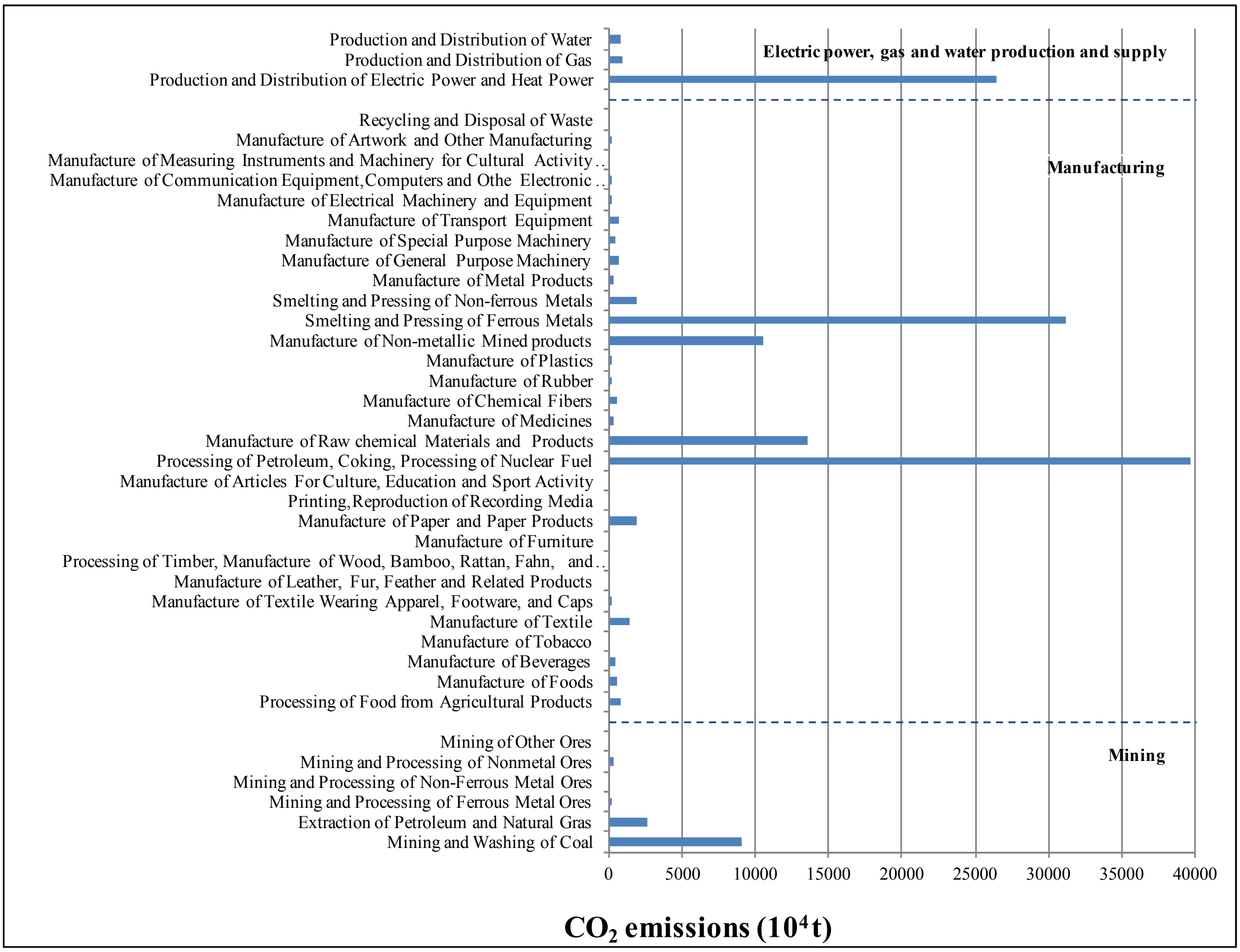


Figure 2. Contribution of energy-related CO_2 emissions in three industrial internal sectors.



As an example, the detailed distribution of carbon emissions from three major industrial internal sectors in 2007 indicated that the major sources of emissions inside industry were due to heavy manufacturing and production and distribution of electric power and heat power. Therein, heavy manufacturing had an overall high carbon emissions level by including high energy consumption sectors, especially the petroleum, chemical products, iron and steel, electrolytic aluminum. In addition, the proportion of carbon emissions from light manufacturing, such as foods, tobacco, furniture etc, were relatively low in the industrial total level (Figure 3).

Figure 3. The distribution of carbon emissions from industrial internal sectors in 2007.



3. Methodology

Selecting the industry sector in China as a case study, we aimed to conduct a year-by-year decomposition analysis of the cumulative effects of influencing factors for China's industrial CO_2 emissions from 1985 to 2007 and also a comparative analysis of differential influences of various factors on different sectors.

3.1. Decomposition Model for CO2 Emissions in Industrial Internal Sectors

The total energy-related industrial CO2 emissions can be expressed in the following way:

$$C=\sum_{i=1}^{3}\sum_{j=1}^{8}C_{ij}=\sum_{i=1}^{3}\sum_{j=1}^{8}\frac{C_{ij}}{E_{ij}}\frac{E_{ij}}{E_i}\frac{E_i}{Y_i}\frac{Y_i}{Y}\frac{Y}{P}P=\sum_{i=1}^{3}\sum_{j=1}^{8}CI_{ij}\cdot ES_{ij}\cdot EI_i\cdot YS_i\cdot PCG\cdot P \tag{1}$$

where index $i = 1, 2$, denote the three major industrial internal sectors, including mining, manufacturing, and electric power, gas and water production and supply, respectively; index $j = 1, 2, \ldots, 8$ denotes eight types of fossil fuels, *i.e.*, coal, coke, crude oil, gasoline, kerosene, diesel oil, fuel oil and natural gas, respectively (considering energy transformation sectors, such as the power sector, are included in the industrial sector, electricity and heat consumption in the final energy demand sectors cannot be considered in the current framework of decomposition to avoid duplicate calculations), consumed by each sector. The meanings of other variables in Equation (1) are described in Table 2.

Table 2. Implication of each variable in Equation (1).

Variable	Implication	Variable	Implication
C	Total amount of CO2 emissions	P	Total population
C_{ij}	The amount of CO2 emitted by fossil fuel j consumed in sector i	CI_{ij}	$CI_{ij} = C_{ij}/E_{ij}$, carbon emissions coefficient for fossil fuels j in sector i
E_i	Total amount of fossil fuel consumed in sector i	ES_{ij}	$ES_{ij} = E_{ij}/E_i$, ratio of fossil fuel j to total fossil fuels in sector i
E_{ij}	The amount of fossil fuel j consumed in sector i	EI_i	$EI_i = E_i/Y_i$, energy intensity of sector i
Y	Total industrial output	YS_i	$YS_i = Y_i/Y$, share of economic output in sector i in total industrial output
Y_i	Economic output of sector i	PCG	Per capita GDP

The changes in CO2 emissions from 0 (base year) to T (target year) can be expressed as follows:

$$\Delta C=C_T-C_0=\Delta C_{CI}+\Delta C_{ES}+\Delta C_{EI}+\Delta C_{YS}+\Delta C_{PCG}+\Delta C_P \tag{2}$$

Therein, ΔC denotes the total effect of CO2 emissions, ΔC_{ES} denotes energy structure effect, ΔC_{YS} denotes economic structure effect, ΔC_{EI} denotes energy intensity effect, ΔC_{PCG} denotes economic activity effect, and ΔC_P denotes population effect (CI represents the CO2 emissions coefficient for various fossil fuels and it is usually a constant and not considered as an investigation factor in this paper). According to the definition of logarithmic mean function, introducing into the weighting function $W_{ij}(t^*)$ [86], Equation (2) can be carried out as follows:

$$\begin{aligned}\Delta C=&\sum_{i=1}^{3}\sum_{j=1}^{8}W_{ij}\left(t^*\right)\ln\left(\frac{ES_{ij,T}}{ES_{ij,0}}\right)+\sum_{i=1}^{3}\sum_{j=1}^{8}W_{ij}\left(t^*\right)\ln\left(\frac{EI_{i,T}}{EI_{i,0}}\right)\\&+\sum_{i=1}^{3}\sum_{j=1}^{8}W_{ij}\left(t^*\right)\ln\left(\frac{YS_{i,T}}{YS_{i,0}}\right)+\sum_{i=1}^{3}\sum_{j=1}^{8}W_{ij}\left(t^*\right)\ln\left(\frac{PCG_T}{PCG_0}\right)\\&+\sum_{i=1}^{3}\sum_{j=1}^{8}W_{ij}\left(t^*\right)\ln\left(\frac{P_T}{P_0}\right)\end{aligned} \tag{3}$$

These components are written as:

$$\begin{aligned}
\Delta C_{ES} &= \sum_{i=1}^{3}\sum_{j=1}^{8}\frac{C_{ij,T}-C_{ij,0}}{\ln C_{ij,T}-\ln C_{ij,0}}\ln\left(\frac{ES_{ij,T}}{ES_{ij,0}}\right)\\
\Delta C_{EI} &= \sum_{i=1}^{3}\sum_{j=1}^{8}\frac{C_{ij,T}-C_{ij,0}}{\ln C_{ij,T}-\ln C_{ij,0}}\ln\left(\frac{EI_{i,T}}{EI_{i,0}}\right)\\
\Delta C_{YS} &= \sum_{i=1}^{3}\sum_{j=1}^{8}\frac{C_{ij,T}-C_{ij,0}}{\ln C_{ij,T}-\ln C_{ij,0}}\ln\left(\frac{YS_{i,T}}{YS_{i,0}}\right)\\
\Delta C_{PCG} &= \sum_{i=1}^{3}\sum_{j=1}^{8}W_{ij}\frac{C_{ij,T}-C_{ij,0}}{\ln C_{ij,T}-\ln C_{ij,0}}\ln\left(\frac{PCG_{T}}{PCG_{0}}\right)\\
\Delta C_{P} &= \sum_{i=1}^{3}\sum_{j=1}^{8}\frac{C_{ij,T}-C_{ij,0}}{\ln C_{ij,T}-\ln C_{ij,0}}\ln\left(\frac{P_{T}}{P_{0}}\right)
\end{aligned} \tag{4}$$

In Equations (3) and (4), the driving force of growth in energy-related industrial CO_2 emissions was decomposed into 5 influencing factors (*ES*, *EI*, *YS*, *PCG*, *P*).

3.2. Decomposition Model for CO_2 Emissions in Different Sectors

The energy-related CO_2 emissions in six sectors can be expressed in the following way:

$$C=\sum_{i=1}^{6}\sum_{j=1}^{8}C_{ij}=\sum_{i=1}^{6}\sum_{j=1}^{8}\frac{C_{ij}}{E_{ij}}\frac{E_{ij}}{E_{i}}\frac{E_{i}}{Y_{i}}\frac{Y_{i}}{Y}\frac{Y}{P}P=\sum_{i=1}^{6}\sum_{j=1}^{8}CI_{ij}\cdot ES_{ij}\cdot EI_{i}\cdot YS_{i}\cdot PCG\cdot P \tag{5}$$

In Equation (5), the index k = 1, 2,…, 6 respectively denote agriculture, industry, construction, transport, storage, and postal services, urban and rural households and business. The meanings of other variables and the decomposition process are the same as those in the model.

4. Results and Discussion

4.1. Decomposition Analysis of Energy-Related Industrial CO_2 Emissions

The present paper offers a year-by-year decomposition analysis of cumulative effects of influencing factors for CO_2 emissions in industrial sectors in China from 1985 which serves as the reference period (Table 3).

The decomposition results show that, till 2007, the cumulative contribution values of all influencing factors varied a lot. Therein, the positive driving factors for industrial CO_2 emissions growth included *ES*, *YS*, *PCG* and *P*, with cumulative contribution of 16 million metric tons, 269 million metric tons, 1.428 billion metric tons and 141 million metric tons respectively. *PCG* was the dominant positive driving factor; *EI* was the only negative driving factor with cumulative contribution value of −744 million metric tons and the cumulative contribution rate of −67.10%. Except for *PCG*, the negative inhibiting effects of *EI* far outweighed the four other positive inhibiting factors for industrial CO_2 emissions growth. This point further indicates that *EI* has been a significant control factor to effectively reduce China's industrial energy-related CO_2 emissions. Energy conservation by both technical and non- technical changes (*e.g.*, behavior and lifestyle) will be the main ways to control the continuous growth of China's industrial energy-related CO_2 emissions.

Table 3. Decomposition result of energy-related industrial CO_2 emissions from 1985 to 2007.

Year	Total		Energy structure		Energy intensity		Economic structure		Economic activity		Population	
	ΔC	d_{total}	ΔC_{ES}	d_{ES}	ΔC_{EI}	d_{EI}	ΔC_{YS}	d_{YS}	ΔC_{PCG}	d_{PCG}	ΔC_P	d_P
1986	2,416.20	100%	57.01	2.36%	−1,174.05	−48.59%	282.38	11.69%	2,652.51	109.78%	598.34	24.76%
1987	5,995.85	100%	168.94	2.82%	−2,847.62	−47.49%	872.78	14.56%	6,517.65	108.70%	1,284.10	21.42%
1988	9,236.44	100%	189.69	2.05%	−6,064.83	−65.66%	2,465.38	26.69%	10,652.69	115.33%	1,993.51	21.58%
1989	11,955.49	100%	277.49	2.32%	−5,813.45	−48.63%	2,923.00	24.45%	11,856.04	99.17%	2,712.42	22.69%
1990	13,212.04	100%	389.53	2.95%	−6,302.61	−47.70%	2,724.52	20.62%	12,977.49	98.22%	3,423.13	25.91%
1991	16,378.96	100%	430.75	2.63%	−10,190.11	−62.21%	5,149.27	31.44%	16,890.79	103.12%	4,098.26	25.02%
1992	19,997.38	100%	469.18	2.35%	−17,316.68	−86.59%	8,459.09	42.30%	23,640.69	118.22%	4,745.09	23.73%
1993	24,271.84	100%	511.20	2.11%	−23,982.48	−98.81%	11,560.61	47.63%	30,757.59	126.72%	5,424.92	22.35%
1994	29,403.84	100%	554.32	1.89%	−30,009.41	−102.06%	14,771.64	50.24%	37,943.97	129.04%	6,143.31	20.89%
1995	34,887.18	100%	765.71	2.19%	−33,776.88	−96.82%	16,671.25	47.79%	44,357.42	127.15%	6,869.68	19.69%
1996	38,888.68	100%	733.06	1.89%	−38,884.55	−99.99%	18,435.52	47.41%	50,921.97	130.94%	7,682.67	19.76%
1997	38,827.83	100%	281.59	0.73%	−46,021.17	−118.53%	19,668.22	50.65%	56,512.94	145.55%	8,386.24	21.60%
1998	34,837.26	100%	316.93	0.91%	−50,164.52	−144.00%	19,016.69	54.59%	57,222.29	164.26%	8,445.87	24.24%
1999	35,357.59	100%	526.96	1.49%	−50,832.35	−143.77%	18,567.06	52.51%	58,549.40	165.59%	8,546.50	24.17%
2000	37,411.77	100%	399.36	1.07%	−56,460.74	−150.92%	19,739.99	52.76%	64,529.73	172.49%	9,203.42	24.60%
2001	39,171.90	100%	466.91	1.19%	−60,644.40	−154.82%	19,984.18	51.02%	69,673.59	177.87%	9,691.61	24.74%
2002	43,716.09	100%	397.08	0.91%	−63,503.75	−145.26%	20,666.99	47.28%	75,948.26	173.73%	10,207.49	23.35%
2003	59,430.41	100%	715.15	1.20%	−61,253.47	−103.07%	23,368.35	39.32%	85,610.91	144.05%	10,989.46	18.49%
2004	74,223.47	100%	793.93	1.07%	−58,328.83	−78.59%	24,796.71	33.41%	95,307.64	128.41%	11,654.02	15.70%
2005	86,430.03	100%	1,308.80	1.51%	−59,671.34	−69.04%	25,185.50	29.14%	107,238.75	124.08%	12,368.32	14.31%
2006	99,639.60	100%	1,524.02	1.53%	−63,542.53	−63.77%	25,640.36	25.73%	122,860.88	123.31%	13,156.85	13.20%
2007	110,951.62	100%	1,601.77	1.44%	−74,444.77	−67.10%	26,899.91	24.24%	142,804.16	128.71%	14,090.52	12.70%

Notes: ΔC_X: The cumulative contributionn value of factor X (10^4 metric tons); d_X: The cumulative contribution rate of factor X (%).

The curve of cumulative contribution variation of influencing factors in Figure 4 shows that, since 1996, the growth of ΔC_{PCG} has been slowed down influenced by the southeastern financial crisis [27,30] and then accelerated again in the latter years. The positive driving effects from economic activity for CO_2 emissions growth were largely impaired in China, which caused ΔC growing stably with a decline and then a rise in the short term accordingly. In addition, Figures 4 and 5 show that all influencing factors contributed differently to the industrial energy-related CO_2 emissions growth in different years and got involved in largely differential influence in respect of time series.

Figure 4. Cumulative contribution values of influencing factors of the energy-related industrial CO_2 emissions.

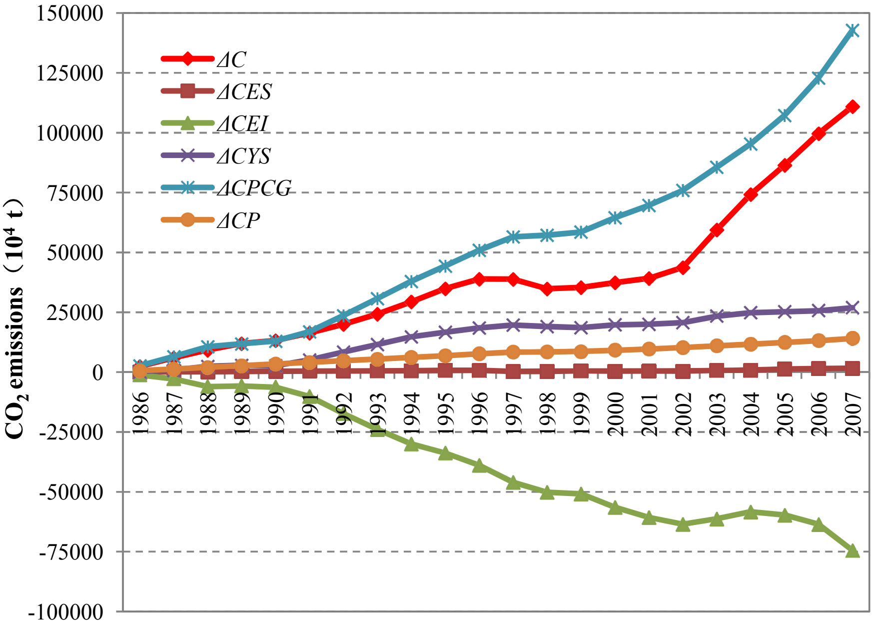
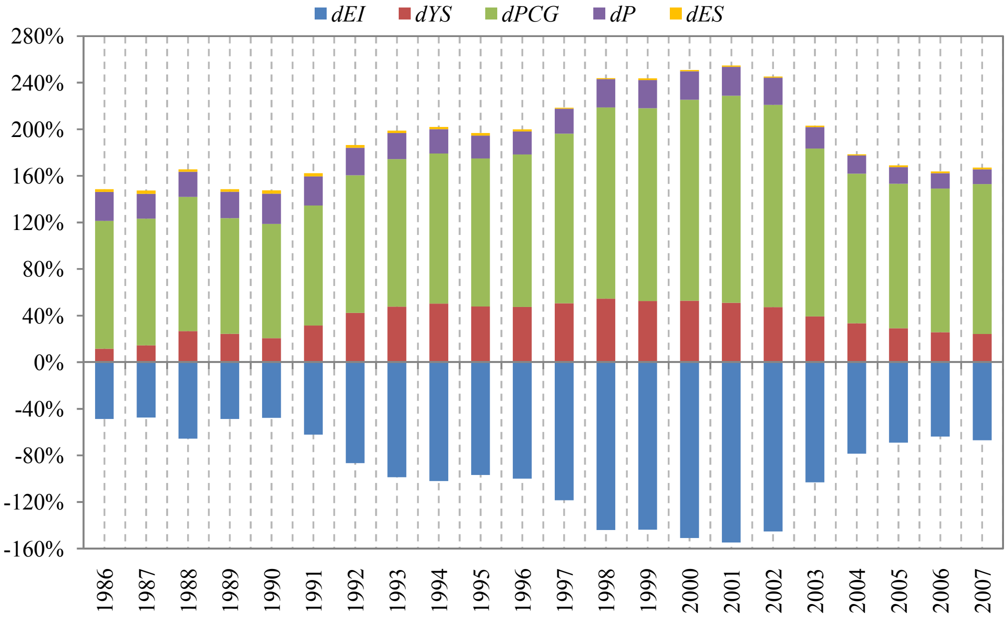


Figure 5. Cumulative contribution rates of influencing factors of the energy-related industrial CO_2 emissions.



4.1.1. Energy Structure Effect

From 1985 to 2007, *ES* showed a weak positive effect on China's industrial CO_2 emissions growth year by year with a low fluctuation. Therein, its contribution value was 570,100 metric tons in 1986, with the contribution rate of 2.36%; the cumulative contribution value was increased to 16.0177 million metric tons in 2009, with the contribution rate decreased to 1.44%. Within the context of the rapid economic development in China, the improvement of industrialization would definitely arouse the surging demand for various fossil fuels such as coal, petroleum and natural gas in different industrial sectors. However, the fuel structure dominated by coal due to the fact that China's natural resources endowment was hard to change obviously in short term. Meanwhile, the energy consumption structure in industrial sectors is obviously not optimized, the proportion of high-carbon energy consumption shows slight growth, *i.e.*, coal consumption rate increased from 80.30% in 1985 to 85.87% in 2007, while petroleum consumption rate decreased from 16.91% in 1985 to 9.42% in 2007. Hence, with increasingly swift industrialization process, the total industrial energy consumption growth and high-carbon energy consumption growth are major causes that *ES* plays a positive driving effect on China's industrial CO_2 emissions. Therefore, one significant measure to reduce industrial CO_2 emissions in the future is involved in continually enhancing adjustment and optimization of energy consumption structure in industrial sectors, increasing low-carbon energy consumption ratio and improving energy use efficiency.

4.1.2. Energy Intensity Effect

As the only negative driving factor for China's industrial energy-related CO_2 emissions growth, *EI* extremely reduces the total industrial CO_2 emissions. From 1985 to 2001, the negative driving effects of *EI* were sharply increased in general, with the cumulative contribution value of −606 million metric tons and the cumulative contribution rate of −154.82%; from 2002 to 2004, the negative driving effects of *EI* for industrial CO_2 emissions growth were decreased to a certain extent, with the cumulative contribution value rebounding from −635 million metric tons in 2002 to 583 million metric tons in 2004 and the cumulative contribution rate rebounding from −145.26% to −78.59%. Since 2005, the negative driving effects of *EI* had been gradually increased, with the cumulative contribution value of −744 million metric tons in 2007.

EI, which represents the input/output characteristics of energy system through the energy consumptions per GDP, is closely bound to many factors such as industrial structure, energy structure and technological progress. In this paper, the energy consumption per industrial output value is used for weighing the energy intensity of industrial sectors to further reflect the overall efficiency of energy economic activities in the industrial sectors. From 1980 to 2007, the energy intensity of all industries was in a sharp fall and the average energy intensity of all industries dropped from 3.78 tce/¥10,000 to 1.31 tce/¥10,000, with the reduction rate of 65.35%. The energy intensity of industrial sectors calculated based upon the constant price of 1985 in the paper indicated that the energy intensity of China's industrial sectors was 15.12 tce/¥10,000 in 1985 and decreased to 4.50 tce/¥10,000 in 2007, with the reduction rate of 70.24% which was more than the average of energy intensity reduction in China. It is thus clear that China's efficiency of energy use has made substantial progress in recent three decades, but the adjustment of industrial structure and energy structure is still quite slow. Within the rapid development of industrialization in China, the growth of total energy consumption is expected to continue. Therefore new technology breakthroughs are preferred, rather than a direct reduction of energy consumption to improve China's efficiency of energy use.

4.1.3. Economic Structure Effect

The economic share effect is primarily displayed as the proportion of industrial output value in GDP which affects CO_2 emissions. The decomposition results show that, *YS* played a positive driving role in China's energy-related industrial CO_2 emissions growth, with the contribution rate in a relatively slow growth. The cumulative effects of *YS* surged before the middle and late 1990s, with 197 million metric tons and the cumulative contribution rate of 50.65% in 1997. Later, its positive driving effects were gradually lessened, with the cumulative effects increased to 269 million metric tons while the cumulative contribution rate decreased to 24.24% in 2007. In recent years, the industrial structure has been adjusted in China to a certain extent, but it still failed to restrain industrial CO_2 emissions growth due to slow progress. China's gross industrial output value accounted for 38.25% of GDP in 1985 and exceeded half of GDP in 2007 [87,88], as China was in that very period of rapid industrialization so that the industry scale was continually expanded and the industrial adjustment lagged behind the demand of economic development for continual industrial expansion. Even if the industrial share kept unchanged, the expansion would still lead to a high energy demand so that CO_2 emission was increased.

4.1.4. Economic Activity Effect

As calculated based upon the constant price in 1985, China's *per capita* GDP was ¥851.76 in 1985, which increased to ¥6524.45 in 2007, corresponding to a growth rate of 604.88%. However, the rapid economic development in China brought with it a huge quantity of energy consumption so that economic development also became the foremost driving factor for industrial CO_2 emissions growth. Viewed from the decomposition results, *PCG* was the largest positive driving factor for China's industrial CO_2 emissions. In terms of time series, the cumulative contribution rate was almost over 100% (Figure 5) with the maximum of 177.87% in 2001, and then suffered from a slow decline and dropped to 128.71% at the end of 2007, excluding special years. Moreover, the cumulative contribution value of *PCG* for China's industrial CO_2 emissions was always rapidly increased (Figure 5). The cumulative contribution value was increased from 26.5251 million metric tons in 1986 to 1.428 billion metric tons in 2007, with annually average increment of 63.7053 million metric tons of CO_2 emissions. As can be seen from the above, China's continuous economic development was a major decisive factor for industrial CO_2 emissions growth, of which the contribution to CO_2 emissions growth was also on the rise. As the largest developing country, China shall not always sacrifice economic development to reduce CO_2 emissions, but coordinate various factors and balance the relationship between emission reduction and development so that normal economic development can be guaranteed and a win-win outcome in both development and emission reduction can be reached.

4.1.5. Population Effect

P also played a positive driving role in China's industrial CO_2 emissions growth. China's population growth rate has declined since 1987, even reaching the lowest point of 0.52% in 2007 due to family planning policy, but the net growth of population was about 7.69 million people on the average from 2000 to 2007, for the huge population base in China. With the improvement of the population-urbanized ratio, growth of household consumption and variation of consumption mode, China's absolutely rapid population growth promoted the continuous growth of economic output and corresponding growth of energy consumption to become the essential conditions to meet the basic demand for national people's survival and development, thus, the energy-related CO_2 emissions were gradually increased. In 1986, the cumulative contribution value of scale effect in China was 5.9834 million metric tons, exceeding 100 million metric tons in 2002 due to continuous population growth and increased to 141 million metric tons at the end of 2009. On the contrary, the cumulative contribution rate of population size underwent the continuous decline year by year, decreasing from 24.76% in 1986 to 12.70% in 2007. The evaluation of all this data over time further indicates that continuous industrial CO_2 emissions growth is one consequence of population growth, but such influence is gradually reduced.

4.2. Decomposition Analysis of Industry Discrepancy

To further discuss the differential influences of various factors for the industry and other sectors, the paper presents a decomposition analysis of the cumulative effects of influencing factors for energy-related CO_2 emissions of six sectors from 1985 to 2007 and also a comparative analysis of differential influences of various factors on the industry. The decomposition results are as follows (Table 4).

Table 4. Decomposition results of CO_2 emissions of six sectors from 1985 to 2007.

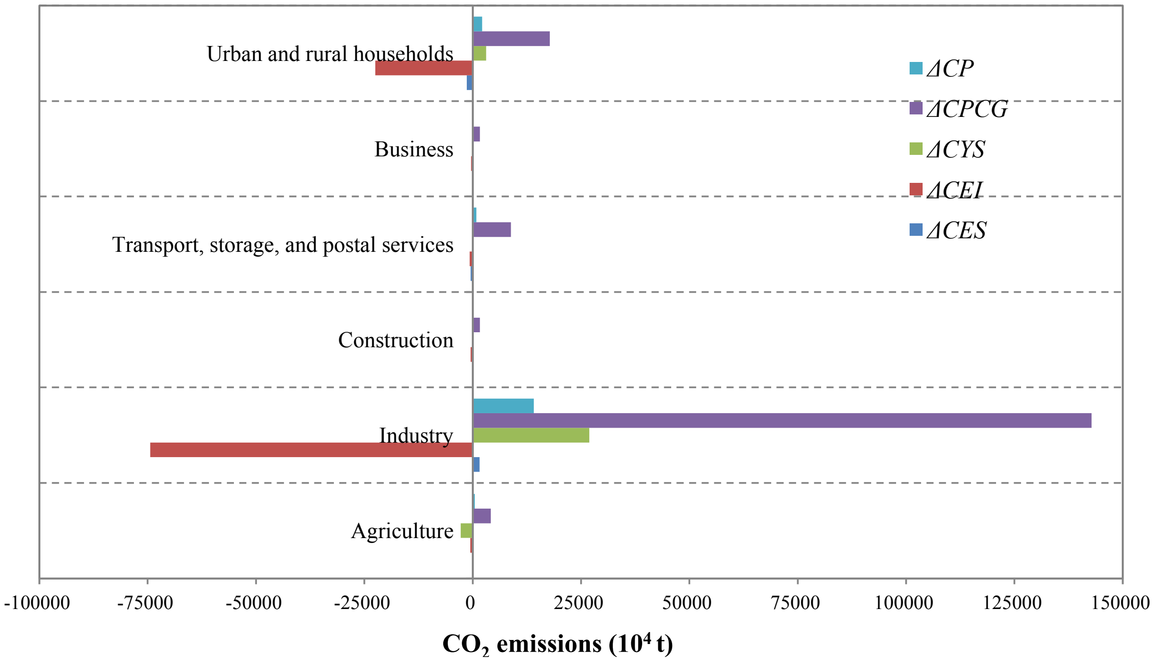
Sector		Agriculture	Industry	Construction	Transport, storage, and postal services	Business	Urban and rural households
Total	ΔC	1,215.83	110,951.62	1,226.41	8,503.05	1,070.7	−793.19
	d_{total}	100%	100%	100%	100%	100%	100%
Energy structure	ΔC_{ES}	−124.24	1,601.77	−54.62	−490.48	−167.46	−1,348.6
	d_{ES}	−10.22%	1.44%	−4.45%	−5.77%	−15.64%	170.02%
Energy intensity	ΔC_{EI}	−554.67	−74,444.77	−494.5	−711.04	−360.42	−22,515.99
	d_{EI}	−45.62%	−67.10%	−40.32%	−8.36%	−33.66%	2,838.65%
Economic structure	ΔC_{YS}	−2,746.71	26,899.91	−46.05	61.36	−218.6	3,100.75
	d_{YS}	−225.91%	24.24%	−3.76%	0.72%	−20.42%	−390.92%
Economic activity	ΔC_{PCG}	4,176.32	142,804.16	1,659.79	8,806.69	1,647.83	17,786.79
	d_{PCG}	343.49%	128.71%	135.34%	103.57%	153.90%	−2,242.43%
Population	ΔC_P	465.14	14,090.52	161.79	836.52	169.34	2,183.84
	d_P	38.26%	12.70%	13.19%	9.84%	15.82%	−275.32%

Notes: ΔC_X: The cumulative contribution value of factor X (10^4 t), d_X: The cumulative contribution rate of factor X (%).

For the cumulative effects of factors for CO_2 emissions from all sectors, both *PCG* and *P* played a significantly positive driving role in CO_2 emissions growth; *EI* on the other hand represented a negative driving effect; except for positive driving effect in the industrial sectors, *ES* played a negative driving role in the rest five sectors (Figure 6), for which the continuous growth of fossil fuel consumption such as coal and petroleum in industrial sectors acted as the major reason; besides, energy consumption was increased with the rapid development of the industry, transportation and residential sector. *YS* played a positive driving role in those three sectors, but it played a negative driving role in three other sectors which were developed slowly to some extent.

Seen from the cumulative contribution values of all driving factors for different sectors, *PCG*, which offered the largest contribution value in all sectors, was the largest positive driving factor for CO_2 emissions growth; *EI* was the largest inhibiting factor for CO_2 emissions growth in five sectors excluding farming, forestry, animal husbandry and fishery; *ES* reflected the substitution of energy consumption. Except for the industry, CO_2 emission was efficiently reduced through the adjustment of energy structure in other sectors. Therein, the residential sector made the most contribution, with the cumulative contribution value of −13.4860 million metric tons (Table 4, Figure 6). For a long time, China’s industrial energy consumption was constituted by coal and petroleum in dominance. Compared with other energy resources, coal and petroleum were of relatively high CO_2 emission coefficients so that *ES* could have a positive driving effect on industrial CO_2 emission growth; *P* produced the maximum cumulative contribution value of 141 million metric tons for the industry, but the minimum cumulative contribution value of 1.6179 million metric tons was reserved for the construction sector. In respect of transportation, the cumulative contribution value of *P* was 8.3652 million metric tons which surpassed the cumulative contribution value of −7.1104 million metric tons of *EI* as a negative inhibiting factor (Table 4, Figure 6). Apart from economic development, the rapid population growth also intensified the burden of transportation and became the second largest driving force for industrial CO_2 emission growth.

Figure 6. Cumulative contribution value of influencing factors of CO_2 emissions in six sectors from 1985 to 2007.



Furthermore, *PCG* and *EI* were fairly obvious in the cumulative effects of residential CO_2 emissions growth. The negative driving effects of *EI* outweighed the positive driving effects of *PCG*. Since the residential energy consumption was closely associated to people’s living habits, consumption patterns and climate change in general, the energy demand growth got slow somewhat and many new energy resources such as solar energy and methane were increasingly used in people’s living, effectively substituted for fossil fuels and also inhibited CO_2 emissions growth to a certain extent. Thus, *EI* was involved in a negative driving effect on the total effect of residential CO_2 emission, that is, CO_2 emissions varied to finally reach the decrement of 7.9319 million metric tons. Meanwhile, the residential sector was the unique whose emission reduction was realized in six sectors from 1985 to 2007.

5. Conclusions and Policy Prescriptions

From 1997 to 2001, China’s industrial CO_2 emissions underwent some different stages ranging from “steadily rising” to “stable with a decline”, and then to “rapid growth” but always held an absolutely dominant place in the total CO_2 emissions of six sectors, which was the biggest carbon emitter in China; in respect of major industrial sectors, the manufacturing got involved in maximum CO_2 emissions, with rapid growth rate; followed by the electric power, gas and water production and supply, such sector was often steadily increased; however, CO_2 emissions from the mining was relatively low and slowly decreased.

In terms of all influencing factors for China's industrial CO_2 emissions, the positive driving factors included *ES*, *PCG*, *YS* and *P*. Therein, *PCG* was the foremost positive driving factor for China's industrial CO_2 emissions growth, so the control of energy-related CO_2 emissions was the grand challenge which China's industrial sectors were confronted with, given that economic development was guaranteed; *P* and *YS* also boosted China's industrial CO_2 emissions growth. Although the decomposition results showed that *P* and *YS* had small contribution values respectively, the population size and industrial structure were highly related to industrial CO_2 emissions so that corresponding driving effects could not be neglected. It is an inevitable trend that continuous population growth and advanced industrialization will cause residential and industrial CO_2 emissions growth; additionally, it is difficult to radically change the overall energy structure with the present dominance of coal, so the energy consumption structure in industrial sectors obviously fails to be optimized and *ES* is also displayed as a slightly positive driving effect. Therefore, with economic development, controlling population growth and optimizing industrial structure are major ways to control China's industrial CO_2 emissions growth.

EI was the only one which played a negative driving role in China's industrial CO_2 emissions growth, largely reducing total industrial CO_2 emissions. Moreover, China's efficiency of energy use has made a substantial progress in recent three decades, but the industrial structure and energy structure adjustment is still quite slow. Along with the rapid development of industrialization, China's industrial sectors still have large space for energy intensity decreases and CO_2 emissions reduction. China shall vigorously boost technical progress to further improve efficiency of energy use and low-carbon development to maximize output in low intensity branches in the future.

All influencing factors had a differential bearing on CO_2 emissions from six sectors. *PCG* always played a positive driving role in all sectors, with the maximum cumulative contribution value; *EI* had a negative driving effect, and other factors presented different effects and contributions according to different sectors. *PCG* and *EI* played a decisive role in driving differential influences of various factors on six sectors.

As seen from the decomposition results, reduction of the energy-related industrial CO_2 emissions is a hard and complex project, related to different factors such as economy, technology, industrial structure and population. The paper presents the following policy recommendations for the development of China's industrial CO_2 emissions reduction in the future:

First and foremost, the control strength of environmental policies shall be intensified in different stages to control continuous CO_2 emissions growth under the industrialization. It is required to establish and implement CO_2 emissions laws and regulations, technical standards, entry threshold for the enterprises of carbon trade and CO_2 emissions, energy conservation and emission reduction and other policies and measures for CO_2 emission reduction.

Furthermore, the industrial structure shall be positively optimized and adjusted. Based on the principle of "Reduction, Re-use, and Recycling" and the requirements for new industrialized road, the effective measures shall be taken to further improve industrial structure and reduce CO_2 emissions. It is required to vigorously develop the tertiary and high-tech industry, especially environment-friendly industry, to make industrial structure develop toward energy conservation and advancement.

In third place, it is necessary to optimize energy consumption structure and strengthen energy conservation. The CO_2 emission reduction technology shall be actively implemented to increase thr efficiency of energy use. The low-carbon energy and renewable energy shall be developed to improve the energy structure.

Finally, it is needed to strengthen publicity and advocate a low-carbon lifestyle. Slowing down global warming and reducing greenhouse gas emissions are associated to lifestyle and values change. Therefore, a continuous education and publicity programme should be conducted to convert people's values for the popularization of a low-carbon lifestyle and low-carbon consumption habits, which are also an effective way for CO_2 emission reduction.

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References

1. The State Council of the People's Republic of China (SCPRC). The 12th Five-Year Plan Outline of National Economy and Social Development of People's Republic of China. Available online: http://news.xinhuanet.com/politics/2011-03/16/c_121193916.htm (accessed on 16 March 2011).
2. Ang, B.W. Decomposition analysis for policymaking in energy: Which is the preferred method? *Energy Policy* **2004**, *32*, 1131–1139.
3. Steenhof, P.; Woudsma, C.; Sparling, E. Greenhouse gas emissions and the surface transport of freight in Canada. *Transp. Res. Part D Transp. Environ.* **2006**, *11*, 369–376.
4. Ang, B.W. Decomposition analysis applied to energy. In *Encyclopedia of Energy*; Cleveland, C.J., Ed.; Elsevier: Amsterdam, The Netherlands, 2004; pp. 761–769.
5. Ang, B.W.; Liu, N. Energy decomposition analysis: IEA model *versus* other methods. *Energy Policy* **2007**, *35*, 1426–1432.
6. Ang, B.W.; Zhang, F.Q. A survey of index decomposition analysis in energy and environmental studies. *Energy* **2000**, *25*, 1149–1176.
7. Ang, B.W.; Liu, F.L. A new energy decomposition method: Perfect in decomposition and consistent in aggregation. *Energy* **2001**, *26*, 537–548.
8. O'Mahony, T.; Zhou, P.; Sweeney, J. The driving forces of change in energy-related CO_2 emissions in Ireland: A multi-sectoral decomposition from 1990 to 2007. *Energy Policy* **2012**, *44*, 256–267.
9. Ang, B.W.; Zhang, F.Q.; Choi, K. Factorizing changes in energy and environmental indicators through decomposition. *Energy* **1998**, *23*, 489–495.
10. Liu, N.; Ang, B.W. Factors shaping aggregate energy intensity trend for industry: Energy Intensity *versus* product mix. *Energy Econ.* **2007**, *29*, 609–635.
11. Ang, B.W.; Mu, A.R.; Zhou, P. Accounting frameworks for tracking energy efficiency trends. *Energy Econ.* **2010**, *32*, 1209–1219.
12. Peters, G.P.; Hertwich, E.G. CO_2 embodied in international trade with implications for global climate policy. *Environ. Sci. Technol.* **2008**, *42*, 1401–1407.

13. Greening, L.A.; Ting, M.; Davis, W.B. Decomposition of aggregate carbon intensity for freight: Comparison of declining trends from 10 OECD countries for the period 1971–1993. *Energy Econ.* **1999**, *21*, 331–361.
14. Pani, R.; Mukhopadhyay, U. Identifying the major player behind increasing global carbon dioxide emissions: A decomposition analysis. *Environmentalist* **2010**, *30*, 183–205.
15. Greening, L.A.; Ting, M.; Krackler, T.J. Effects of changes in residential end-uses and behavior on aggregate carbon intensity: Comparison of 10 OECD countries for the period 1970–1993. *Energy Econ.* **2001**, *23*, 153–178.
16. Greening, L.A. Effects of human behavior on aggregate carbon intensity of personal transportation: Comparison of 10 OECD countries for the period 1970–1993. *Energy Econ.* **2004**, *26*, 1–30.
17. Choi, K.H.; Ang, B.W. A time-series analysis of energy-related carbon emissions in Korea. *Energy Policy* **2001**, *29*, 1155–1161.
18. Oh, I.; Wehrmeyer, W.; Mulugetta, Y. Decomposition analysis and mitigation strategies of CO_2 emissions from energy consumption in South Korea. *Energy Policy* **2010**, *38*, 364–377.
19. Bhattacharyya, S.C.; Ussanarassamee, A. Decomposition of energy and CO_2 intensities of Thai industry between 1981 and 2000. *Energy Econ.* **2004**, *26*, 765–781.
20. Paul, S.; Bhattacharya, R.N. CO_2 Emission from energy use in India: A decomposition analysis. *Energy Policy* **2004**, *32*, 585–593.
21. Luciano, C.F.; Shinji, K. Decomposing the decoupling of CO_2 emissions and economic growth in Brazil. *Ecol. Econ.* **2011**, *70*, 1459–1469.
22. Luciano, C.F.; Shinji, K. Decomposition of CO_2 emissions change from energy consumption in Brazil: Challenges and policy implications. *Energy Policy* **2011**, *39*, 1495–1504.
23. Tunc, G.I.; Türüt-Asık, S.; Akbostancı, E.; Gipek, T.; Serap, T.A.; Elif, A. A decomposition analysis of CO_2 emissions from energy use: Turkish case. *Energy Policy* **2009**, *37*, 4689–4699.
24. Kwon, T.H. Decomposition of factors determining the trend of CO_2 emissions from car travel in Great Britain (1970–2000). *Ecol. Econ.* **2005**, *53*, 261–275.
25. Hatzigeorgiou, E.; Polatidis, H.; Haralambopoulos, D. CO_2 Emissions in Greece for 1990–2002: A decomposition analysis and comparison of results using the arithmetic mean divisia index and logarithmic mean divisia index techniques. *Energy* **2011**, *33*, 492–499.
26. Wu, L.B.; Kaneko, S. Driving forces behind the stagnancy of Chinas energy-related CO_2 emissions from 1996 to 1999: The relative importance of structural change, intensity change and scale change. *Energy Policy* **2005**, *33*, 319–335.
27. Wu, L.B.; Kaneko, S.; Matsuoka, S. Dynamics of energy-related CO_2 emissions in China during 1980 to 2002: The relative importance of energy supply-side and demand-side effects. *Energy Policy* **2006**, *34*, 3549–3572.
28. Xu, G.Q.; Liu, Z.Y.; Jiang, Z.H. Decomposition model and empirical study of carbon emissions for China, 1995–2004 [in Chinese]. *China Popul. Resour. Environ.* **2006**, *16*, 158–161.
29. Song, D.Y.; Lu, Z.B. The factor decomposition and periodic fluctuations of carbon emission in China [in Chinese]. *China Popul. Resour. Environ.* **2009**, *3*, 18–24.
30. Fan, Y.; Liu, L.C.; Wu, G.; Tsai, H.T.; Wei, Y.M. Changes in carbon intensity in China: Empirical findings from 1980–2003. *Ecol. Econ.* **2007**, *62*, 683–691.

31. Zhang, M.; Mu, H.L.; Ning, Y.D.; Song, Y.C. Decomposition of energy-related CO_2 emission over 1991–2006 in China. *Ecol. Econ.* **2009**, *68*, 2122–2128.
32. Sun, J.W.; Zhao, R.Q.; Huang, X.J.; Chen, Z.G. Research on carbon emission estimation and factor decomposition of China from 1995 to 2005. *J. Nat. Resour.* **2010**, *25*, 1284–1295.
33. Zhang, Y.; Zhang, J.Y.; Yang, Z.F.; Li, S.S. Regional differences in the factors that influence China's energy-related carbon emissions, and potential mitigation strategies. *Energy Policy* **2011**, *39*, 7712–7718.
34. Wu, F.; Fan, L.W.; Zhou, P.; Zhou, D.Q. Industrial energy efficiency with CO_2 emissions in China: A nonparametric analysis. *Energy Policy* **2012**, *49*, 164–172.
35. Wang, S.S.; Zhou, D.Q.; Zhou, P.; Wang, Q.W. CO_2 Emissions, energy consumption and economic growth in China: A panel data analysis. *Energy Policy* **2011**, *39*, 4870–4875.
36. Wang, H.T.; Mu, S.R. The characteristics and trend of carbon emissions in Beijing. *Urban Studies* **2010**, *17*, 55–61.
37. Zhou, S.Y.; Chen, H.; Li, S.C. Resources use and greenhouse gas emissions in urban economy: Ecological input–output modeling for Beijing 2002. *Commun. Nonlinear Sci. Numer. Simul.* **2010**, *15*, 3201–3231.
38. Liu, C.C. An extended method for key factors in reducing CO_2 emissions. *Appl. Math. Comput.* **2007**, *189*, 440–451.
39. Zhao, M.; Zhang, W.G.; Yu, L.Z. Carbon emissions from energy consumption in Shanghai city. *Res. Environ. Sci.* **2009**, *22*, 984–989.
40. Brownstone, D.; Golob, T.F. The impact of residential density on vehicle usage and energy consumption. *J. Urban Econ.* **2010**, *65*, 91–98.
41. Glaser, E.L.; Kahn, M.E. The greenness of cities: Carbon dioxide emissions and urban development. *J. Urban Econ.* **2010**, *26*, 51–75.
42. Dhakal, S. Urban energy use and carbon emissions from cities in China and policy implications. *Energy Policy* **2009**, *37*, 4208–4219.
43. Diakoulaki, D.; Mandaraka, M. Decomposition analysis for assessing the progress in decoupling industrial growth from CO_2 emission in the EU manufacturing sector. *Energy Econ.* **2007**, *29*, 636–664.
44. Freeman, S.L.; Niefer, M.J.; Roop, J.M. Measuring industrial energy intensity: Practical issues and problems. *Energy Policy* **1997**, *25*, 703–714.
45. Ang, B.W.; Choi, K.H. Decomposition of Aggregate energy and gas emission intensities for industry: A refined divisia index method. *Energy J.* **1997**, *18*, 59–73.
46. Timilsina, G.R.; Shrestha, A. Factors affecting transport sector CO_2 emissions growth in Latin American and Caribbean countries: An LMDI decomposition analysis. *Int. J. Energy Res.* **2009**, *33*, 396–414.
47. Ediger, V.S.; Huvaz, O. Examining the sectoral energy use in Turkish economy (1980–2000) with the help of decomposition analysis. *Energy Convers. Manag.* **2006**, *47*, 732–745.
48. Zhang, M.Y.; Huang, X.J. Effects of industrial restructuring on carbon reduction: An analysis of Jiangsu Province, China. *Energy* **2012**, *44*, 515–526.
49. Liu, L.; Fan, Y.; Wu, G.; Wei, Y. Using LMDI method to analyze the change of China's industrial CO2 emissions from final fuel use: An empirical analysis. *Energy Policy* **2007**, *35*, 5892–5900.

50. Ren, S.G.; Fu, X.; Chen, X.H. Regional variation of energy-related industrial CO_2 emissions mitigation in China [in Chinese]. *China Econ. Rev.* **2012**, *23*, 1134–1145.
51. Zhao, M.; Tan, L.R.; Zhang, W.G.; Ji, M.H.; Liu, Y.; Yu, L.Z. Decomposing the influencing factors of industrial carbon emissions in Shanghai using the LMDI method. *Energy* **2010**, *35*, 2505–2510.
52. National Bureau of Statistics of China. *China Statistical Yearbook 1986*; China Statistics Press: Beijing, China, 1986.
53. National Bureau of Statistics of China. *China Statistical Yearbook 1987*; China Statistics Press: Beijing, China, 1987.
54. National Bureau of Statistics of China. *China Statistical Yearbook 1988*; China Statistics Press: Beijing, China, 1988.
55. National Bureau of Statistics of China. *China Statistical Yearbook 1989*; China Statistics Press: Beijing, China, 1989.
56. National Bureau of Statistics of China. *China Statistical Yearbook 1990*; China Statistics Press: Beijing, China, 1990.
57. National Bureau of Statistics of China. *China Statistical Yearbook 1991*; China Statistics Press: Beijing, China, 1991.
58. National Bureau of Statistics of China. *China Statistical Yearbook 1992*; China Statistics Press: Beijing, China, 1992.
59. National Bureau of Statistics of China. *China Statistical Yearbook 1993*; China Statistics Press: Beijing, China, 1993.
60. National Bureau of Statistics of China. *China Statistical Yearbook 1994*; China Statistics Press: Beijing, China, 1994.
61. National Bureau of Statistics of China. *China Statistical Yearbook 1995*; China Statistics Press: Beijing, China, 1995.
62. National Bureau of Statistics of China. *China Statistical Yearbook 1996*; China Statistics Press: Beijing, China, 1996.
63. National Bureau of Statistics of China. *China Statistical Yearbook 1997*; China Statistics Press: Beijing, China, 1997.
64. National Bureau of Statistics of China. *China Statistical Yearbook 1998*; China Statistics Press: Beijing, China, 1998.
65. National Bureau of Statistics of China. *China Statistical Yearbook 1999*; China Statistics Press: Beijing, China, 1999.
66. National Bureau of Statistics of China. *China Statistical Yearbook 2000*; China Statistics Press: Beijing, China, 2000.
67. National Bureau of Statistics of China. *China Statistical Yearbook 2001*; China Statistics Press: Beijing, China, 2001.
68. National Bureau of Statistics of China. *China Statistical Yearbook 2002*; China Statistics Press: Beijing, China, 2002.
69. National Bureau of Statistics of China. *China Statistical Yearbook 2003*; China Statistics Press: Beijing, China, 2003.
70. National Bureau of Statistics of China. *China Statistical Yearbook 2004*; China Statistics Press: Beijing, China, 2004.

71. National Bureau of Statistics of China. *China Statistical Yearbook 2005*; China Statistics Press: Beijing, China, 2005.
72. National Bureau of Statistics of China. *China Statistical Yearbook 2006*; China Statistics Press: Beijing, China, 2006.
73. National Bureau of Statistics of China. *China Statistical Yearbook 2007*; China Statistics Press: Beijing, China, 2007.
74. National Bureau of Statistics of China. *China Statistical Yearbook 2008*; China Statistics Press: Beijing, China, 2008.
75. National Bureau of Statistics of China. *China Energy Statistical Yearbook 1986*; China Statistics Press: Beijing, China, 1987.
76. National Bureau of Statistics of China. *China Energy Statistical Yearbook 1989*; China Statistics Press: Beijing, China, 1990.
77. National Bureau of Statistics of China. *China Energy Statistical Yearbook 1991–1996*; China Statistics Press: Beijing, China, 1998.
78. National Bureau of Statistics of China. *China Energy Statistical Yearbook 1997–1999*; China Statistics Press: Beijing, China, 2001.
79. National Bureau of Statistics of China. *China Energy Statistical Yearbook 2000–2002*; China Statistics Press: Beijing, China, 2004.
80. National Bureau of Statistics of China. *China Energy Statistical Yearbook 2004*; China Statistics Press: Beijing, China, 2005.
81. National Bureau of Statistics of China. *China Energy Statistical Yearbook 2005*; China Statistics Press: Beijing, China, 2006.
82. National Bureau of Statistics of China. *China Energy Statistical Yearbook 2006*; China Statistics Press: Beijing, China, 2007.
83. National Bureau of Statistics of China. *China Energy Statistical Yearbook 2007*; China Statistics Press: Beijing, China, 2008.
84. National Bureau of Statistics of China. *China Energy Statistical Yearbook 2008*; China Statistics Press: Beijing, China, 2008.
85. Intergovernmental Panel on Climate Change (IPCC). 2006 Intergovernmental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories, Volume 2 Energy. Available online: http://www.ipcc-nggip. iges.or.jp/public/2006gl/vol2.html (accessed on 1 April 2007).
86. Ang, B.W.; Choi, K. Decomposition of aggregate energy and gas emission intensities for industry: A refined divisia index method. *Energy J.* **1997**, *18*, 59–73.
87. National Bureau of Statistics of China (NBSC). Statistical Communiqué of the People's Republic of China on the 1985 National Economic and Social Development [in Chinese]. In *Gazette State Council of the People's Republic of China*; NBSC: Beijing, China, 1986; Volume 6, pp. 131–134.
88. National Bureau of Statistics of China (NBSC). Statistical Communiqué of the People's Republic of China on the 2007 national economic and social development [in Chinese]. *China Stat.* **2008**, *3*, 4–9.