Research Article

A Factor Decomposition on China's Carbon Emission from 1997 to 2012 Based on IPAT-LMDI Model

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We probe into the key factors that possess significant effects on China's CO₂ emissions during 1997–2012 on the basis of IPAT-LMDI model. Carbon dioxide emissions are specifically decomposed into CO₂ emission intensity, energy structure, energy intensity, industrial structure, economic output, and population scale effects. Results indicate that the paramount driving factors that resulted in the growth of CO₂ emissions are economic output, population scale, and energy structure. In contrast, energy intensity and industrial structure generally play an outstanding role in reducing emissions. This paper constructs a new weight assessment system by introducing “contribution value-significant factor-effect coefficient” to replace “contribution value-contribution rate” in the previous literature. According to the most significant positive effect and the most negative effect from the conclusion, we point out the effective policies that can not only accelerate the target of “China's carbon emissions per unit of GDP could be cut down by 40–45% by 2020, from 2005 levels,” but also have crucial significance on the low-carbon economic development strategy of China.

1. Introduction

Nowadays, the world economy is in a period of transition to a low-carbon economy, while China is facing a stage of rapid development of industrialization and urbanization. Economic growth gives rise to the augmentation of energy consumption and CO₂ emissions [1]. China is the largest developing country in the world with the rapid economic development. China's GDP has increased (from 7225.34 to 29533.57 billion Yuan) sharply at the average annual rate of 9.84%, and the per capita GDP has increased (from 5873.91 to 21865.47 Yuan) dramatically at the average annual rate of 9.16% [2]. The total GDP has run up to 5878.61 billion dollars by 2010 exceeding Japan, turning into the second largest economy in the world. At the same time, China's primary energy consumption raised sharply from 1.38 to 3.62 billion ton coal equivalent (tec) during 1997–2012 [2]. With the persistent focus on climate change from all countries in the world, carbon emissions have captured growing attention of our government. China's carbon emissions keep on rising fleetly with relevant energy consumption level, from 3528.02 million tons in 1997 to 9774.47 million tons in 2012. China's energy-related carbon emissions have reached 7.03 billion

tons by 2008, surpassing the United States to become the world's largest emitter for the first time. That makes China's international pressure increase in response to climate change issues. China possesses an ambitious goal to reduce carbon emissions intensity by 40–45% of the 2005 level by 2020. Carbon emissions will constraint China's energy consumption in the process of the increased economy.

The IPAT identity was first proposed by Professors Ehrlich and Holdren to depict the influence on the environment of growing population [3, 4]. Nakicenovic used a reformulation of this IPAT identity known as the Kaya equation to be the basis for the GHG emissions calculations, projections, and scenarios conducted by the Intergovernmental Panel on Climate Change [5]. Two main methods are used for decomposition of carbon emission factors: structural decomposition analysis (SDA) and index decomposition analysis (IDA) [6, 7]. In recent years, many scholars have done multitude research on carbon emissions with the SDA and they found a host of practical significant conclusions [8–11]. Ang put forward the log Mean Divisia Index in the first place [12]. The log Mean Divisia Index (LMDI) can not only be used to decompose multiple factors with zero residual errors, but it can also be used to solve the problem of insufficient

data. With this method, carbon emissions can be resolved quantitatively into several effects [13, 14]. Ang and Wang et al. came to the conclusion by using the LMDI method that economic growth is a leading cause of carbon emissions and energy intensity is seen as essential effect if China's carbon emissions are looked forward to being reduced over the long term [15, 16]. Chunbo, Tunc, and Claudia explained the primary element affecting the change of China's carbon emissions. Turkey and Mexico applied the LMDI approach to decompose carbon emissions [17–19]. Paul and Bhattacharya pointed out that energy intensity, industrial structure, the change of GDP, and emissions from several types of fossil fuels were four effects affecting carbon emissions in India [20]. Sun worked out the differences in carbon emissions intensity from Sweden and Finland [21]. Choi and Ang used the index decomposition methods to analyze carbon emissions from energy consumption [22]. Factors of carbon emission in Turkey were decomposed by Ipek Tunç et al. into economic growth effect, industrial structure effect, energy sources effect, energy efficiency effect, and carbon emission coefficient effect [23]. It is also suitable to study China's energy-related carbon emission by applying the completed decomposition technique [24–29]. Li and Ou analyzed the influence factors of carbon emission intensity in China during 1995–2010 by using the modified LMDI (Kaya) model and obtained that the most crucial negative factor affecting carbon emissions intensity was energy intensity effect [30]. Liu et al. made the decomposition on carbon emission factors for 36 Chinese industrial sectors from 1998 to 2005 by the LMDI method and reached that energy intensity was the top-drawer factor leading to carbon emissions changes [31]. Xu et al. researched factors affecting carbon emissions during 1995–2011 by using LMDI theory and found that the energy intensity was the most paramount inhibitory factor [32]. Wei et al. and Wu et al. pointed to the most significant conclusion on some general information for carbon emissions and the fundamental driving factors [33, 34]. Previous studies have demonstrated that energy-related carbon emissions in China increased significantly in the literature. For example, the growth of cement output largely promotes the energy consumption leading to the increase of carbon emissions in the cement industry. Coal products have been the dominant fuel for thermal power generation and the economic activity effect is the major driving force in carbon emissions in electricity. Residential energy consumption (REC) is China's second-largest energy use category. China's price reform in the field of energy plays a key role in reducing REC. Besides, there is bidirectional causality between carbon emissions and energy consumption based on the panel data, and so do energy consumption and economic growth. According to the studies, some important policies of the empirical results have been put forward in the literature. In contrast, few studies depict the factors affecting carbon emissions from different industries and different species of energy with data.

This study analyzed the influencing factors of CO₂ emissions from eight kinds of energy (coal, coke, crude oil, gasoline, kerosene, diesel oil, fuel oil, and natural gas) in eight industries sectors (excavation; manufacturing; electric power, gas, and water production and supply; agriculture;

construction; transportation, storage, and postal services; wholesale, retail trade, and food services; and other sectors). It is more accurate to decompose CO₂ emissions in every single industry according to the segmentation of carbon dioxide emission coefficient. Then, we probed factors affecting the growth of CO₂ emissions owing to China's energy consumption based on the LMDI model. Most importantly, the method of “contribution value-significant factor-effect coefficient” makes up the deficiency in the concept and algorithm. Besides, we explored the relative effect size of each effect coefficient and gained the most significant positive effect and the most negative effect, making it easier for the government to draw up an array of targeted measures and policy adjustment. However, the inadequacy of this method of effect coefficient may be the case that the contribution value of each effect is 0. In addition, a few shortcomings remain possible in the paper. For CO₂ emissions, coefficient remains the same, so that CO₂ emission intensity effects are considered zero from the results, and this makes how to decompose the effect size be the research direction in the future. Based on the empirical study, we obtain the relative effect size of each factor on CO₂ emissions and put forward a slice of practical policy. These will have the important practical significance on the realization of emission reduction targets and the further development of low-carbon economy.

2. Decomposition Methodology

2.1. IPAT Model. The IPAT accounting model, first proposed by Professors Ehrlich and Holdren in the early 1970s, is a widely applied model to express the impact on environment of economic development [3, 4]. In other words, the environmental problem is the integrated impact of population, economy, and technology. The basic equation of IPAT model can be stated as follows:

$$I = P \times A \times T, \quad (1)$$

where I denotes environment load; P is population; A is GDP per capita, namely, richness degree; and T is environmental load per unit of GDP, that is technology level. The environmental impact equation into the IPAT model of carbon emissions is equivalent to the Kaya model as follows:

$$\text{CO}_2 = P \times \frac{\text{GDP}}{P} \times \frac{E}{\text{GDP}} \times \frac{\text{CO}_2}{E}, \quad (2)$$

where GDP/P denotes richness degree; E/GDP is energy intensity, mostly concerned with technology; CO_2/E is carbon emissions intensity, mostly concerned with energy structure.

According to the relevant knowledge of calculus, (2) can be transformed into the following equation:

$$\begin{aligned} d(\ln \text{CO}_2) &= d(\ln P) + d\left(\ln \frac{\text{GDP}}{P}\right) + d\left(\ln \frac{E}{\text{GDP}}\right) \\ &\quad + d\left(\ln \frac{\text{CO}_2}{E}\right). \end{aligned} \quad (3)$$

This paper verifies China's energy-related carbon emissions changes from 1997 to 2012 by formula (3). The average

annual rate about each parameter on the right of the formula is shown as follows:

$$\begin{aligned} d(\ln P) &= 0.63\%, \\ d\left(\ln \frac{\text{GDP}}{P}\right) &= 9.16\%, \\ d\left(\ln \frac{E}{\text{GDP}}\right) &= -2.77\%, \\ d\left(\ln \frac{\text{CO}_2}{E}\right) &= 0.21\%. \end{aligned} \quad (4)$$

Therefore,

$$\begin{aligned} d(\ln \text{CO}_2) &= 0.63\% + 9.16\% - 2.77\% + 0.21\% \\ &= 6.81\%. \end{aligned} \quad (5)$$

However, the average annual rate of carbon emissions according to real statistic increased by 7.03% is approximately 0.22% of the residuals. We can see that the equation of the Kaya decomposition appeared residual. That is, it caused unbalance at both sides of the equation. Lead, once again, to an inadequate explanation for the change of carbon emissions.

In this paper, China's energy-related CO₂ emissions is decomposed into CO₂ emissions intensity effect, energy structure effect, energy intensity effect, industrial structure effect, economic output effect (per capita GDP), and population effect based on the equation of energy-related carbon emissions as follows:

$$C = \sum_{i,j} C_{i,j} = \sum_{i,j} \frac{C_{i,j}}{E_{i,j}} \times \frac{E_{i,j}}{E_i} \times \frac{E_i}{Q_i} \times \frac{Q_i}{Q} \times \frac{Q}{P} \times P. \quad (6)$$

The following variables appeared in the above equation.

C is the total CO₂ emissions.

$C_{i,j}$ is CO₂ emissions from consumption of fossil fuel j in sector i .

$E_{i,j}$ is energy consumption from fossil fuel j in sector i .

E_i is total energy consumption in sector i .

Q_i is the GDP output of sector i .

Q is GDP.

P is population.

The carbon dioxide emissions utilizing this method can be rewritten as follows:

$$C = \sum_{i,j} C_{i,j} = \sum_{i,j} F_{i,j} \times M_{i,j} \times R_i \times H \times Y \times P. \quad (7)$$

The following definition is adopted within the above magnitude.

$F_{i,j} = C_{i,j}/E_{i,j}$ is the CO₂ emissions coefficient.

$M_{i,j} = E_{i,j}/E_i$ is the share of fossil fuel j over the total fossil fuels in sector i , namely, energy structure effect.

$R_i = E_i/Q_i$ is energy intensity in sector i , namely, energy intensity effect.

$H = Q_i/Q$ is the proportion of economic output in sector i over the total industrial output, namely, industrial structure effect.

$Y = Q/P$ is per capita GDP, that is, economic output effect.

P is population effect.

2.2. On the Decomposition of Carbon Emissions by LMDI. Logarithmic Mean Divisia Index (LMDI II) is a method which is used to decompose CO₂ emissions factors in this research. The following equation indicates the changes in carbon emissions from year 0 to year T :

$$\begin{aligned} \Delta C &= C^T - C^0 \\ &= \Delta C_F + \Delta C_M + \Delta C_R + \Delta C_H + \Delta C_Y + \Delta C_P, \end{aligned} \quad (8)$$

where ΔC represents the total CO₂ emissions change; ΔC_F represents CO₂ emissions intensity; ΔC_M represents energy structure effect; ΔC_R represents energy intensity effect; ΔC_H represents industrial structure effect; ΔC_Y represents economic output effect; and ΔC_P represents population effect. 0 and T represent the base year and the target year. According to Logarithmic Mean Divisia Index theory [12–14], the decomposition results are shown as follows:

$$\begin{aligned} \Delta C_F &= \sum_{i=1}^8 \sum_{j=1}^8 \left[L(C_{i,j}^T, C_{i,j}^0) \times \ln \frac{F_{i,j}^T}{F_{i,j}^0} \right], \\ \Delta C_M &= \sum_{i=1}^8 \sum_{j=1}^8 \left[L(C_{i,j}^T, C_{i,j}^0) \times \ln \frac{M_{i,j}^T}{M_{i,j}^0} \right], \\ \Delta C_R &= \sum_{i=1}^8 \sum_{j=1}^8 \left[L(C_{i,j}^T, C_{i,j}^0) \times \ln \frac{R_i^T}{R_i^0} \right], \\ \Delta C_H &= \sum_{i=1}^8 \sum_{j=1}^8 \left[L(C_{i,j}^T, C_{i,j}^0) \times \ln \frac{H^T}{H^0} \right], \\ \Delta C_Y &= \sum_{i=1}^8 \sum_{j=1}^8 \left[L(C_{i,j}^T, C_{i,j}^0) \times \ln \frac{Y^T}{Y^0} \right], \\ \Delta C_P &= \sum_{i=1}^8 \sum_{j=1}^8 \left[L(C_{i,j}^T, C_{i,j}^0) \times \ln \frac{P^T}{P^0} \right]. \end{aligned} \quad (9)$$

We define

$$L(C_{i,j}^T, C_{i,j}^0) = \begin{cases} \frac{C_{i,j}^T - C_{i,j}^0}{\ln C_{i,j}^T - \ln C_{i,j}^0} & C_{i,j}^T \neq C_{i,j}^0 \\ C_{i,j}^T & C_{i,j}^T = C_{i,j}^0 \end{cases} \quad (10)$$

At the same time, $F \neq 0$, $M \neq 0$, $R \neq 0$, $H \neq 0$, $Y \neq 0$, $P \neq 0$.

Since the CO₂ emissions coefficients of various types of fossil fuels remaining the same, ΔC_F is zero.

The lack of LMDI model, being applied to make the factor decomposition based on the existing references, is the disunity from each impact factor of weighting algorithm, the insufficiency on significance of the positive and negative effects, and the defects of the existing algorithms on “contribution rate.” The specific calculation methods of “contribution rate” can be divided into two kinds: one kind is to use contribution rate of each factor divided by the sum of all factors, getting the “contribution rate” lack of discrimination. Another is to calculate the proportion of each positive (negative) contribution value in all by wielding separately the positive (negative) contribution value, getting the distinction between “positive contribution rate” and “negative contribution rate.” In this paper, the use of the unique algorithm which created “contribution value-significant factor-effect coefficient” to substitute “contribution value-contribution rate” in the former documents overcame the defect of the existing method. This method is suitable in case that the total contribution value of each effect is negative even for the special case of 0. So, a significant comparative research on all influence factors was conducted in this paper to figure out the most significant positive effect and the most negative effect.

The significant factor refers to the ratio of the absolute value of each effect contribution value over the sum of absolute values of each effect contribution value, recording ζ . The greater the significant factor (the maximum value is 1), the more the effect on carbon emissions from the same factor; namely, the effect is more obvious. The smaller the significant factor (the minimum value is 0), the less the effect on carbon emissions from the same factor; namely, the effect is more weak. The definition of each significant factor is shown as follows:

$$\begin{aligned}
 \zeta_F &= \frac{|\Delta C_F|}{|\Delta C_F| + |\Delta C_M| + |\Delta C_R| + |\Delta C_H| + |\Delta C_Y| + |\Delta C_P|}, \\
 \zeta_M &= \frac{|\Delta C_M|}{|\Delta C_F| + |\Delta C_M| + |\Delta C_R| + |\Delta C_H| + |\Delta C_Y| + |\Delta C_P|}, \\
 \zeta_R &= \frac{|\Delta C_R|}{|\Delta C_F| + |\Delta C_M| + |\Delta C_R| + |\Delta C_H| + |\Delta C_Y| + |\Delta C_P|}, \\
 \zeta_H &= \frac{|\Delta C_H|}{|\Delta C_F| + |\Delta C_M| + |\Delta C_R| + |\Delta C_H| + |\Delta C_Y| + |\Delta C_P|}, \\
 \zeta_Y &= \frac{|\Delta C_Y|}{|\Delta C_F| + |\Delta C_M| + |\Delta C_R| + |\Delta C_H| + |\Delta C_Y| + |\Delta C_P|}, \\
 \zeta_P &= \frac{|\Delta C_P|}{|\Delta C_F| + |\Delta C_M| + |\Delta C_R| + |\Delta C_H| + |\Delta C_Y| + |\Delta C_P|}.
 \end{aligned} \tag{11}$$

The significant factor denotes the effect size, relatively. It can not explain its impact properties. Therefore, we introduce a new index called the effect coefficient to consider the influence of specific properties synthetically. Effect coefficient refers to the product between each effect coefficient and the sign of the effect of contribution value, recording e . Effect coefficient, with the sign of positive, indicates that the effect has a positive effect on carbon emissions, called the positive effect. In contrast, we called it the negative effect.

The minus of the effect of contribution value needs to be extracted when counting the effect coefficient, so we draw into the following sign function:

$$\text{Sgn}(x) = \begin{cases} 1, & x > 0, \\ 0, & x = 0, \\ -1, & x < 0. \end{cases} \tag{12}$$

Effect coefficient of each effect is as follows:

$$\begin{aligned}
 e_F &= \text{Sgn}(\Delta C_F) \cdot \zeta_F, \\
 e_M &= \text{Sgn}(\Delta C_M) \cdot \zeta_M, \\
 e_R &= \text{Sgn}(\Delta C_R) \cdot \zeta_R, \\
 e_H &= \text{Sgn}(\Delta C_H) \cdot \zeta_H, \\
 e_Y &= \text{Sgn}(\Delta C_Y) \cdot \zeta_Y, \\
 e_P &= \text{Sgn}(\Delta C_P) \cdot \zeta_P.
 \end{aligned} \tag{13}$$

Because $\text{Sgn}(x) \cdot |x| \equiv x$ is constant for any variable x , the effect coefficient of each effect can be expressed as

$$\begin{aligned}
 e_F &= \frac{\Delta C_F}{|\Delta C_F| + |\Delta C_M| + |\Delta C_R| + |\Delta C_H| + |\Delta C_Y| + |\Delta C_P|}, \\
 e_M &= \frac{\Delta C_M}{|\Delta C_F| + |\Delta C_M| + |\Delta C_R| + |\Delta C_H| + |\Delta C_Y| + |\Delta C_P|}, \\
 e_R &= \frac{\Delta C_R}{|\Delta C_F| + |\Delta C_M| + |\Delta C_R| + |\Delta C_H| + |\Delta C_Y| + |\Delta C_P|}, \\
 e_H &= \frac{\Delta C_H}{|\Delta C_F| + |\Delta C_M| + |\Delta C_R| + |\Delta C_H| + |\Delta C_Y| + |\Delta C_P|}, \\
 e_Y &= \frac{\Delta C_Y}{|\Delta C_F| + |\Delta C_M| + |\Delta C_R| + |\Delta C_H| + |\Delta C_Y| + |\Delta C_P|}, \\
 e_P &= \frac{\Delta C_P}{|\Delta C_F| + |\Delta C_M| + |\Delta C_R| + |\Delta C_H| + |\Delta C_Y| + |\Delta C_P|}.
 \end{aligned}$$

$$e_p = \frac{\Delta C_p}{|\Delta C_F| + |\Delta C_M| + |\Delta C_R| + |\Delta C_H| + |\Delta C_Y| + |\Delta C_P|} \quad (14)$$

The formulas (14) stand for the effect coefficient of each factor on carbon emissions. These formulas can clearly reflect the extent of influence and the characteristics of impact. The positive effect coefficient shows that the effect can promote the increase of carbon emissions. On the contrary, the negative effect coefficient indicates the inhibition of carbon emissions.

3. Date and Analysis

3.1. Sources of Data. This paper chose the period from 1997 to 2012 to make the factor decomposition on China's carbon emission, considering that a legally binding Kyoto Protocol was signed in 1997, setting the mandatory emissions targets for the first time. China subsequently joined in WTO in 2001, carbon emission drastically increase with the rapid economic growth in the next few years. The government proposed that the target of "Carbon emissions per unit of GDP could be cut down by 17% by 2015, from 2010 levels." The change of policy after 2012 would greatly affect the trend of carbon emissions. To highlight the degree of influence of each effect at these tipping points, we employed the data during 1997–2012. In addition, the data sources could support longer period for the study based on the accessibility and authenticity of data.

This paper draws up a detailed analysis of the economic output and the energy consumption in all sectors (excavation; manufacturing; electric power, gas, and water production and supply; agriculture; construction; transportation, storage, and postal services; wholesale, retail trade, and food services; other sectors). The part mainly analyzes the energy consumption of coal, coke, crude oil, gasoline, kerosene, diesel oil, fuel oil, and natural gas. This research employed annual data of GDP and population and energy consumption from China Statistical Yearbook [1]. GDP and the economic output (billion Yuan) are transformed to unified standard prices for the base period of 1997. The population data are calculated with the average from the end of the adjacent two years. The energy consumption of all departments is transformed into ton coal equivalent (tec) based on Intergovernmental Panel on Climate Change (IPCC) [35]. The energy consumption unit is defined as million tons of standard coal and carbon emissions are set at millions of tons.

Because the data involved range during the calculation of CO_2 is wide, normally the compilation of emission inventory is conducted by the government and research institutions. Currently, there are massive ways of compiling emission inventory, yet no unified and authoritative method has been formed, especially the research on oxidation coefficient of different fuels. This paper referred to a slice of methods provided from researches of IPCC and other scholars and then improved the calculation method of carbon emissions by subdividing the carbon emissions coefficient. With the improved method, we calculated the carbon emissions

FIGURE 1: Energy consumption in China from 1997 to 2012.

of energy consumption in eight sectors and obtained the energy-related carbon emissions from 1997 to 2012.

The specific calculation formulas are shown as follows:

$$C = \sum_{i,j} C_{i,j} = \sum_{i=1}^8 \sum_{j=1}^8 E_{i,j} \times K_{i,j}, \quad (15)$$

$$K_{i,j} = Q_j \times N_j \times O_{i,j},$$

where $C_{i,j}$ denotes CO_2 emissions from consumption of fossil fuel j in sector i , $E_{i,j}$ denotes energy consumption of fossil fuel j in sector i , $K_{i,j}$ denotes CO_2 emissions coefficient of fossil fuel j in sector i , Q_j denotes the average net calorific value, N_j denotes carbon emissions factor of fossil fuel j , and $O_{i,j}$ denotes carbon oxidation coefficient of fossil fuel j in sector i .

3.2. Analysis of Data. The results of energy-related CO_2 emissions coefficient according to the improved method are shown in Table 1. Energy consumption and CO_2 emissions from each department during 1997–2012 are shown in Tables 2 and 3.

Energy activity is an important source of carbon emissions in China. The phenomenon on the incomplete combustion of energy occurs frequently in the process of burning. Thus, besides considering the emission factors of the whole energy, we need to consider the coefficient of oxidation of all energy. Table 1 indicates carbon emissions coefficient of energy in each department. It will be a more precise way to solve energy-related carbon emissions with the segmentation of carbon emissions coefficient.

Figure 1 demonstrates the various kinds of energy consumption from 1997 to 2012. Figure 3 demonstrates industrial energy consumption, the total energy consumption, and energy-related CO_2 emissions. As shown in Figure 3, the trend of energy-related CO_2 emissions in the industry is broadly in line with the total CO_2 emissions. There is

TABLE 1: Carbon dioxide emission coefficient for various departments (unit: KgCO₂/Kg).

Year	Excavation	Manufacturing	Electric power, gas, and water production and supply	Agriculture	Construction	Transportation, storage, and postal services	Wholesale, retail trade, and food services	Other
Coal	1.7781	1.7781	1.7781	1.5823	1.5823	1.5823	1.5823	1.7781
Coke	2.9513	2.9513	2.9513	2.9513	2.9513	2.9513	2.9513	2.9513
Crude oil	3.0038	3.0038	3.0038	3.0038	3.0038	3.0038	3.0038	3.0038
Gasoline	2.9251	2.9251	2.9251	2.9251	2.9251	2.9251	2.9251	2.9251
Kerosene	3.0179	3.0179	3.0179	3.0179	3.0179	3.0179	3.0179	3.0179
Diesel oil	3.0973	3.0973	3.0973	3.0973	3.0973	3.0973	3.0973	3.0973
Fuel oil	3.1683	3.1683	3.1683	3.1683	3.1683	3.1683	3.1683	3.1683
Natural gas	21.6219	21.6219	21.6219	21.6219	21.6219	21.6219	21.6219	21.6219

TABLE 2: Annual time series of energy consumption in China from 1997 to 2012 (unit: Mtce).

Year	Coal	Coke	Crude oil	Gasoline	Kerosene	Diesel oil	Fuel oil	Natural gas
1997	994.65	106.14	248.11	48.73	10.03	77.10	54.98	24.02
1998	924.96	107.61	248.51	48.98	9.88	76.97	54.70	24.90
1999	902.63	101.58	270.71	49.74	12.13	90.80	56.20	26.42
2000	1007.82	105.31	303.32	51.57	12.82	99.17	55.33	30.12
2001	972.29	115.90	304.90	52.93	12.00	104.30	55.00	28.54
2002	1027.66	119.91	322.06	55.17	12.93	111.71	55.34	30.19
2003	1225.61	148.61	356.04	59.92	13.03	122.53	60.29	35.30
2004	1412.84	175.50	410.71	69.09	15.21	144.19	68.34	40.50
2005	1656.11	243.88	429.81	71.43	15.84	159.88	60.60	57.47
2006	1821.93	270.95	460.65	77.14	16.55	172.45	62.41	69.00
2007	1948.22	283.34	486.18	81.21	18.30	182.09	59.39	86.67
2008	2007.87	290.45	507.13	90.43	19.04	197.18	46.25	99.91
2009	2113.14	309.39	544.71	90.82	21.18	200.45	40.40	110.02
2010	2230.31	327.24	612.51	101.32	25.66	213.23	53.69	131.43
2011	2449.69	370.72	628.10	108.82	26.73	227.82	52.33	160.42
2012	2518.96	382.47	666.86	119.79	28.79	247.21	52.62	179.80

a continued gently rising trend of energy consumption during 1997–2002 and 2006–2010, and so do CO₂ emissions. During 2002–2006, energy consumption increased rapidly along with CO₂ emissions corresponding to the rapid rise. Energy consumption has a fast-growing trend during 2010–2012 too. The total energy consumption increased at an average annual rate of 6.80% (from 1563.76 to 4196.49 million tons), and CO₂ emissions were raised at an average annual rate of 7.03% (from 3528.02 to 9774.47 million tons) during 1997–2012. China's primary energy consumption grew from 1381.73 million tons to 3617.32 million tons. The ratio of coal (coal and coke) over the total energy consumption gently reduced from 70.39% to 69.12%, the proportion of oil (crude oil, gasoline, kerosene, diesel oil, and fuel oil) decreased from 28.07% to 26.58%, and the ratio of natural gas sharply increased from 1.58% to 4.32%. Despite the fact that the consumption of natural gas accounts for the proportion increases year by year, coal consumption has been the main energy consumption (the proportion is about 70%). Therefore, CO₂ emissions are mainly caused by the consumption of coal. This makes the control of coal become the main way to reduce CO₂ emissions.

Figure 2 demonstrates energy-related CO₂ emissions in the eight sectors from 1997 to 2012. As shown in the chart, because of the rapid development of manufacturing industry and electric power, gas, and water production and supply industry, CO₂ emissions from manufacturing industry which is the largest sector of CO₂ emissions account for more than 50% of total CO₂ emissions, exceeding the ratio over 30% from electric power, gas, and water production and supply industry. The transportation industry accounts for about 5%.

Carbon dioxide emissions slightly increased at an average annual rate of 3.17% during 1997–2002, sharply increased at an average annual rate of 13.71% during 2002–2006, and then increased at an average annual rate of 5.71% during 2006–2010, with a 6.55% increase during 2010–2012. Combined with Figures 1–3, energy consumption and CO₂ emissions had a growing trend since China joined WTO in 2001 and kept a gentle increase tendency because of the global financial crisis in 2008. Overall, China's CO₂ emissions rapidly grow at an average annual rate of 7.03% from 1997 to 2012. It is urgent to control the rapid growth of CO₂ emissions, especially to enhance the management level in the manufacturing

TABLE 3: Annual time series of carbon dioxide emissions in China during 1997–2012.

Year	Excavation	Manufacturing	Electric power, gas, and water production and supply	Agriculture	Construction	Transportation, storage, and postal services	Wholesale retail trade, and food services	Other
1997	312.63	1921.08	973.50	77.14	15.68	137.05	26.12	64.82
1998	282.65	1831.24	965.93	78.47	20.07	152.37	28.28	59.52
1999	273.86	1807.17	989.19	78.89	19.51	174.61	30.69	66.04
2000	340.43	2006.27	1082.04	42.95	20.79	211.27	28.41	67.31
2001	339.58	2054.86	1141.15	43.79	20.88	216.85	28.03	68.47
2002	327.23	2093.60	1303.91	47.21	21.48	231.68	28.89	70.52
2003	401.22	2430.96	1549.97	53.90	22.70	260.28	30.71	75.13
2004	302.95	2970.25	1778.53	65.18	26.53	309.43	34.63	88.41
2005	360.40	3373.23	1971.85	73.37	29.06	347.12	39.08	87.80
2006	373.27	3665.59	2231.64	75.63	31.58	383.36	41.54	93.12
2007	414.58	3815.56	2452.00	71.58	31.55	415.53	44.29	101.69
2008	434.65	4009.35	2493.91	67.46	29.96	429.96	41.92	102.65
2009	468.05	4208.16	2644.60	69.55	32.82	442.46	47.67	104.40
2010	521.82	4562.88	2764.34	74.30	37.66	485.88	49.55	113.03
2011	552.50	4908.10	3109.14	77.87	39.95	528.07	55.57	124.56
2012	585.31	5115.06	3174.20	80.34	39.39	586.52	60.02	133.63

FIGURE 2: Carbon dioxide emissions of different sectors in China from 1997 to 2012.

and electric power, gas, and water production and supply industry.

4. Factors Decomposition of CO₂ Emissions

4.1. Results of Decomposition. According to IPAT equation and improved LMDI theory [15], carbon dioxide emissions are decomposed into six influential factors, including CO₂

FIGURE 3: Energy consumption and CO₂ emissions in China from 1997 to 2012.

emissions intensity effect, energy structure effect, energy intensity effect, industrial structure effect, economic output effect, and population effect; we also figured out the total effect for energy-related CO₂ emissions and the contribution value of each effect in China from 1997 to 2012. The results are shown in Tables 4 and 5.

It can be seen from Table 4 that the energy structure effect has negative impact on CO₂ emissions every year during 1997–1999 and 2006–2010 and 2001–2002 and 2003–2004 and

TABLE 4: Annual time series decomposition results from 1997 to 2012 (unit: million tons).

Year	Total effect	Energy structure effect	Energy intensity effect	industry structure effect	Economic output effect	Population effect
1997-1998	-109.4871	-1.7313	-275.6457	-93.7646	228.3628	33.2918
1998-1999	21.4415	-14.0674	-200.1312	-16.0364	222.0020	29.6745
1999-2000	359.4614	0.2811	25.1612	41.7187	263.8472	28.4531
2000-2001	114.1639	4.4553	-150.5583	-47.1924	279.4508	28.0084
2001-2002	211.1651	-4.4379	-104.3862	-29.1264	322.2080	26.9076
2002-2003	700.3627	16.0271	171.1570	86.8637	398.5222	27.7928
2003-2004	748.1505	-3.9766	215.8047	38.9266	466.6497	30.7462
2004-2005	705.9677	42.1127	-42.0590	71.8748	599.2378	34.8015
2005-2006	613.8349	4.8132	-223.0458	46.3947	748.9156	36.7572
2006-2007	451.0658	-3.2350	-376.1556	-111.5281	904.8411	37.1434
2007-2008	262.7867	-9.3576	381.5340	-796.9310	649.2422	38.2991
2008-2009	407.8675	-0.2058	11.0418	-291.3561	649.5419	38.8457
2009-2010	591.6323	-18.2824	-130.1869	-85.3780	785.3577	40.1220
2010-2011	786.2802	15.8330	146.4642	-175.8375	756.7241	43.0964
2011-2012	378.7056	-11.9456	-52.5474	-443.0089	839.5163	46.6913
1997-2012	6243.3986	16.2825	-603.5531	-1804.3810	8114.4194	520.6308

TABLE 5: Annual time series effect coefficient for each contribution value from 1997 to 2012.

Year	Total effect	Energy structure effect	Energy intensity effect	industry structure effect	Economic output effect	Population effect
1997-1998	-0.1730	-0.0027	-0.4356	-0.1482	0.3609	0.0526
1998-1999	0.0445	-0.0292	-0.4153	-0.0333	0.4607	0.0616
1999-2000	1.0000	0.0008	0.0700	0.1161	0.7340	0.0792
2000-2001	0.2240	0.0087	-0.2954	-0.0926	0.5483	0.0550
2001-2002	0.4335	-0.0091	-0.2143	-0.0598	0.6615	0.0552
2002-2003	1.0000	0.0229	0.2444	0.1240	0.5690	0.0397
2003-2004	0.9895	-0.0053	0.2854	0.0515	0.6172	0.0407
2004-2005	0.8935	0.0533	-0.0532	0.0910	0.7584	0.0440
2005-2006	0.5791	0.0045	-0.2104	0.0438	0.7066	0.0347
2006-2007	0.3148	-0.0023	-0.2625	-0.0778	0.6315	0.0259
2007-2008	0.1401	-0.0050	0.2034	-0.4249	0.3462	0.0204
2008-2009	0.4116	-0.0002	0.0111	-0.2940	0.6554	0.0392
2009-2010	0.5585	-0.0173	-0.1229	-0.0806	0.7414	0.0379
2010-2011	0.6910	0.0139	0.1287	-0.1545	0.6650	0.0379
2011-2012	0.2717	-0.0086	-0.0377	-0.3179	0.6024	0.0335
1997-2012	7.3788	0.0246	-1.1043	-1.2573	9.0584	0.6574

2011-2012, but it has a positive impact during 1999-2001 and 2004-2006 and 2002-2003 and 2010-2011. The energy intensity effect has a negative impact during 1997-1999 and 2000-2002 and 2004-2007 and 2009-2010 and 2011-2012, while the rest of years stay positive. The industry structure effect has negative impact on CO₂ emissions every year during 1997-1999 and 2000-2002 and 2006-2012, yet it has a positive one during 2002-2006. The economic output effect and population scale effect play the same roles of positive impact for CO₂ emissions during 1997-2012. Figure 4 shows that there are generally the similar trends between effect

coefficient of industrial structure and total effect coefficient. Therefore, we can draw a conclusion that the change trend of industrial structure can directly affect the total effect.

As can be seen clearly from Figure 3, the changes of CO₂ emissions can be divided into four stages: the first stage (from 1997 to 2002) is that CO₂ emissions increases smoothly; the second (from 2002 to 2006) is that CO₂ emissions raises high speed; the third (from 2006 to 2010) is the slow growth of CO₂ emissions; the final session (from 2010 to 2012) involves the large scale rise of CO₂ emissions year by year. This paper made a more specific decomposition on four stages and

TABLE 6: Various stages of decomposition effect based on LMDI during 1997–2012.

Year	1997–2002	2002–2006	2006–2010	2010–2012
Contribution value				
ΔC_M	−15.5004	58.9763	−31.0808	3.8874
ΔC_R	−705.5600	121.8569	−113.7667	93.9168
ΔC_H	−144.4011	244.0598	−1285.1932	−618.8465
ΔC_Y	1315.8709	2213.3253	2988.9829	1596.2404
ΔC_P	146.3353	130.0976	154.4102	89.7877
Significant factors				
M	0.0260	0.0213	0.0181	0.0033
R	1.1823	0.0440	0.0664	0.0806
H	0.2420	0.0882	0.7501	0.5312
Y	2.2051	0.7995	1.7445	1.3702
P	0.2452	0.0470	0.0901	0.0771
Effect coefficient				
M	−0.0260	0.0213	−0.0181	0.0033
R	−1.1823	0.0440	−0.0664	0.0806
H	−0.2420	0.0882	−0.7501	−0.5312
Y	2.2051	0.7995	1.7445	1.3702
P	0.2452	0.0470	0.0901	0.0771
The most significant positive effect	Y	Y	Y	Y
The most significant negative effect	R	NO	H	H

FIGURE 4: Effect coefficients of each contribution value from 1997 to 2012.

obtained the most significant positive effect and the most negative effect of each stage. The decomposition results are as shown in Table 6.

As seen from Table 6, the most significant positive effect of each stage is always the economic output effect (per capita GDP). In recent years, the most significant negative effect is the industrial structure effect in all stages. However, the national government does not pay enough attention to the industry structure effect. If we intend to reduce CO₂ emissions dramatically, we should strengthen the adjustment of industrial structure.

4.2. Energy Structure Effect. The energy structure means the pose and proportion of the primary energy and secondary energy in the total output or consumption of energy. The amount of carbon emissions from fossil fuels is different based on the IPCC in 2006 [35]. This paper took the lower limit value of emission factors, respectively, from coal, oil, and natural gas for reference, such that coal was 94600 KG/TJ, oil was 73300 KG/TJ, and natural gas was 56100 KG/TJ. At the same time providing the same heat, carbon emissions from three types of fuel are not identical and we can know carbon emissions from coal are 1.29 and 1.69 times higher than oil and natural gas, relatively. Therefore, energy structure has a great impact on carbon emissions in case of having the same heat.

Figure 5 announces that energy structure effect is roughly in line with the trend of effect coefficient. Two stages where energy structure effect has negative impact on CO₂ emissions during 1997–2000 and 2006–2012 restrain the increase of carbon emissions. From Figure 3, CO₂ emissions keep smoothly moving in the two stages. As seen from Figure 6, coal is the main source of energy consumption, followed by oil and natural gas. Moreover, the trend upon yearly changes of coal consumption is very consistent with the trend of energy structure effect. This illustrates that the ratio of coal consumption directly affects carbon emissions, with other factors almost remaining unchanged. Since China joined WTO in 2001, the rapid development of economy promotes energy consumption, especially a large number of coal consumption during the period of 2004–2005. As shown in Figure 5, the obvious fluctuation from the coefficient of energy structure effect also intensified the growth of CO₂

FIGURE 5: Energy structure effect and effect coefficient for carbon dioxide emissions in China during 1997–2012.

FIGURE 6: Consumption of coal, oil and natural gas, and the change quantity during 1997–2012.

emissions. Coal consumption drastically reduced due to the impact of the financial crisis of 2008, and China's energy structure still focused on coal. In recent years, although the use of hydropower and other renewable energy sources has increased, the proportion of coal consumption in the energy structure is still too high.

4.3. Energy Intensity Effect. Energy intensity refers to the ratio of energy utilization and economic output reflects economic benefits from energy utilization. Energy intensity in this paper refers to the ratio of energy consumption in each sector and economic output in each sector. The higher the energy intensity, the more the carbon emission of per unit GDP. Energy intensity is a uniform metric of the input-output property of the energy structure in units of energy per unit of GDP and exhibits the level of efficiency from energy and economic behavior. Ideally, there is a powerful conception to see the decrease of energy intensity as a symbol of the

FIGURE 7: Energy intensity effect and effect coefficient for carbon dioxide emissions in China during 1997–2012.

improvement of energy efficiency, which is usually caused by technological advance. The reduction of energy intensity will have a negative impact on carbon emissions on condition that other factors maintain unchanged.

In Figure 7, the trend of energy intensity effect is basically consistent with the trend of effect coefficient. The energy intensity effect had a negative influence on carbon emissions during 1997–1999 and 2000–2002 and 2004–2007 and 2009–2010 and 2011–2012, with the opposite during the rest of years. Energy intensity effect can cause the inhibition of carbon emissions. Energy consumption sharply increased with the rapid development of economy after joining WTO; energy intensity effect would, of course, rise, gradually increasing the positive impact, and then become a positive driving force of carbon emissions. The fluctuation of energy intensity effect coefficients at the same stage illustrates that the share of energy intensity effect is also increasing. Over the next few years, the state has already begun to put a tighter lid on its efficiency of energy utilization, and energy intensity effect falls subsequently, having been in inhibition.

4.4. Industrial Structure Effect. Industrial structure refers to the proportion of economic output in each sector accounted for GDP. As seen from Table 1, the decomposed results in this research illustrate that industrial structure effect is the uppermost negative driving force to carbon emissions. According to the previous literatures [24–27], it is not strange that it has not been noticed by policymakers before, since the inhibitory effects of industrial structure on CO_2 emissions are not so obvious. From the analysis data of research in the paper, that is mostly because industrial structure effect has been the negative driving force during 2006–2012, especially during the period of 2010–2012 (from 2010 to 2011 is -175.8375 and from 2011 to 2012 is -443.0089), we can see that industrial structure effect to a large extent restrains the growth of CO_2 emissions. As shown in Figure 8, due to the impact of global financial crisis of 2008, there was a sharp decline in industrial structure effect and effect coefficient also dropped significantly. The inhibitory effect on CO_2 emissions this moment is very obvious and the proportion is up to 40%.

TABLE 7: Department decomposition results of industrial structure effect from 1997 to 2012.

Sector	1997–2012	1997–2002	2002–2006	2006–2010	2010–2012
Excavation	59.28	−17.36	28.06	−28.32	76.89
Manufacturing	−301.59	−108.29	185.24	−55.09	−323.45
Electric power, gas, and water production and supply	−1502.79	−57.94	71.32	−1130.58	−385.60
Agriculture	−38.64	−17.55	−14.26	−6.82	0.00
Construction	5.83	−1.76	1.83	4.60	1.16
Transportation, storage, and postal services	−65.78	28.94	−28.27	−71.89	5.45
Wholesale retail trade, and food services	6.89	1.58	−2.35	4.54	3.10
Other	32.42	27.96	2.49	−1.63	3.60
Total industrial structure effect	−1804.38	−144.40	244.06	−1285.19	−618.85

FIGURE 8: Industrial structure effect and effect coefficient for carbon dioxide emissions in China during 1997–2012.

The adjustment strength on industrial structure from state continuously strengthens in recent years. There is a further decomposition on different stages of industrial structure effect in different industries from 1997 to 2012 from Table 7 and it is gained that the most significant inhibition impacts on China's CO₂ emissions in every stage are manufacturing sector and electric power, gas, and water production and supply sector. The reason why industrial structure effect has prominent negative impact is that the specific weight of economic output in manufacturing and electric power, gas, and water production and supply sectors over the national GDP is decreasing. Government should properly adjust the economic output in manufacturing and electric power, gas, and water production and supply sectors to effectively control carbon emissions.

4.5. Economic Output Effect. Economic output effect called per capita GDP reflects the social average living standards and macroeconomic performance. As for the developing countries, carbon emission caused by consumption patterns is higher when per capita GDP is higher. It is an effective tool to understand and grasp the macroeconomic performance of a country or region. It mirrors both the growth of economy and quality of life of much of the world's population. Energy is the key ingredient, which stands by economic development. Conversely, energy consumption rises thanks

FIGURE 9: Economic output effect and effect coefficient for carbon dioxide emissions in China during 1997–2012.

to the rapid urbanization and industrialization, and so does carbon emission. In general, carbon emissions and economic development are closely bound up. From Table 4, the per capita GDP is the supreme positive driving factor to CO₂ emissions during 1997–2012. As analyzed from Figure 9, economic output effect had been rising from 1997 to 2007, peaked in 2007, and started to fall subsequently. Owing to the global financial crisis of 2008, it basically maintained mild in the period from 2008 to 2009 and broadly remained flat for the period from 2007 to 2008. However, the effect coefficient of economic output has a significant increase compared to the last year. This illustrates that all the effects being affected by the global financial crisis lead to the addition in the proportion of per capita GDP over total effects. During 1997–2012, the national GDP (from 7225.34 to 29533.57 billion Yuan) is raised at an average annual rate of 9.84%. Meanwhile, per capita GDP was enhanced at an average annual rate of 9.16%. The growth of per capita GDP led directly to the build-up of carbon emissions. Accordingly, economic output is one of the significant factors that should be considered to take an array of down-to-earth measures to cut carbon emissions.

4.6. Population Scale Effect. Population scale effect refers to the influence of demographic shifts on carbon emissions.

FIGURE 10: Population scale effect and effect coefficient for carbon dioxide emissions in China during 1997–2012.

With the accelerated progress of urbanization, a substantial increase in carbon emissions results from the dramatic growth of the city population.

Table 4 reveals that the population scale effect plays a positive role on CO_2 emissions, and we can see that carbon emissions will grow if population increases. The increase in population associated with the urbanization which is the significant factor of the massive cement demand in big cities and traffic infrastructure construction can set off the growing carbon emissions. On the other hand, energy consumption caused by accretion of population might promote carbon emissions as well. Figure 10 reveals that population effect has maintained an upward trend since 2011, while the population effect coefficient has been in a downward trend. The results illustrate that the share of population effect is coming down. Nevertheless, thanks to the impact of the financial crisis, the contribution value of each effect has a drop while the share of population effect has risen.

This paper counts the aggregate contribution of each effect on CO_2 emissions during 1997–2012 on the basis of factor decomposition of LMDI. As a whole, economic output effect, population effect, and energy structure effect are positive driving forces on CO_2 emissions; and energy intensity effect and industrial structure effects have done just the opposite. As shown in Figure 11, the economic output effect (share of contribution is 129.97%) has a primary positive impact on CO_2 emissions, with the impact of population effect (8.34%) and energy structure effect (0.26%) being in the next place. We are not fully aware that we can tinker up energy structure which is the cardinal inhibiting element contributing -28.90% to debase CO_2 emissions. The energy intensity effect plays the part of inhibitory action with the contribution value of -9.67% .

5. Summaries and Policy Applications

5.1. Summaries. This research aims at ascertaining the cardinal element affecting CO_2 emissions in China to furnish a succession of down-to-earth policies with the low-carbon

FIGURE 11: The contribution of different effects to carbon emissions in China during 1997–2012.

economy concerned. The energy-related CO_2 emissions are resolved into energy structure, energy intensity, industrial structure, economic output, and population scale effects. We seek in depth the elements affecting China's carbon dioxide emissions from diverse industries and multiple kinds of fossil fuels. This paper has a more rounded strategy compared with the most existing decomposition of China when it comes to diverse industries and multiple kinds of fossil fuels in China in particular. The decomposed results are summarized as follows.

- (1) This paper fosters a new weight determination method by drawing “contribution value-significant factor-effect coefficient” and applies effect coefficient of each contribution value to character the size of relative effect on carbon emissions. Furthermore, we make further efforts to divide up the most significant positive effect and the most negative effect of four years period. As acquired from the research, the most significant positive effect has always been economic output effect from 1997 to 2012. The most significant negative effect in recent years is the industrial structure effect. This method provides the comprehensive and intuitive analyses of the factors affecting carbon dioxide emissions and it is more convenient for the government to furnish a succession of down-to-earth policies and targeted policy shift.
- (2) The total energy consumption increased at an average annual rate of 6.80% and CO_2 emissions raised at an average annual rate of 7.03% during 1997–2012. The ratio of coal over the total energy consumption gently reduced from 70.39% to 69.12%, the proportion of oil decreased from 28.07% to 26.58%, and the ratio of natural gas sharply increased from 1.58% to 4.32%. Despite the fact that the consumption of natural gas accounts for the proportion increases year by year, coal consumption has been the cardinal energy consumption.

- (3) Through the empirical analysis, it is informed that there exists coherent tendency between industrial CO₂ emissions and the total CO₂ emissions, by and large. The supreme origin of China's carbon emissions is industry, in which manufacturing and electric power, gas, and water production and supply are the sectors above the average of energy consumption. Manufacturing is the largest department of CO₂ emissions accounting for more than 50%, followed by electric power, gas, and water production and supply sector with 30%; the last is excavation with 5%. Generally speaking, carbon emissions are largely caused by energy consumption in industry. During 1997–2012, the share of coal consumption changed from 85.12% to 87.81% in industry, the ratio of coal consumption in manufacturing varied from 79.12% to 77.51%, while the ratio in electric power, gas, and water production and supply sector was modified from 96.91% to 99.82%.
- (4) As a whole, economic output possesses the significant positive impact on carbon emissions, and population effect and energy structure effect followed. Xu et al. stated that economic output effect with the contribution of 159.41% was shown to be the cardinal driving force, and population effect (5.51%) and energy structure effect (2.64%) followed. On the contrary, the energy intensity effect acted as the key constraining force with −61.52%, and the industrial structure effect with −6.04% followed [32]. Our empirical study emphasizes that economic output effect is shown to be the cardinal driving force in China's CO₂ emissions with 129.97%, and population effect with 8.34% and energy structure effect with 0.26% followed. The industrial structure acts as a master brake on China's CO₂ emissions contributing −28.90%, whose potential has not been explored for the moment, even if energy intensity effect (−9.67%) holds a certain degree of inhibition impact on CO₂ emissions. Compared with the previous studies, the reason why industrial structure effect possesses the prominent inhibitions on CO₂ emissions is that the state strengthens the supervision of industrial production in recent years. The specific weight of economic output in manufacturing and electric power, gas, and water production and supply sectors over GDP drops significantly. Therefore, the government ought to carry out an army of measures to manipulate carbon emissions.

5.2. Policy Applications. At present, an ocean of vital sectors still relies heavily on the low price of energy in China. The approach of low-carbon economy prefers to draw attention to other facets rather than transform the energy structure. A round of targeted steps should be drawn up to boost the goal of “energy intensity could lessen 16%” in the 12th Five-Year Plan Outline and the target of “China aims to cut carbon emissions per unit of GDP by 40–45% at the level of 2005 by 2020.” Accordingly, we put forward the following tips.

The first and foremost, it is gained that coal is the largest origin of energy consumption based on the carbon emissions coefficients from Intergovernmental Panel on Climate Change (IPCC) [35]. The long-term circumstance will hold the line in virtue of the trait of energy structure in China and the high share of coal consumption. In addition, carbon emissions would absolutely augment as a result of the industrialization and urbanization. Since coal has always been and will remain as the uppermost origin of energy consumption, one of the top-drawer elements to minify carbon emissions is energy substitution. An array of less-polluting energy which contained certain renewable energy such as wind or sunlight or tidal energy, natural gas, and nuclear power could be applied taking the place of coal to dominate emissions. The country ought to strengthen the degree of the development of new energy and develop the technology of both high energy-efficient and clean fuel energy. It is a vital avenue for disposing energy crisis and cutting down the carbon emissions caused by fossil energy consumption to capitalize on renewable energy in China.

There is one more point; according to the results from this research, energy intensity effect is an inhibitory factor. Accordingly, we should reduce the energy intensity and improve energy utilization efficiency. China ought to transform the pattern of economic growth and capture its attention to both the quantity and the quality of its growth to boost shift from extensive economy to intensive. China ought to regard the development of light industry whose energy intensity has a relatively low level and products with higher margins as all-important task. On the other hand, China ought to speed up weeding out the laggard production processes and facility to arouse industrial technological innovation.

The last but not the least, China ought to adjust and optimize the industrial structure to cut down the share of industry over the national economy and quicken the development of the tertiary industry. In the paper, industrial structure effect plays the crucial negative part on CO₂ emissions. The government should put the greatest emphasis on economic output of manufacturing sector and electric power, gas, and water production and supply sector. China is obliged to expedite the step of industrial structure which needs to be adjusted, enhance scientific input, and focus on high-technology industries to effectively depress carbon emissions.

Conflict of Interests

The authors declare that there is no conflict of interests.

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