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Decomposition and Decoupling Analysis of Carbon Emissions in Xinjiang Energy Base, China

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Abstract: China faces a difficult choice of maintaining socioeconomic development and carbon emissions mitigation. Analyzing the decoupling relationship between economic development and carbon emissions and its driving factors from a regional perspective is the key for the Chinese government to achieve the 2030 emission reduction target. This study adopted the logarithmic mean Divisia index (LMDI) method and Tapio index, decomposed the driving forces of the decoupling, and measured the sector's decoupling states from carbon emissions in Xinjiang province, China. The results found that: (1) Xinjiang's carbon emissions increased from 93.34 Mt in 2000 to 468.12 Mt in 2017. Energy-intensive industries were the key body of carbon emissions in Xinjiang. (2) The economic activity effect played the decisive factor to carbon emissions increase, which account for 93.58%, 81.51%, and 58.62% in Xinjiang during 2000–2005, 2005–2010, and 2010–2017, respectively. The energy intensity effect proved the dominant influence for carbon emissions mitigation, which accounted for −22.39% of carbon emissions increase during 2000–2010. (3) Weak decoupling (WD), expansive coupling (EC), expansive negative decoupling (END) and strong negative decoupling (SND) were identified in Xinjiang during 2001 to 2017. Gross domestic product (GDP) per capita elasticity has a major inhibitory effect on the carbon emissions decoupling. Energy intensity elasticity played a major driver to the decoupling in Xinjiang. Most industries have not reached the decoupling state in Xinjiang. Fuel processing, power generation, chemicals, non-ferrous, iron and steel industries mainly shown states of END and EC. On this basis, it is suggested that local governments should adjust the industrial structure, optimize energy consumption structure, and promote energy conservation and emission reduction to tap the potential of carbon emissions mitigation in key sectors.

Keywords: decoupling; carbon emissions; analysis; Xinjiang

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1. Introduction

It is undisputed that greenhouse gases accelerated the speed of global warming from Intergovernmental Panel on Climate Change reports [1,2]. Greenhouse gases are regarded as the key reason for global warming [3], while carbon emissions from fossil fuel combustion are regarded as the direct contributor to greenhouse gases [4]. In the context of global warming, carbon emissions have become a strong focus in academia [5,6]. Given that, countries have joined in the procession of carbon emissions mitigation. Since 1978, China has experienced sustained growth and has become the fastest growing country in the whole world [7]. This, along with rapid socioeconomic development, has made China the largest carbon-emitting country [8]. In the meantime, China is also facing continuous international pressure to slow down carbon emissions. As a responsible nation, China declared to achieve the carbon emissions peak by around 2030 [9]. To achieve these ambitious goals, China urgently needs to coordinate carbon emissions and socioeconomic development. Currently, China is still in the process of rapid development, and maintaining the economic growth to abate carbon emissions is still a huge challenge [10]. On the premise of not damaging the stable socioeconomic development, and achieving a win-win situation between economic growth and carbon emission reduction, China must speed up the process of decoupling its economy from carbon emissions [11]. Currently, studies about the relationship between carbon emissions and socioeconomic development can be divided into three classifications. The first is using the Kuznets theory to identify the relationship between economic growth and environmental pollution, but it cannot effectively identify the specific stage of the contradiction between environment and economy [12]. The second is to study the influencing factors on carbon emission by index decomposition analysis [13,14]. The third focus is on the decoupling analysis of carbon emissions. Decoupling analysis can identify the main parts of environmental contradictions in complex relationships, and then provide real-time dynamic indicators of the relationship between environmental pollution and economic growth. Decoupling shows the asynchronous change between the economy and environmental damage, that is, the economy no longer depends on environmental damage [15]. Decoupling analysis was originally proposed by the Organisation for Economic Cooperation and Development (OECD), which reflects the asynchronous changes between economic growth, resource consumption, and environmental impact, and decoupling is divided into absolute decoupling and relative decoupling [16]. Decoupling analysis is a better method to study the balance between carbon emissions and the economic development [17]. Since 2010, scholars have adopted decoupling analysis to analyze the decoupling relationship between economic growth and environmental change and the influencing factors leading to decoupling changes. Additionally, these studies first concerning the decoupling states [18], second focusing on the decoupling degree of sub-sectors, such as transportation [19], manufacturing [20], construction [21], and agriculture [22]. These studies analyzed the changes of coupling state and the influence of factors but failed to explore the contribution of each subsector to the decomposition factors. In addition, few studies include decoupling analysis and attribution analysis. By combining index decomposition analysis, the decoupling index can be used to explore the influence of each sub-department on the decomposition factor [23,24]. Therefore, it is meaningful to differentiate and analyze the effect of decoupling and its reasons in sector levels [25,26].

For the sake of achieving a win-win situation in carbon mitigation, China has sped up the process of decoupling its economy from carbon emissions [17]. How to achieve a coordinated economy and carbon emissions is also worth exploring [27,28]. There are significant regional differences among the 34 regions in China. Differentiated regional development strategies indicate that there are major differences that vary among regions [29,30]. If the decoupling relationship at the provincial level is not fully understood, the implementation efficiency of national policies or strategies will be weak [31,32]. As one of five national comprehensive energy bases, Xinjiang province in northwest China exports an average of 99.76 million tons of standard coal per year to other provinces since 2000, leading to a massive shift in carbon emissions [33,34]. Thanks to the cost advantages of resources and energy, Xinjiang relies heavily on resource endowment, making the energy-intensive sector occupy a key position in the industrial structure [35,36]. Therefore, Xinjiang has become one of the regions where carbon emissions have been growing rapidly since 2000 [29]. Currently, the research on carbon emissions in Xinjiang is classified as accounting for carbon emissions [30], attribution analysis [27,34], decoupling analysis [11], scenarios analysis, and policy simulation for carbon emissions mitigation [6,31]. Studies on the impact of carbon emissions in Xinjiang have achieved impressive results, but most of them focus on the analysis of economic development and influencing factors. In the existing relevant research, the impact of sectoral factors on the decoupling of economic growth and carbon emissions has not been effectively discussed, and the contribution of sub-sectors to the decoupling driving factors has not been studied. This paper is no longer limited to the judgment of decoupling status and trend, but further studies the reasons behind decoupling and recognizes the impact of various driving factors and the contribution of various industrial sub-sectors. So, we used Kaya and LMDI methods to further decouple the relationship between carbon emission and economic growth in Xinjiang, then analyze the impact of various driving factors and clarify the contribution of sectors decoupling states. Finally, this manuscript aims to accurately identify the key industries of carbon emissions, analyze the mechanism of drivers to decoupling, and provide policy advice for sustainable development in Xinjiang.

2. Study Area

Located in the arid region of northwest China, Xinjiang autonomous region (73°−96° E, 34°−50° N) is the largest province in China (Figure 1). Being far away from the ocean and surrounded by Kunlun, Tien Shan, and Altay mountains, a temperate continental climate dominates Xinjiang, which makes the terrain complex and rich tourism resources in Xinjiang. As the largest province of China, Xinjiang is undergoing rapid economic growth and a growing population in recent years. For example, Xinjiang's GDP in 2017 hit RMB 914.95 billion, with an increase of 10.61% since 2000, which brought GDP per capita to more than RMB 37421. The permanent resident population of Xinjiang was 24.45 million at the end of 2017, with 47.23% living in the urban area [28]. All of this eventually led to the fast-growing demand of energy resources since 2000. The consumption of fossil fuels has greatly promoted economic development, which accelerated the growth of carbon emissions. Xinjiang's carbon emissions accounted for about 4.61% in China, but GDP only accounted for 1.35% in 2015. As one of five national comprehensive energy bases in China, Xinjiang tops the list of the proven reserves of coal, gas, and oil in the national total resources [29]. The proportion of fossil energy consumption was relatively high in the energy consumption structure during 2000−2017, the percent of coal, oil, and natural gases were 66.41%, 13.36%, and 8.82% in 2017, respectively. Rich resources make the energy-intensive industrial sectors as the main industry in Xinjiang. From the change trend of industrial structure, the proportion of secondary industry and tertiary industry were increasing, while the proportion of primary industry was decreasing. In 2017, the proportion of primary industry, secondary industry, and tertiary industry in GDP were 14.32%, 39.83%, and 45.85%, respectively.

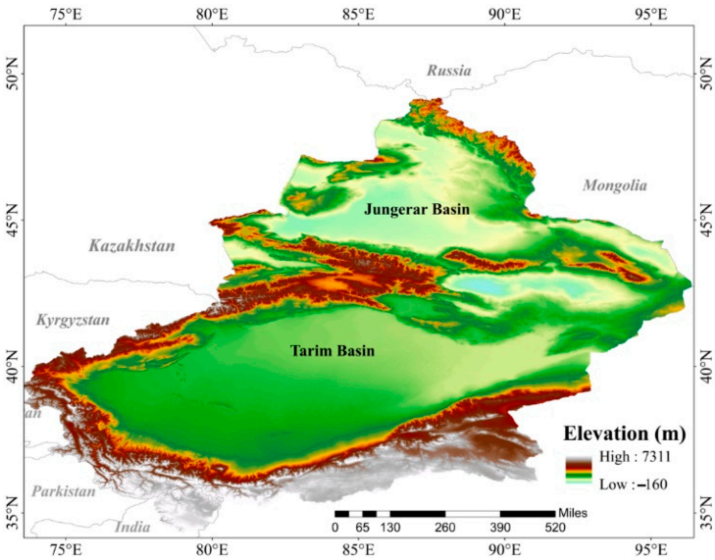

Figure 1. The geographical location of Xinjiang.

3. Methodology and Data

3.1. Calculation of Carbon Emissions

According to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, carbon emissions from fossil energy consumption can be calculated as [37]:

$$C_t = \sum jE_t^j \times Lcv_j \times Cf_t^j \times O_j \quad (1)$$

where C_t is carbon emissions in the year t, j denotes different fossil energy. E_t^j represents the consumption of the fuel j in the year t, and Lcv_j denotes the lower calorific value of the fuel j, Cf_t^j is the emissions factors of the fuel j in the year t, and O_j represents the oxidation rate of the fuel j.

3.2. Kaya Identity

Kaya identity is essentially a quantitative and empirical model, which is conducive to integrating various factors such as economy, population, energy, technology, and policy for model simulation [29]. Population, GDP per capita, energy intensity, and emission coefficient are the main indicators to analyze the carbon emission situation of a region. The Kaya identity can be expressed as follows [29]:

$$C = \frac{C}{E} \times \frac{E}{G} \times \frac{G}{P} \times P \quad (2)$$

where C, P, G, E denote carbon emissions, population scale, GDP, and energy consumption, respectively. To decompose absolute carbon emission change and discuss the effects at the sub-sector level, this paper applied the Kaya identity to analyze the increase in carbon emission [29]. The total carbon emissions from sectors in year t are C^t, so Equation (2) can be expanded as follows [10]:

$$C^t = \sum_i C_i^t = \sum_i \frac{C_i^t}{E_i^t} \cdot \frac{E_i^t}{G_i^t} \cdot \frac{G_i^t}{G^t} \cdot \frac{G^t}{P^t} \cdot P^t = \sum_i CI_i^t \cdot EI_i^t \cdot S_i^t \cdot G^t \cdot P^t \quad (3)$$

where C_i^t, E_i^t, and G_i^t represent the carbon emissions, energy consumption, and GDP, respectively, of sector i in year t. P^t is the total active population in year t. CI_i^t denotes the carbon coefficient caused by changes in energy consumption type of sector i in year t. EI_i^t is the energy intensity of sector i in year t, S_i^t is the economic structure of sector i in year t, and G^t is the GDP per capita in year t.

3.3. Logarithmic Mean Divisia Index (LMDI)

Generally speaking, the LMDI method is a further extension of Kaya identity. The LMDI method has several practical advantages from the application viewpoint. First, LMDI gives perfect decomposition, the results do not contain an unexplained residual term, which simplifies the result interpretation. Second, the results given by the multiplicative LMDI possess the following additive property. Third, there exists a simple relationship between multiplicative and additive decomposition, which makes separate decomposition using the multiplicative and additive schemes unnecessary. Finally, LMDI is consistent in aggregation [33]. Many studies have discussed the influence of different scales drivers on carbon emissions [33,34]. Therefore, this paper applied the LMDI method to discuss the effects of population, GDP per capita, economic structure, energy intensity, and emission coefficient on carbon emission in Xinjiang. The total change of carbon emissions from the baseline year o to the report year t can be expressed as follows [33,34]:

$$\Delta C = C_t - C_o = \Delta C_{CI} + \Delta C_{EI} + \Delta C_S + \Delta C_G + \Delta C_P \quad (4)$$

The change of carbon emissions between the base year o and the target year t is denoted as ΔC. The ΔC can be decomposed as the following factors, namely the carbon coefficient effect (denoted by ΔC_{CI}), energy intensity effect (denoted by ΔC_{EI}), economic activity effect (denoted by ΔC_S), GDP per capita effect (denoted by ΔC_G), population effect (denoted by ΔC_P). Based on the LMDI method, the effect of Equation (4) can be expressed as follows:

$$\Delta C_{CI} = \sum_i [\frac{C_i^t - C_i^o}{\ln C_i^t - \ln C_i^o} \cdot \ln(\frac{CI_i^t}{CI_i^o})] \quad (5)$$

$$\Delta C_{EI} = \sum_i [\frac{C_i^t - C_i^o}{\ln C_i^t - \ln C_i^o} \cdot \ln(\frac{EI_i^t}{EI_i^o})] \quad (6)$$

$$\Delta C_S = \sum_i [\frac{C_i^t - C_i^o}{\ln C_i^t - \ln C_i^o} \cdot \ln(\frac{S_i^t}{S_i^o})] \quad (7)$$

$$\Delta C_G = \frac{C^t - C^o}{\ln C^t - \ln C^o} \ln \frac{G^t}{G^o} \quad (8)$$

$$\Delta C_P = \frac{C^t - C^o}{\ln C^t - \ln C^o} \ln \frac{P^t}{P^o} \quad (9)$$

3.4. Decoupling Model

According to the decoupling theory, if the economic growth rate is faster than that of carbon emissions there is a decoupling relationship. As a well-known decoupling method, Tapio's decoupling model uses flexible incremental analysis to explore the decoupling effect and there are eight decoupling states (Figure 2). Tapio does not measure the absolute economic value but uses the decoupling elasticity index to assess the sensitivity of incremental value [15]. According to Tapio decoupling, from a benchmark year *0* to year t, the decoupling indicator of carbon emission (C) and GDP (G) is defined as D^t. This paper calculated D^t using the following formula:

$$D^t = \frac{\%\Delta C}{\%\Delta G} = \frac{\frac{C^t - C^o}{C^o}}{\frac{G^t - G^o}{G^o}} \quad (10)$$

$$= \sum_i \frac{G^o}{C^o} \cdot \frac{\Delta C_{CI}^t + \Delta C_{EI}^t + \Delta C_S^t + \Delta C_G^t + \Delta C_p^t}{\Delta G^t} \quad (11)$$

$$= \sum_i \frac{\Delta C_{CI}^t / C^o}{\Delta G^t / G^o} + \frac{\Delta C_{EI}^t / C^o}{\Delta G^t / G^o} + \frac{\Delta C_S^t / C^o}{\Delta G^t / G^o} + \frac{\Delta C_G^t / C^o}{\Delta G^t / G^o} + \frac{\Delta C_p^t / C^o}{\Delta G^t / G^o} \quad (12)$$

$$= \sum_i D_{CI}^t + D_{EI}^t + D_S^t + D_G^t + D_P^t \quad (13)$$

where D_{CI}^t, D_{EI}^t, D_S^t, D_G^t, D_P^t denote the decoupling indicators of carbon coefficient sub-indicator, energy intensity sub-indicator, economic structure sub-indicator, GDP per capita sub-indicator, and population sub-indicator, respectively.

According to the correlation between economic development and energy pressure, the decoupling state can be divided into two main types: relative decoupling and absolute decoupling. When the economic growth rate is much higher than the material consumption, it means relative decoupling, which is called weak decoupling. When the material consumption decreases with the economic growth, it means absolute decoupling, which is called strong decoupling. Expansive negative decoupling shows an unreasonable development mode, economic development at the expense of a large number of energy consumption, and environmental pollution. Expansive coupling is the most common model at present, which represents the close dependence and mutual promotion between economy and energy (Figure 2). However, in the long run, the expansive coupling is not conducive to sustainable economic development. As for the other four decoupling states, economic growth is negative and undesirable.

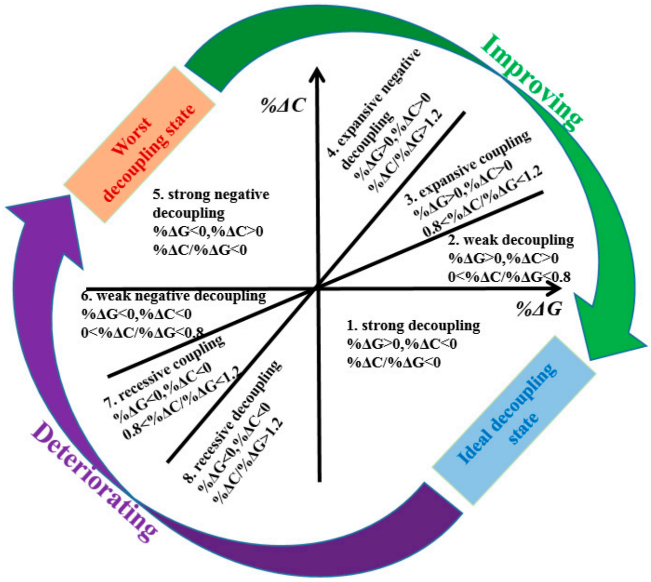

Figure 2. Decoupling states of carbon emissions from GDP. Notes: the decoupling state: 1. strong decoupling; 2. weak decoupling; 3. expansive coupling; 4. expansive negative decoupling; 5. strong negative decoupling; 6. weak negative decoupling; 7. recessive coupling; 8. recessive decoupling.

3.5. Data Description

Based on data availability, the time series data used in the paper is from 2000 to 2017. Data on energy, economy, and population were collected from the Xinjiang Statistical Yearbook (2001–2018) [38]. Sector carbon emission refers to the energy consumption in different sectors. Energy consumption only refers to primary energy. Time series of GDP data adjusted according to the constant price in 2010 to avoid the impact of inflation.

4. Results and Discussion

4.1. Change of Carbon Emissions in Xinjiang

Based on the Equation (1) this paper calculated energy-related carbon emissions in Xinjiang. Figure 3 shows the trends of carbon emissions during 2000–2017, which has a significant increase from 93.34 million tons (Mt) in 2000 to 468.12 Mt in 2017, with an increase of 4.55 times and the average annual growth reached 10.16%. The industry is the largest carbon emissions sector, which increased by 6.51 times during 2000–2017. Carbon emissions from industry increased from 50.55 Mt in 2000 to 336.62 Mt in 2017, accounting for 61.17% in 2000 and 90.82% in 2017, respectively (Figure 4). After 2000, under the strategies and policies of Western Development, Counterpart aid to Xinjiang, and The Belt and Road Initiative, Xinjiang's national economic development entered a new period, energy development has been further upgraded, and carbon emissions have shown exponential growth.

Energy-intensive industries were the major body of carbon emissions. Carbon emissions from energy-intensive industries (fuel processing, power generation, chemicals, non-ferrous, iron and steel, ceramics, and cement) accounted for 89.51% of total carbon emissions in 2017. Carbon emissions from fuel processing and power generation increased from 35.81 and 9.87 Mt in 2000 to 122.73 and 127.26 Mt in 2017, which accounted for 43.56% and 11.72% in 2000 to 26.96% and 27.83% of total carbon emissions in Xinjiang in 2017, respectively (Figures 3 and 4). Additionally, carbon emissions from fuel processing and power generation witnessed a growth of 3.42 and 12.81 times, respectively. Compared with the energy-intensive industries, carbon emissions from mining industries and manufacturing industries (foods and tobacco, textile, pulp and paper, and other manufacturing) were relatively low, with an annual average of 8.94 and 5.72 Mt in 2017, respectively. Regarding carbon emissions from life consumption, it is clear that there was a continuous increase during 2000–2017, with a raise of 1.96 times. Carbon emissions from trade and catering increased from 1.23 Mt in 2000 to 2.86 Mt in 2017 (Figure 3). Carbon emissions from agriculture and service experienced a slight increase of 64.26% and 38.64%, respectively, and carbon emissions from construction increased by 3.62% (Figure 4). Research indicated that carbon emissions have all shifted to heavy industry sectors in Xinjiang [33,34]. In addition, those studies have shown that carbon emissions were mainly emitted by energy-intensive industries [33]. Due to the abundance of resources, the energy-intensive subsector has resource and cost advantages. The current situation of economic development level has promoted Xinjiang to give priority to the development of resource- and energy-intensive industries, such as metal production, supply, smelting, and stamping.

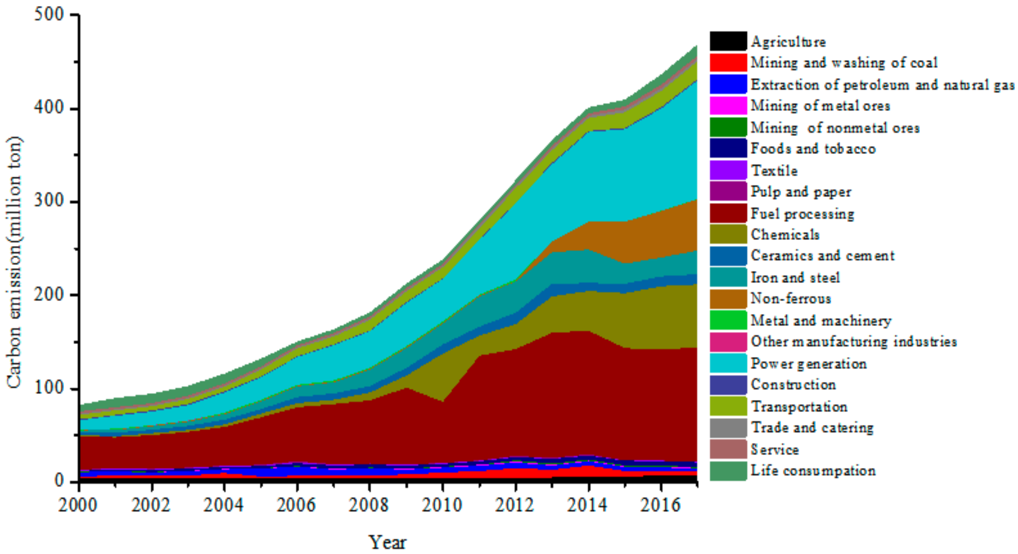

Figure 3. Trends of carbon emissions from sectors in Xinjiang during 2000–2017.

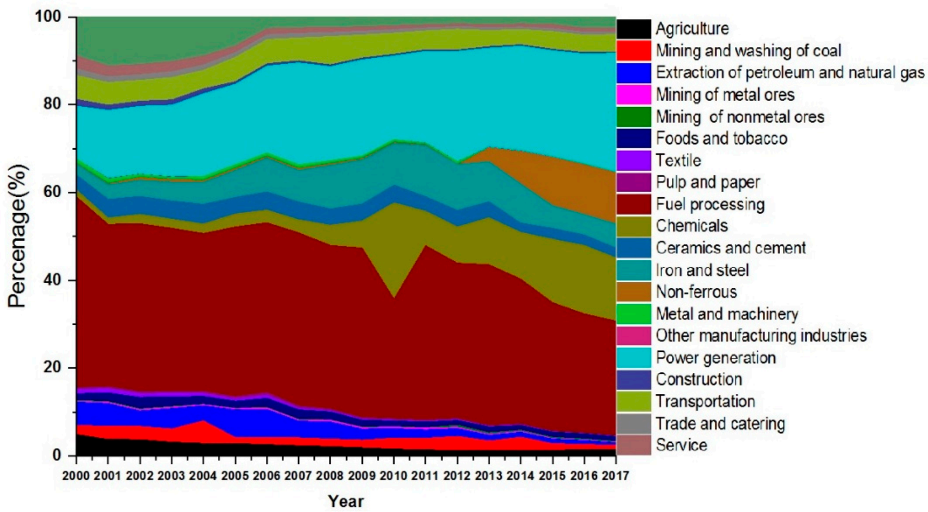

Figure 4. Percentage of carbon emissions from sectors in Xinjiang during 2000–2017.

4.2. Decomposition Analysis

Based on the Equations (2)–(10) this paper conducted a decomposition analysis of energy-related carbon emissions in Xinjiang. The decomposition results of carbon emissions are shown in Figure 5 and the findings are as follows: GDP per capita effect appeared as the key factor in carbon emissions increase during 2000–2017, which is in consensus with the previous results (Figure 6). It is clear that the GDP per capita effect caused carbon emissions to account for 93.58%, 81.51%, and 58.62% in Xinjiang during 2000–2005, 2005–2010, and 2010–2017, respectively (Figure 5). Since 2000, Xinjiang has experienced rapid socioeconomic development with an average growth rate achieved by 10.62%, and it is non-negligible that economic development was supported by fossil energy consumption, which (equivalent to coal) increased from 0.33 billion tons to 1.73 billion tons from 2000 to 2017. Since 2000, Xinjiang adheres to economic construction as the center, with the exploration and development of mineral resources, the proportion of economic output value of the heavy industry in Xinjiang's GDP continues to rise. During this period, Xinjiang's economy grew rapidly, with an average annual growth rate of 12.52%, GDP per capita effect shows a strong positive effect and has become the decisive factor affecting the growth of carbon emissions. These results are consistent with the study of Wang et al. [32]. As a less developed region, Xinjiang's top priority is to make sure socioeconomic development, so it is foreseeable that the GDP per capita effect will be a key reason for the carbon emissions increase in the future.

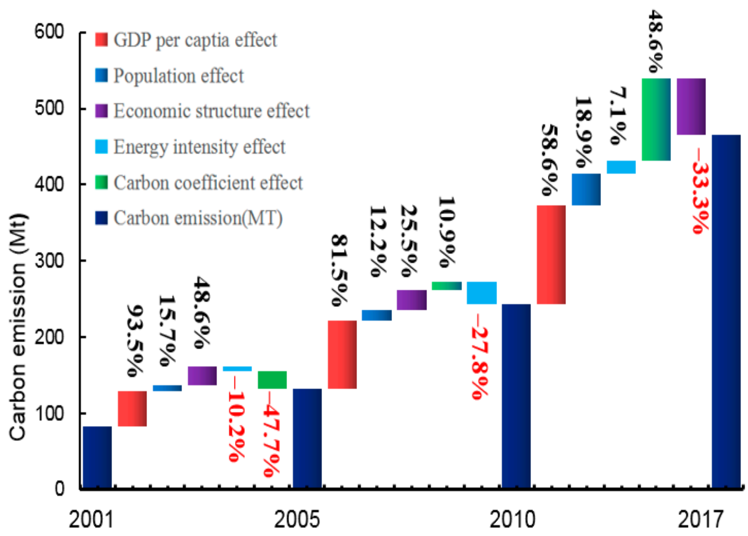

Figure 5. Decomposition of carbon emissions in Xinjiang during 2000–2017.

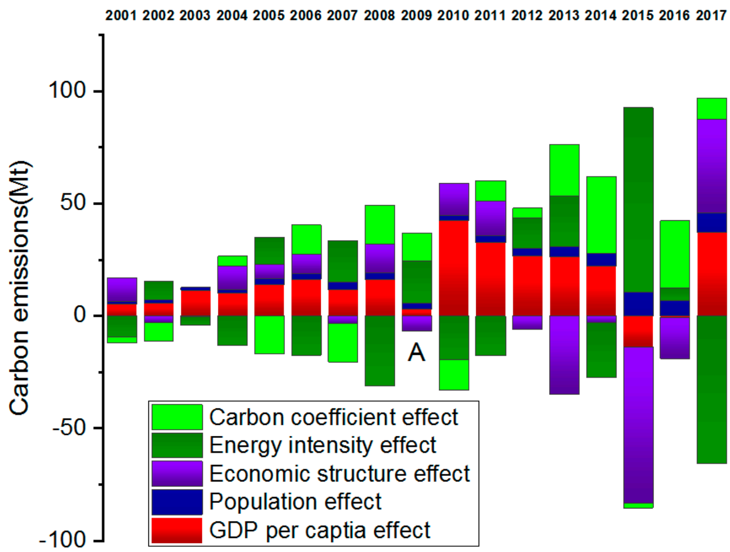

Figure 6. Attribution of factors to carbon emissions in Xinjiang during 2000–2017.

Population effect was also another key driver of the carbon emissions increase during 2000–2017 (Figure 6). According to the decomposition results, the population effect caused carbon emissions to account for 15.71%, 12.26%, and 18.96% in Xinjiang during 2000–2005, 2005–2010, and 2010–2017, respectively (Figure 5). Xinjiang's population expanded by 32.22% during 2000–2017, which resulted in 63.52 Mt carbon emissions, and it explained the effect of population on carbon emissions increase. Under the background of socioeconomic development, people will pursue more comfortable living environments. This led directly to soaring energy consumption, which promotes rapid growth in carbon emissions [31]. Economic structure effect also a driver of the increase in carbon emissions during 2000–2017. According to the decomposition results, the economic structure effect caused carbon emissions to account for 48.62%, 25.59%, and −33.37% in Xinjiang during 2000–2005, 2005–2010, and 2010–2017, respectively (Figure 5). Carbon emissions resulting from economic structure adjustment increased by 49.81 Mt, which accounted for 30.56% of the total emissions during 2000–2010. Currently, Xinjiang is in the middle stage of industrialization. Rich energy resources have promoted the priority development of high energy consuming industries such as metal production, supply, and smelting. The heavy industry supported by the coal chemical industry and steel industry is the main part of Xinjiang's economic growth. However, under the condition of low energy utilization efficiency in most coal chemical industries, which is not conducive to Xinjiang's carbon emission reduction [29]. Meanwhile, the economic structure effect caused carbon emissions of −74.13 million tons during 2010–2017 (Table 1). In the meantime, it also should be noted that the percentage of industry's GDP decreased gradually from 41.21% in 2010 to 29.96% in 2017 in Xinjiang. It means that the adjustment of economic structure offsets the carbon emissions from industry during 2010–2017. Compared with the heavy chemical industry, the service industry is a non-energy intensive industry with low emission intensity. Encouraging the development of the service industry is a possible way to reduce the impact of structural effects [34]. Therefore, Xinjiang should vigorously promote the transformation of leading industries from secondary industry to tertiary industry and support low-carbon industries through fiscal policies in the future.

Table 1. Attribution of factors to carbon emissions in Xinjiang during 2000–2017 (Mt).

	GDP Per Captia Effect	Population Effect	Economic Structure Effect	Energy Intensity Effect	Carbon Coefficient Effect
2000–2005	46.63	7.83	24.25	−5.10	−23.78
2005–2010	90.01	13.53	25.57	−30.79	12.11
2010–2017	130.35	42.16	−74.13	15.80	108.17

The energy intensity effect proved to be the key factor to inhibiting carbon emissions increase in Xinjiang. According to the decomposition results, the energy intensity effect accounts for −10.21%, −27.84%, and 7.16% in carbon emissions change during 2000–2005, 2005–2010, and 2010–2017, respectively (Figure 5). Energy intensity decreased during 2000–2010, which resulted in a −35.89 Mt emissions reduction (Table 1), accounted for −22.39% of emissions changes (Figure 5). However, the energy intensity effect caused 15.80 Mt carbon emissions during 2010–2017. Since 2000, the energy intensity effect has played an important role in reducing industrial carbon emissions in Xinjiang, but from the perspective of the change trend, the emission reduction effect of this factor has gradually weakened. Compared with other provinces, Xinjiang is still an economically underdeveloped region. In 2000, China implemented a "Western development" strategy and comprehensively improved the economic and social development level of the western region. With the full implementation of the "Western development" strategy, the level of fixed asset investment in Xinjiang has increased significantly, the percentage of 70% of investment in socioeconomic development came from local government, and 34% of the capital was invested in the resource-intensive industries and energy industries (fuel processing, power generation, chemicals, non-ferrous, iron and steel, extraction of petroleum and natural gas, mining and washing of coal). Under the support of a series of strategic arrangements and policies for the "Western development" strategy, relying on abundant mineral resources and energy, the exploration and development of mineral resources in Xinjiang have been further upgraded. The construction of oil and gas chemical industry bases and coal chemical industry bases has been expanding. The proportion in the GDP value of the secondary industry has increased from 38% in 2001 to 47% in 2010 [38]. Although Xinjiang is rich in oil and natural gas resources, the resource and price advantages of coal make it the first choice of energy consumption for a long time. In order to narrow the regional development gap and take into account the rich coal resources in Xinjiang, China has implemented a differentiated industrial policy for Xinjiang and listed it as one of the main bases of the coal chemical industry in China. As a result, the energy consumption structure in Xinjiang is dominated by fossil fuels, with an annual average of 94%, of which coal accounts for an annual average of 63%. After 2010, local governments increased investment, and Xinjiang's economic development improved. However, large-scale investment promoted the rapid development of resource-intensive industries, and outdated industrial sectors and production processes are also common. Therefore, transforming resource advantages into economic advantages and technological progress of high energy consuming industries are the key to the sustainable development of Xinjiang [11]. In the future, Xinjiang should increase investment in improving energy efficiency. The increase in technology investment will not only help to reduce production emissions, but also promote the development of enterprises to low-carbon production.

The carbon coefficient effect was another restricting factor for carbon emissions increase. The carbon coefficient effect led to the −7.34% increase in carbon emission in Xinjiang during 2000–2010, but the contribution of the carbon coefficient effect was positive almost every year during 2010–2017, which increased by 108.17 Mt (Table 1). It is found that the carbon coefficient effect inhibits the growth of carbon emissions, which is the result of the transformation of energy structure from high-carbon coal consumption to low-carbon natural gas consumption. This shows that reducing coal consumption will be the main strategy to curb carbon emissions. Since 2015, Xinjiang has taken a lot of measures to reduce coal consumption, such as replacing coal with natural gas for heating in winter. Although the decline in coal consumption is limited, it still contributed to the carbon emission reduction in Xinjiang. Therefore, in the long run, the energy structure dominated by coal needs to be changed. In addition, Xinjiang is rich in wind and solar energy resources, but the utilization rate is still low. Therefore, the diversification of energy consumption structure has great potential and advantages, which further highlights the high substitution rate of coal in Xinjiang with wind and solar energy [28].

4.3. Decoupling Analysis

4.3.1. Decoupling State

Based on the Equations (11)–(13) this paper conducted a decoupling analysis of energy-related carbon emissions in Xinjiang. The decoupling relationship between GDP and carbon emissions shows in Table 2 and Figure 7. There are four decoupling states that appeared during 2000–2017 in Xinjiang (Table 1). Weak decoupling (WD) occurred in 2001–2003, 2010, and 2017. Expansive coupling (EC) occurred in 2003–2005, 2007–2008, and 2011. Expansive negative decoupling (END) occurred in 2006, 2009, 2012–2014, and 2016. Strong negative decoupling (SND) occurred in 2015. This shows that Xinjiang's carbon emissions were still increasing, and the growth rate was greater than the economic growth. Since 2000, different decoupling states have shown that the decoupling degree of carbon emission in Xinjiang was not stable. After 2003, WD was broken by EC. At the same time, the decoupling elasticity coefficient showed a stable upward trend, and the decoupling elasticity fluctuated between 0.8–1.5. This means that the decoupling state between carbon emission and economic output in Xinjiang was vulnerable to external shocks such as the macroeconomic environment. From the perspective of decoupling elasticity, it has changed greatly since 2003, and the elasticity has increased significantly, indicating that the effect of emission reduction was weak. Overall, Xinjiang's carbon emissions exhibit no decoupling states with GDP growth, which also means that carbon emissions increase with economic development.

Table 2. Decoupling elasticity index in Xinjiang during 2000–2017.

Year	ΔC%	ΔG%	D	Decoupling State
2001	0.06	0.09	0.70	WD
2002	0.06	0.09	0.62	WD
2003	0.10	0.16	0.62	WD
2004	0.14	0.13	1.14	EC
2005	0.17	0.16	1.07	EC
2006	0.19	0.15	1.22	END
2007	0.09	0.10	0.87	EC
2008	0.11	0.12	0.93	EC
2009	0.17	0.03	5.81	END
2010	0.12	0.23	0.54	WD
2011	0.18	0.15	1.19	EC
2012	0.15	0.11	1.43	END
2013	0.13	0.10	1.36	END
2014	0.10	0.08	1.25	END
2015	0.02	−0.01	−2.25	SND
2016	0.06	0.01	4.01	END
2017	0.07	0.11	0.66	WD

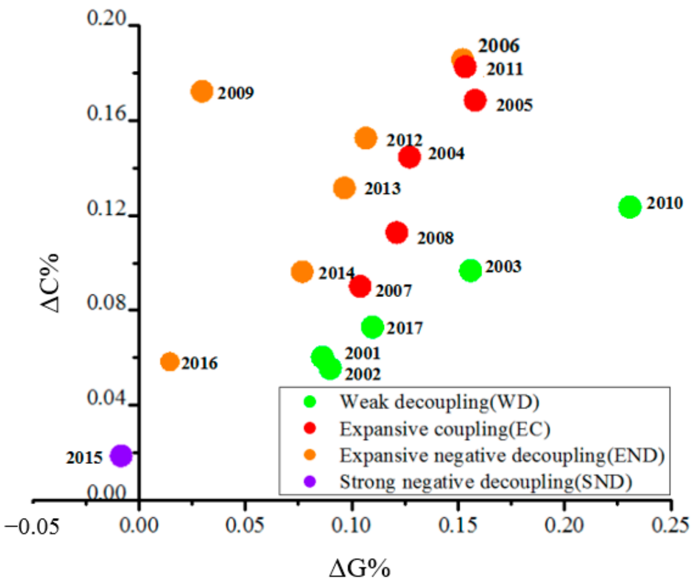

Figure 7. Decoupling states in Xinjiang during 2000–2017.

4.3.2. Decomposition of Decoupling

To better intuitively distinguish the contribution value of factors that affect the decoupling relationship, the decoupling elasticity was further decomposed into GDP per capita elasticity, population elasticity, economic structure elasticity, energy intensity elasticity, and carbon coefficient elasticity. The decomposition results show in Figure 8. Theoretically, population and GDP per capita are the driving factors of increasing carbon emissions, while the improvement of economic structure, energy intensity, and carbon intensity are the contributing factors to decoupling.

Figure 8 shows that the elasticity coefficient of GDP per capita was relatively stable, and the elasticity coefficient fluctuated from 0.8 to 0.9 for many years. The decoupling states of GDP per capita were mainly END and EC during 2001–2017. This also means that economic development has a major inhibitory influence on the decoupling of carbon emissions (Figure 9), and these results are consistent with the study of Zhang et al. [11]. After 2000, due to the vigorous development of industrial and infrastructure construction, Xinjiang's industrial economic growth rate has accelerated, with the large-scale construct of energy-intensive industries such as steel, coal, and chemical has brought a large amount of energy consumption, which accelerated the growth of carbon emissions from energy consumption. It can be seen from Figure 8 that the trend of population elasticity mainly fluctuated from 0 to 0.5 during 2001–2017, and the decoupling states of population elasticity were mainly WD during 2001–2017. The expanding population size has a weak inhibitory effect on the decoupling of carbon emissions in Xinjiang (Figure 9), indicating that the growth of population size increases the total carbon emissions, which is due to the increase in employment–population in the secondary industry by the expansion of industrial-scale and the acceleration of urbanization. Therefore, if the decoupling flexibility of population size is reduced, only by continuously improving the quality of employees themselves, so that their working ability can be improved, and can the carbon emissions of the equipment manufacturing industry be reduced [20].

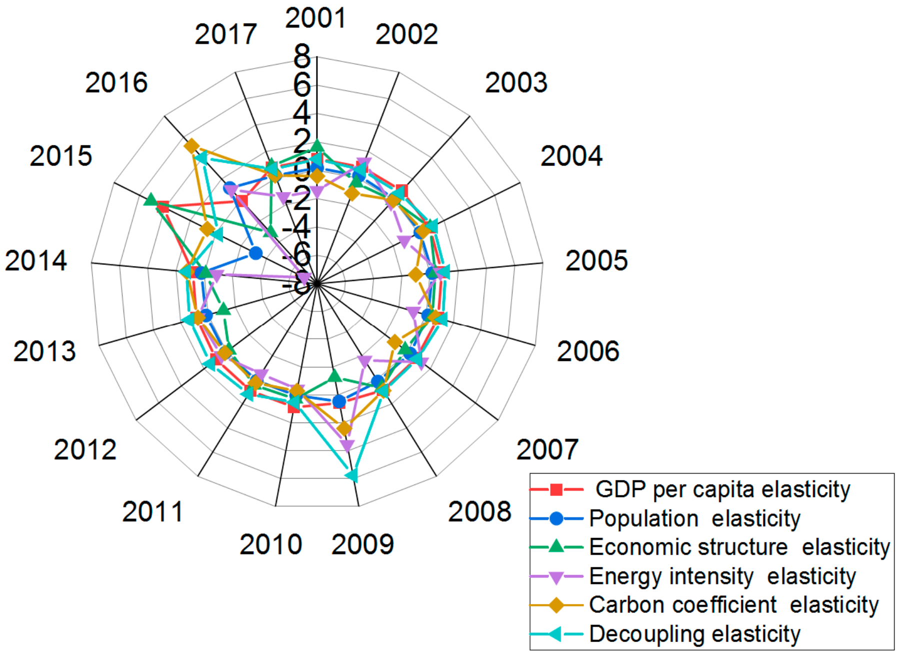

Figure 8. Decoupling sub-indicator for carbon emissions during 2000–2017.

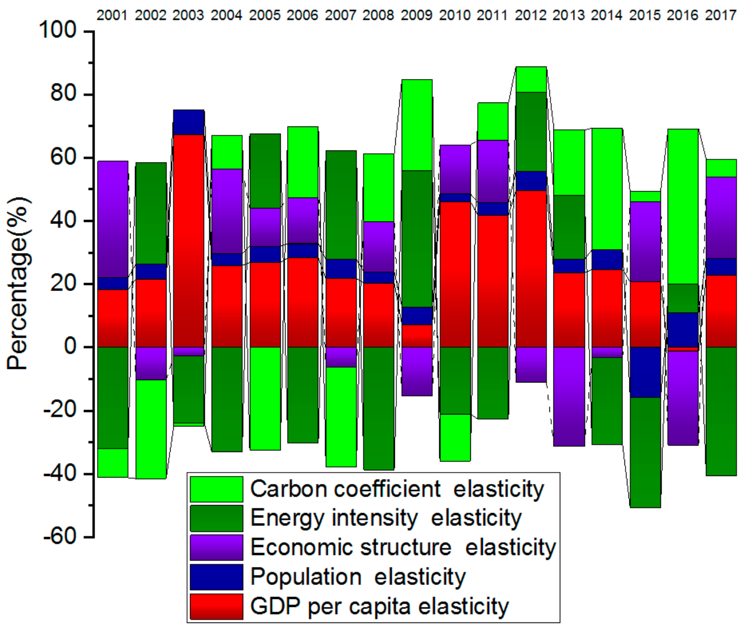

Figure 9. Contribution of factors to decoupling in Xinjiang during 2000–2017.

It can be seen that the elasticity of the economic structure changed greatly, with an average fluctuation of 2~−2 during 2001–2017 (Figure 8). The decoupling states of economic structure elasticity were mainly WD and SD from 2001 to 2014 (Figure 8), which shows that the efforts to reduce carbon emissions by adjusting the economic structure are effective, and it also shows that the measure of adjusting the economic structure has the greatest potential for the reduction of carbon emission. Economic structure elasticity fluctuated significantly from 2015 to 2017, mainly due to the slowdown of social and economic development in Xinjiang, which was influenced by the impact of China's economy entering the "New Normal" [27]. From the perspective of economic structure elasticity, the elasticity value of economic structure was mostly in a state of WD, indicating that the economic structure changes promote the decoupling of carbon emissions (Figure 9), and suggesting that the future adjustment of Xinjiang's economic structure is a necessary link for the decoupling of carbon emission. Due to the resource endowment and cost advantages, the energy-intensive sectors have the characteristic of high emissions, which deteriorated carbon emissions in Xinjiang since 2008 [11]. With the industrial demand for fossil energy rapidly increasing during 2001–2017, and industrial structure effect was the main factor to limit the decoupling. Xinjiang increased its investment in infrastructure construction in 2010, but outdated industrial processes were still common, and the poor technological level was obstructive to realizing the decoupling in Xinjiang [32].

As for the energy intensity elasticity, it can be seen from the contribution degree of energy intensity elasticity in Figure 8 that the energy intensity elasticity changes alternately between positive and negative, and negative in most years from 2001 to 2017. Energy intensity elasticity mainly was positive during 2008–2014, which was due to the gradual development of traditional industries, and the large consumption of coal and fossil energy ignoring the high efficiency and intensification of energy utilization. Since 2015, the energy intensity elasticity has turned negative, which has greatly promoted the decoupling of carbon emissions (Figure 9). This is because the industrial layout has been continuously optimized, the economic efficiency has been effectively improved, and the energy intensity has decreased significantly due to the extensive use of clean energy. Relevant studies have shown that energy intensity was the main factor to promote decoupling and this finding is consistent with previous studies [11]. In a word, the change trends of energy intensity elasticity and decoupling elasticity of carbon emissions from 2001 to 2017 were generally consistent, indicating that the decoupling between economic growth and carbon emissions in Xinjiang was mainly caused by the improvement of energy efficiency. The carbon coefficient elasticity was generally in the decoupling state (Figure 8). Carbon coefficient elasticity was mainly negative, fluctuates between 0 and changes slightly, and entered the adjustment state after 2006. After 2006, the elasticity of carbon intensity in Xinjiang began to rise inversely, which gradually became a factor to restrain the decoupling of carbon emissions. The fluctuation of carbon coefficient elasticity shows the potential for industrial energy conservation and emission reduction in Xinjiang, and the overall industrial structure has not yet entered an efficient and low-carbon development model [33]. General speaking carbon coefficient elasticity promotes the decoupling of carbon emissions, but its effect was relatively weak (Figure 9).

4.3.3. Decoupling State on Sectors

In order to better explain the decoupling relationship and clarify the reduction direction of sectors, this section follows Tapio's decoupling to analyze the decoupling elasticity of sectors from 2001 to 2017. It can be seen that sectors decoupling elasticity shows a downward trend during 2001–2005 in Xinjiang (Table 3). Chemicals, iron, and steel, non-ferrous mainly show states of END and EC during 2006–2017, indicating that carbon emissions rose sharply and gradually exceeded the sectors' GDP growth. During this period, Xinjiang increased and strengthened the investment and construction of traditional industries such as steel, building materials, and chemical industry in the industrial sector, and the pressure of emission reduction in the industry was relatively severe [33]. In order to cut off the link between industrial economic growth and carbon emission in the future, it is necessary to strengthen the emission reduction of chemical, iron, and steel, non-ferrous [34]. These industries' energy intensity was relatively high, and there is still large room for emissions mitigation. With the improvement of energy utilization efficiency, it is propitious for the realization of energy conservation and emission reduction targets. Mining of nonmetal ores, textile, pulp and paper, transportation, trade and catering, and service mainly shows states of EC, END, SND, and WD, which indicates the severe situation of sectors' carbon emission. Additionally, it means that the situation of high energy consumption and high emission is still common. Carbon emission and the added value of GDP in these sectors were increasing, but the increase in carbon emission was generally greater than that of GDP. The energy utilization efficiency of these sectors was low, and there is a large room for emission reduction in those sectors. Mining and washing of coal, extraction of petroleum and natural gas, and fuel processing mainly show states of END, SND, and WD. Due to the application of low-carbon technology, the growth of carbon emissions was effectively controlled during 2001–2017. Power generation mainly shows states of END, EC, and WD, which means economic growth along with the increase in carbon emissions, but the growth rate of carbon emissions was greater than that of GDP. The main reason is the high proportion of coal consumption in the energy consumption structure is still common. In the future, Xinjiang must increase the proportion of renewable energy such as wind and optoelectronics in the field of power generation.

Generally speaking, Xinjiang has experienced a rapid increase in carbon emissions with economic growth, and economic development is at the initial stage of industrialization. Most industries have not reached the ideal decoupling state and there is great potential for emission mitigation in the future. Mining and washing of coal, extraction of petroleum and natural gas, fuel processing, chemicals, iron and steel, non-ferrous, power generation were mainly shown states of END and EC during 2001–2017, these industries were mainly energy and resource-intensive industries, which make a great contribution to the economy in Xinjiang, and the trend of sector's GDP and carbon emission were regular. Xinjiang should vigorously control the development of these industries and enhance industrial competitiveness so as to gradually transition to the ideal decoupling situation in the future. From the trend of the sector's decoupling elasticity (Table 3), it is found that the labor-intensive industries are WD states in most years, indicating that the overall effect of emission mitigation in these industries was obvious, which shows that the effectiveness of energy conservation and emission reduction has been significantly improved and the emission reduction effect has achieved initial results.

On the basis of energy endowment and resources, economic underdevelopment promotes Xinjiang to give priority to resource development for economic growth, which is not conducive to the decoupling process [11]. Therefore, the transformation of resource advantage into an economic advantage and technological progress of resource and energy-intensive industries will be the linchpin to achieving socioeconomic sustainable development in Xinjiang [34]. This also means that the energy-intensive industries play a decisive role in realizing the decoupling of carbon emissions in Xinjiang [6]. In the future, the mitigation of carbon emissions in Xinjiang should be by reducing the proportion of energy-intensive industries' GDP, increasing investment, and improving energy efficiency to decouple economic development from carbon emissions increase.

Table 3. Sectors' decoupling states during 2000–2017.

Strong decoupling(SD) Weak decoupling(WD) Expansive coupling(EC) Expansive negative decoupling(END) Strong negative decoupling(SND) Weak negative decoupling(WND) Recessive coupling(EC) Recessive decoupling(RD)	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Agriculture	RD	WD	SD	WD	EC	END	SD	WD	WD	SD	SND	WD	END	END	SND	END	SD
Mining and washing of coal	END	WD	EC	END	RD	WD	END	WD	WD	END	EC	END	RD	END	RD	RD	SD
Extraction of petroleum and natural gas	SND	RD	EC	SD	END	WD	RD	END	WND	SD	WD	SND	RD	RC	WND	WND	SD
Mining of metal ores	EC	EC	WD	SND	EC	WD	SND	END	SD	WD	END	WD	SND	WND	WND	RC	SND
Mining of nonmetal ores	RD	SD	SD	RD	SND	EC	SND	SD	SND	SD	WD	SND	SD	SD	WND	WND	WD
Foods and tobacco	END	END	SD	SD	RD	END	WD	SD	WD	SD	END	SD	END	SD	END	SND	SND
Textile	SND	SD	SND	SD	SD	END	SD	WND	SND	SD	END	SND	RD	SD	END	SD	EC
Pulp and paper	EC	SND	WD	END	SND	END	SD	RD	RD	WD	SND	WD	SND	END	SD	WD	SND
Fuel processing	SD	SND	WD	WD	WD	WD	SND	WD	SND	SD	END	SND	SND	WND	WND	WND	WD
Chemicals	SD	END	WD	EC	END	WD	WD	END	END	END	SD	END	END	END	SND	END	SD
Ceramics and cement	END	WD	WD	SND	RC	END	WD	WD	EC	WD	SD	END	END	SD	SND	WD	WD
Iron and steel	WD	WD	END	WD	END	END	WD	EC	SND	WD	END	END	WND	SND	RC	RD	WD
Non-ferrous	SND	END	SD	RD	END	WD	WD	RD	SND	WD	SD	SD	END	END	END	END	WD
Metal and machinery	EC	SD	WND	END	SND	END	WD	SD	WD	EC	SD	END	SD	RD	SND	WND	END
Other manufacturing industries	END	RD	WD	SD	END	WD	WD	SD	SD	END	SND	SND	END	SD	SD	SND	SND
Power generation	END	WD	END	EC	WD	EC	END	WD	END	SD	EC	END	WD	WD	SND	SND	WD
Construction	SD	WD	EC	WD	SD	WD	SD	WD	WD	SD	EC	WD	END	WD	WD	WD	WD
Transportation	SND	SD	SND	SD	SND	END	END	END	SD	END	WD	WD	SD	WD	END	EC	WD
Trade and catering	SD	WD	EC	WD	WND	END	WD	WD	WD	WD	SD	WD	EC	RD	SND	WD	SD
Service	SD	WD	EC	SD	SD	WD	SD	SD	SD	WD	WD	SD	EC	WD	END	END	SD

5. Conclusions and Policy Recommendations

5.1. Conclusions

Features, driving forces, and decoupling analysis of carbon emission in Xinjiang during 2001–2017 were conducted. This paper calculates the trend of energy-consumption carbon emissions, based on the LMDI method to discuss the effect of population scale, GDP per capita, industrial structure, energy intensity, and carbon intensity on the changes in carbon emissions. Then, Tapio's model was used to explore the decoupling relationship and the driving factors of the decoupling are discussed. The conclusion follows that:

(1) Carbon emissions from Xinjiang increased from 93.34 Mt in 2000 to 468.12 Mt in 2017, with an increase of four times and an average annual growth rate of 10.68%. Energy-intensive industries are the key body of carbon emissions in Xinjiang. Fuel processing, power generation, chemicals, non-ferrous, iron and steel, ceramics, and cement accounted for 89.51% of total carbon emissions in 2017.

(2) GDP per capita effect was the key factor in the increase in carbon emissions. Population effect and economic structure effect were also the drivers of the carbon emissions increase. The energy intensity effect proved the major inhibiting factor for carbon emissions increase. The carbon coefficient effect was also another inhibiting factor for carbon emissions, but its effect was relatively weak.

(3) WD, EC, END, and SND occurred in Xinjiang during 2001–2017. GDP per capita elasticity had a major inhibitory effect on the decoupling of carbon emissions. Population elasticity and economic structure elasticity were mainly WD. Energy intensity elasticity was the most important factor in the decoupling in Xinjiang. Most industries have not reached the ideal decoupling state in Xinjiang. Energy-intensive industries mainly showed states of END and EC.

5.2. Policy Recommendations

Based on the above research results, the following policy recommendations are put forward to promote the decoupling of economic growth and carbon emissions in Xinjiang.

(1) Adjust the industrial structure. Xinjiang need to change the mode of industrial growth and speed up the process of "new industrialization". The internal structure of energy-intensive industries should be optimized and adjusted in combination with the existing industrial, encourage the development of renewable energy, power generation, modern chemical manufacturing, equipment manufacturing, new materials, and reduce the energy related carbon emissions in the industrial sector.

(2) Optimize the energy structure. The energy consumption structure dominated by coal is an important reason for the continuous growth of carbon emissions in Xinjiang. In addition to increasing the consumption proportion of oil and natural gas, Xinjiang should also expand renewable energy at the same time to adjust the energy utilization structure. The development and distribution of wind and solar energy should be comprehensively planned to increase their use.

(3) Promote energy conservation and emission reduction. The energy efficiency of key industries in Xinjiang is significantly lower than the national average, reflecting the great potential of energy conservation and emission reduction in Xinjiang. Energy-intensive industries should be committed to technological innovation and upgrading in key industries. It is also effective to eliminate backward enterprises or introduce clean technology to improve energy efficiency.

The limitations of this study mainly come from the lack of analysis for decision-makers, which is the common weakness of empirical research. In China, development decisions are often top-down. The central government issues orders according to the current socioeconomic situation and forward-looking forecasts, and local governments implement them. The implementation of the national environmental protection policy will have a significant impact on the carbon emission reduction in Xinjiang. Therefore, in terms of environmental protection and emission reduction, local governments can formulate certain emission reduction policies according to local characteristics. Regions with power production and supply as the main body should pay attention to the technological upgrading and emission transformation of the power industry. The chemical and non-ferrous metal industry should pay more attention to the formulation of emission standards and control of pollution, so as to reduce carbon emissions from emission sources. It is necessary to consider the local actual foundation and the actual situation of carbon emissions, as well as the economic development priorities of Xinjiang, and it is also crucial to improve the ability of lower government departments to implement policies.

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References

1. IPCC. *Climate Change 2013: The Physical Science Basis*; Cambridge University Press: Cambridge, MA, USA; New York, NY, USA, 2013.
2. IPCC. *Climate Change 2021: The Physical Science Basis*; Cambridge University Press: Cambridge, MA, USA; New York, NY, USA, 2021.
3. Shuai, C.; Shen, L.; Jiao, L.; Wu, Y.; Tan, Y. Identifying key impact factors on carbon emission: Evidences from panel and time-series data of 125 countries from 1990 to 2011. *Appl. Energy* **2017**, *187*, 310–325. [CrossRef]
4. Gasbarro, F.; Iraldo, F.; Daddi, T. The drivers of multinational enterprises' climate change strategies: A quantitative study on climate-related risks and opportunities. *J. Clean. Prod.* **2017**, *160*, 8–26. [CrossRef]
5. Wu, H.; Liang, H.; Roy, K.; Harrison, E.; Fang, Z.; De Silva, K.; Collins, N.; Lim, J.B.P. Analyzing the Climate Change Potential of Residential Steel Buildings in New Zealand and Their Alignment in Meeting the 2050 Paris Agreement Targets. *Buildings* **2022**, *12*, 290. [CrossRef]
6. Qin, J.; Tao, H.; Zhan, M.; Munir, Q.; Brindha, K.; Mu, G. Scenario Analysis of Carbon Emissions in the Energy Base, Xinjiang Autonomous Region, China. *Sustainability* **2019**, *11*, 4220. [CrossRef]
7. Liu, D.; Xiao, B. Can China achieve its carbon emission peaking? A scenario analysis based on STIRPAT and system dynamics model. *Ecol. Indic.* **2018**, *93*, 647–657. [CrossRef]
8. Liu, Z.; Guan, D.; Wei, W.; Davis, S.J.; Ciais, P.; Bai, J.; Peng, S.; Zhang, Q.; Hubacek, K.; Marland, G. Reduced carbon emission estimates from fossil fuel combustion and cement production in China. *Nature* **2015**, *524*, 335. [CrossRef]
9. Shan, Y.; Guan, D.; Liu, J.; Mi, Z.; Liu, Z.; Liu, J.; Schroeder, H.; Cai, B.; Chen, Y.; Shao, S. Methodology and applications of city level CO_2 emission accounts in China. *J. Clean. Prod.* **2017**, *161*, 1215–1225. [CrossRef]
10. Liu, X.; Li, S. A comparison analysis of the decoupling carbon emissions from economic growth in three industries of Heilongjiang province in China. *Environ. Sci. Pollut. R.* **2021**, *28*, 65200–65215. [CrossRef]
11. Zhang, X.; Zhao, Y.; Wang, C.; Wang, F.; Qiu, F. Decoupling effect and sectoral attribution analysis of industrial energy-related carbon emissions in Xinjiang, China. *Ecol. Indic.* **2018**, *97*, 1–9. [CrossRef]
12. Ahmad, N.; Du, L.; Lu, J.; Wang, J.; Li, H.; Hashmi, M. Modelling the CO_2 emissions and economic growth in Croatia: Is there any environmental Kuznets curve? *Energy* **2017**, *123*, 164–172. [CrossRef]
13. Wu, R.; Dong, J.; Zhou, L.; Zhang, L. Regional Distribution of Carbon Intensity and its Driving Factors in China: An Empirical Study Based on Provincial Data. *Pol. J. Environ. Stud.* **2018**, *27*, 1331–1341. [CrossRef]
14. Zhang, P.; He, J.; Hong, X.; Zhang, W.; Qin, C.; Pang, B.; Li, Y.; Liu, Y. Regional-Level Carbon Emissions Modelling and Scenario Analysis: A STIRPAT Case Study in Henan Province, China. *Sustainability* **2017**, *9*, 2342. [CrossRef]
15. Tapio, P. Towards a theory of decoupling: Degrees of decoupling in the EU and the case of road traffic in Finland between 1970 and 2001. *Transp. Policy* **2005**, *12*, 137–151. [CrossRef]
16. Chen, J.; Wang, P.; Cui, L.; Huang, S.; Song, M. Decomposition and decoupling analysis of CO_2 emissions in OECD. *Appl. Energy* **2018**, *231*, 937–950. [CrossRef]
17. Wang, Q.; Jiang, R. Is china's economic growth decoupled from carbon emissions? *J. Clean. Prod.* **2019**, *225*, 1194–1208. [CrossRef]
18. Wang, F.; Xu, H. Decoupling elasticity of carbon emissions and economic growth of transportation industry in Zhejiang province and its influencing factors. *J. Environ. Prot. Ecol.* **2021**, *22*, 750–759.

19. Wang, Y.; Xie, T.; Yang, S. Carbon emission and its decoupling research of transportation in Jiangsu Province. *J. Clean. Prod.* **2017**, *142*, 907–914. [CrossRef]
20. Jin, B.; Han, Y. Influencing factors and decoupling analysis of carbon emissions in China's manufacturing industry. *Environ. Sci. Pollut. R.* **2021**, *28*, 64719–64738. [CrossRef] [PubMed]
21. Wu, Y.; Chau, K.; Lu, W.; Shen, L.; Shuai, C.; Chen, J. Decoupling relationship between economic output and carbon emission in the Chinese construction industry. *Environ. Impact Assess.* **2018**, *71*, 60–69. [CrossRef]
22. Luo, Y.; Long, X.; Wu, C.; Zhang, J. Decoupling CO_2 emissions from economic growth in agricultural sector across 30 Chinese provinces from 1997 to 2014. *J. Clean. Prod.* **2017**, *159*, 220–228. [CrossRef]
23. Zhang, M.; Wang, W. Decouple indicators on the CO_2 emission-economic growth linkage: The Jiangsu Province case. *Ecol. Indic.* **2013**, *32*, 239–244. [CrossRef]
24. Zhao, X.; Zhang, X.; Li, N.; Shao, S.; Geng, Y. Decoupling economic growth from carbon dioxide emissions in China: A sectoral factor decomposition analysis. *J. Clean. Prod.* **2017**, *142*, 350–356. [CrossRef]
25. Miao, W.; Chao, F. Using an extended logarithmic mean Divisia index approach to assess the roles of economic factors on industrial CO_2 emissions of China. *Energy Econ.* **2018**, *76*, 101–114.
26. Li, K.; Lin, B. The improvement gap in energy intensity: Analysis of China′s thirty provincial regions using the improved DEA (data envelopment analysis) model. *Energy* **2015**, *84*, 589–599. [CrossRef]
27. Wang, C.J.; Fei, W. Examining the driving factors of energy related carbon emissions using the extended STIRPAT model based on IPAT identity in Xinjiang. *Renew. Sustain. Energy Rev.* **2017**, *67*, 51–61. [CrossRef]
28. Guo, B.; Geng, Y.; Dong, H.; Liu, Y. Energy-related greenhouse gas emission features in China's energy supply region: The case of Xinjiang. *Renew. Sustain. Energy Rev.* **2016**, *54*, 15–24. [CrossRef]
29. Qin, J.; Tao, H.; Cheng, C.; Brindha, K.; Zhan, M.; Ding, J.; Mu, G. Analysis of Factors Influencing Carbon Emissions in the Energy Base, Xinjiang Autonomous Region, China. *Sustainability* **2020**, *12*, 1089. [CrossRef]
30. Shan, Y.; Liu, J.; Liu, Z.; Xu, X.; Shao, S.; Wang, P.; Guan, D. New provincial CO_2 emission inventories in China based on apparent energy consumption data and updated emission factors. *Appl. Energy* **2016**, *184*, 742–750. [CrossRef]
31. Huo, J.; Yang, D.; Zhang, W.; Wang, F.; Wang, G.; Fu, Q. Analysis of influencing factors of CO_2 emissions in Xinjiang under the context of different policies. *Environ. Sci. Policy* **2015**, *45*, 20–29. [CrossRef]
32. Wang, C.; Wang, F. Structural Decomposition Analysis of Carbon Emissions and Policy Recommendations for Energy Sustainability in Xinjiang. *Sustainability* **2015**, *7*, 7548–7567. [CrossRef]
33. Xia, F.; Zhang, X.; Cai, T.; Wu, S.; Zhao, D. Identification of key industries of industrial sector with energy-related CO_2 emissions and analysis of their potential for energy conservation and emission reduction in Xinjiang, China. *Sci. Total Environ.* **2020**, *708*, 134587. [CrossRef] [PubMed]
34. Wang, C.; Wang, F.; Zhang, X.; Zhang, H. Influencing mechanism of energy-related carbon emissions in Xinjiang based on IO-SDA model. *J. Geogr. Sci.* **2016**, *71*, 1105–1118.
35. Wang, H.K.; Zhang, Y.X.; Lu, X.; Nielsen, C.P.; Bi, J. Understanding China's carbon dioxide emissions from both production and consumption perspectives. *Renew. Sustain. Energ. Rev.* **2015**, *52*, 189–200. [CrossRef]
36. Yang, Z.; Liu, Y. Does population have a larger impact on carbon dioxide emissions than income? Evidence from a cross-regional panel analysis in China. *Appl. Energy* **2016**, *180*, 800–809.
37. IPCC. *IPCC Guidelines for National Greenhouse Gas Inventories*; Institute for Global Environmental Strategies Press: Kanagawa, Japan, 2006.
38. Xinjiang Bureau of Statistics. *Xinjiang Statistical Yearbook*; Peking Info. Press: Beijing, China, 1991–2017. (In Chinese)