sustainability

MDPI

Article

Carbon Emissions from Manufacturing Sector in Jiangsu Province: Regional Differences and Decomposition of Driving Factors

Ping Zhou and Hailing Li *

Business School, Hunan Agricultural University, Changsha 410128, China; zhou_ping2022@163.com
* Correspondence: hilynn_lee1027@csu.edu.cn

Abstract: Based on the Tapio decoupling model, this paper discusses the decoupling relationship between the economic growth and carbon emissions of the manufacturing sector in southern Jiangsu, northern Jiangsu and middle Jiangsu during the 13th Five-Year-Plan period. By using the LMDI method, the carbon emissions and influencing factors of 31 subindustries of the manufacturing sector in Jiangsu Province from 2016 to 2020 were quantitatively analyzed by region and industry. The main findings are as follows: (1) during the 13th Five-Year-Plan period, the growth rate of the energy consumption and carbon emissions of the manufacturing sectors in southern Jiangsu, northern Jiangsu and middle Jiangsu slowed down, and the industrial structure was increasingly optimized; (2) economic growth is the primary driving force behind the manufacturing carbon emissions in the three regions of Jiangsu Province, while energy intensity is the main factor that affects the carbon-emission differences among the manufacturing subsectors in the different regions; (3) improving the energy efficiency of high-emission-intensity industries, such as the ferrous metal smelting and calendering industry, chemical industry and textile industry, is the key to reducing the carbon emissions of the manufacturing sector in the different regions of Jiangsu in the future. Jiangsu Province should promote the upgrading of the manufacturing-industry structure, and it should encourage the high-energy-consumption industry to reduce its energy intensity by technological innovation to achieve the goal of emission reduction and economic growth.

Keywords: Tapio decoupling; carbon emissions; low-carbon transformation; sustainable development; Jiangsu

check for updates

Citation: Zhou, P.; Li, H. Carbon Emissions from Manufacturing Sector in Jiangsu Province: Regional Differences and Decomposition of Driving Factors. *Sustainability* **2022**, *14*, 9123. https://doi.org/10.3390/su14159123

Academic Editors: Hirofumi Fukuyama and Yong Tan

Received: 17 June 2022
Accepted: 22 July 2022
Published: 25 July 2022

1. Introduction

In September 2020, President Xi Jinping of the People's Republic of China pointed out, at the 75th United Nations General Assembly, that China's carbon dioxide emissions will peak by 2030, and that China will achieve carbon neutrality by 2060. To achieve this goal, the Chinese government proposed, in the 14th Five-Year Plan, to support those provinces with conditions that can take the lead to reach the carbon-emission peak, requiring them to formulate action plans for carbon-emission peaking before 2030 [1,2].

Jiangsu, which is located in the Yangtze River Economic Belt, has 13 prefecture-level cities, and it is the only province where all the prefecture-level cities are among the top 100 in China (see Figure 1). In 2021, the added value of manufacturing in Jiangsu Province accounted for 35.8% of the regional gross domestic product (GDP) and 13.3% of the national GDP, ranking it first in China [3,4]. Furthermore, as the largest manufacturing province in China, Jiangsu Province has 40 industrial sectors, and its extensive development is accompanied by large amounts of energy consumption and carbon emissions. During the 13th Five-Year-Plan period, the industrial energy consumption accounted for more than 70% of the total energy consumption in Jiangsu, and SO_2 and NO_x accounted for 86% and 52% of the province, respectively [4]. The implementation of the national strategic deployment of "carbon peak and carbon neutrality", and the realization of low-carbon and green economic development, are important tasks that are faced by Jiangsu Province in the "14th Five-Year Plan" period.

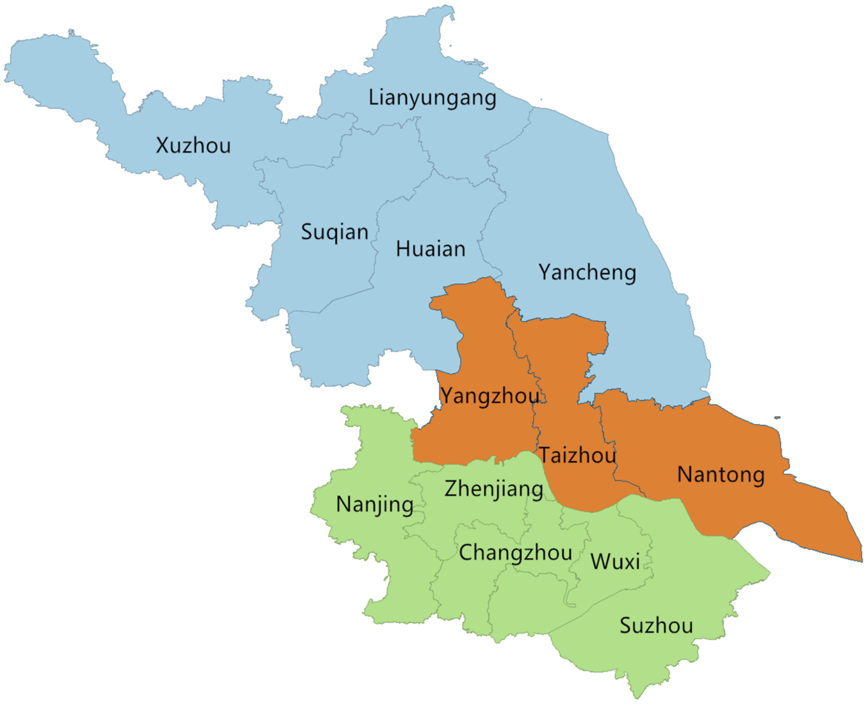

Figure 1. Map of Jiangsu Province (northern Jiangsu in blue, middle Jiangsu in yellow and southern Jiangsu in green).

The existing studies have been paying attention to carbon emissions for a long time, and there have been extensive discussions on the exponential decomposition of the influencing factors of carbon-emission change. However, most studies are conducted at the national level, and there are few studies that specifically focus on the driving factors of carbon emissions in provincial and regional manufacturing industries. Based on different geographical locations and levels of economic development, Jiangsu has formed three regions: southern Jiangsu, northern Jiangsu and middle Jiangsu (seen in Figure 1). There are large differences in the levels of green regional development in Jiangsu Province, with the highest green-development index in southern Jiangsu, the second highest in middle Jiangsu and the lowest in northern Jiangsu. Therefore, researching the decoupling relationship and the main driving factors of the manufacturing carbon emissions and industrial development in different regions is of great significance to the realization of low-carbon transformation and development in Jiangsu Province.

Based on existing research, this paper analyzes the decoupling statuses of the carbon emissions in the manufacturing subindustries of southern Jiangsu, northern Jiangsu and middle Jiangsu from 2016 to 2020, based on the Tapio decoupling model. We adopted the LMDI decomposition method, which measures the main driving factors of carbon emissions in the manufacturing subindustries of different regions. The main contributions of this paper are as follows: (1) the decomposition results are extended to the provincial regional level and industry level, and the decoupling index is used to explore the regional and industry differences in the carbon emissions in Jiangsu Province from a more detailed dimension; (2) a subindustry LMDI decomposition model was constructed to reveal the main driving forces of the carbon-emission differences among the three regional manufacturing subindustries, so as to provide a reference for the study of carbon-emission-reduction schemes for the manufacturing sector in Jiangsu Province. This has important reference significance for Jiangsu Province and will allow it to formulate economic adjustment and energy policies under different industrial sectors, clarify the responsibility and obligation of carbon-emission reduction, transform the economic growth mode and promote the harmonious development of the economy and environment.

The rest of this paper is as follows: In Section 2, we present the literature review; we present the methodology in Section 3; in Section 4, we present the results and discussions; in Section 5, we present the conclusion and policy suggestions.

2. Literature Review

The decoupling between carbon emissions and economic growth is considered to be the key to achieving green economic development. The linkage between economic growth and environmental pollution or resource consumption was first described by the Organization for Economic Cooperation and Development (OECD) as "decoupling" [5]. Traditionally, researchers have explored the main factors that affect energy consumption and environmental pollution based on different methods, including the frameworks of index decomposition analysis (IDA) [6,7] and structural decomposition analysis (SDA) [8,9]. Derived from the framework of IDA, the LMDI model has been widely applied to evaluate the efficiency in the energy and environmental sectors [10–12]. In addition, based on the study of Tapio [13], eight possible decoupling statuses were analyzed, and researchers have investigated and analyzed the decoupling statuses at various research levels with the Tapio model combined with LMDI theory [14]. In recent years, decoupling theory has been widely used for research on the decoupling relationship between economic growth and carbon emissions.

Many existing studies have focused on the country level [15–24] and region or city levels [25–29], exploring different decoupling statuses and the factors that affect economic growth and carbon emissions. At the country level, Chen et al. [30] indicated that the main factors that affect the carbon dioxide emissions of OECD countries were the energy intensity and per capita GDP, based on the LMDI model and the Kaya identity framework. Shuai et al. [31] found that higher-income-level groups had more possibilities of reaching their desired decoupling statuses than lower-income-level groups after identifying the income-level groups and decoupling statuses of 133 countries. In contrast to the above studies, Wang and Su [22] explored the impacts of urbanization and industrialization on decoupling by the Granger causality test and Johansen cointegration theory. Song et al. [32] used the case of China and the United States to distinguish the decoupling statuses of regions at different economic-development levels by studying the internal economic relationship between the decoupling model and the environmental Kuznets curve hypothesis. At the regional or city level, Dong et al. [33] decomposed the decoupling index into eight affecting factors at the regional level, with the investigation of the spatial and temporal heterogeneities in the influencing factors in each province of China. Wang et al. [34] comparatively studied the decoupling statuses, trends and effects of carbon emissions from economic growth between Beijing and Shanghai from the whole and sectoral perspectives. Liu et al. [35] analyzed the decoupling relationship between economic growth and industrial carbon emissions from 13 prefecture-level cities in Jiangsu Province.

Some researchers have studied the decoupling of output growth from carbon emissions at the sector level, such as in the agricultural industry [36], aircraft-related industry [37], metal industry [38,39], construction industry [40], manufacturing industry [41], power industry [42,43], transportation industry [34,40,44–46] and the whole industry [47–50]. Lu et al. [51] divided the industry into three main departments that consist of 38 subindustries, based on the importance of the sectoral dimension, and they analyzed the main factors that affect the energy-related industrial carbon emissions in Jiangsu, which is one province of China. Yang et al. [52] analyzed the decoupling elasticity and factors of industrial growth and carbon emissions in different Chinese regions, and they evaluated the contributions of different sectors. Wen and Li [53] analyzed the drivers of the industrial carbon emissions in 30 provinces of China based on optimized spectral clustering and proposed CE-reduction strategies. In addition, some scholars have also analyzed the decoupling statuses and trends between the industrial added value and carbon emissions from the perspectives of different industrial subindustries. For example, Song et al. [54] studied the decoupling status and CE-reduction potential of China's transport sector, and they pointed out that the main impact factor was the economic-growth effect. Hang et al. [55] explored the decoupling status and affecting factors between the carbon emissions and industrial added values of manufacturing considering the heterogeneity in China's manufacturing subindustries.

These existing studies have analyzed and evaluated the decoupling statuses and trends between economic variables and carbon emissions from the country, regional and city levels, and from a department perspective. However, few studies have comparatively researched the changes in the decoupling statuses and trends in manufacturing from different regions. Given this, based on the Tapio decoupling framework and the LMDI model, this study explores the decoupling of carbon emissions and manufacturing industrial added value and its affecting factors from a regional perspective. Furthermore, this paper evaluates the decoupling statuses, trends and affecting factors of the key subindustries by considering the heterogeneities in the regions and their policies. This research provides the theoretical basis for the low-carbon development of Jiangsu's different regions and different manufacturing subindustries, and it provides a policy reference for the overall coordinated development of manufacturing in Jiangsu, and even the whole country.

3. Methodology

3.1. LMDI Model

This paper selects the extended LMDI as the decomposition model of carbon emissions from the industrial sector i, which can be expressed as Equation (1):

$$\begin{aligned} C_i &= \sum_j C_{ij} = \sum_j \left(\frac{C_{ij}}{E_{ij}} \times \frac{E_{ij}}{IN_{ij}} \times \frac{E_i}{IN_i} \times \frac{IN_i}{G} \times G\right) \\ &= \sum_j \left(CE_{ij} \times ES_{ij} \times EI_{ij} \times IG_i \times G\right) \end{aligned} \tag{1}$$

where C_i represents the carbon emissions from the industrial sector i; C_{ij} represents the carbon emissions caused by the fossil energy consumption of energy j from the industrial sector i; E_{ij} represents the fossil energy consumption of energy j from the industrial sector i; E_i represents the energy consumption of the industrial sector i; IN_i represents the industrial added value of the industrial sector i; G represents the gross regional GDP; CE_{ij} represents the CE factor of energy j from the industrial sector i; ES_{ij} represents the ratio of the energy j consumption to total energy consumption; EI_{ij} represents the energy intensity of the industrial sector i; IG_i represents the ratio of industrial added value of the industrial sector i to the region's GDP.

The change in carbon emissions in a period t, ΔC_i is decomposed into five affecting factors, as shown in Equation (2) (carbon emissions, energy structure, energy intensity, industrial structure and industrial development), by using the LMDI model:

$$\Delta C_i = \Delta C_{i,CE} + \Delta C_{i,ES} + \Delta C_{i,EI} + \Delta C_{i,IG} + \Delta C_{i,G} \tag{2}$$

The five driving factors can also be expressed by Equations (3)–(8):

$$\Delta C_{i,CE} = \sum_j L(C_{i,j}^t, C_{i,j}^{t-1}) \ln(CE_{i,j}^t / CE_{i,j}^{t-1}) \tag{3}$$

$$\Delta C_{i,ES} = \sum_j L(C_{i,j}^t, C_{i,j}^{t-1}) \ln(ES_{i,j}^t / ES_{i,j}^{t-1}) \tag{4}$$

$$\Delta C_{i,EI} = \sum_j L(C_{i,j}^t, C_{i,j}^{t-1}) \ln(EI_{i,j}^t / EI_{i,j}^{t-1}) \tag{5}$$

$$\Delta C_{i,IG} = \sum_j L(C_{i,j}^t, C_{i,j}^{t-1}) \ln(IG_{i,j}^t / IG_{i,j}^{t-1}) \tag{6}$$

$$\Delta C_{i,G} = \sum_j L(C_{i,j}^t, C_{i,j}^{t-1}) \ln(G_{i,j}^t / G_{i,j}^{t-1}) \tag{7}$$

$$L(C_{i,j}^t, C_{i,j}^{t-1}) = \begin{cases} (C_{i,j}^t - C_{i,j}^{t-1})/(lnC_{i,j}^t - \ln C_{i,j}^{t-1}), C_{i,j}^t \neq C_{i,j}^{t-1} \\ C_{i,j}^t, C_{i,j}^t = C_{i,j}^{t-1} \end{cases} \tag{8}$$

3.2. Tapio Decoupling Model

Based on the decoupling coefficient defined by Tapio (2005) [13], the decoupling elasticity of the industry i can be measured as Equation (9):

$$D_i = \frac{\Delta C_i / C_i^0}{\Delta GDP_i / GDP_i^0} \tag{9}$$

By combining the LMDI model with the decoupling method, the decoupling status and coefficient between carbon emissions and industrial added value in different manufacturing sectors in different regions of Jiangsu are analyzed. By combining Equation (2) with Equation (9), the elasticity D_i is decomposed into five factors:

$$\begin{aligned} D_i &= \frac{(\Delta C_{i,CE} + \Delta C_{i,ES} + \Delta C_{i,EI} + \Delta C_{i,IG} + \Delta C_{i,G})/C_i^0}{\Delta GDP_i / GDP_i^0} \\ &= \frac{\Delta C_{i,CE}/C_i^0}{\Delta GDP_i/GDP_i^0} + \frac{\Delta C_{i,ES}/C_i^0}{\Delta GDP_i/GDP_i^0} + \frac{\Delta C_{i,EI}/C_i^0}{\Delta GDP_i/GDP_i^0} + \frac{\Delta C_{i,IG}/C_i^0}{\Delta GDP_i/GDP_i^0} + \frac{\Delta C_{i,G}/C_i^0}{\Delta GDP_i/GDP_i^0} \\ &= d_{CE} + d_{CE} + d_{CE} + d_{CE} + d_{CE} \end{aligned} \tag{10}$$

where d_{CE}, d_{ES}, d_{EI}, d_{IG} and d_G represent the five determinants for the decoupling index of the industry (i): the elasticity of the CE-intensity factor, energy-structure (ES) factor, energy-intensity (EI) factor, industrial-structure (IG) factor and industrial-development (G) factor.

In this paper, all kinds of energy uses are converted into corresponding standard coal, and the CE coefficient (C) generated by the complete combustion of standard coal per ton is calculated according to the fixed value recommended by the Energy Research Institute of the National Development and Reform Commission. Therefore, only d_{EI}, d_{IG}, and d_G are included in the decomposition factor for the decoupling index of industry i.

Based on the decoupling-elastic-coefficient (D) value, the decoupling status can be classified into three categories and eight subcategories, as shown in Table 1 (Tapio, 2005) [13].

Table 1. The Tapio decoupling statuses.

Decoupling Status		% C	% GDP	D
Negative decoupling	Expansive Negative Decoupling (END)	+	+	(1.2, +∞)
	Weak Negative Decoupling (WND)	−	−	[0, 0.8)
	Strong Negative Decoupling (SND)	+	−	(−∞, 0)
Decoupling	Recessive Decoupling (RD)	−	−	(1.2, +∞)
	Weak Decoupling (WD)	+	+	[0, 0.8)
	Strong Decoupling (SD)	−	+	(−∞, 0)
Coupling	Expansive Coupling (EC)	+	+	[0.8, 1.2]
	Recessive Coupling (RC)	−	−	[0.8, 1.2]

3.3. Data Source

This paper analyzes the decoupling between the industrial added value of manufacturing and carbon emissions in southern Jiangsu, northern Jiangsu and middle Jiangsu, based on the Tapio model. According to the industry classification of the Industrial Classification for National Economic Activities (ICNEA) (NBSC, 2017), this paper divides the manufacturing industry into 31 subindustries, and it investigates the heterogeneities in the decoupling statuses and trends of the manufacturing subindustries between the carbon emissions and industrial added value in different regions. In addition, according to the industrial-added-value proportion of the total manufacturing industrial added value, the decoupling factors of the key subindustries are analyzed in different regions of Jiangsu. The data on economic change and industrial energy consumption were collected from the statistical yearbooks of JSY during the period from 2016 to 2020.

4. Results and Discussions

4.1. Comparison of Decoupling Statuses, Trends and Decomposition Factors of Manufacturing in Three Regions

4.1.1. Decoupling Statuses and Trends of Manufacturing in Different Regions

According to the results of Table 2, during the 13th Five-Year-Plan period, the decoupling statuses of the manufacturing in southern Jiangsu, middle Jiangsu and northern Jiangsu were different [7,30,34,40,56]. Moreover, the decoupling status of middle Jiangsu was similar to that of northern Jiangsu. Specifically, the manufacturing in southern Jiangsu exhibited expansive negative decoupling in 2016–2017, weak decoupling in 2017–2018, strong decoupling in 2018–2019 and expansive negative decoupling in 2019–2020. The decoupling status of manufacturing in northern Jiangsu in 2016–2017 exhibited strong decoupling, expansive coupling in 2018–2019, and expansive negative decoupling in 2019–2020; the decoupling elastic coefficients of northern Jiangsu were −0.4875 in 2017–2018 and 3.4339 in 2019–2020. The reason may be the implementation of differentiated regional development policies. To promote and attain coordinated regional development, the Jiangsu provincial government put forward clear policies for supporting manufacturing development in northern Jiangsu and middle Jiangsu.

Table 2. The decoupling statuses of the manufacturing industries in southern Jiangsu, northern Jiangsu and middle Jiangsu.

		% C	**% GDP**	**D**	**Status**
Southern Jiangsu	2016–2017	0.1198	0.0529	2.2665	END
	2017–2018	0.0002	0.0795	0.0028	WD
	2018–2019	−0.0573	0.0251	−2.2842	SD
	2019–2020	0.0902	0.0021	42.4151	END
Northern Jiangsu	2016–2017	−0.1186	0.3398	−0.349	SD
	2017–2018	−0.0974	0.1997	−0.4876	SD
	2018–2019	0.1124	0.1357	0.8279	EC
	2019–2020	0.4184	0.1218	3.4339	END
Middle Jiangsu	2016–2017	−0.0768	0.1332	−0.5766	SD
	2017–2018	−0.1264	0.1732	−0.7297	SD
	2018–2019	0.1034	0.0872	1.1853	EC
	2019–2020	0.225	0.0982	2.2926	END

4.1.2. Comparison of the Decomposition Factors among the Three Regions

This paper further analyzes the factors that affect the decoupling statuses of the manufacturing in these three regions based on the LMDI model. As can be seen from Table 3, the energy intensity (d_EI) was the main driving factor that affected the decoupling elastic coefficients in southern Jiangsu, middle Jiangsu and northern Jiangsu, followed by the industrial-development factor (d_G). From a timespan perspective, the decoupling elastic coefficients in northern Jiangsu and middle Jiangsu showed an upward trend, while they showed a downward trend during 2016–2019 in southern Jiangsu. The energy-intensity factors in northern Jiangsu and middle Jiangsu changed from negative to positive, the industrial-development factors of the three regions were generally positive and the industrial-structure factors were quite different from each other. The proportion of industrial-development factors exceeded the proportion of energy-intensity factors in 2018-2019, which was when the statuses of northern Jiangsu and middle Jiangsu exhibited coupling.

Table 3. The decoupling factors affecting the decoupling elasticity in southern Jiangsu, northern Jiangsu and middle Jiangsu.

	Period	d_EI	d_IG	d_G	D
Southern Jiangsu	2016–2017	1.2348	−0.01	1.0417	2.2665
	2017–2018	−0.9595	0.0083	0.9541	0.0028
	2018–2019	−3.2433	0.0062	0.9529	−2.2842
	2019–2020	41.3717	0.1497	0.8936	42.4151
Northern Jiangsu	2016–2017	−1.1577	0.069	0.7397	−0.349
	2017–2018	−1.3542	0.0163	0.8503	−0.4876
	2018–2019	−0.1615	0.0365	0.9529	0.8279
	2019–2020	2.3043	0.0378	1.0917	3.4339
Middle Jiangsu	2016–2017	−1.4789	−0.0353	0.9376	−0.5766
	2017–2018	−1.5924	0.0109	0.8518	−0.7297
	2018–2019	0.1778	0.0114	0.9962	1.1853
	2019–2020	1.235	0.0158	1.0418	2.2926

According to the above empirical analysis, in northern Jiangsu and middle Jiangsu, which were more affected by policies, industrial-development factors and industrial-structure factors played greater roles, and the industrial development in southern Jiangsu was still more dependent on energy. Due to the policy requirements for environmental protection and industrial-structure upgrading, the manufacturing subindustries in the three regions still faced severe decoupling pressures.

4.2. Analysis of the Decoupling Statuses, Trends and Decomposition Factors of Key Subindustries in the Three Regions

This paper analyzed the decoupling statuses and trends of each manufacturing subindustry in three regions. Tables A1–A4 show the decoupling elastic coefficients of 31 manufacturing subindustries in southern Jiangsu, northern Jiangsu and middle Jiangsu from 2016 to 2020 (see the Appendix A, Tables A1–A4). In general, the decoupling statuses of the manufacturing development were not the same among the regions, but they tended to be the same during the research period, and simultaneously, the number of subindustries transitioning from the decoupling status to the negative decoupling status increased. This indicates that, although the green development of the manufacturing sector in Jiangsu Province achieved periodic achievements in the 13th Five-Year-Plan period, there was still a certain gap between the green-development level of the manufacturing industry and developed countries and advanced regions in China. For example, energy-intensive industries accounted for 80% of the industrial energy consumption, and coal consumption accounted for more than 50%.

Due to limited space, this paper selected the subindustries that accounted for more than 10% of the total manufacturing industrial added value as the key subindustries for the analysis of the decoupling statuses, trends, and decomposition factors. Therefore, three manufacturing subindustries were chosen in each region, including subindustries 26 (chemical raw materials and chemical products), 31 (nonmetallic mineral products) and 39 (communication equipment, computers and other electronic equipment) in southern Jiangsu; subindustries 26 (chemical raw materials and chemical products), 31 (nonmetallic mineral products) and 36 (equipment for special purposes) in northern Jiangsu; and subindustries 17 (textiles), 26 (chemical materials and chemical products) and 37 (transportation equipment) in middle Jiangsu.

4.2.1. Analysis of the Decoupling Statuses and Trends of Key Subindustries

Table 4 shows the decoupling statuses, trends and decomposition factors of these subindustries in different regions from 2011 to 2015.

Table 4. The decoupling statuses of key manufacturing subindustries in three regions.

Region	Industry	Period	Proportion	% C	% GDP	D	Status
Southern Jiangsu	26	2016–2017	13.64%	0.3244	−0.0130	−24.8926	SND
		2017–2018	9.59%	−0.0944	−0.3329	0.2835	WND
		2018–2019	9.89%	0.0853	0.0470	1.8163	END
		2019–2020	10.13%	0.0692	−0.0143	−4.8292	SND
	31	2016–2017	16.71%	0.4571	−0.0760	−6.0176	SND
		2017–2018	15.77%	0.0944	−0.1044	−0.9038	SND
		2018–2019	14.93%	−0.0849	−0.0392	2.1671	RD
		2019–2020	13.15%	0.1018	−0.1522	−0.6688	SND
	39	2016–2017	18.59%	−0.3489	0.2112	−1.6518	SD
		2017–2018	18.88%	−0.1132	−0.0364	3.1106	RD
		2018–2019	19.32%	−0.0128	0.0378	−0.3392	SD
		2019–2020	18.69%	0.0786	−0.0683	−1.1510	SND
Northern Jiangsu	26	2016–2017	11.20%	0.0774	0.0990	0.7824	WD
		2017–2018	12.70%	−0.0617	0.2173	−0.2838	SD
		2018–2019	11.71%	0.0054	0.0044	1.2215	END
		2019–2020	11.45%	0.7221	0.1515	4.7666	END
	31	2016–2017	12.97%	−0.4341	0.1160	−3.7436	SD
		2017–2018	11.11%	−0.0864	−0.0803	1.0767	RC
		2018–2019	10.12%	0.3854	−0.0080	−48.1417	SND
		2019–2020	10.05%	0.5420	0.1698	3.1923	END
	36	2016–2017	10.64%	−0.1190	0.4759	−0.2500	SD
		2017–2018	11.53%	0.0008	0.1638	0.0050	WD
		2018–2019	10.59%	−0.0027	0.0002	−16.1790	SD
		2019–2020	17.27%	0.5022	0.9216	0.5449	WD
Middle Jiangsu	17	2016–2017	10.67%	−0.1410	0.0015	−96.2740	SD
		2017–2018	11.01%	−0.0078	0.0222	−0.3494	SD
		2018–2019	9.99%	−0.0170	−0.0762	0.2235	WND
		2019–2020	9.39%	0.0478	0.0597	0.8008	EC
	26	2016–2017	16.00%	0.0450	0.1851	0.2432	WD
		2017–2018	16.88%	−0.0826	0.0454	−1.8185	SD
		2018–2019	17.37%	0.1235	0.0475	2.5987	END
		2019–2020	14.30%	0.0265	−0.0713	−0.3720	SND
	37	2016–2017	14.28%	3.8703	−0.0397	−97.4965	SND
		2017–2018	12.83%	−0.9376	−0.1099	8.5334	RD
		2018–2019	12.76%	0.0799	0.0124	6.4478	END
		2019–2020	12.18%	1.0600	0.0770	13.7650	END

In southern Jiangsu, the carbon emissions of subindustries 26 and 31 completely increased, and those of subindustry 39 decreased. However, the industrial added values of all these subindustries decreased in total. In 2017–2018, subindustry 26 exhibited weak negative decoupling, subindustry 31 exhibited strong negative decoupling and subindustry 39 exhibited strong decoupling. In 2019–2020, subindustries 26, 31 and 39 all exhibited strong negative decoupling. During the research period, subindustry 26 always exhibited negative decoupling, subindustry 31 mainly exhibited negative decoupling and subindustry 39 mainly exhibited decoupling. The decoupling statuses of all three subindustries exhibited strong negative decoupling overall, and the industrial added values from all three subindustries fluctuated; however, carbon emissions rose in subindustries 26 and 31. In comparison, the decoupling status of subindustry 39 was better than those of the other two industries.

In northern Jiangsu, the carbon emissions and industrial added value of the three subindustries completely increased. In 2017–2018, subindustry 26 exhibited weak decoupling; subindustry 31 exhibited recessive decoupling, which was a large change from the previous year of 2012; subindustry 36 exhibited weak decoupling. In 2019–2020, subindustry 26 exhibited expansive negative decoupling, which was similar to the previous year; subindustry 31 exhibited expansive negative decoupling; subindustry 36 exhibited weak decoupling. During the study period, subindustry 36 was always in a decoupling status, while subindustries 26 and 31 exhibited expansive negative decoupling overall. The carbon emissions and industrial added value of the three subindustries showed trends of fluctuating increases; in comparison, subindustry 36 achieved a better decoupling of carbon emissions and industrial added value.

In middle Jiangsu, the carbon emissions of subindustries 26 and 37 completely increased, and those of subindustry 17 decreased, although the industrial added value of all these subindustries increased overall. In 2017–2018, subindustry 17 exhibited strong decoupling, subindustry 31 exhibited weak decoupling and subindustry 37 exhibited strong negative decoupling. In 2019–2020, subindustry 17 exhibited expansive coupling, subindustry 31 exhibited expansive negative decoupling and subindustry 37 exhibited expansive negative decoupling. Subindustries 17 and 31 both changed greatly from the previous year. During the research period, the decoupling statuses of the three subindustries changed significantly.

In all, for the key subindustries of the manufacturing sector in southern Jiangsu, northern Jiangsu and middle Jiangsu, the decoupling statuses of the subindustries in southern Jiangsu had negative decoupling statuses for the longest time, which was quite different from the other two regions. Through the regional coordinated development policy of promoting the transfer of the factors of production between different regions, the decoupling statuses of the manufacturing subindustries in the three regions gradually converged, and the level of coordinated development among the regions continued to improve.

4.2.2. Analysis of the Decomposition Factors of Key Industries in Three Regions

First, this paper analyzed and compared the decomposition factors of subindustry 26 in the three regions. According to the results of Table 5, the proportion of the subindustry 26 industrial added value in the three regions fluctuated downward, and the variation trends in the decoupling elastic coefficients were quite different. Specifically, during the 13th Five-Year-Plan period, the energy intensity was the main factor that influenced subindustry 26 in southern Jiangsu, while the industrial structure and industrial development were the main factors that influenced subindustry 26 in northern Jiangsu. The factors of energy intensity and industrial structure had greater influences on the carbon emissions of subindustry 26 in middle Jiangsu.

Table 5. The decomposition factors of subindustry 26 (chemical raw materials and chemical products) in southern Jiangsu, northern Jiangsu and middle Jiangsu from 2016 to 2020.

Region	Period	d_EI	d_IG	d_G	D	Status
Southern Jiangsu	2016–2017	−26.0549	1.166	−0.0038	−24.8926	SND
	2017–2018	−0.8742	1.0073	0.1504	0.2835	WND
	2018–2019	0.7979	0.6962	0.3221	1.8163	END
	2019–2020	−5.8709	−1.7043	2.746	−4.8292	SND
Northern Jiangsu	2016–2017	−0.2077	0.1023	0.8877	0.7824	WD
	2017–2018	−1.1605	0.5622	0.3145	−0.2838	SD
	2018–2019	0.221	−18.6649	19.6654	1.2215	END
	2019–2020	3.5296	−0.1967	1.4337	4.7666	END
Middle Jiangsu	2016–2017	−0.6948	0.7678	0.1702	0.2432	WD
	2017–2018	−2.7554	1.1374	−0.2004	−1.8185	SD
	2018–2019	1.5625	0.6375	0.3986	2.5987	END
	2019–2020	−1.4231	2.761	−1.7099	−0.372	SND

According to the above empirical results, as a major chemical province, the industrial level of the chemical industry in Jiangsu Province has yet to be optimized, and the environmental-protection level of the enterprises is not high enough. This shows that the low-carbon transformation of the chemical industry in the 14th Five-Year-Plan period still has a long way to go, and it is urgent to systematically reconstruct a green-chemical-industry system that conforms to the laws of industrial development.

Second, this paper analyzed and compared the decomposition factors of subindustry 31 in southern Jiangsu and northern Jiangsu. Table 6 shows the analysis results. It can be seen from Table 6 that the proportion of the subindustry 31 industrial added value in these two regions showed a downward trend, while the elastic coefficient of its decoupling changed in the opposite direction. According to the results of Table 6, the energy intensity was also the main influencing factor on the carbon emissions in subindustry 31.

Table 6. The decomposition factors of subindustry 31 (nonmetallic mineral products) in southern Jiangsu and northern Jiangsu from 2016 to 2020.

Region	Period	d_EI	d_IG	d_G	D	Status
Southern Jiangsu	2016–2017	−7.2804	1.2635	−0.0007	−6.0176	SND
	2017–2018	−2.009	0.5782	0.5271	−0.9038	SND
	2018–2019	1.191	1.331	−0.3549	2.1671	RD
	2019–2020	−1.808	0.8766	0.2626	−0.6688	SND
Northern Jiangsu	2016–2017	−4.465	0.1651	0.5563	−3.7436	SD
	2017–2018	0.08	1.8368	−0.8401	1.0767	RC
	2018–2019	−49.3287	13.8796	−12.6926	−48.1417	SND
	2019–2020	2.0363	−0.0491	1.205	3.1923	END

Furthermore, this paper decomposed the decoupling elastic coefficients of the remaining key subindustries in the three regions, and analyzed the main affecting factors, such as subindustry 39, subindustry 36, subindustry 17 and subindustry 37 (seen in Table 7). Specifically, energy intensity was the main factor that affected the decoupling elasticity of subindustry 39 in southern Jiangsu during the 13th Five-Year-Plan period, while industrial structure and industrial development were the main factors of subindustry 36 from 2018 to 2019 in northern Jiangsu. At other times, energy intensity was the most influential factor. In middle Jiangsu, the energy-intensity factor was still the main factor behind the decoupling elastic coefficients of subindustry 17 and subindustry 37.

During the 13th Five-Year-Plan period, southern Jiangsu accelerated the development of subindustry 39 (communication equipment, computers and other electronic-equipment industries), and the decoupling of the industrial added value and carbon emissions was achieved. Northern Jiangsu actively promoted the development of subindustry 36 (special-equipment manufacturing). During the research period, this subindustry mainly exhibited decoupling, and the decoupling of the carbon emissions and industrial added value was also achieved. The trend of decoupling in the superior subindustry in middle Jiangsu was not obvious, and high-quality development was not fully realized.

Table 7. The decomposition factors of other subindustries in southern Jiangsu, northern Jiangsu and middle Jiangsu from 2016 to 2020.

Region	Industry	Period	d_EI	d_IG	d_G	D
Southern Jiangsu	39	2016–2017	−2.3895	0.7375	0.0002	−1.6518
		2017–2018	2.1507	−0.4026	1.3624	3.1106
		2018–2019	−1.3144	0.5937	0.3815	−0.3392
		2019–2020	−2.2270	0.4971	0.5789	−1.1510
Northern Jiangsu	36	2016–2017	−1.0183	0.6013	0.1670	−0.2500
		2017–2018	−0.9215	0.4957	0.4308	0.0050
		2018–2019	−17.1776	−512.1090	513.1075	−16.179
		2019–2020	−0.3297	0.6557	0.2189	0.5449
Middle Jiangsu	17	2016–2017	−97.2011	−18.5937	19.5208	−96.274
		2017–2018	−1.3346	1.4109	−0.4257	−0.3494
		2018–2019	−0.8078	1.2636	−0.2323	0.2235
		2019–2020	−0.1935	−1.0687	2.0630	0.8008
Middle Jiangsu	37	2016–2017	−99.9910	4.3925	−1.8980	−97.4965
		2017–2018	8.1753	0.3289	0.0292	8.5334
		2018–2019	5.4148	−0.4641	1.4971	6.4478
		2019–2020	12.3520	−0.8803	2.2932	13.7650

Notes: subindustry 39 represents communication equipment, computers and other electronic equipment; subindustry 36 represents equipment for special purposes; subindustry 17 represents textiles; subindustry 37 represents transportation equipment.

5. Conclusions and Policy Implications

5.1. Research Conclusions

This paper calculated the decoupling statuses between the manufacturing industry's carbon emissions and industrial added value in southern Jiangsu, northern Jiangsu and middle Jiangsu from 2016 to 2020, based on the Tapio model, and it explored the driving factors of carbon emissions that affect the decoupling status of each manufacturing subindustry with the LMDI model. The main findings are as follows:

1. During the 13th Five-Year-Plan period, the coordinated development level of the three regions gradually improved, but there was still a large gap. There were also significant differences in the carbon emissions and carbon-emission intensities among the different subsectors of the manufacturing industry in southern Jiangsu, northern Jiangsu and middle Jiangsu;
2. Industrial development is the most important driving factor of the manufacturing carbon emissions in southern Jiangsu, northern Jiangsu and middle Jiangsu, and especially for the industries with high-emission intensities, which are represented by ferrous metal smelting and calendering, the chemical industry and the textile industry; the contribution of the economic-activity effect to carbon emissions is the most significant;
3. Energy intensity is the most important driving force of carbon-emission reduction, and the most important influencing factor on the carbon-emission differences among the manufacturing subindustries in southern Jiangsu, northern Jiangsu and middle Jiangsu. The energy-intensity gap between high- and low-energy-intensity industries is further widening, and there is still a lot of room for improvement in the energy efficiencies of traditional high-emission-intensity industries.

5.2. Policy Recommendations

Based on these findings, the policy implications are as follows:

1. There is a need to clarify the carbon-peaking tasks of the key industries in different regions of Jiangsu Province, and to support key industries and enterprises to take the lead in achieving carbon peaking. The government should regard the ferrous-metal-smelting and calendering industry, with high total carbon emissions and high-

carbon-emission intensity, as the top priority of the carbon-peak work during the 14th Five-Year-Plan period. According to the characteristics of the industrial structures in different regions, the government should specify the carbon-peak tasks for the key industries in each region, and it should formulate relevant policy documents to guide enterprises to improve their energy efficiencies and reduce their carbon-emission intensities;

2. By combining the characteristics of the different regions in middle Jiangsu, southern Jiangsu and northern Jiangsu, the government should formulate differentiated carbon-peaking and carbon-neutrality action plans. Different regions should include the "3060" dual carbon target in their development plans, and they should actively explore the realization path to carbon peak and carbon neutrality. For example, the south of Jiangsu Province, with its developed economy and high industrial concentration, is a key area of energy consumption and carbon emissions, and it should be strongly encouraged to achieve green development through the adoption of new technologies and procarbon emissions;
3. There is a need to accelerate the development and application of energy-saving technologies and promote the optimization and upgrading of the industrial structure of Jiangsu Province. The upgrading of the industrial structure is an important means to promote energy conservation and emission reduction, but the industrial structure is unchangeable in the short term. Therefore, reducing carbon emissions by improving the technical level is the key to energy conservation and emission reduction in the Jiangsu manufacturing industry, through vigorously promoting scientific and technological innovation, promoting the industrial-structure upgrading of Jiangsu Province, promoting regional coordinated development and finally realizing the green economic transformation of Jiangsu Province.

5.3. Limitations and Future Research

Similar to most studies, some improvements could be made to this research. The energy-consumption data come from larger subindustries than small and medium enterprises, and so the overall values are smaller than the actual data. On the other hand, the LMDI model cannot reflect the changes in the factor structure and technological level for the whole economic field but can only reflect the changes in direct energy use. Therefore, due to the limitations of the method we have chosen, it is difficult to determine the influence of carbon emissions from one subindustry on those from other subindustries. However, our method fits our data, and the results are reliable. Further studies are still needed to determine the decoupling relationship between carbon emissions and the industrial added value from other inputs, and to calculate the direct and indirect impacts between different subindustries with other methods, such as SDA, which captures the greater impact of the economic structure and is easily extended to multiple regions.

In future research, some new methods should be tried to analyze the more specific driving factors of carbon emissions, such as the combination of DEA–LMDI based on input–output data; meanwhile, it is necessary to attempt to select more provinces and regions with different characteristics as research objects, such as Guangdong, the Yangtze River Delta region and the Pearl River Delta region, which could obtain more comprehensive research results to put forward more constructive suggestions.

Author Contributions: Conceptualization, H.L.; methodology, H.L.; formal analysis, P.Z. and H.L.; data curation, P.Z.; writing—original draft preparation, P.Z. and H.L.; writing—review and editing, P.Z. and H.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A

Table A1. The decoupling statuses of manufacturing subindustries of three regions in 2016–2017.

Period	Industry	Southern Jiangsu				Northern Jiangsu				Middle Jiangsu			
		% C	% GDP	D	State	% C	% GDP	D	State	% C	% GDP	D	State
2016–2017	13	0.0238	0.0881	0.2703	WD	−0.0628	−0.0273	2.3026	RD	0.1206	−0.0091	−13.2353	SND
2016–2017	14	−0.0729	−0.0093	7.8735	RD	−0.1038	0.0495	−2.0980	SD	0.0601	0.0789	0.7618	WD
2016–2017	15	−0.9859	−0.7222	1.3652	RD	−0.0267	0.0463	−0.5773	SD	−0.0326	−0.0610	0.5339	WND
2016–2017	16	−0.0207	0.0000	0.0000	SD	−0.0480	0.2918	−0.1643	SD	–	–	–	SD
2016–2017	17	−0.0371	−0.2419	0.1535	WND	−0.0848	−0.0521	1.6274	RD	−0.1410	0.0015	−96.2740	SD
2016–2017	18	0.0548	0.2357	0.2325	WD	−0.4263	−0.1699	2.5099	RD	0.6224	1.9206	0.3241	WD
2016–2017	19	0.0465	0.1043	0.4457	WD	−0.0600	0.0194	−3.0928	SD	−0.7793	0.2771	−2.8127	SD
2016–2017	20	−0.1331	−0.0578	2.3007	RD	−0.0572	0.0433	−1.3221	SD	−0.2735	−0.1114	2.4561	RD
2016–2017	21	−0.0918	4.1195	−0.0223	SD	158.1224	18.0095	8.7800	END	0.0103	−0.0056	−1.8372	SND
2016–2017	22	0.0699	0.0815	0.8578	EC	0.0387	−0.0599	−0.6467	SND	−0.0536	−0.0017	31.1985	RD
2016–2017	23	0.1258	−0.1713	−0.7346	SND	−0.0038	0.0772	−0.0491	SD	−0.9334	−0.9806	0.9519	RC
2016–2017	24	−0.2986	0.0534	−5.5936	SD	−0.4235	−0.1924	2.2012	RD	−0.9536	0.0934	−10.2073	SD
2016–2017	25	−0.0907	0.0100	−9.0538	SD	−0.1642	−0.0011	149.2618	RD	0.0375	0.1084	0.3458	WD
2016–2017	26	0.3244	−0.0130	−24.8926	SND	0.0774	0.0990	0.7824	WD	0.0450	0.1851	0.2432	WD
2016–2017	27	0.0406	0.4305	0.0942	WD	0.5103	0.0666	7.6668	END	−0.2045	−0.0390	5.2495	RD
2016–2017	28	−0.1046	−0.0636	1.6446	RD	−0.2601	0.0427	−6.0902	SD	−0.0586	−0.0509	1.1521	RC
2016–2017	29	−0.3309	0.1487	−2.2261	SD	0.1030	0.2298	0.4482	WD	0.0137	0.0906	0.1507	WD
2016–2017	30	0.0073	0.2272	0.0322	WD	−0.1478	−0.0804	1.8375	RD	−0.3165	−0.0773	4.0956	RD
2016–2017	31	0.4571	−0.0760	−6.0176	SND	−0.4341	0.1160	−3.7436	SD	−0.5571	−0.0795	7.0065	RD
2016–2017	32	−0.7078	−0.0196	36.0664	RD	0.0483	−0.2336	−0.2069	SND	−0.1483	−0.0012	128.3436	RD
2016–2017	33	−0.0767	0.0071	−10.8125	SD	−0.0646	−0.2569	0.2517	WND	0.0497	0.0141	3.5247	END
2016–2017	34	0.1475	−0.0673	−2.1909	SND	−0.1529	1.5850	−0.0965	SD	0.0458	0.0854	0.5365	WD
2016–2017	35	0.1139	1.0146	0.1123	WD	22.2128	−0.2056	−108.0512	SND	0.5838	−0.1520	−3.8405	SND
2016–2017	36	−0.0428	−0.0323	1.3244	RD	−0.1190	0.4759	−0.2500	SD	−0.0812	0.0345	−2.3540	SD
2016–2017	37	−0.3040	−0.2323	1.3088	RD	0.6344	9.4036	0.0675	WD	3.8703	−0.0397	−97.4965	SND
2016–2017	38	−0.0837	−0.0278	3.0084	RD	0.0258	0.3767	0.0684	WD	−0.1710	0.5792	−0.2952	SD
2016–2017	39	−0.3489	0.2112	−1.6518	SD	1.3365	2.3222	0.5755	WD	−0.8791	−0.3968	2.2156	RD
2016–2017	40	4.9610	0.1538	32.2598	END	−0.9831	−0.9577	1.0265	RC	0.0246	−0.0182	−1.3525	SND
2016–2017	41	0.7211	0.8073	0.8932	EC	0.1648	0.1811	0.9102	EC	0.0289	0.0977	0.2956	WD
2016–2017	42	−0.4930	−0.1270	3.8804	RD	0.9698	−0.6934	−1.3986	SND	−0.3775	−0.0653	5.7838	RD
2016–2017	43	86.8205	13.5568	6.4042	END	–	–	–	SD	−0.9929	−0.8830	1.1245	RC

Table A2. The decoupling statuses of manufacturing subindustries of three regions in 2017–2018.

Period	Industry	Southern Jiangsu				Northern Jiangsu				Middle Jiangsu			
		% C	% GDP	D	State	% C	% GDP	D	State	% C	% GDP	D	State
2017–2018	13	−0.1008	0.1502	−0.6706	SD	0.0481	0.1057	0.4554	WD	−0.0977	−0.0266	3.6710	RD
2017–2018	14	0.4785	0.1261	3.7939	END	0.0044	0.2377	0.0184	WD	−0.0858	0.0547	−1.5691	SD
2017–2018	15	0.0589	−0.1517	−0.3882	SND	−0.1337	−0.0861	1.5525	RD	0.0899	−0.6864	−0.1309	SND
2017–2018	16	−0.0708	0.0000	0.0000	SD	4.2689	1.1384	3.7501	END	–	–	–	SD
2017–2018	17	0.0040	0.0511	0.0792	WD	−0.0481	−0.0924	0.5208	WND	−0.0078	0.0222	−0.3494	SD
2017–2018	18	0.1894	0.8769	0.2160	WD	0.7014	0.9786	0.7168	WD	0.2927	−0.0740	−3.9545	SND
2017–2018	19	0.9807	−0.0098	−100.3330	SND	0.1253	0.0391	3.2041	END	−0.1537	0.0577	−2.6647	SD
2017–2018	20	0.0043	0.0204	0.2118	WD	0.1600	0.1163	1.3752	END	−0.1870	−0.0330	5.6674	RD
2017–2018	21	−0.4063	0.1478	−2.7497	SD	−0.9137	0.0222	−41.1774	SD	0.0000	0.2010	0.0000	SD
2017–2018	22	−0.0081	−0.0373	0.2160	WND	−0.2289	−0.2786	0.8215	RC	−0.4943	−0.0768	6.4382	RD
2017–2018	23	0.1870	0.1323	1.4139	END	−0.9084	−0.2393	3.7961	RD	8.9570	26.1612	0.3424	WD
2017–2018	24	0.3589	0.0916	3.9178	END	−0.0280	0.1521	−0.1838	SD	−0.1676	−0.0209	8.0081	RD
2017–2018	25	0.2314	0.0977	2.3689	END	0.2007	0.1748	1.1478	EC	−0.0102	−0.1395	0.0729	WND
2017–2018	26	−0.0944	−0.3329	0.2835	WND	−0.0617	0.2173	−0.2838	SD	−0.0826	0.0454	−1.8185	SD
2017–2018	27	0.2261	−0.1980	−1.1420	SND	0.2500	0.0700	3.5745	END	−0.1519	0.0326	−4.6639	SD
2017–2018	28	0.0685	0.0254	2.6973	END	−0.2861	−0.0409	6.9907	RD	0.0843	−0.0405	−2.0830	SND
2017–2018	29	0.0831	−0.0572	−1.4521	SND	−0.0138	0.0504	−0.2732	SD	−0.0022	−0.0299	0.0737	WND
2017–2018	30	−0.3209	−0.1828	1.7551	RD	0.0941	−0.0305	−3.0830	SND	−0.2030	0.1334	−1.5216	SD
2017–2018	31	0.0944	−0.1044	−0.9038	SND	−0.0864	−0.0803	1.0767	RC	−0.1980	−0.6358	0.3115	WND
2017–2018	32	0.0744	−0.0275	−2.7021	SND	−0.0859	0.3537	−0.2427	SD	3.3627	1.5898	2.1152	END
2017–2018	33	−0.1420	−0.0433	3.2750	RD	0.1653	0.1950	0.8478	EC	0.0699	0.0583	1.1984	EC
2017–2018	34	−0.1315	0.0591	−2.2258	SD	−0.1128	0.5436	−0.2075	SD	−0.0988	0.0389	−2.5369	SD
2017–2018	35	0.0813	0.2345	0.3466	WD	−0.9877	−0.4270	2.3133	RD	0.2763	−0.0237	−11.6376	SND
2017–2018	36	−0.3015	0.1262	−2.3894	SD	0.0008	0.1638	0.0050	WD	−0.1365	2.1902	−0.0623	SD
2017–2018	37	0.1464	−0.0500	−2.9275	SND	−0.1458	0.1152	−1.2655	SD	−0.9376	−0.1099	8.5334	RD
2017–2018	38	3.7538	0.1121	33.4831	END	−0.1403	−0.1455	0.9640	RC	0.0484	−0.0499	−0.9695	SND
2017–2018	39	−0.1132	−0.0364	3.1106	RD	0.1002	0.3471	0.2887	WD	−0.1326	0.0225	−5.9039	SD
2017–2018	40	−0.7024	−0.2392	2.9367	RD	−0.0603	−0.8335	0.0723	WND	0.0071	0.3042	0.0233	WD
2017–2018	41	0.0950	0.9577	0.0992	WD	−0.0636	−0.8531	0.0745	WND	0.1833	0.0455	4.0238	END
2017–2018	42	0.0839	0.0787	1.0664	EC	−0.0029	0.3233	−0.0091	SD	−0.0092	−0.0167	0.5487	WND
2017–2018	43	−0.7456	−0.4766	1.5646	RD	−0.3083	1.3331	−0.2313	SD	−0.8700	−0.5858	1.4852	RD

Table A3. The decoupling statuses of manufacturing subindustries of three regions in 2018–2019.

Period	Industry	Southern Jiangsu				Northern Jiangsu				Middle Jiangsu			
		% C	% GDP	D	State	% C	% GDP	D	State	% C	% GDP	D	State
2018–2019	13	−0.0050	−0.0735	0.0676	WND	0.2537	0.0943	2.6891	END	−0.0293	−0.0487	0.6018	WND
2018–2019	14	−0.3007	−0.0071	42.5305	RD	0.0109	0.1040	0.1052	WD	−0.0228	0.4005	−0.0570	SD
2018–2019	15	1.1817	−0.1760	−6.7159	SND	−0.0766	0.2110	−0.3632	SD	0.1508	0.6606	0.2283	WD
2018–2019	16	−0.2017	0.0000	0.0000	SD	−0.6424	0.6984	−0.9198	SD	–	–	–	SD
2018–2019	17	−0.0121	0.0324	−0.3749	SD	0.1737	0.0530	3.2760	END	−0.0170	−0.0762	0.2235	WND
2018–2019	18	−0.0802	−0.0108	7.4047	RD	−0.0884	−0.2656	0.3329	WND	0.4570	−0.2082	−2.1946	SND
2018–2019	19	0.1987	−0.0192	−10.3270	SND	0.1020	0.1115	0.9154	EC	0.2243	−0.0660	−3.3962	SND
2018–2019	20	0.4903	0.4631	1.0587	EC	0.0169	0.0174	0.9665	EC	−0.0166	0.0556	−0.2992	SD
2018–2019	21	0.2463	0.0676	3.6429	END	−0.4643	−0.4195	1.1069	RC	−0.0028	0.0000	0.0000	SD
2018–2019	22	−0.0871	−0.0263	3.3120	RD	0.0432	0.7564	0.0571	WD	0.8502	0.2935	2.8972	END
2018–2019	23	4.1583	−0.2928	−14.2007	SND	7.8803	0.1749	45.0596	END	0.2004	4.5933	0.0436	WD
2018–2019	24	0.0633	0.0095	6.6495	END	2.9608	1.0243	2.8905	END	0.0249	0.1407	0.1771	WD
2018–2019	25	0.0133	0.0137	0.9728	EC	0.0157	−0.0891	−0.1761	SND	−0.0458	−0.1245	0.3675	WND
2018–2019	26	0.0853	0.0470	1.8163	END	0.0054	0.0044	1.2215	END	0.1235	0.0475	2.5987	END
2018–2019	27	0.3036	0.0994	3.0546	END	0.2122	−0.1329	−1.5970	SND	0.1007	0.2270	0.4437	WD
2018–2019	28	0.1386	−0.0273	−5.0804	SND	−0.0447	−0.0512	0.8721	RC	−0.0474	−0.0671	0.7063	WND
2018–2019	29	0.1591	0.0178	8.9364	END	0.3080	0.1385	2.2234	END	0.0787	−0.1209	−0.6506	SND
2018–2019	30	−0.1694	0.0001	−1131.7328	SD	0.0031	0.4563	0.0068	WD	−0.0202	−0.0137	1.4723	RD
2018–2019	31	−0.0849	−0.0392	2.1671	RD	0.3854	−0.0080	−48.1417	SND	0.1628	0.4169	0.3905	WD
2018–2019	32	−0.2145	−0.2213	0.9692	RC	−0.0132	0.2541	−0.0518	SD	−0.7926	−0.5725	1.3845	RD
2018–2019	33	0.0907	0.1513	0.5992	WD	0.2460	0.1948	1.2627	END	0.0003	0.0030	0.0833	WD
2018–2019	34	0.2415	0.1539	1.5694	END	−0.4937	0.1599	−3.0887	SD	3.9916	0.5455	7.3174	END
2018–2019	35	0.3115	−0.0507	−6.1377	SND	0.1637	0.2085	0.7851	WD	0.9511	0.2134	4.4560	END
2018–2019	36	0.1736	0.0123	14.1035	END	−0.0027	0.0002	−16.1790	SD	10.2368	0.0123	830.2161	END
2018–2019	37	4.2307	0.0584	72.4684	END	0.7059	−0.5101	−1.3839	SND	0.0799	0.0124	6.4478	END
2018–2019	38	−0.4087	−0.0728	5.6122	RD	0.1627	−0.0663	−2.4537	SND	0.0301	−0.0164	−1.8350	SND
2018–2019	39	−0.0128	0.0378	−0.3392	SD	−0.2654	0.1346	−1.9713	SD	0.1109	0.0317	3.4996	END
2018–2019	40	0.5048	0.1749	2.8869	END	0.9309	40.3453	0.0231	WD	0.0020	−0.0918	−0.0215	SND
2018–2019	41	−0.0035	0.1312	−0.0267	SD	0.1826	0.5829	0.3133	WD	0.1400	−0.2000	−0.7001	SND
2018–2019	42	−0.5212	−0.0330	15.8109	RD	0.5122	−0.2901	−1.7655	SND	0.0189	0.0910	0.2079	WD
2018–2019	43	0.3286	−0.0349	−9.4224	SND	0.1836	0.8197	0.2240	WD	138.8960	12.8453	10.8129	END

Table A4. The decoupling statuses of manufacturing subindustries of three regions in 2019–2020.

Period	Industry	Southern Jiangsu				Northern Jiangsu				Middle Jiangsu			
		% C	% GDP	D	State	% C	% GDP	D	State	% C	% GDP	D	State
2019–2020	13	0.1233	−0.1278	−0.9644	SND	0.5086	0.0807	6.2992	END	0.2054	−0.0382	−5.3778	SND
2019–2020	14	0.1503	0.0385	3.9037	END	0.0183	−0.0224	−0.8162	SND	0.3115	1.5709	0.1983	WD
2019–2020	15	−0.0455	0.3191	−0.1425	SD	−0.0883	0.1439	−0.6139	SD	0.5918	0.2458	2.4077	END
2019–2020	16	−0.0458	0.0000	0.0000	SD	0.2245	0.0116	19.3086	END	–	–	–	SD
2019–2020	17	0.0021	0.0415	0.0509	WD	−0.0911	0.1508	−0.6044	SD	0.0478	0.0597	0.8008	EC
2019–2020	18	1.0643	0.0060	176.3757	END	0.5684	1.0607	0.5359	WD	−0.3881	−0.5166	0.7514	WND
2019–2020	19	−0.0470	0.0756	−0.6209	SD	0.7085	0.6693	1.0586	EC	7.8090	0.1684	46.3834	END
2019–2020	20	11.9393	−0.1596	−74.8185	SND	0.3452	0.2949	1.1705	EC	−0.4579	−0.0399	11.4857	RD
2019–2020	21	0.0809	0.0374	2.1611	END	0.0000	0.0000	0.0000	SD	0.3588	0.3347	1.0722	EC
2019–2020	22	0.1555	−0.0136	−11.4419	SND	−0.1782	−0.0446	3.9928	RD	0.3948	0.3834	1.0297	EC
2019–2020	23	−0.8491	0.2735	−3.1048	SD	0.0428	0.0992	0.4313	WD	−0.5818	−0.9191	0.6330	WND
2019–2020	24	0.1117	0.0311	3.5951	END	0.0000	0.0036	0.0000	SD	0.0333	0.3914	0.0852	WD
2019–2020	25	−0.0114	−0.1521	0.0751	WND	0.4550	0.1007	4.5170	END	−0.0258	−0.4682	0.0551	WND
2019–2020	26	0.0692	−0.0143	−4.8292	SND	0.7221	0.1515	4.7666	END	0.0265	−0.0713	−0.3720	SND
2019–2020	27	2.5993	0.0968	26.8540	END	−0.3489	0.9757	−0.3576	SD	0.4795	2.5025	0.1916	WD
2019–2020	28	0.0908	0.1961	0.4633	WD	0.9813	−0.1078	−9.1072	SND	−0.0292	−0.0536	0.5450	WND
2019–2020	29	0.0303	0.1559	0.1944	WD	−0.0702	−0.0386	1.8189	RD	−0.0556	1.8732	−0.0297	SD
2019–2020	30	−0.0258	0.2100	−0.1226	SD	−0.0931	−0.0808	1.1526	RC	0.0303	0.2870	0.1057	WD
2019–2020	31	0.1018	−0.1522	−0.6688	SND	0.5420	0.1698	3.1923	END	3.1528	0.1442	21.8587	END
2019–2020	32	0.0475	−0.0199	−2.3887	SND	0.1695	−0.3351	−0.5059	SND	0.0676	0.0835	0.8090	EC
2019–2020	33	−0.1307	−0.1445	0.9045	RC	−0.1238	−0.0569	2.1739	RD	0.2330	0.0857	2.7206	END
2019–2020	34	−0.2631	−0.1460	1.8025	RD	0.1137	−0.2919	−0.3894	SND	0.0417	−0.1453	−0.2869	SND
2019–2020	35	−0.1828	0.1951	−0.9368	SD	−0.5284	−0.1963	2.6913	RD	−0.2245	0.4129	−0.5437	SD
2019–2020	36	0.0100	0.1143	0.0875	WD	0.5022	0.9216	0.5449	WD	−0.8739	−0.5939	1.4716	RD
2019–2020	37	−0.7033	−0.0578	12.1687	RD	−0.6702	0.0876	−7.6542	SD	1.0600	0.0770	13.7650	END
2019–2020	38	−0.4789	0.0766	−6.2513	SD	−0.0355	0.1212	−0.2932	SD	−0.2649	0.2124	−1.2468	SD
2019–2020	39	0.0786	−0.0683	−1.1510	SND	0.3994	0.5984	0.6674	WD	0.6285	0.4692	1.3395	END
2019–2020	40	0.0853	0.1011	0.8433	EC	4.0370	−0.3195	−12.6362	SND	0.1151	0.3449	0.3337	WD
2019–2020	41	5.2892	−0.2930	−18.0539	SND	6.0398	0.5641	10.7068	END	1.5307	0.7020	2.1805	END
2019–2020	42	−0.5716	−0.0953	5.9966	RD	−0.2749	1.9982	−0.1376	SD	5.0293	0.1072	46.9108	END
2019–2020	43	0.5929	3.5638	0.1664	WD	0.7335	0.4119	1.7807	END	15.1724	−0.4976	−30.4908	SND

Table A5. Industrial classification for the manufacturing industry.

Code	Name
13	Farm and sideline food procarbon emissions
14	Food
15	Beverage
16	Tobacco
17	Textiles
18	Textiles and garments, shoes, hats
19	Leather, fur, feathers and other products
20	Wood procarbon emissions and furniture making
21	Furniture
22	Paper making and paper products
23	Copies of printing and recording mediums
24	Cultural and educational sporting goods
25	Oil procarbon emissions, coking and nuclear fuel
26	Chemical raw materials and chemical products
27	Pharmaceuticals
28	Chemical fiber
29	Rubber products
30	Plastic products
31	Nonmetallic mineral products
32	Ferrous metal smelting and rolling
33	Nonferrous metal smelting and rolling
34	Fabricated metal products
35	General machinery
36	Equipment for special purposes
37	Transportation equipment
38	Electrical equipment and machinery
39	Communication equipment, computer and other
40	Instrumentation, stationary and office supplies
41	Other manufacturing
42	Waste-resource carbon-emission comprehensive-utilization industry
43	Metal products, machinery and equipment repair

References

1. Xu, H.; Tang, A.; Pittock, J. The dark side of ambition: Side-effects of China's climate policy. *Environ. Res. Lett.* **2021**, *16*, 111001. [CrossRef]
2. Robinson, S.A.; Blair, C.; McDonough, M. China's climate ambition: Revisiting its First Nationally Determined Contribution and centering a just transition to clean energy. *Energy Policy* **2021**, *155*, 112350.
3. National Bureau of Statistics of China. National Development and Reform Commission. In *CSY (China Statistical Yearbook)*; National Bureau of Statistics of China: Beijing, China, 2011–2016.
4. The Statistical Yearbook of Jiangsu, 2015–2020. In *JSY (Jiangsu Statistical Yearbook)*; National Bureau of Statistics of China: Beijing, China, 2015–2020.
5. OECD (Organization for Economic Co-operation and Development). Indicators to Measure Decoupling of Environmental Pressure from Economic Growth. Sustainable Development. 2002. Available online: http://www.oecd.org/env/indicators-modelling-outlooks/1933638.pdf (accessed on 20 January 2020).

6. Ang, B.W.; Goh, T. Index decomposition analysis for comparing emission scenarios: Applications and challenges. *Energy Econ.* **2019**, *83*, 74–87. [CrossRef]
7. Zhang, C.; Su, B.; Zhou, K.; Yang, S. Analysis of electricity consumption in China (1990–2016) using index decomposition and decoupling approach. *J. Clean. Prod.* **2019**, *209*, 224–235. [CrossRef]
8. Su, B.; Ang, B.W. Multi-region comparisons of emission performance: The structural decomposition analysis approach. *Ecol. Indic.* **2016**, *67*, 78–87. [CrossRef]
9. Wang, H.; Ang, B.W.; Su, B. Multiplicative structural decomposition analysis of energy and emission intensities: Some methodological issues. *Energy* **2017**, *123*, 47–63. [CrossRef]
10. Dong, B.; Zhang, M.; Mu, H.; Su, X. Study on decoupling analysis between energy consumption and economic growth in Liaoning Province. *Energy Policy* **2016**, *97*, 414–420. [CrossRef]
11. Wang, W.; Liu, X.; Zhang, M.; Song, X. Using a new generalized LMDI (logarithmic mean Divisia index) method to analyze China's energy consumption. *Energy* **2014**, *67*, 617–622. [CrossRef]
12. Zhang, M.; Bai, C. Exploring the influencing factors and decoupling state of residential energy consumption in Shandong. *J. Clean. Prod.* **2018**, *194*, 253–262. [CrossRef]
13. 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]
14. Song, Y.; Zhang, M. Using a new decoupling indicator (ZM decoupling indicator) to study the relationship between the economic growth and energy consumption in China. *Nat. Hazards* **2017**, *88*, 1013–1022. [CrossRef]
15. Pan, X.; Guo, S.; Xu, H.; Tian, M.; Pan, X.; Chu, J. China's carbon intensity factor decomposition and carbon emission decoupling analysis. *Energy* **2022**, *239*, 122175. [CrossRef]
16. Wang, Q.; Jiang, R. Is China's economic growth decoupled from carbon emissions? *J. Clean. Prod.* **2019**, *225*, 1194–1208. [CrossRef]
17. Zhao, Y.; Su, Q.; Li, B.; Zhang, Y.; Wang, X.; Zhao, H.; Guo, S. Have those countries declaring "zero carbon" or "carbon neutral" climate goals achieved carbon emissions-economic growth decoupling? *J. Clean. Prod.* **2022**, *363*, 132450. [CrossRef]
18. Andreoni, V.; Galmarini, S. Decoupling economic growth from carbon dioxide emissions: A decomposition analysis of Italian energy consumption. *Energy* **2012**, *44*, 682–691. [CrossRef]
19. Roinioti, A.; Koroneos, C. The decomposition of CO_2 emissions from energy use in Greece before and during the economic crisis and their decoupling from economic growth. *Renew. Sustain. Energy Rev.* **2017**, *76*, 448–459. [CrossRef]
20. Vavrek, R.; Chovancova, J. Decoupling of Greenhouse Gas Emissions from Economic Growth in V4 Countries. *Procedia Econ. Financ.* **2016**, *39*, 526–533. [CrossRef]
21. Wang, H.; Ang, B.W.; Su, B. A Multi-region Structural Decomposition Analysis of Global CO_2 Emission Intensity. *Ecol. Econ.* **2017**, *142*, 163–176. [CrossRef]
22. Wang, Q.; Su, M. The effects of urbanization and industrialization on decoupling economic growth from carbon emission—A case study of China. *Sustain. Cities Soc.* **2019**, *51*, 101758. [CrossRef]
23. Zhang, Y.-J.; Da, Y.-B. The decomposition of energy-related carbon emission and its decoupling with economic growth in China. *Renew. Sustain. Energy Rev.* **2015**, *41*, 1255–1266. [CrossRef]
24. Zhao, X.; Zhang, X.; Shao, S. Decoupling CO_2 emissions and industrial growth in China over 1993–2013: The role of investment. *Energy Econ.* **2016**, *60*, 275–292. [CrossRef]
25. Chen, B.; Yang, Q.; Li, J.S.; Chen, G.Q. Decoupling analysis on energy consumption, embodied GHG emissions and economic growth—The case study of Macao. *Renew. Sustain. Energy Rev.* **2017**, *67*, 662–672. [CrossRef]
26. Li, L.; Shan, Y.; Lei, Y.; Wu, S.; Yu, X.; Lin, X.; Chen, Y. Decoupling of economic growth and emissions in China's cities: A case study of the Central Plains urban agglomeration. *Applied Energy* **2019**, *244*, 36–45. [CrossRef]
27. Song, Y.; Sun, J.; Zhang, M.; Su, B. Using the Tapio-Z decoupling model to evaluate the decoupling status of China's CO_2 emissions at provincial level and its dynamic trend. *Struct. Change Econ. Dyn.* **2020**, *52*, 120–129. [CrossRef]
28. Wang, Q.; Hang, Y.; Zhou, P.; Wang, Y. Decoupling and attribution analysis of industrial carbon emissions in Taiwan. *Energy* **2016**, *113*, 728–738. [CrossRef]
29. Li, J.; Li, M. Research of Carbon Emission Reduction Potentials in the Yellow River Basin, Based on Cluster Analysis and the Logarithmic Mean Divisia Index (LMDI) Method. *Sustainability* **2022**, *14*, 5284. [CrossRef]
30. Chen, J.; Wang, P.; Cui, L.; Huang, S.; Song, M. Decomposition and decoupling analysis of CO_2 emissions in OECD. *Applied Energy* **2018**, *231*, 937–950. [CrossRef]
31. Shuai, C.; Chen, X.; Wu, Y.; Zhang, Y.; Tan, Y. A three-step strategy for decoupling economic growth from carbon emission: Empirical evidences from 133 countries. *Sci. Total Environ.* **2019**, *646*, 524–543. [CrossRef]
32. Song, Y.; Zhang, M.; Zhou, M. Study on the decoupling relationship between CO_2 emissions and economic development based on two-dimensional decoupling theory: A case between China and the United States. *Ecol. Indic.* **2019**, *102*, 230–236. [CrossRef]
33. Dong, F.; Li, J.; Wang, Y.; Zhang, X.; Zhang, S.; Zhang, S. Drivers of the decoupling indicator between the economic growth and energy-related CO2 in China: A revisit from the perspectives of decomposition and spatiotemporal heterogeneity. *Sci. Total Environ.* **2019**, *685*, 631–658. [CrossRef]
34. Wang, Q.; Wang, S. A comparison of decomposition the decoupling carbon emissions from economic growth in transport sector of selected provinces in eastern, central and western China. *J. Clean. Prod.* **2019**, *229*, 570–581. [CrossRef]

35. Liu, J.; Li, H.; Liu, T. Decoupling Regional Economic Growth from Industrial CO_2 Emissions: Empirical Evidence from the 13 Prefecture-Level Cities in Jiangsu Province. *Sustainability* **2022**, *14*, 2733. [CrossRef]
36. 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]
37. Yu, J.; Shao, C.; Xue, C.; Hu, H. China's aircraft-related CO_2 emissions: Decomposition analysis, decoupling status, and future trends. *Energy Policy* **2020**, *138*, 111215. [CrossRef]
38. Ren, S.; Hu, Z. Effects of decoupling of carbon dioxide emission by Chinese nonferrous metals industry. *Energy Policy* **2012**, *43*, 407–414. [CrossRef]
39. Wang, M.; Feng, C. Decoupling economic growth from carbon dioxide emissions in China's metal industrial sectors: A technological and efficiency perspective. *Sci. Total Environ.* **2019**, *691*, 1173–1181. [CrossRef]
40. Wu, Y.; Tam, V.W.; Shuai, C.; Shen, L.; Zhang, Y.; Liao, S. Decoupling China's economic growth from carbon emissions: Empirical studies from 30 Chinese provinces (2001–2015). *Sci. Total Environ.* **2019**, *656*, 576–588. [CrossRef]
41. Ren, S.; Yin, H.; Chen, X. Using LMDI to analyze the decoupling of carbon dioxide emissions by China's manufacturing industry. *Environ. Dev.* **2014**, *9*, 61–75. [CrossRef]
42. Wang, Q.; Jiang, X.; Li, R. Comparative decoupling analysis of energy-related carbon emission from electric output of electricity sector in Shandong Province, China. *Energy* **2017**, *127*, 78–88. [CrossRef]
43. Xie, P.; Gao, S.; Sun, F. An analysis of the decoupling relationship between CO2 emission in power industry and GDP in China based on LMDI method. *J. Clean. Prod.* **2019**, *211*, 598–606. [CrossRef]
44. Engo, J. Decoupling analysis of CO2 emissions from transport sector in Cameroon. *Sustain. Cities Soc.* **2019**, *51*, 101732. [CrossRef]
45. 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]
46. Zhu, C.; Yang, S.; Liu, P. Study on the Factors Influencing on the Carbon Emissions of Shaanxi Province's Transportation Industry in China. *Sustainability* **2022**, *14*, 8610. [CrossRef]
47. Feng, J.-C.; Zeng, X.-L.; Yu, Z.; Bian, Y.; Li, W.-C.; Wang, Y. Decoupling and driving forces of industrial carbon emission in a coastal city of Zhuhai, China. *Energy Rep.* **2019**, *5*, 1589–1602. [CrossRef]
48. 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.* **2019**, *97*, 1–9. [CrossRef]
49. Zheng, X.; Wang, R.; He, Q. A city-scale decomposition and decoupling analysis of carbon dioxide emissions: A case study of China. *J. Clean. Prod.* **2019**, *238*, 117824. [CrossRef]
50. Zhou, X.; Zhang, M.; Zhou, M.; Zhou, M. A comparative study on decoupling relationship and influence factors between China's regional economic development and industrial energy–related carbon emissions. *J. Clean. Prod.* **2017**, *142*, 783–800. [CrossRef]
51. Lu, Q.; Yang, H.; Huang, X.; Chuai, X.; Wu, C. Multi-sectoral decomposition in decoupling industrial growth from carbon emissions in the developed Jiangsu Province, China. *Energy* **2015**, *82*, 414–425. [CrossRef]
52. Yang, L.; Yang, Y.; Zhang, X.; Tang, K. Whether China's industrial sectors make efforts to reduce CO_2 emissions from production?—A decomposed decoupling analysis. *Energy* **2018**, *160*, 796–809. [CrossRef]
53. Wen, L.; Li, Z. Provincial-level industrial CO2 emission drivers and emission reduction strategies in China: Combining two-layer LMDI method with spectral clustering. *Sci. Total Environ.* **2020**, *700*, 134374. [CrossRef]
54. Song, Y.; Zhang, M.; Shan, C. Research on the decoupling trend and mitigation potential of CO_2 emissions from China's transport sector. *Energy* **2019**, *183*, 837–843. [CrossRef]
55. Hang, Y.; Wang, Q.; Zhou, D.; Zhang, L. Factors influencing the progress in decoupling economic growth from carbon dioxide emissions in China's manufacturing industry. *Resour. Conserv. Recycl.* **2019**, *146*, 77–88. [CrossRef]
56. Liu, J.; Yang, Q.; Ou, S.; Liu, J. Factor decomposition and the decoupling effect of carbon emissions in China's manufacturing high-emission subsectors. *Energy* **2022**, *248*, 123568. [CrossRef]