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What Type of Industrial Agglomeration Is Beneficial to the Eco-Efficiency of Northwest China?

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Abstract: The contradiction between industrial economic development and the ecological environment in Northwest China is prominent, so the green transformation of industrial economy in this region is imperative. From the perspective of industrial ecology, this study uses economic and environmental statistics from Northwest China from 2006 to 2018 as well as the Krugman specialization index and entropy index methods to calculate the degree of different types of industrial agglomeration in Northwest China. The eco-efficiency of Northwest China is calculated by the global SBM-DDF model. On this basis, the stochastic effect panel tobit regression model is used to analyze the influence and mechanism of different types of industrial agglomeration on eco-efficiency in Northwest China. The results show that the concentration of specialization has a significantly negative effect on the eco-efficiency of Northwest China at the level of 1%. Excepting Ningxia, the eco-efficiency of other provinces has been improved with the decrease of industrial specialization. The influence of the related diversification agglomeration on the eco-efficiency in Northwest China shows a U curve. The degree of industrial correlation diversification in Qinghai and Ningxia is less than the critical value 1.45, whereas Shaanxi, Gansu, and Xinjiang have crossed the inflection point. The unrelated diversification agglomeration has a negative effect on the eco-efficiency of Northwest China at the level of 1%, and the degree of industrial independent diversification in Shaanxi Province has decreased slightly, which is beneficial to the improvement of eco-efficiency. By contrast, other provinces have increased considerably. The conclusion can provide a theoretical basis for industrial green transformation path selection and related policy formulation in Northwest China.

Keywords: sustainable development; industrial agglomeration; eco-efficiency; industrial transformation; Northwest China

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1. Introduction

The seven geographical regions of China include Northeast, North, East, Central, South, Southwest, and Northwest China, which is divided according to the administrative unit; the purpose of this division is to facilitate the statistics of social and economic indicators [1]. The largest of the seven geographical regions is Northwest China, which covers Shaanxi Province, Ningxia Hui Autonomous Region, Gansu Province, Qinghai Province, and Xinjiang Uygur Autonomous Region. The total area of administrative divisions is 3.07 million square kilometers, accounting for about 31.98% of the country's land area. At the end of 2018, the total population was 103 million, accounting for about 7.24% of the country's total population (Figure 1). At present, the contradiction between economic development and resource and environmental protection in Northwest China is prominent [2]. On one hand, the economic development of Northwest China is highly dependent on energy resources [3] because the Northwest region is rich in energy and mineral resources; its coal, oil, and nonferrous metal reserves are among the highest in the country, which relies on these resources. These regions have formed an industrial structure dominated by resource-based industries such as coal mining and washing, oil mining and processing, and nonferrous metal smelting and processing [4]. On the other hand, the ecological sensitivity of Northwest China is high and widely distributed, and drought and water shortage, desert spread, and poor land quality primarily characterize this sensitivity [5]. In addition, Northwest China is an important region to undertake the industrial transfer of eastern coastal areas under the background of the Development of Western China, which increases the pressure for further ecological environment management in Northwest China [6]. Therefore, from the perspective of industrial ecology, it is crucial to promote economic transformation, especially industrial transformation in China, to realize sustainable development in the region.

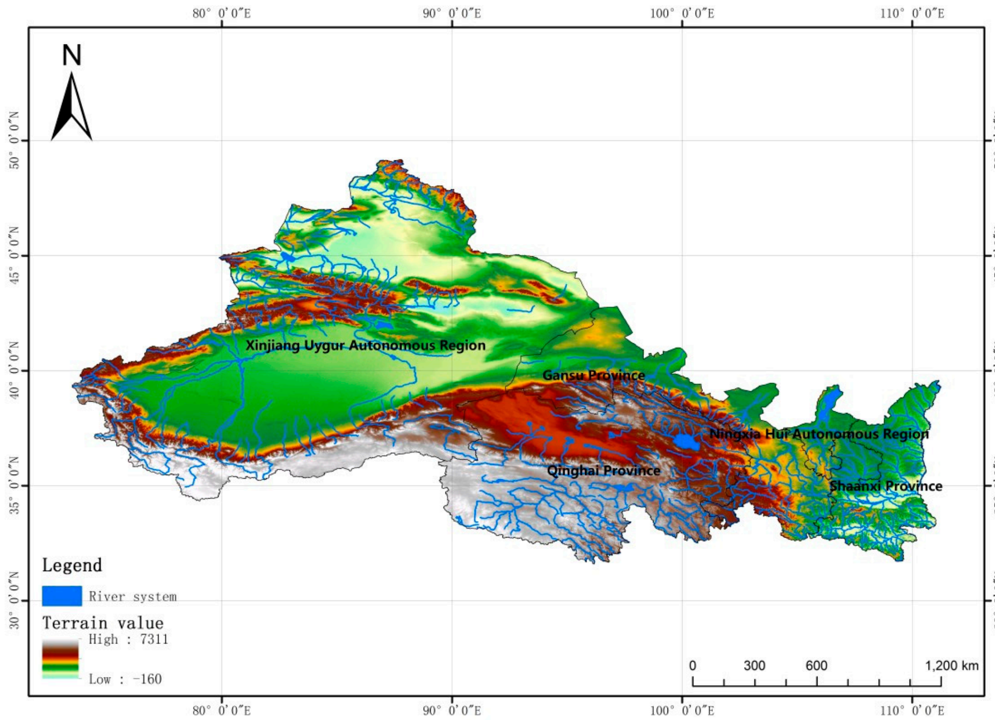

Figure 1. Northwest China. (Source: Author's collation based on this article).

Industrial ecology is "the science of studying sustainability" [7–9]. The International Society of Industrial Ecology ascribes the discipline of industrial ecology to the 1989 article "Strategies for Manufacturing" published in Scientific American [10]. Industrial ecology is a new interdisciplinary subject that examines the relationship between human production activities and their dependent resources and environment from the perspective of resource bottlenecks and environmental constraints [11]. The subject primarily involves the relationship between enterprises' behavior and their dependent environment. The purpose is to understand and optimize the relationship between economy and environment to realize the efficiency, stability, and sustainability of human production activities [12,13]. In the field of industrial ecology, a series of theories and methods have been developed (e.g., life cycle analysis, material flow analysis, material flow analysis, and input–output analysis) that are used to analyze the relationship between social economic systems and natural ecosystems on enterprise, park, city, region, country, and global scales [14,15]. Eco-efficiency is one of the most important quantitative analysis methods in the field of industrial ecology [16,17] and is also called ecological benefit. The World Council for Sustainable Development of Business Enterprises put the method forward in 1992 [18]. Among other factors, eco-efficiency requires economic activities to take into account economic benefits, resource utilization efficiency, and ecological and environmental benefits [19,20] "while providing products and services with price advantages to meet basic human needs and improve the quality of life [and] reduce the intensity of resource consumption and environmental impact throughout the life cycle to a level which is consistent with the estimated carrying capacity of the Earth" [21]. As an important index to measure the coordinated development of economy and ecological environment, eco-efficiency is an important basis to reflect the coordinated development of economy and environment caused by industrial agglomeration [22,23]. The existing research on eco-efficiency mainly focuses on its influencing factors [24,25] and its determination and evaluation in agriculture [26], ocean [27,28], industry [29], and urban ecological transformation [30,31]. In recent years, eco-efficiency determination has grown more diverse. For example, Dychkhoff adds a preferred structure based on the traditional data envelopment analysis (DEA) model [32]. Sarkis tries to use six DEA models to calculate and compare the eco-efficiency of power plants [33]. The slack-based model (SBM) and the directional distance function (DDF) are combined to form the SBM-DDF model to calculate industrial eco-efficiency [34]. This method not only solves the problem of inaccurate calculation of input or output relaxation in the DDF model but also eliminates the fault of the traditional DEA model to take pollutant emission as an input variable—a measure method in accordance with reality [35].

To explore effective ways to reduce the pressure caused by industrial activities on the ecological environment, achieving regional sustainable development is necessary [36]. New economic geography holds that industrial agglomeration, as a special form of industrial spatial organization in the process of economic and social development, is an important carrier of regional production activities and environmental governance [37]. Most scholars believe there is an environmental Kuznets curve between industrial agglomeration and resource use [38–40]. Industrial agglomeration can improve the efficiency of resource utilization, production efficiency, and industrial level through the mechanisms of technology spillover, input–output correlation, and facility sharing [41,42]. However, some scientists think industrial agglomeration may also produce negative externalities such as pollution agglomeration and resource competition [43–45]. Industrial agglomeration is widely regarded as an important way of industrial transformation in resource-based areas [46,47]. According to the differentiation of realization forms, industrial agglomeration can be subdivided into specialization, related diversification, and irrelevant diversification [48]. Industrial specialization agglomeration refers to the high convergence of enterprises in the same industry in a specific region [49]. Industrial-related diversification agglomeration refers to the phenomenon that different industry enterprises with a strong technological association level gather in specific regions; industrial-unrelated diversification agglomeration refers to the phenomenon that different industry enterprises with a weak technological association level gather in specific regions [50]. Studies have shown the external effects of different types of industrial agglomeration, such as specialization, related diversification, and irrelevant diversification [49,51].

So, what are the different types of industrial agglomeration levels in Northwest China, and which are the key areas and important ecological barriers for the Development of Western China? What is the ecological environment level in Northwest China? What are the effects of different types of industrial agglomeration on the ecological environment in Northwest China? Under the background of sustainable development, a discussion of the aforementioned questions will promote the comprehensive management of the ecological environment and the green transformation and development of Northwest China's regional economy.

2. Materials and Methods

2.1. Methods

Using the industrial ecology perspective and economic and environmental statistics from Northwest China from 2006 to 2018, this study selected various methods to study the effects of different types of industrial agglomeration on Northwest China's ecological environment. To explore the appropriate industrial transformation, the study focuses on Northwest China to formulate industrial green transformation-related policies to provide its basis. First, the Krugman specialization index and entropy index are used to measure the degree of industrial agglomeration. Next, the global SBM-DDF model is used to measure the eco-efficiency of Northwest China. Finally, the stochastic effect panel tobit regression model is used to analyze the influence of different types of industrial agglomeration on eco-efficiency in Northwest China and to investigate the influence effect of different industrial agglomeration types on the region's ecological environment. The results of this study will also provide ideas for the choice of industrial agglomeration path in other resource-based areas.

2.1.1. Measuring Methods for Industrial Agglomeration

In this study, the Krugman specialization index is calculated by using the index of industrial industry sales output value to measure the degree of industrial specialization [52]. According to the input–output relationship and technical distance between different industries, the entropy index method is used to measure the degree of industrial agglomeration under the mode of related diversification and independent diversification [50].

The formula for calculating the degree of specialization is as follows:

$$spe = \sum_{k=1}^{n} |E_{ik}/E_i - E_k/E| \tag{1}$$

The *spe* indicates the degree of specialization; the E_{ik}/E_i indicates i the share of the k industry sales output value in the industrial sector in the regional industrial sector; and E_k/E indicates the sales value of k industries in the national industrial sector that accounted for the share of the total industrial sales. The *spe* threshold is (0,2). The greater the value, the higher the degree of specialization; otherwise, the degree of specialization will be lower.

In the process of measuring the degree of industrial agglomeration under the mode of related diversification and independent diversification, in this study, thirty-five double-digit industries in the industrial sector are divided into four categories [53]. The entropy index of employees in large industries is used to express independent diversification, and the weighted sum of entropy index of employees in subdivision industries in large industries indicates related diversification. The formulas are as follows:

$$urd = \sum_{k=1}^{N} V_k \ln(\frac{1}{V_k}) \tag{2}$$

$$V_k = \sum_{l=1}^{M_k} V_l \tag{3}$$

$$rd = \sum_{k=1}^{N} V_k H_k \tag{4}$$

$$H_k = \sum_{l=1}^{M_k} \frac{V_l}{V_k} \ln(\frac{1}{V_l/V_k}) \tag{5}$$

The *rd* and *urd* indicate the degree of related diversification and unrelated diversification; the k indicates the large industries according to the input–output relationship and the technical distance; the l indicates the subdivision industries in the large industries; the N indicates the number of subdivision industries in the large industries; the M_k indicates k

number of subdivisions in large industries; and the V indicates the proportion of employees to the total number of industrial employees. The greater the value of the *rd* threshold [0,1.37], the stronger the degree of correlation diversification. The greater the value of the *urd* threshold [0,2.69], the higher the degree of independent diversification.

2.1.2. Measuring Methods for Industrial Eco-Efficiency

This study combines the SBM and the DDF to form the SBM-DDF model, which will be used to calculate industrial eco-efficiency [34,35]. Suppose the DMU$_j$ represents a decision unit with J decision units. Each DMU uses M inputs $x = (x_i, x_2, \cdots, x_m) \in R_M^+$ to produce N expected output $a = (a_1, a_2, \cdots, a_n) \in R_N^+$ and Q non-expected output $b = (b_1, b_2, \cdots, b_q) \in R_Q^+$, then the product may be set as follows:

$$\begin{aligned} P^t(x^t) = \{(a^t, b^t) : \sum_{j=1, j\neq k}^{J} \lambda^t a_{jn}^t \geq a_{kn}^t, \forall_n; \sum_{j=1, j\neq k}^{J} \lambda_j^t b_{jq}^t \leq b_{kq}^t, \forall_q; \\ \sum_{j=1, j\neq k}^{J} \lambda_j^t x_{jm}^t \leq x_{jm}^t, \forall_m; \sum_{j=1, j\neq k}^{J} \lambda_j^t = 1, \lambda_j^t \geq 0, \forall_j\} \end{aligned} \tag{6}$$

The r represents the weight of the observed value of the decision unit; the ownership weight is non-negative and the sum is 1, indicating the scale reward is variable. To improve the intertemporal comparability of industrial eco-efficiency in the research period, the global production possibility set $P^G = \{P^1 \cup \cdots \cup P^T\}$ is obtained by constructing the production possibility set in the whole period [54]. A global SBM-DDF model considering super efficiency [55] is as follows:

$$\begin{aligned} & \overline{S_V^t}(x^{i,j}, a^{i,j}, b^{i,j}, d^x, d^a, d^b) \\ & = \tfrac{1}{2}\max\left[\tfrac{1}{N}\sum_{m=1}^{M} \tfrac{s_m^x}{d_m^x} + \tfrac{1}{N+K}\left(\sum_{n=1}^{N} \tfrac{s_n^a}{d_n^a} + \sum_{k=1}^{K} \tfrac{s_q^b}{d_q^b}\right)\right] \\ & s.t. \sum_{j=1, j\neq k}^{J} \lambda_j^t x_{jm}^t + s_m^x \leq x_{km}^t, \forall_m \\ & \sum_{j=1, j\neq k}^{J} \lambda_j^t a_{jn}^t - s_n^a \geq a_{kn}^t, \forall_n \\ & \sum_{j=1, j\neq k}^{J} \lambda_j^t b_{jq}^t + s_q^b \leq b_{kq}^t, \forall_q \\ & \sum_{j=1, j\neq k}^{J} \lambda_j^t = 1 \\ & s_m^x \geq 0, \forall_m; s_n^a \geq 0, \forall_n; s_q^b \geq 0, \forall_q; \lambda_j^t \geq 0, \forall_j \end{aligned} \tag{7}$$

The x, a, b means input, expected output, and non-expected output, respectively; λ represents parameters to be evaluated; $(x^{i,j}, a^{i,j}, b^{i,j})$ represents input and output vectors for the j DMU of the period; (d^x, d^a, d^b) means the input and output expansion values are positive direction vectors; and (s_n^x, s_m^a, s_q^b) represents input and output relaxation vectors. From the perspective of input–output, this study selects the consumption of natural resources such as water, land, and energy, as well as the consumption of social and economic factors such as labor and capital, the economic value created by industrial activities as the expected output, and the pollutant emissions from industrial activities as the non-expected output (Table 1).

Table 1. Quantitative measurement variable of industrial eco-efficiency.

Variable Type		Variable Name	Variable Explanation
Input indicator	Natural resource input	Water consumption	Total industrial water
		Land consumption	Area of industrial construction land
		Energy consumption	Total industrial energy consumption
	Social and economic factor input	Labor input	Number of industrial employees
		Capital input	Industrial fixed assets
Output indicator	Desirable output	Economic value creation	Industrial value added
	Undesirable output	Wastewater discharge	COD emissions industrial wastewater
			Ammonium nitrogen emissions from industrial wastewater
		Waste gas discharge	SO_2 emissions from industrial emissions
			Smoke (dust) emissions from industrial waste gas
		Solid waste discharge	Emissions from industrial solid waste

(Source: Author's collation based on this article).

2.1.3. Panel Tobit Regression Model

The industrial eco-efficiency calculated based on the global SBM-DDF model is greater than 0, so the Stata15.0 software is used to analyze the impact of industrial agglomeration on the eco-efficiency tobit regression model [56]. Through the likelihood ratio (LR) test, the results show the P-value is significant, so the random effect panel tobit model is used to analyze the eco-efficiency of industrial agglomeration and resource-based areas in Northwest China. Because existing research has not reached an agreement on the influence of industrial agglomeration on eco-efficiency, the linear and nonlinear propositions between them are investigated respectively. The regression model is as follows:

$$Y_{it} = \alpha + \mu_{it} + \eta X_{it} + \varepsilon_{it} \tag{8}$$

The Y_{it} is the explained variable, which indicates the industrial eco-efficiency of the t period of i provinces; μ_{it} is the function form of the explanatory variable α, and ε_{it} are intercept terms and random disturbance terms; and X_{it} is a control variable. The μ_{it} can be (λspe), $(\lambda spe + \delta spe^2)$, (λrd), $(\lambda rd + \delta rd^2)$, (λurd), or $(\lambda urd + \delta urd^2)$ in this study, resulting in six regression models, followed by models 1 through 6. According to existing literature, in addition to the situation of industrial agglomeration, the factors that affect eco-efficiency include the level of regional development, energy structure, the degree of opening to the outside world, technological progress, the intensity of environmental regulation, and the degree of marketization [57]. The ratio of per capita GDP (*pgdp*), coal consumption to total energy consumption (*estur*), Chinese and foreign investment in industrial enterprises (*open*), research and development funds and industrial added value of industrial enterprises above the previous period (*tech*), the ratio of a completed investment in industrial pollution control to industrial added value (*envir*), and the ratio of main business income of nonstate-owned enterprises to the main business income of enterprises above scale (*mark*) are measured and included in the regression model in the form of control variables.

2.2. Data

Because of the limited availability of data and the consistency of statistical caliber, the period of this study is 2006–2018. The data needed in this paper are from China Statistical Yearbook [58], China Industrial Statistics Yearbook [59], China Environmental Statistics Yearbook [60], and five provinces (districts) in Northwest China [61–65]. The stock of industrial fixed assets is estimated by the perpetual inventory method, and the depreciation rate is based on Shan's study [66], which set it at 11.0. Industrial added value is converted into a comparable price based on the year 2000, which eliminates the influence of price change factors.

3. Results and Discussion

3.1. Industrial Agglomeration in Northwest China 2006–2018

Based on Formulas (1) through (5), the three types of industrial agglomeration in Northwest China are measured. The concrete results are shown in Table 2.

Table 2. Industrial agglomeration in Northwest China 2006–2018.

Type	Region	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Specialization	Shaanxi	0.71	0.73	0.75	0.73	0.70	0.69	0.66	0.64	0.61	0.53	0.53	0.51	0.50
	Qinghai	1.15	1.13	1.09	1.08	1.06	1.05	1.03	1.00	1.00	0.99	0.97	0.97	0.96
	Ningxia	0.85	0.86	0.84	0.83	0.83	0.86	0.89	0.93	0.92	0.93	0.93	0.92	0.91
	Gansu	0.88	0.89	0.86	0.87	0.88	0.90	0.89	0.86	0.83	0.72	0.72	0.71	0.71
	Xinjiang	1.10	1.03	1.01	1.00	0.92	0.94	0.91	0.83	0.82	0.83	0.81	0.80	0.79
	Mean	0.94	0.93	0.91	0.90	0.88	0.89	0.76	0.85	0.84	0.80	0.79	0.78	0.77
Related diversification	Shaanxi	1.77	1.78	1.79	1.79	1.81	1.73	1.74	1.83	1.83	1.83	1.82	1.82	1.81
	Qinghai	1.51	1.47	1.39	1.45	1.43	1.3	1.30	1.3	1.31	1.31	1.30	1.29	1.29
	Ningxia	1.34	1.32	1.31	1.32	1.37	1.35	1.33	1.32	1.33	1.37	1.36	1.36	1.35
	Gansu	1.55	1.46	1.43	1.41	1.40	1.35	1.31	1.34	1.34	1.35	1.36	1.36	1.39
	Xinjiang	1.60	1.55	1.58	1.57	1.63	1.58	1.58	1.58	1.59	1.60	1.58	1.58	1.56
	Mean	1.55	1.52	1.50	1.51	1.53	1.46	1.45	1.47	1.48	1.49	1.48	1.48	1.48
Unrelated diversification	Shaanxi	1.24	1.25	1.24	1.23	1.23	1.22	1.22	1.24	1.24	1.24	1.23	1.22	1.21
	Qinghai	1.24	1.25	1.25	1.26	1.26	1.31	1.32	1.32	1.33	1.34	1.32	1.32	1.30
	Ningxia	1.30	1.31	1.31	1.31	1.31	1.33	1.32	1.32	1.33	1.34	1.33	1.32	1.32
	Gansu	1.31	1.29	1.28	1.28	1.27	1.25	1.24	1.23	1.22	1.22	1.20	1.20	1.18
	Xinjiang	1.18	1.17	1.18	1.19	1.21	1.21	1.25	1.29	1.25	1.30	1.29	1.29	1.28
	Mean	1.25	1.25	1.25	1.25	1.26	1.26	1.27	1.28	1.27	1.29	1.27	1.27	1.26

(Source: Author's collation based on this article).

From the point of view of the whole Northwest China region, there are obvious differences in the time trend of different types of industrial agglomeration from 2006–2018. The degree of industrial specialization in Northwest China is decreasing generally, and the average degree of specialization is decreasing from 0.94 to 0.77. The degree of industrial-related diversification in Northwest China shows a trend of decreasing first and then rising. The average of the relevant diversification levels decreased from 1.55 fluctuations in 2006 to 1.45 in 2012, then gradually rebounded to 1.48 in 2018. The average value of independent degree of industrial diversification in Northwest China fluctuates around 1.25. It shows that, in the 2006–2018 period, industrial agglomeration in Northwest China showed a trend of diversification and fluctuation. Because Northwest China is in the initial or rising stage of industrial agglomeration, at the same time, the industrial transfer from the eastern coastal area to the northwest inland area under the strategy of western development is ongoing. This means Northwest China has ushered in the opportunity for industrial agglomeration; therefore, the industrial agglomeration there has clearly changed in recent years.

From the perspective of different administrative regions in Northwest China, in 2006–2018, there are differences in the form and degree of industrial agglomeration in different administrative regions. The degree of industrial specialization agglomeration in Shaanxi took 2008 as the dividing point, showing a trend of weak rise first and then a weak decline. The overall decline was 0.21, and the degree of independent diversification agglomeration in Shaanxi decreased by 0.03. Shaanxi's industrial-related diversification agglomeration increased by 0.04. The degree of industrial specialization agglomeration, related diversification agglomeration, and unrelated diversification agglomeration in Ningxia is increasing, with increases of 0.06, 0.01, and 0.02, respectively. The degree of industrial specialization agglomeration and independent diversification agglomeration in Gansu showed a downward trend, with decreases of 0.17 and 0.02, respectively, whereas the degree of industrial-related diversification agglomeration in Gansu increased by 0.01. The degree of industrial specialization agglomeration and related diversification agglomeration in Qinghai decreased by 0.19 and 0.22, respectively, whereas the degree of independent diversification agglomeration in Qinghai increased by 0.06. The degree of industrial specialization agglomeration and related diversification agglomeration in Xinjiang decreased by 0.22 and 0.04, respectively, whereas the degree of independent diversification agglomeration in Xinjiang increased by 0.12. This shows that, in the 2006–2018 period, all types of industrial agglomeration in different administrative regions in Northwest China changed significantly. Because of the difference of traditional industry in different administrative regions, they have different forms of industrial agglomeration when adjusting the present situation of industrial agglomeration and undertaking industries in eastern coastal areas [48]. For example, the traditional industries in Xinjiang and Qinghai belong to mineral resources collection and rough processing; the industrial foundation is weak, so the degree of unrelated diversification agglomeration in the process of industrial agglomeration is higher. The industrial categories of Shaanxi, Gansu, and Ningxia are more complete than those of Xinjiang and Qinghai, so their industrial-related diversification is more concentrated.

3.2. Level of Industrial Eco-Efficiency in Northwest China 2006–2018

Based on Formulas (6) and (7), the industrial eco-efficiency of Northwest China is measured, and the concrete results are shown in Table 3.

Table 3. Industrial eco-efficiency of resource-based areas from 2006 to 2018.

Region	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Shaanxi	0.97	0.99	1.00	1.03	1.05	1.04	1.06	1.04	1.05	1.08	1.00	1.11	1.13
Qinghai	0.88	0.89	0.88	0.76	0.79	0.82	0.81	0.85	0.89	0.91	0.92	0.94	0.94
Ningxia	0.67	0.66	0.66	0.61	0.62	0.58	0.57	0.57	0.56	0.53	0.52	0.53	0.56
Gansu	0.97	1.00	0.89	0.87	0.85	0.85	0.83	0.82	0.82	0.83	0.84	0.84	0.86
Xinjiang	0.96	1.01	1.00	1.02	1.11	1.04	1.01	1.03	1.02	1.17	1.19	1.21	1.21
Meane	0.89	0.91	0.89	0.86	0.88	0.87	0.86	2.72	0.87	0.90	0.89	0.93	0.94

(Source: Author's collation based on this article).

From 2006 to 2018, the industrial eco-efficiency in Northwest China fluctuated. The eco-efficiency of different administrative regions in Northwest China demonstrates clear changes. The industrial eco-efficiency of Ningxia and Gansu is decreasing year by year (0.11 and 0.09, respectively), whereas other provinces' industrial eco-efficiency has increased. Among them, the increase seen in Xinjiang and Shaanxi is relatively large (0.25 and 0.16, respectively), and the increase in Qinghai is relatively small (only 0.06). It shows that eco-efficiency fluctuates considerably in Northwest China, and the gap of eco-efficiency among various provinces is increasing gradually. The above results and existing research form a solid mutual confirmation [44,56].

3.3. Influence of Industrial Agglomeration on Eco-Efficiency in Northwest China

Based on Formula (8), the relationship among industrial specialization agglomeration, industrial-related diversification agglomeration, industrial-unrelated diversification agglomeration, and eco-efficiency in Northwest China is measured empirically. The concrete results are shown in Table 4.

In model 1 and model 2, the regression coefficients of industrial specialization agglomeration (*spe*) are negative at different significant levels, indicating specialization agglomeration has a significant negative effect on industrial eco-efficiency in Northwest China. From 2006 to 2018, the degree of industrial specialization in most resource-based provinces decreased, which was beneficial to eco-efficiency. This is due to the fact that as a typical resource-based area, the industrial specialization agglomeration in Northwest China usually shows resource-based enterprises collect in the region, the contribution rate of technological progress is low, and the efficiency of resource development and utilization is limited. This can lead easily to an increase in pollutant emissions that may exceed the ecological environment capacity [67,68]. This result confirms the conclusion that the "crowding effect" produced by industrial specialization agglomeration will aggravate industry's pollution intensity level [48]. This shows that by reducing the concentration of specialization, it can effectively promote the ecological upgrading of local industries, form a backward mechanism for enterprises, and then improve the efficiency of energy conservation and emissions reduction.

Table 4. Regression results of the impact of industrial agglomeration on eco-efficiency in Northwest China.

Explanatory Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
spe	−0.433 *** (−2.85)	−1.862 ** (−2.25)				
spe^2		0.813 (1.56)				
rd			−0.147 (−1.13)	−4.376 *** (−2.97)		
rd^2				1.45 *** (2.65)		
urd					−0.436 * (−1.95)	−0.287 (−0.07)
urd^2						−0.061 (−0.06)
pgdp	−0.174 *** (−3.75)	−0.162 *** (−3.49)	−0.117 *** (−2.74)	−0.146 *** (−3.45)	−0.088 * (−1.98)	−0.087 * (−1.79)
$pgdp^2$	0.036 *** (4.65)	0.034 *** (4.39)	0.029 *** (3.84)	0.033 *** (4.47)	0.025 *** (3.27)	0.025 *** (3.21)
estu	−0.944 *** (−5.51)	−0.999 *** (−5.76)	−0.963 *** (−5.57)	−0.936 *** (−5.89)	−0.934 *** (−5.65)	−0.935 *** (−5.51)
open	−0.162 (−0.22)	−0.196 (−0.25)	0.047 (0.06)	0.026 (0.04)	0.279 (0.38)	0.279 (0.38)
tech	6.78 ** (2.17)	7.609 ** (2.44)	6.975 ** (2.14)	5.073 * (1.75)	6.781 ** (2.10)	6.804 ** (2.05)
envir	2.825 (0.89)	3.25 (1.07)	4.180 (1.27)	2.662 (0.82)	6.967 ** (1.98)	6.954 ** (1.96)
mark	0.019 * (1.68)	0.008 (0.58)	0.022 * (1.85)	0.018 * (1.67)	0.014 (1.01)	0.014 (1.01)
Constant	1.762 *** (8.28)	2.413 *** (5.39)	1.454 *** (6.27)	4.546 *** (4.01)	1.776 *** (5.98)	1.677 (0.53)
Observations	50	50	50	50	50	50
Number of ID	5	5	5	5	5	5

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. *spe*: Specialization; *rd*: Related diversification; *urd*: Unrelated diversification; *pgdp*: Regional development level; *estur*: Energy structure; *open*: The opening degree to the outside world; *tech*: Technical progress; *envir*: Environmental regulation intensity; *mark*: Degree of marketization. (Source: Author's collation based on this article).

In model 3 and model 4, the influence of industrial-related diversification agglomeration (*rd*) on industrial eco-efficiency in Northwest China has the U curve characteristic; the critical value is 1.45. By the end of 2018, the degree of industrial diversification between Shaanxi and Xinjiang was higher than the critical value (1.45), which had a positive effect on eco-efficiency; however, Qinghai and Ningxia were still less than the critical value, which inhibited the improvement of eco-efficiency. This is because the diversification agglomeration in Northwest China mainly revolves around resource-based industries. When the relevant diversification level is lower than the critical value, most enterprises' resource consumption, energy consumption, and environmental performance are not good, the negative impact on resources and environment is high, the economic added value is low, and the economic benefit is poor. The combined treatment of pollutants has not attracted attention, and the effect of a circular economy and scale of pollution control has not appeared [56]. The division of labor and cooperation among enterprises is based primarily on the needs of product production; the consciousness of technological innovation is weak, and the level of resource development and utilization and production technology has not been significantly improved. However, when the degree of relevant diversification exceeds the critical value, cross-border cooperation and exchange among enterprises tend to be frequent; knowledge spillover promotes the development and utilization of resources technology, production efficiency, and the sharing of some resources, information, infrastructure, and pollution control facilities among enterprises; and production costs are reduced. More importantly, the relevant diversification agglomeration contributes to the formation of industrial symbiosis. On one hand, the product transaction among different enterprises may be completed in the agglomeration area, which can effectively reduce not only the material loss and waste in the transportation process but also the time and transportation costs of the transaction. On the other hand, the byproduct or waste of one enterprise may become the raw material or intermediate input of another, which is beneficial to the recycling of resources and wastes, thus improving the efficiency of resource utilization and reducing the discharge of pollutants and wastes.

In model 5 and model 6, the industrial unrelated diversification agglomeration (*urd*) has a significant negative effect on industrial eco-efficiency in Northwest China. From 2006 to 2018, the degree of industrial independent diversification in Shaanxi and Gansu decreased slightly, which promoted the improvement of eco-efficiency. However, in other provinces, especially Xinjiang and Qinghai, the degree of industrial independent diversification increased significantly, which inhibited the improvement of eco-efficiency. The main reason is that when the technology distance is long and the input–output correlation degree is low, knowledge overflow is difficult, technological innovation is difficult, and resource utilization and production efficiencies are difficult to improve. At the same time, information, technology, the labor force, and resources are difficult to share among enterprises, and the search and transaction costs of enterprise elements rise. Critically, resource-based independent diversification often means emerging or high-tech industries outside resource-based industries are concentrated in the region. Although these industries have high technology and high added value, they require high talent, capital, environment, and other factors. However, for a long time, the viscous effect of resource-based industries on production factors and the extrusion effect on other industries have led to a lack of high-quality talent, finance, and environment in resource-based areas; a low matching degree between the supply of production factors and the demand for advanced production factors in emerging industries; less input–output correlation between advanced high-tech enterprises and traditional enterprises; difficulty in forming industrial symbionts; and difficulty in multilevel resources recycling.

Among most models, there is a U curve relationship between regional development level and industrial eco-efficiency in Northwest China. When the level of regional development is low, people pay more attention to economic benefits, the mode of production is extensive, and the problems of resources waste, environmental pollution, and ecological destruction are serious. When the level of regional development is high, the ecological environment and social economy become the focus of attention, and eco-efficiency begins to improve. The coal-based energy structure is inconducive to the improvement of industrial eco-efficiency because coal consumption often brings SO_2 (sulfur dioxide), dust, smoke, and other pollutants [69,70]. The effect of foreign investment on industrial eco-efficiency is limited, which is related to the application and diffusion of advanced production technology and management experience in terms of foreign-funded enterprises in local areas. Technological progress has improved industrial eco-efficiency effectively, and pollution control has a limited effect on eco-efficiency. Reducing the proportion of state-owned enterprises is beneficial to the improvement of industrial eco-efficiency because the market economy is beneficial to the free flow of production factors and optimal resources allocation.

4. Conclusions

To deeply understand the influence and mechanism of the three industrial agglomeration modes of specialization, related diversification, and independent diversification on eco-efficiency in the Northwest China region, this study applied linear and nonlinear models to the data from five provinces in the region from 2006 to 2018. The conclusions are as follows.

Specialized agglomeration has a significantly negative effect on eco-efficiency in Northwest China, which is inconducive to industrial green transformation in the area. This is due to the fact that the industrial specialization agglomeration in Northwest China is usually characterized by resource-based industry agglomeration; the energy consumption of these industries is large and the clean production technology is backward, so it is easy to cause environmental pollution and ecological damage. During the research period, the increase of specialization and agglomeration in Ningxia led to the decline of local eco-efficiency. Therefore, Ningxia must adjust its industrial development strategy and diversify its modern industrial system as soon as possible.

The influence of related diversification agglomeration on eco-efficiency in Northwest China presents a U curve characteristic. From the analysis of measurement results, correlation diversification is the relatively effective path of industrial green transformation in Northwest China. During the research period, the degree of industrial diversification in Qinghai and Ningxia was less than the critical value, and the eco-efficiency was poor. This is because the early industrial-related diversification agglomeration in Northwest China mainly revolves around resource-based industries. At this time, the circular economy effect and the scale effect of joint pollution control have not appeared, which is manifested in the poor performance of enterprises' resource efficiency, energy efficiency, and environmental efficiency. However, cross-border exchanges and cooperation among enterprises tend to increase with the increase of related diversification agglomeration, which promotes the improvement of resource utilization technology, production efficiency, and energy efficiency. At this time, it is easy to form a symbiotic state among enterprises, which is conducive to improving resource recycling efficiency and the waste resource conversion rate as well as reducing energy consumption.

Unrelated diversification agglomeration has a negative effect on eco-efficiency, which is inconducive to industrial green transformation in Northwest China. This is due to the difficulty of knowledge spillover, resource utilization efficiency, and production efficiency. Because resource sharing is difficult to realize, production and operation costs rise. The dependence of resource-based industries on production factors and the exclusion of other industries lead to a poor matching degree of supply and demand of advanced production factors and difficulty recycling energy. During the study period, with the exception of Shaanxi and Gansu, the local eco-efficiency was reduced in most provinces because of the increase of independent industrial diversification.

Because Northwest China is in the initial or rising stage of industrial agglomeration, the industrial transfer from the eastern coastal area to the northwest inland area under the western development strategy is ongoing. This indicates that Northwest China has ushered in the opportunity for industrial agglomeration. However, in the process of industrial undertaking, many agglomeration areas have the clear characteristics of quick success and instant benefit and are blind to industrial choice. Therefore, in the process of undertaking the transfer of industry in Northwest China, we should select the industry according to the regional industrial foundation, perfect the industrial access mechanism, improve the level of industrial diversity vigorously, and realize the development of industrial linkage.

The optimization of industrial structure in Northwest China should not only give full play to the role of environmental regulation in promoting industrial structure but also demonstrate the win–win situation between environmental protection and industrial structure upgrading [71]. Although the energy resources reserves in Northwest China are among the highest in the country, they are relatively backward in energy production efficiency and utilization efficiency compared with developed countries and regions. Therefore, we should encourage the northwest region to build an open economy and improve the efficacy of energy conservation and emissions reduction. On one hand, local enterprises must be actively encouraged to learn advanced environmental protection technology from abroad, strengthen international exchanges and cooperation, adhere to the green and low carbon orientation, and promote openness, tolerance, and complementary advantages among countries. On the other hand, enterprises should strengthen economic exchanges with other regions in China, promote the dynamic balance of various elements with positive economic activities, and reduce the pressure on local resources and environment. In addition, local governments can promote energy conservation and emissions reduction efficiency with corresponding policy incentives, such as improving the relevant price and financial support policies for energy conservation and emissions reduction of outstanding industrial enterprises to implement preferential policies. The government must provide relevant rewards and punishments or control policies to promote energy conservation and emission reduction, strengthen the implementation of government laws and regulations, and strengthen the awareness of local governments' environmental responsibility. The government should strengthen the inspection and supervision of energy conservation and emission reduction, implement punitive prices or blacklist enterprises with high pollution emissions, and suspend and deal with such enterprises' related projects according to law. The whole of society must set up ecological ethics thought, change environmental protection behavior from passive to active, actively organize and carry out green energy saving and emissions reduction education, encourage and guide society to support green consumption and production, assiduously create a positive atmosphere for energy conservation and emissions reduction, and build economic development as well as an environmentally friendly social movement.

In this paper, industrial agglomeration is divided into three types from the perspective of agglomeration externality difference: specialization agglomeration, related diversity agglomeration, and independent diversity agglomeration. Compared with existing literature, agglomeration is regarded as a whole [5,23,36] that can improve the accuracy of research conclusions and the pertinence of decision-making. However, this paper has the following shortcomings. In terms of content, limited by the availability of more detailed industry data, it does not examine fully the relationship between the correlation of different pollution-type industries and the correlation between unrelated diversity and pollution emissions, which needs to be analyzed further in future research to obtain detailed data.

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