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Exploring the Impact of Financial Development on Water–Energy Efficiency in Western China

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Abstract: The western region of China is a fundamental ecological protection barrier for China. The conflict between regional economic development and ecological environmental protection has always existed in the region. This study first evaluated the water–energy efficiency (WEE) of 11 provinces in western China from 2011 to 2019 using the super-slacks-based model with undesirable outputs and analyzed their spatiotemporal characteristics. It then investigated the influence of financial development level on WEE. The results indicate that (a) the WEE in Western China was at a relatively low level, showing an upward trend from 2011 to 2016 and fluctuating after 2016; (b) financial development levels had U-shaped impacts on the WEE of Western China, which reduced at first and then rose; (c) increasing technological innovation capabilities and trade openness had positive impacts on WEE in Western China, while urbanization level had a negative effect on WEE; and (d) an examination of robustness using two different methods showed that the test results are consistent with the above conclusions. Therefore, this study has robustness. We also put forward corresponding policy suggestions, such as increasing financial support for clean and low-carbon industries, increasing input in science and technology, vigorously developing cleaner and environmentally friendly foreign trade, and implementing a new type of urbanization strategy, to promote the WEE of Western China.

Keywords: water–energy efficiency; financial development level; influence mechanism

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1. Introduction

In 2000, the central government of China started to implement a western development program to narrow the gap in economic development between the eastern and western regions that focused on infrastructure construction, ecological environment protection, industrial development, and so on. Since then, the economic strength of Western China has seen phenomenal growth [1,2]. The gross domestic product (GDP) of Western China has gone from around CNY 1.73 trillion in 2000 to over CNY 24.19 trillion in 2021, a 13-fold increase [3]. Since the second-tier industries, especially mineral and energy industries, are the pillar industries of Western China, their rapid development has inevitably led to resource and environmental problems. According to the data from the National Bureau of Statistics of China (NBSC), the GDP of Western China amounted to 21.17% of the total Chinese GDP in 2021 [3]. However, Western China consumes 53.6% and 28.7% of the country's water and energy, respectively, and its chemical oxygen demand (water pollutant) and SO_2 (air pollutant) account for 27.9% and 43.8% of the country's total emissions, respectively [4]; therefore, the improvements in utilization efficiency of both water and energy resources are key factors in achieving sustainable development in Western China.

Water–energy efficiency(WEE) is a type of comprehensive efficiency that measures the sustainable development of the economy and the environment and increases economic inputs while saving the resources of water and energy and reducing ecological and environmental impacts. Scholars have applied the ratio evaluation method, the ecological

footprint method, stochastic frontier analysis (SFA), and data envelopment analysis (DEA) to calculate WEE. Among them, DEA methods have been the most widely applied in related research [5–7], as these methods consider the relative efficiency of inputs and outputs of decision-making units (DMUs) without setting specific functions [8–13].

Theoretically, financial development may have a significant impact on WEE: when financial resources flow to high-energy, high-emission, and high-pollution industries [14,15], WEE may be inhibited; if financial resources flow to investments in energy and water-saving, environmental protection industries, and green technological innovation in high-energy-consumption industries [16–19], WEE may be promoted. However, existing studies have mainly focused on how financial development affects energy use efficiency [20–23], natural resource efficiency [24–26], and ecological efficiency [27], leaving a research gap in the impact of financial development on WEE. The central government of China has given extensive financial support to its western region since the western development strategy was implemented in 2000, and the financial industry in Western China has a certain degree of development. The total deposits and loans of banks in Western China have increased from CNY 3.78 trillion in 2000 to CNY 77.75 trillion in 2021 [3]. If this financial development is closely connected with the balance between resource exploitation, environmental protection, and economic development, how does financial development affect the WEE of Western China? For the time being, the effect of financial development on WEE has not really been researched in Western China. It is necessary to judge the specific influence of financial development on regional WEE.

In order to deal with the inadequacies in previous studies, this paper evaluates the WEE by utilizing a efficiency SBM with undesirable outputs for 11 provinces in Western China from 2011 to 2019 and then applies the Tobit model to test the nonlinear relationship between the financial development and WEE. The contributions of this paper are as follows: (a) this research gives a theoretical analysis of the influence mechanism of financial development on WEE; (b) it uses Western China as a sample for the empirical research of the impacts of financial development on WEE, which is not addressed in the existing literature on this topic; (c) it investigates the mechanism through which financial development impacts WEE in Western China, and the results are used as a basis to formulate countermeasures to increase WEE from the perspective of financial development; and (d) this paper evaluates WEE by utilizing a super SBM with undesirable outputs, which fully considers the impact of input and output slack variables on efficiency level, thus accurately measuring the efficiency values [28]. Subsequently, we analyze the spatiotemporal characteristics of WEE in Western China, which provides a scientific basis for the development of targeted eco-environmental protection strategies in various regions.

The remaining sections are as follows: the Materials and Methodology Section demonstrates the research region, theoretical hypotheses, variables, and research methods. The Calculation of the Results of WEE Section shows the spatiotemporal characteristics of WEE. The Empirical Results Section shows the test results on the impact of financial development on WEE. The Conclusions Section summarizes the whole paper, provides policy implications, and makes suggestions for future investigation.

2. Materials and Methodology

2.1. Research Region

This paper takes 11 provinces as research objects in Western China (Tibet was not involved in the research objects) (Figure 1). Since 2000, when the Chinese Western Development Strategy was implemented, the financial industry in the western region has grown rapidly, which has given extensive support to large-scale infrastructure and industrialized construction. This has also caused serious emissions in the western region (Figure 2).

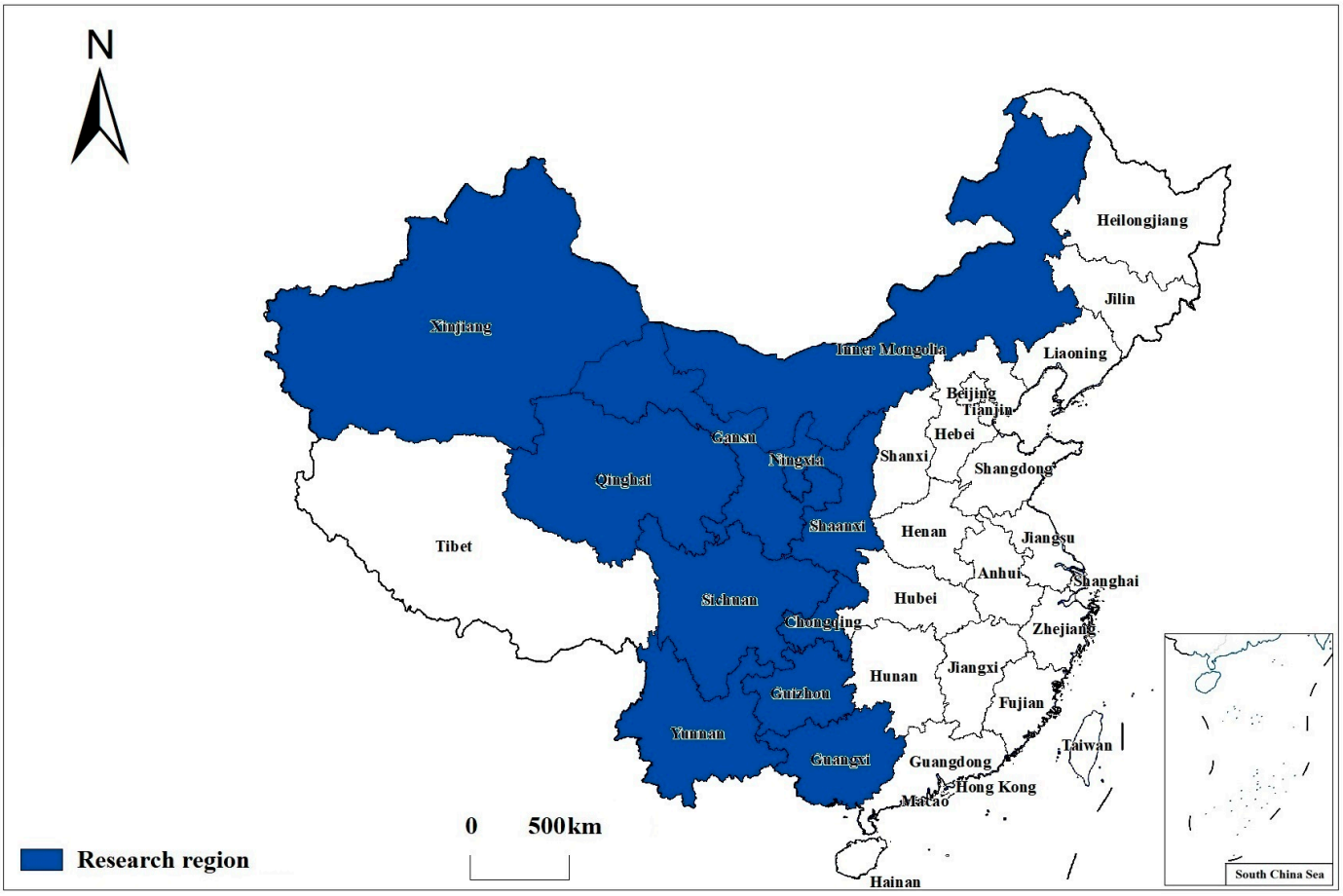

Figure 1. The research areas.

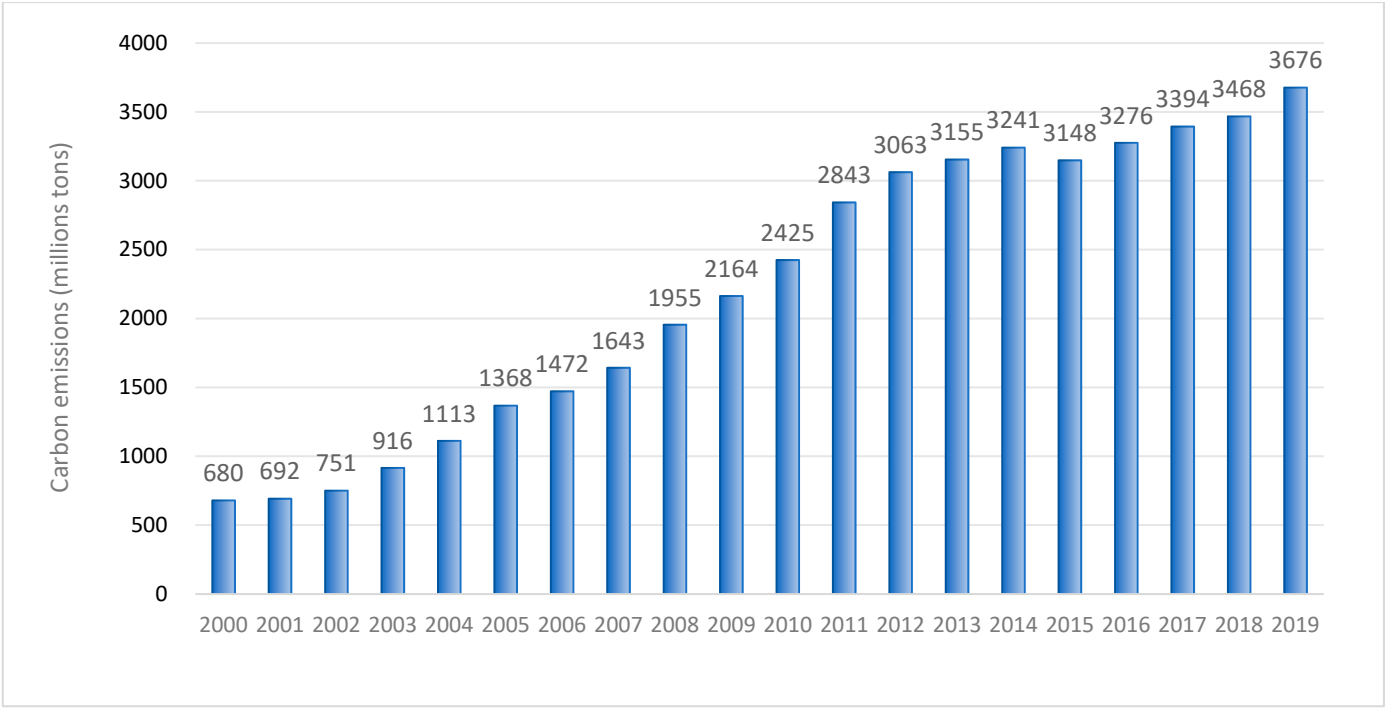

Figure 2. The change trend for CO_2 emissions in Western China.

2.2. Theoretical Hypotheses

The influence of financial development on the environment is double-edged [15]. On the one hand, a robust financial system can optimize capital allocation and facilitate investment in environmentally friendly technologies and practices, and the environmentally friendly industry is supported to obtain financing at a low cost [29], thus improving regional WEE. On the other hand, financial development can further promote economic growth via loan money to enterprises for expanded production and to individuals and households to acquire goods and services for personal consumption [30,31]. This may increase resource consumption and have a negative effect on the environment.

From a mechanism analysis, we can see that this financial development will affect WEE in two opposite ways. As far as Western China is concerned, the region is a relatively backward region in the development of its social economy, its financial system is imperfect, and the impact of financial development may be negative at this stage. However, it may experience positive effects in the future with the improvement of both governmental support for the environmental protection industry and financial market mechanisms. Based on the above theoretical analysis, we propose the following hypotheses:

Hypothesis 1. *Financial development is having a negative influence on the WEE in Western China at this stage.*

Hypothesis 2. *There may be a U-shaped relationship between financial development and WEE in Western China.*

2.3. Measurement Indicators of WEE

Taking into account certain studies [32,33], capital stock, water, energy, and labor are selected as four input indicators, GDP as the desired output indicator, and CO_2 emissions, SO_2 emissions, and chemical oxygen demand (COD) emissions as the three undesirable output indicators (Tables 1 and 2).

Table 1. Assessment indicator system of WEE.

Primary Indicators	Secondary Indicators	Unit
Input	Capital stock	CNY 100 million
	Employees	10,000 people
	Water consumption	10^8 L
	Energy consumption	10,000 tons of standard coal
Desired output	GDP	CNY 100 million
Undesired output	CO_2 emissions	10,000 tons
	SO_2 emissions	10,000 tons
	COD emissions	10,000 tons

Table 2. Descriptive statistics of the input and output variables.

Indicators	Obs	Mean	Std. Dev.	Min	Max
Capital stock	300	81,747.3	46,811.9	14,356.0	220,072.6
Employees	300	1917.0	1231.6	309.2	4889.0
Water consumption	300	176.5	146.9	25.8	590.1
Energy consumption	300	11,104.8	5182.8	3189.0	25,346.0
GDP	300	12,428.1	8236.0	1370.4	40,929.9
CO_2 emissions	300	252.4	152.6	36.9	794.3
SO_2 emissions	300	47.5	34.1	4.3	140.9
COD emissions	300	36.6	31.6	2.0	130.2

This paper refers to the perpetual inventory method to estimate the capital stock, and its formula is $Kit = Iit + (I - \mu)Kit - 1$, where K indicates the capital stock, I denotes the fixed assets investment, μ denotes the depreciation rate, i represents the province, and t is the year. Following Zhang et al. [34], μ is 9.6%, and the capital stock of 2011 was equal to the fixed assets investment of 2011 over 10%. The data on fixed assets investments were collected from the Statistics Yearbook of Chinese Investment in Fixed Assets (2012–2018) [35] and NBSC [3].

This paper totals the primary energy consumption as the energy consumption, the total social water resource consumption as the water consumption input, and the social employment in each province as the labor input in the WEE calculation model. The data on energy consumption were collected from the China Energy Statistical Yearbook (2012–2020) [36] and CEIdata [37]. The data on labor and water consumption were all collected from the China Statistical Yearbook(CSY) (2012–2020) [38]. As national key monitoring targets, CO_2, SO_2, and COD emissions were selected as the three undesired output indicators. The data on SO_2 and COD emissions were collected from NBSC. The data on CO_2 emissions were collected from Carbon Emission Accounts and Datasets [39].

2.4. Explanatory Variables

In this paper, WEE is the dependent variable, and financial development level is the core independent variable. The control variables include technical progress level (TPL), trade openness (TO), and urbanization level (UL). Definitions of all variables are in Table 3.

Table 3. The variables and measuring methods.

Explanatory Variable	Definition of the Variable
Financial development level (FDL)	Proportion of the balance of deposits and loans of the financial sector to GDP (%)
Economic development level (EDL)	GDP per capita (10^4 CNY)
Technical progress level (TPL)	Patent applications granted per 100,000 people (item)
Trade openness (TO)	Proportion of foreign trade to GDP (%)
Urbanization level (UL)	Proportion of urban resident population to total population (%)

Financial development level. As the financing channels for most enterprises are dominated by the banking system in China, financial development needs to be closely related to the credit activities of banks. As per the existing measurement of the financial development level by Hao et al. [40], Yue et al. [41], and Li et al. [42], we use the ratio of the balance of deposits and loans of the financial sector to the GDP as a proxy for regional financial development. To verify the nonlinear effect of financial development level on WEE, its quadratic term was tested. The data were collected from NBSC [3].

Technical progress affects economic development, which further affects environmental performance. This paper selected patent applications granted per 100,000 people to represent the technical progress level. The data came from the CSY [38]. To develop foreign trade and introduce advanced technology in a plain way is a firm policy of China. Referring to Liu et al. [43] and Zhou et al. [44], we selected the proportion of foreign trade to GDP to measure trade openness. The data came from the Statistical Yearbook of the Western Provinces (2012–2020) [45].

Urbanization rate. To some extent, urbanization means not only the scale expansion of the urban residents and land but also economic growth, adjustment in the industry structure, and transitions in consumer demand, which will inevitably affect WEE. We used the proportion of the permanent population to the total population in the region to indicate urbanization level. The data came from the CSY (2012–2020) [38] (Table 4).

Table 4. Descriptive statistics of variables.

Variable	Obs	Mean	Std. Dev.	Min	Max
WEE	300	0.297	0.246	0.143	1.322
FDL	300	0.577	0.126	0.338	0.896
$(FDL)^2$	300	0.349	0.16	0.114	0.803
TPL	300	0.014	0.025	0.0002	0.161
TO	300	0.284	0.307	0.013	1.464
UL	300	0.134	0.072	0.053	0.505

This paper applied the LLC test and IPS, Fisher ADF, and Fisher PP to test the unit root of panel data. Table 5 shows the test results. The variables WEE, FDL, $(FDL)^2$, TPL, TO, and UL were all at stationary levels, but TPL failed to pass the test. After that, the first-order difference was tested; all the variables passed the test of significance level (1%). Therefore, we continued to explore the cointegration relationship of WEE, FDL, $(FDL)^2$, TPL, TO, and UL with a Kao cointegration test. As Table 6 shows, the trace statistic value is −7.786939 and passes the significance level test (1%), implying that there is a long-term stable equilibrium relationship among all variables [46,47].

Table 5. The results of unit root tests.

Variable	LLC	IPS	ADF	PPF
WEE	−11.9481 ***	−6.11468 ***	152.341 ***	199.878 ***
FDL	−3.33500 ***	−5.91793 ***	157.305 ***	205.280 ***
$(FDL)^2$	−3.33753 ***	−5.96022 ***	158.030 ***	204.819 ***
TPL	−5.21782 ***	3.00560	53.0643	94.4681 ***
TO	−10.3179 ***	−6.37599 ***	154.090 ***	217.399 ***
UL	−14.1928 ***	−8.41060 ***	189.454 ***	203.491 ***
ΔWEE	−18.8751 ***	−10.9482 ***	239.256 ***	367.000 ***
ΔFDL	−27.1807 ***	−15.6469 ***	314.377 ***	438.939 ***
$\Delta(FDL)^2$	−26.1491 ***	−14.8848 ***	304.708 ***	437.622 ***
ΔTPL	−13.6601 ***	−6.59951 ***	164.387 ***	202.049 ***
ΔTO	−18.2888 ***	−10.4291 ***	229.337 ***	371.708 ***
ΔUL	−23.2331 ***	−11.7919 ***	256.873 ***	363.885 ***

Note: *** $p < 0.01$.

Table 6. The results of the Kao cointegration test.

	t-Statistic	Prob.
Augmented Dickey–Fuller	−7.786939	0.000 ***
Residual variance	0.009824	
HAC variance	0.002697	

Note: *** $p < 0.01$.

2.5. Methods

2.5.1. The Super SBM Model with Undesirable Outputs

To measure WEE in Western China, we used the super-slacks-based model (SBM) with undesirable outputs to calculate the WEE value, which is an improved DEA approach. The super SBM model can use slack variables in the objective function, which can more effectively estimate the efficiency problem under the undesired output, allow the efficiency score to be higher than 1, and easily rank efficient DMUs. Following Tone [48], Cooper et al. [49], and Zhao et al. [50], the specific form is

$$\gamma^* = \min \left[\frac{\frac{1}{M}\sum_{i=1}^{M} \frac{\overline{x}i}{xi0}}{\frac{1}{S1+S2}\left(\sum_{r=1}^{S1} \frac{\overline{y}_r^g}{y_{ro}^g} + \sum_{r=1}^{S2} \frac{\overline{y}_r^b}{y_{ro}^b}\right)} \right] \quad (1)$$

$$s.t \begin{cases} \overline{x} \geq \sum_{j=1,\neq 0}^{N} \eta_j x_j \\ \overline{y}^g \leq \sum_{j=1,\neq 0}^{N} \eta_j {y^g}_j \\ \overline{y}^b \geq \sum_{j=1,\neq 0}^{N} \eta_j {y^b}_j \\ \overline{x} \geq x0, \overline{y}^g \leq y_0^g, \overline{y}^b \geq y_0^b, \overline{y}^g \geq 0, \eta \geq 0, \end{cases} \quad (2)$$

where γ^* stands for the value of WEE; its range can be greater than 1. x, y, and b indicate input, desirable output, and undesirable output, respectively.

2.5.2. Tobit

Since the WEE values of this paper were all greater than 0 in the super SBM with undesirable outputs, which is a restricted dependent variable, if the traditional ordinary least squares (OLS) model is applied for calculation, the data with possible zero values will not be represented entirely, which will lead to calculation bias. The Tobit model can avoid the bias caused by the OLS model based on the principle of maximum likelihood estimation [51–54]. The specific form is as follows:

$$\begin{aligned} {Y_{it}}^* &= \beta_o + \beta_t X_{it} + \varepsilon_{it} \\ Y_{it} &= \begin{cases} Y_{it}^* & \text{if} \quad Y_{it}^* > 0 \\ 0 & \text{if} \quad Y_{it}^* \leq 0 \end{cases} \end{aligned} \quad (3)$$

where Y_{it} denotes the explained variable (WEE), X_{it} indicates the explanatory variable, β_0 is the constant term, β represents the estimated coefficient vector, ε_{it} denotes the random error disturbance term, and ε_{it}~$(0, \sigma^2)$.

3. Calculation Results of WEE

Table 7 shows the WEE evaluation results. The mean evaluation value was 0.620 of all provinces during the research period, which indicates that Western China has yet to reach the production frontier and is still far from achieving economic and environmental coordination. Regarding the mean efficiency of each province (Figure 3), that of Chongqing was 1.088, indicating that Chongqing had become a benchmark for other provinces in terms of the coordination of both economic and environmental development. Sichuan also had a high level of WEE, and it remained on the production frontier (except in 2016). The average WEE of Chongqing was 0.988, the WEEs of Shaanxi, Yunnan, and Guangxi were larger than the regional average, and their annual mean WEE values were 0.824, 0.764, and 0.661 during the research period, respectively. The annual mean WEE values of Inner Mongolia and Xinjiang were 0.591 and 0.49, and the WEE of Inner Mongolia approached the average level of Western China. However, Guizhou, Gansu, Qinghai, and Ningxia had the lowest WEEs, and their mean WEE values from 2011 to 2019 were 0.388, 0.368, 0.334, and 0.321, respectively, indicating that these provinces have poor economic and environmental coordination.

On the trend of changes in WEE, during the research period, the WEEs of most provinces (except Chongqing) significantly reduced. Specifically, the WEEs of Guizhou, Ningxia, and Qinghai had significant declines during this period; the WEEs of these three provinces were 0.446, 0.383, and 0.401, respectively, in 2011, but they reduced to 0.344, 0.282, and 0.294, respectively, by 2019; their descent rates were 22.9%, 26.4%, and 26.7%, respectively. Inner Mongolia, Xinjiang, Shaanxi, and Yunnan all had similar change trends for WEE, which kept them on the production frontier in the initial periods, but their WEEs

reduced significantly in the later periods. In contrast, there was a notable upward tendency between 2011 and 2017 for the WEE of Chongqing, which has reduced a little since 2018, but the WEE of Chongqing is still on the production frontier. Guangxi and Sichuan have had fluctuations in WEE; the highest point was Guangxi in 2011(1.014), and its lowest point was in 2019 (0.390). For Sichuan, the WEE kept it in the production frontier and showed low-amplitude fluctuations of WEE over the research period, except in 2016. The WEE of Gansu first dropped and then rose slowly, but the lowest point was in 2017 (0.329) (Figure 4).

Table 7. The WEE evaluation results.

Province	2011	2012	2013	2014	2015	2016	2017	2018	2019	Mean
Inner Mongolia	1.037	1.030	1.012	0.392	0.377	0.364	0.365	0.370	0.373	0.591
Guangxi	1.014	1.005	0.598	0.566	0.543	0.424	1.001	0.407	0.390	0.661
Chongqing	1.042	1.049	1.072	1.068	1.070	1.120	1.133	1.121	1.121	1.088
Sichuan	1.061	1.060	1.060	1.056	1.057	0.596	1.000	1.002	1.003	0.988
Guizhou	0.446	0.429	0.422	0.413	0.397	0.353	0.343	0.344	0.344	0.388
Yunnan	1.011	1.009	1.010	1.006	1.003	0.453	0.460	0.460	0.463	0.764
Shaanxi	1.041	1.026	1.022	1.008	0.737	0.649	0.644	0.658	0.634	0.824
Gansu	0.432	0.417	0.388	0.378	0.355	0.337	0.329	0.333	0.344	0.368
Qinghai	0.401	0.385	0.358	0.351	0.327	0.299	0.298	0.295	0.294	0.334
Ningxia	0.383	0.373	0.349	0.337	0.316	0.291	0.280	0.281	0.282	0.321
Xinjiang	1.015	1.003	0.401	0.383	0.356	0.317	0.307	0.312	0.313	0.490
Mean	0.808	0.799	0.699	0.633	0.594	0.473	0.560	0.508	0.505	0.620

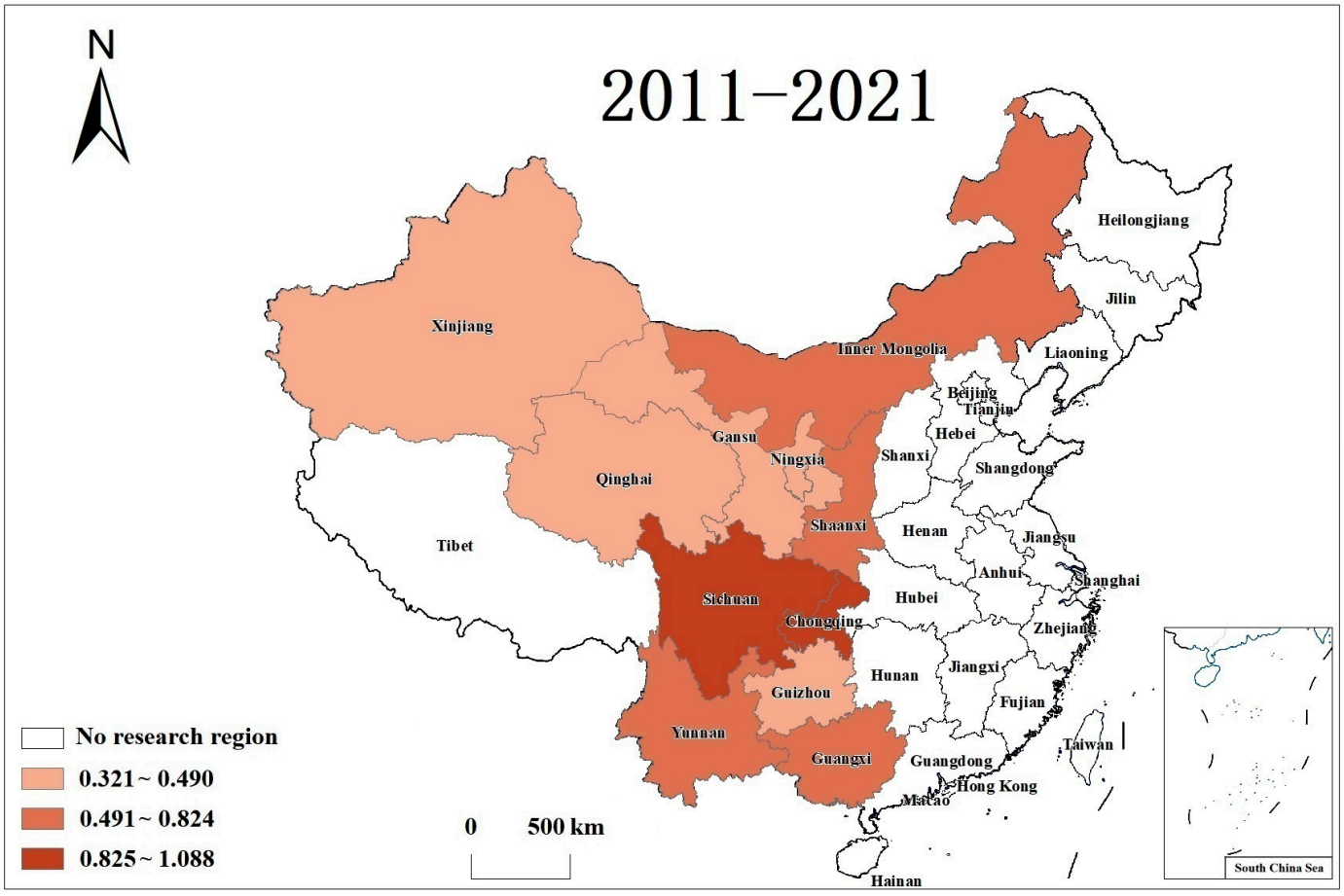

Figure 3. The average WEE value from 2011 to 2019.

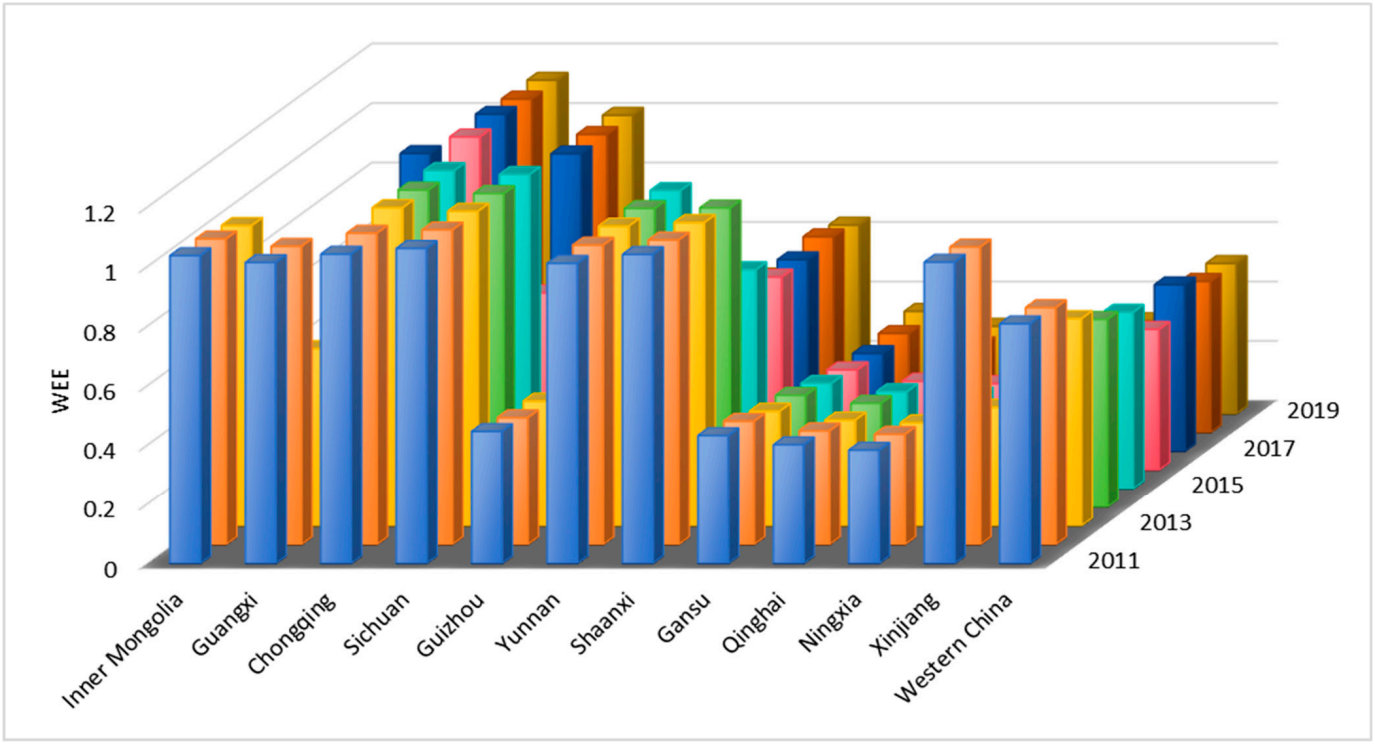

Figure 4. The change trend for WEE.

4. Regression Analysis

4.1. Benchmark Regression

In this paper, the financial development level quadratic item is introduced into the Tobit model due to the nonlinear relationship that may exist between financial development level and WEE. The test models are as follows:

$$WEEit = \beta 1FDLit + \varepsilon it \quad \text{(Model 1)}$$

$$WEEit = \beta 1FDLit + \beta 2TPLit + \beta 3TOit + \beta 4ULit + \varepsilon it \quad \text{(Model 2)}$$

$$WEEit = \beta 1FDLit + \beta 2(FDL)^2 it + \beta 3TPLit + \beta 4TOit + \beta 5ULit + \varepsilon it \quad \text{(Model 3)}$$

where *FDL* and $(FDL)^2$ refer to the financial development level and its square value, respectively. *TPL*, *TO*, and *UL* refer to technical progress level, trade openness, and urbanization level, respectively. The test results are shown in Table 8.

Table 8. Benchmark regression results.

Variable	Model (1)	Model (2)	Model (3)
FDL	−0.0019524 ***	−0.0022833 ***	−0.0076465 ***
$(FDL)^2$			8.24×10^{-6} ***
TPL		0.0528824 ***	0.0619275 ***
TO		0.0122782 ***	0.0127573 ***
UL		−0.0140034 ***	−0.0169583 ***
Constant	1.231819	1.687492	2.631563

Note: *** $p < 0.01$.

Models (1) and (2) in Table 8 were applied to validate Hypothesis 1. The coefficients of the financial development level were −0.0019524 *** and −0.0022833 ***, respectively, and both passed the 1% significance test, which indicates that the financial development level exerted a significant negative effect on WEE, whether the control variables were

doped or not. In Model (3), the coefficient of the secondary term of financial development level was 8.24 $\times$ 10^{-6} ***, which passed the test of significance level (1%), indicating a U-shaped relationship between financial development level and WEE, which perfectly confirms Hypothesis 2. The WEE of most provinces in Western China is in the decline stage of the U-shaped curve, as the coefficients of the financial development level are significantly positive; that is, the WEE declines with an increase in financial development level in the current stage.

While Western China is still in the early stages of economic and financial development, the financial industry's regulations are not perfect, and the financial market is not allocating resources properly; national industrial policy has guided financial resources toward the real estate industry, mineral and energy industry, and other important regional industries to realize economic benefits, or infrastructure construction to improve the investment environment, which has caused large resource consumption and pollution emissions and inhibited WEE. Though some policies are guiding the flow of financial resources to green technological innovation in high-energy, high-emission, high-pollution industries, the technological accumulation of Western China remains weak, and this financial development has had a negative effect on WEE. However, this situation cannot go on forever. With improvements in economic and financial development levels, the continuous improvement of the financial market system, and more government emphasis on the importance of environmental protection, more financial resources will flow into green technological innovation in high-energy, high-emission, high-pollution industries, modern service industries, and high-tech industries. This will make the effects of financial development more obvious, and the impacts of financial development on WEE will become more positive in the future.

In terms of control variables, technological innovation has a positive influence on WEE. Western China possesses abundant natural resources, and improving its technological innovation may be helpful in improving WEE. However, the proportion of R&D expenditures in GDP rose from 1.14% in 2010 to 1.4% in 2019, which still leaves a gap at the national level: many provinces still need to increase their investment in R&D. Trade openness has had a significantly positive influence on WEE. Under the policy of opening to the outside world and the Belt and Road Initiative, the market in Western China has become more open. The research period for this paper was 2010–2019, and the early extensive economic development mode has since been abandoned. Instead, a new high-quality development mode is being pursued. The central government of China has implemented a series of policies in Western China to impel an energy-intensive transition to mitigate the associated environmental impact. As a result, the quality of foreign trade has improved, and its structure has become more reasonable. Urbanization levels have significantly negative effects on WEE. During the study period, Western China was in a stage of rapid urbanization, and the regional urbanization level grew from 41.4% in 2010 to 55.9% in 2019, which also raised the problem of ecological–environmental overload. Western China should steadily promote urbanization to make the economy, society, and ecology develop harmoniously.

4.2. Robustness Test

We used two methods to explore the robustness of these results further. First, we took the explained variables with a 1-period lag to avoid the appearance of reverse causality. The test results are shown in Table 9. Second, we eliminated certain key years. Since 2011 and 2016 were the maximum and minimum years of WEE, we chose to eliminate both. The test results are shown in Table 10. The regression results of the Robustness Test display that the signs and significance levels of the coefficients are basically the same as the benchmark regression results. Therefore, the regression results are considered to be robust.

Table 9. The regression results of Robustness Test 1.

Variable	Model (4)	Model (5)	Model (6)
FDL	−0.0017303 ***	−0.0021757 ***	−0.0070005 ***
$(FDL)^2$			7.58×10^{-6} ***
TPF		0.0592721 ***	0.0684755 ***
TO		0.0118269 ***	0.012271 ***
UL		−0.0134414 ***	−0.0166138 ***
Constant	1.150064	1.606428	2.460012

Note: *** $p < 0.01$.

Table 10. The regression results of Robustness Test 2.

Variable	Model (7)	Model (8)	Model (9)
FDL	−0.0018294 ***	−0.0021457 ***	−0.0068765 ***
$(FDL)^2$			7.21×10^{-6} **
TPF		0.0583557 ***	0.0656827 ***
TO		0.0114469 ***	0.0120934 ***
UL		−0.014897 ***	−0.0174692 ***
Constant	1.206182	1.680015	2.519533

Note: ** $p < 0.05$, *** $p < 0.01$.

5. Conclusions

The existing research does not cover the exploration of the influence of financial development on WEE in Western China. This study fills this gap by proposing the super SBM, which includes undesirable outputs, measures the WEE of Western China from 2011–2019, and then explores the impact of FDL on WEE in Western China. The research outcomes are as follows: (a) The overall WEE level of the western region was at a low level during the research period. Chongqing was the only province that exhibited a high level of WEE, which achieved the coordination between economic development and ecological environmental protection. There was an extreme lack of economic and environmental coordination in Guizhou, Gansu, Ningxia, and Qinghai. (b) From the perspectives of the change trends for WEE, the WEEs of most provinces (except Chongqing) significantly reduced during the research period. (c) In the benchmark model, financial development levels had a U-shaped impact on the WEE of Western China, which reduced at first and then rose. At present, financial development has negative impacts on WEE, while the tipping point has not yet arrived. As for the control variables, increasing technological innovation capabilities and trade openness can promote WEE, while urbanization shows a negative influence on WEE. (d) After conducting the robustness test, the empirical test results are consistent with that of the benchmark model. Therefore, the research results are robust.

Based on the results of this study, we now offer some policy recommendations: (a) The government should adopt fiscal policies to improve the allocation of financial resources and promote the arrival of the turning point at which the impact of financial development on WEE will transform into a positive correlation. Differentiated borrowing standards should be implemented to support clean and low-carbon industries, such as new and renewable energy, new and high-tech industries, modern service industries, and so on. The government could also subsidize and cut taxes for clean and low-carbon industries to promote WEE. (b) The western provinces of China should reinforce their abilities of independent innovation by increasing the R&D investment, setting up a special R&D fund, and building high-level innovation platforms that promote deep integration among production, education, and research. Therefore, they can accelerate the transformation and application of scientific and technological achievements. A reasonable environmental regulation policy should be formulated to eliminate outdated and high-energy-consuming production equipment. It is necessary to establish a reasonable and efficient technology market trading system by using big data, artificial intelligence, and other technical means

to promote technological innovation and achievement transformation. (c) A cleaner and more environmentally friendly foreign trade model should be implemented based on the positive effect of trade openness on WEE. Local governments should establish and improve a mechanism for green products in accordance with international requests to promote green merchandise and service exports to global markets. Green industrial coagglomeration should be vigorously supported in export processing zones. (d) A new type of urbanization strategy should replace the traditional extensive urbanization pattern. Urban land should be intensively utilized for low-energy-consumption and pollution industries, such as advanced manufacturing and productive service industries. The urban infrastructure should be better planned to meet the growth of urban populations. Vocational skills training should be provided to increase the incomes and employment of migrant workers.

However, there are some limitations in this research. First, we took 11 provinces as the sample due to the lack of municipal- and county-level sample data. Therefore, other scholars could conduct related studies based on municipal- and county-level sample data in the future. Second, future research may be extended to specific industries, such as the cement, steel, and metals industries, which can provide more targeted industry policies for pollution reduction. Third, this paper only explores the nonlinear effect of financial development on WEE and neglects the conduction mechanism. In the forthcoming time, scholars can investigate the conduction mechanism between financial development and WEE. In the end, when measuring financial development level, we only considered deposit and loan indicators, which makes this paper one-sided. Therefore, more indicators should be considered to measure financial development levels comprehensively in future research.

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