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Digital linkage and innovation promotion: An empirical study on the development of green economy in China and Belarus under the background of the belt and road initiative

Xin Song[1], Wenyuan Han[2], Zining Wang[3], Xinwen Cheng[4], Luo Zongyu[5]*
[1]Belarusian State University, Minsk, Republic of Belarus.
[2]Internotional Institute of Management and Business, Minsk, Republic of Belarus.
[3]Human Resources Office, Hainan Vocational and Technical College,570216, Haikou, China.
[4]Shinawatra University, Bangtoey Subdivision, Samkhok District, Pathum Thani Province, Thailand.
[5]Agricultural Development Bank of China Lincang Branch, YunNan, China; 605826690@qq.com (L.Z.).

Abstract: This study focuses on the economic cooperation between China and Belarus in the digital field against the backdrop of the Belt and Road Initiative. Through the panel regression model, multi-dimensional data such as the economic value of scientific and technological innovation output and the level of digitalization in the five Central Asian countries and countries along the Belt and Road are analyzed. The results show that after considering geographical and economic factors, the positive impact of scientific and technological innovation value on promoting innovation has weakened, highlighting the importance of regional cooperation in the Belt and Road Economic Circle. Further analysis confirmed that China is an ideal partner for Belarus in the economic field. The study recommends strengthening cooperation between the two countries in scientific and technological innovation, digital economic levels, and overall economic construction to promote the harmonious and innovative development of green economic digitalization.
Keywords: *Coupling analysis, Digital economy, Green economy, Regression model, TEP.*

1. Introduction

1.1. Literature Review

With the rapid development of the global economy, green economic growth has become the focus of international attention. The concept of green economy was first proposed by the United Nations Environment Programme (UNEP), aiming to achieve harmonious coexistence of economic growth and environmental sustainability [1]. Combing through the existing literature, Liu and Ding [2] proposed in "Digital Economy and Green High-quality Development of Industry—A Study on Mechanism and Regional Heterogeneity" that green technologies such as desulfurization and denitrification, ecological restoration, and pollution source monitoring, which are induced by the new generation of information technology, can effectively improve production processes and processes, enhance the market fit of products and services, and promote the transformation and upgrading of the manufacturing industry towards energy conservation and emission reduction, carbon reduction and pollution reduction, and conservation and intensive use Liu and Ding [2]. Zhang and Tu [3] states that technological innovation plays an irreplaceable role as the endogenous driving force of the green transformation of the manufacturing industry. Technological change is conducive to the integration of factor resources, optimization of energy structure, and improvement of production efficiency in the manufacturing industry Zhang and Tu [3]. Li and Yao [4] emphasized in "The Impact of Digital Infrastructure Investment on Green Growth of China's Manufacturing Industry: Spatial Effect and Mechanism

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* Correspondence: 605826690@qq.com

Analysis" that the digital economy can promote the green transformation of the manufacturing industry by promoting technological progress, but it will also widen the technological gap and inhibit green growth [4]. Therefore, paying close attention to regional environmental changes and minimizing the negative impact of manufacturing transformation and upgrading will be the key to achieving the dual transformation of "low-carbon development and industrial upgrading" in traditional manufacturing, and it is also a key consideration for the development of the China-Belarus "Silk Road" green economy.

Existing research mainly focuses on the empirical analysis of micro data, focusing on promoting high-quality development or transformation and upgrading of the manufacturing industry, and rarely uses macro data to conduct empirical research on the impact of regional digital economy development on the green transformation of the manufacturing industry. Under the background of the "Belt and Road" initiative, China's cooperation with Belarus and other countries in these areas and its specific impact on green economic growth need to be further explored. Based on this, on the one hand, this paper focuses on exploring the impact mechanism of digital economic development on the green transformation of the manufacturing industry under the background of the Belt and Road Initiative, and analyzes multi-dimensional data such as the economic value of scientific and technological innovation output and the level of digitalization in the five Central Asian countries and Eastern European countries through a panel regression model. On the other hand, this study aims to fill this research gap and provide new perspectives and strategic recommendations for promoting green economic growth in countries along the "Belt and Road".

2. Methodology

2.1. Low-Carbon Green Development Performance Measurement

2.1.1. Environmental Production Technology

Referring to the environmental technology proposed by Fare et al., each country is regarded as a DMU. Assuming that each DMU uses N inputs x= (x 1,…,x N) ∈, produces Q “desirable” outputs y= (y 1,…,y Q) ∈ and L “undesirable” outputs b= (b 1 ,…,b L) ∈, then the input-output combination of the mth DMU in the tth period can be recorded as (, ,), and the environmental production technology is expressed as [5-7].

$$P^t = \{(x^t, y^t, b^t) : x_n^t \geqslant \sum_{k=1}^{K} \lambda_k^t \cdot x_{kn}^t, \forall n; y_q^t \leqslant \sum_{k=1}^{K} \lambda_k^t \cdot y_{kq}^t, \forall q; \tag{1}$$

$$b_l^t = \sum_{k=1}^{K} \lambda_k^t \cdot b_{kl}^t, \forall l; \tag{2}$$

$$\sum_{k=1}^{K} \lambda_k^t = 1, \lambda_k^t \geqslant 0, \forall k\} \tag{3}$$

In formula (1), I am the weight corresponding to each DMU observation value. The two constraints on the weight variable mean that the production technology is set as variable scale returns (vrs). The distance function is usually used to solve environmental technology problems. Compared with the setting network of "undesirable" and "desirable" output expansion in the same proportion in the traditional distance function, the directional distance function (DDF) is more in line with the measurement analysis method of environmental production technology, because it requires the output to be adjusted according to the direction vector g, and then reach the production practice frontier in the year-on-year increase or decrease. Its expression is.

$$\vec{D}_0(x, y, b; g) = \sup\{\beta : (y, b) + (\beta g_y + \beta(-g_b)) \in P(x)\}$$

According to Chung, et al. [8] the directional vector of output adjustment can be expressed as g = (- g b. g y) to represent the reduction of "undesirable" output and the increase of "desirable" output [9-11].

Analysis of factors affecting low-carbon green TFP growth Based on the calculation results in the previous article, this paper empirically examines the factors affecting regional green TFP growth in countries along the Belt and Road based on a panel data model, in order to provide useful policy inspiration for improving the green development performance level of various countries or regions, and thus constructs an empirical analysis model with green TFP as the dependent variable [12].

$$lntfp_{it} = \beta_0 + \beta_1 \cdot lncapital_{it} + \beta_2 \cdot lnlabor_{it} + \beta_3 \cdot lnenergy_{it} + \quad (1)$$

$$\beta_4 \cdot lngdp_{it} + \beta_5 \cdot lngdp_{it}^2 + \beta_6 \cdot lnCI_{it} + \beta_7 \cdot lnur_{it} + \beta_8 \cdot lnst_{it} + \quad (2)$$

$$\beta_9 \cdot trade_{it} + \delta_i + \mu_t + e_{it} \quad (3)$$

Formula (3), lnt f p it is the green TFP of the ith region in the tth year, and the relevant influencing factors are capital input, labor input, energy consumption input, GDP per capita representing the level of regional economic development, the square term of GDP per capita, carbon intensity, urbanization development (urbanization rate), industrial structure (the proportion of industrial added value in GDP), foreign trade development (the proportion of total import and export trade in GDP), etc. β 0 is the intercept term, β 1 ~ β 9 are the estimated coefficients of each influencing factor, δ i is the individual effect, μ t is the time effect , and e it is the random interference term. In addition, in order to reduce the possible heteroscedasticity and volatility of the data sample, all variables in the analysis model are logarithmically processed.

3. Data Collection

3.1. Indicator Selection and Data Sources

Considering the serious lack of data in some countries, the research object is locked in 52 countries along the "Belt and Road", and the evaluation of low-carbon green development performance is based on the measurement of technical efficiency and total factor productivity. Combined with the availability of relevant data, the research period is set as 1995~ 2023, so as to unify the statistical caliber of various countries and conduct subsequent comparative analysis. Referring to previous research literature and taking into account the availability of relevant indicator data, three factors such as capital, labor and energy consumption are selected as input variables, and regional gross domestic product (GDP) and CO2 emissions are regarded as "consensus" and "unconsensus" outputs respectively, and then the evaluation framework of the low-carbon green development performance level of countries along the route is constructed. Among them, capital input (represented by the total amount of fixed asset formation), labor input, GDP, etc. are all obtained from the World Bank database, and the final energy consumption and CO2 emissions are from the positive A statistical database. As shown in Table 1, the fluctuation range of the observed values of the 52 countries along the route is large, which indicates that the input and output factors of the region are extremely unstable during the investigation period; from the coefficient of variation, the capital investment of the countries along the route varies the most from year to year, and the energy consumption investment varies relatively the least. In addition, the maximum and minimum values of carbon emissions vary greatly, with the maximum value of 9190.74 million tons corresponding to China's total carbon emissions in 2013, and the minimum value of 1.43 million tons corresponding to Albania's carbon emissions in 1997. In fact, these two countries are also the countries with the highest and lowest carbon emissions in the countries along the route [11, 13-16].

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Table 1.
Descriptive statistics of variables (1995-2023).

Variable	Observations	Maximum	Minimum	Mean	Standard Deviation	Coefficient of variation
Capital investment (billion US dollars)	1144	48414.8	0.6	684.8	3483.7	5.1
Labor input (10,000 people)	1144	78914.9	13.2	3553.9	11843.8	3.3
Energy consumption input (10,000 tons of standard coal)	1144	281343.6	76.0	9066.1	28493.4	3.1
GDP (US$ billion)	1144	11379.5	8.6	2157.3	8112.5	3.8
CO_2 emissions (10,000 tons)	1144	919074.0	143.0	23879.1	88920.8	3.7

In order to examine the changes in relevant indicators of countries along the route during the sample period, the formula n=(X2023 / X1995)^(1/22)-1 (n is the average annual growth rate, X represents each variable) is used to calculate the total average annual growth rate of each indicator: ① The total average annual growth rate of GDP of countries along the route is 8.8%, among which China's annual average GDP growth is the fastest (13.2%), and Greece's annual average GDP growth rate is the lowest (1.6%); ② The total annual average growth rate of capital investment is 10%, among which Georgia has the largest increase (18.3%), while Greece and Yemen have negative growth; ③ The total annual average growth rate of labor input is only 1.2%, and the annual average growth rate of most countries is far below 5%, among which 11 countries including Albania have negative growth; ④ The total annual average growth rate of energy consumption is 2.8%, which is lower than the total annual average growth rate of CO2 emissions (3.4%). Nearly 65% of countries have achieved growth in annual carbon emissions during the survey period. It can be seen that the growth rate of capital investment in countries along the Belt and Road is generally faster than the growth rate of GDP, which reveals the important role of capital investment in driving economic growth in countries along the Belt and Road; at the same time, CO2 emissions in more than half of the countries are showing a steady growth trend [12, 17]. In fact, the proportion of carbon emissions from countries along the Belt and Road to the world's total carbon emissions has been steadily increasing since 2000, reaching 54% in 2023, which means that reducing carbon emissions is indeed a key link in coordinating environmental and development issues in the process of building the Belt and Road.

Table 2.
Annual average efficiency of low-carbon green development technologies in countries along the Belt and Road.

Serial number	nation	ete	Serial number	nation	ete	Serial number	nation	ete	Serial number	nation	ete
1	Albania	1.2714	14	Georgia	0.6636	27	Sri Lanka	0.45	40	Russia	1.1819
2	Armenia	1.0383	15	Greece	1.0887	28	Lithuania	0.5625	41	Saudi Arabia	1.0955
3	Azerbaijan	0.2944	16	Croatia	0.6065	29	Latvia	0.6457	42	Singapore	1.1148
4	Bangladesh	0.5233	17	Hungary	0.4874	30	Moldova	0.8366	43	Slovakia	0.4579
5	Bulgaria	0.4526	18	Indonesia	0.4982	31	Macedonia	0.7155	44	slovenia	0.6661
6	Bosnia and Herzegovina	0.4698	19	India	0.8667	32	Mongolia	0.7542	45	Thailand	0.4038
7	Belarus	0.2247	20	Iran	0.3041	33	Malaysia	0.3612	45	Tajikistan	1.9425
8	Brunei	2.5057	21	Israel	1.0874	34	Nepal	0.8347	46	Turkmenistan	0.1949
9	China	1.5046	22	Jordan	0.3586	35	Oman	0.6433	47	Türkiye	1.1656
10	Cyprus	1.178	23	Kazakhstan	0.2965	36	Pakistan	0.8747	48	Ukraine	0.2536
11	Czech Republic	0.3992	24	Kyrgyzstan	0.6811	37	The Philippines	0.4181	49	Uzbekistan	0.1877
12	Egypt	0.6192	25	Cambodia	1.0015	38	Poland	0.8506	50	Vietnam	0.2054
13	Estonia	0.4316	26	Lebanon	0.5149	39	Romania	0.3709	51	Yemen	0.8642

Note: The order of 1 to 52 is shown in Table 2.

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3.2. Measurement of Technical Efficiency of Low-Carbon Green Development

Table 2 lists the annual average value of low-carbon green development technical efficiency (referred to as ete) of the 52 countries along the route. It can be seen that the development efficiency level of most countries is still very backward, and there are also large differences between countries. From 1995 to 2023, the technical efficiency of low-carbon green development in the 52 countries showed an overall downward trend, with a decrease of 11%. The total annual average value of ete was 0.7196, which means that low-carbon green development has only reached 72% of the optimal level, and there is still great room for improvement and potential for exploration. From the perspective of regional division[18]: ① The total annual average ete of the 10 East Asian countries is 0.8768, among which Brunei, China, Cambodia, Singapore and other 4 countries have achieved the best annual low-carbon green development level; ② The total annual average ete of the 13 West Asian and North African countries is 0.7559, among which Armenia, Champaign, Israel, Saudi Arabia, Turkey and other 5 countries have achieved the best annual low-carbon green development level, while Azerbaijan and other 3 countries have significantly lower annual low-carbon green development levels; ③ The total annual average ete of the 5 South Asian countries is 0.7099, and the annual low-carbon green development level of each country has not reached the best; ④ The total annual average ete of the 8 Southern European countries is 0.7052, among which only Albania and Greece have achieved the best annual low-carbon green development level; ⑤ The total annual average ete of the 5 Central Asian countries is 0.7060, and the annual low-carbon green development level of each country has not reached the best level. ⑥ the total annual average ELE of the seven Eastern European countries is 0.5909. Except for Russia, the annual average low-carbon green development of the remaining countries is far below the optimal level. ⑦ as the region with the lowest efficiency level of low-carbon green development among the seven regions, the total annual average ETE of the four Central European countries is only 0.5488, and the annual average ETE of each country is less than 1. It can be seen that the overall level of low-carbon green development efficiency of European countries along the "Belt and Road" is not as optimistic as that of Asian countries.

Figure 1 reveals the differences in the traditional technical efficiency TE and low-carbon green development technical efficiency ET of the 52 countries along the route. After considering environmental factors, the corresponding technical efficiency scores of nearly 65% of the countries have declined to varying degrees, especially in China, where the annual average TE is 3.2197 and the annual average ET has dropped to 1.5046. It can be seen that if the environmental factors are ignored, the actual measurement of technical efficiency will be biased, that is, the actual technical efficiency level will be overestimated.

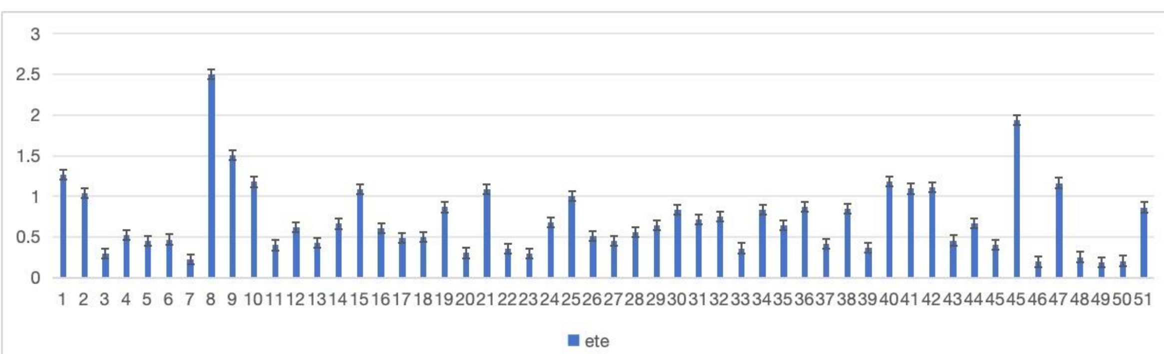

Figure 1.
Average annual technical efficiency scores of 52 countries along the Belt and Road [18].

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3.3. Low-Carbon Green TFP Index Measurement

According to calculations (see Table 3), the overall low-carbon green TFP of the countries along the route has an average annual decline of -1.33% from 1995 to 2023. Among them, pure technological progress (PTP=0.0685) is an important contributor to TFP growth, while the improvement of pure efficiency (PEC=0.0001) and the improvement of scale efficiency (SEC=0.0001) have relatively small contributions to IFP growth. The change in technological scale (TSC=0.0820) largely offsets the contribution of the first three decomposition indicators to TFP growth, resulting in a negative growth in the total annual average TFP. During the inspection period, the overall low-carbon green TFP of the countries along the route has declined to varying degrees since 1999, with the largest decline in 2011 (-5.21%), and the fluctuation of the decline during the period was also large.

In order to reveal the inherent law of the change of TFP index of the 52 countries along the route over time, the calculation results of TFP index of each country over the years are sorted out by time period, and the annual average TFP index of each country and its decomposition over the past 20 years are listed. ① From 2000 to 2005, the total annual average TFP showed negative growth (-0.62%), while the number of countries with annual average TFP growth increased to 23, among which Armenia, Bulgaria, Bosnia and Herzegovina, Belarus, Mongolia and Vietnam achieved growth in low-carbon green TFP from 1995 to 2005; ② From 2005 to 2010, the number of countries with annual average TFP growth decreased to 10, and the total annual average decline in low-carbon green TFP increased to 2.56%, and more than 80% of the countries experienced a decline in annual average TFP to varying degrees; ③ From 2010 to 2023, the number of countries with annual average low-carbon green TFP growth increased again to 21, and the total annual average decline in low-carbon green TFP was 2.09%, among which Russia and Tajikistan have achieved growth in TFP since 2000. During the entire survey period, only 12 countries, including Bangladesh, achieved an average annual low-carbon green TFP growth, while the low-carbon green TFP of most countries declined to varying degrees. Among them, 29 countries, including Albania, achieved improvements in pure efficiency, 11 countries achieved progress in pure technology, 25 countries, including Armenia, achieved improvements in scale efficiency, and 29 countries, including Albania, saw their technology move toward CRS.

As shown in Table 3, under the traditional TFP framework, the overall average TFP index of the countries along the route is -0.0098, which means that the overall TFP has decreased by 0.98%. The improvement of scale efficiency and the change of technology scale are important contributing forces to promote regional TFP growth, but the changes in pure efficiency and pure technology have a significant negative effect on TFP growth. The average annual decline in low-carbon green TFP is 0.35 percentage points higher than that in the traditional analysis framework. Among them, the improvement of scale efficiency is still an important force to promote the growth of regional TFP, but its influence on low-carbon green TFP is significantly weaker than that in the traditional analysis framework. The changes in the other three decomposition indicators have the opposite effect on TFP in the two analysis frameworks. From the perspective of each region: ① Only the five Central Asian countries achieved growth in annual low-carbon green TFP, and this was mainly due to pure technological progress and improvement in pure efficiency; ② Changes in pure technology and pure efficiency are also important contributing forces to the growth of annual TFP in the eight Southern European countries, but are a significant inhibitory force that hinders the growth of low-carbon green TFP in the ten East Asian countries; ③ For the five South Asian countries and the seven Eastern European countries, changes in pure efficiency and technological scale are contributing forces to regional TFP growth, while the regression of pure technology and the reduction of scale efficiency have inhibited regional TFP growth; ④ All decomposition indicators of the annual average TFP index of the 13 countries in West Asia and North Africa are less than 0, which leads to the region's annual average decline in low-carbon green TFP ahead of other regions; ⑤ The improvement of scale efficiency is currently the only contributing force that can promote the growth of annual average TFP in the four Central European countries, and the other three decomposition indicators are all reverse forces.

Table 3.
TFP decomposition of 52 countries and regions along the Belt and Road from 1995 to 2023.

	Indicator decomposition	PEC	PTP	SEC	TSC	TFP
Traditional TFP		-0.0021	-0.0115	0.0021	0.0017	-0.0098
Green TFP	52 countries overall	0.0001	0.0685	0.0001	-0.0820	-0.0133
	East Asian 10 countries	-0.0174	-0.0543	0.0229	0.0380	-0.0108
	13 countries in West Asia and North Africa	-0.0022	-0.0157	-0.0088	-0.0010	-0.0277
	Central Asian 5 countries	0.0076	0.6650	-0.0030	-0.6670	0.0026
	South Asia 5 countries	0.0130	-0.0222	-0.0007	0.0061	-0.0039
	7 Eastern European countries	0.0005	-0.0148	-0.0013	0.0047	-0.0110
	Central European 4 countries	-0.0030	-0.0135	0.0004	-0.0015	-0.0176
	8 Southern European countries	0.0145	0.1563	-0.0105	-0.1691	-0.0087

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Table 4.
Model test and panel regression results.

variable	cons	lncapital	lnlabor	lnenergy	lngdp	lngdp²	ln	lnur	lnst	lntrade	R^2	Wald
FGLS	2.162***	-0.269***	0.463***	-0.138**	-0.687***	0.06	0.068	0.246***	-0.034	-0.143***	--	279.07
	-3.64	(-6.16)	-7.86	(-2.94)	(-4.74)	-7.36	(-1.88)	-3.91	(-0.75)	(-4.83)		0
PCSE	2,162**	-0.269***	0.463***	-0.138***	-0.687***	0.06	0.068**	0.246***	-0.034	-0.143***	0.2	1142.66
	-2.8	(-6.01)	-7.49	(-3.73)	(-4.00)	-6.27	(-2.84)	-6.09	(-1.07)	(-8.25)		0
As	-12.68	-	-	-	-	-	-	-	-	-	-	-
Hausmann	45.86***	-	-	-	-	-	-	-	-	-	-	-
BP - LM	4806.20***	-	-	-	-	-	-	-	-	-	-	-
Wooldridge	19.27***	-	-	-	-	-	-	-	-	-	-	-
Modified Wald	23668.38***	-	-	-	-	-	-	-	-	-	-	-

Note: p<0.05, * p<0.0l, * p<0.001.

3.4. Analysis of Factors Affecting Low-Carbon Green TFP Growth in Countries Along the Belt and Road

After using LLC method and Kao method to conduct panel unit root and cointegration test on relevant variables, a panel regression analysis is conducted on the data samples of 52 countries along the route according to formula (10). Taking into account the problems of autocorrelation and heteroskedasticity in the model, FCLS is used for panel regression. At the same time, PCSE estimation results are also reported for robustness. Now we mainly analyze the PCSE estimation results (see Table 4). It can be seen that, except for industrial structure, the other explanatory variables have passed the significance test. Specifically, the factors that have a significant positive impact on the overall low-carbon green TFP growth of countries along the route include labor input, urbanization development, and the square of economic development level. With the acceleration of urbanization in countries along the route, it has not only promoted the rapid growth of the regional economy, but also made the advantages of talent, science and education in the regions along the route continue to be highlighted [19, 20]. This will gradually drive the improvement of regional technological research and development capabilities to a large extent, and ultimately promote regional TFP growth. It is worth noting that the estimated coefficient of economic development level is -0.687, and its square term coefficient is 0.060, and both passed the test at the significance level of 0.1%, which means that there is a clear U-shaped relationship between the overall economic growth of the countries along the route and low-carbon green TFP.

According to the research results in Table 4, among the countries along the Belt and Road, factors such as economic development, capital investment, foreign trade development, energy consumption, carbon intensity and industrial structure have hindered the growth of low-carbon green total factor productivity (TFP). Under the development concept of "digital linkage and innovation enhancement", China and Belarus can gain valuable experience from these research results, promote green economic development, and achieve sustainable growth under the "Belt and Road" initiative. It has a significant negative impact on the growth of low-carbon green TFP [21]. For every 1% increase in capital investment, low-carbon green TFP will significantly decrease by 0.269%. The demand for fixed asset investment in infrastructure and basic industrial construction in countries along the route continues to grow. This is mainly because there is a large gap between the local infrastructure such as transportation, telecommunications, electricity, health and basic industrial levels and the abundant resources and huge consumer market demand. However, while the blind expansion of investment scale has promoted regional economic growth, it has also had an adverse impact on the regional industrial structure and technological level, making these regions more sensitive to climate change. Therefore, China and Belarus need to make reasonable plans when investing capital to avoid blind expansion. As the world's main production and consumption areas of fossil energy, the countries along the route have long maintained a share of over 70% in overall energy consumption. This results in high carbon emissions per unit of energy consumption, especially in Asian countries in the middle zone, which have relatively low levels of economic development and are highly dependent on fossil energy. Due to factors such as insufficient technological research and development capabilities, limited capital investment, and relatively backward environmental protection concepts, the development of clean energy in these countries is slow, which in turn has hindered the growth of TFP. Based on this, China and Belarus should increase investment in the research and development and use of clean energy [22].

Carbon intensity also has a negative impact on TFP growth. During the period 1995-2023, the carbon intensity of countries along the route showed a downward trend, from 0.0024 tons of carbon/million US dollars in 1995 to 0.0008 tons of carbon/million US dollars in 2023 [23]. With the continuous advancement of the construction of the "Belt and Road", the exchange and sharing of advanced production technologies and energy-saving and pollution-reduction technologies are becoming more frequent, and carbon intensity is expected to continue to decline significantly. It is estimated that for every 1% reduction in carbon intensity, TFP will increase by about 0.068%. This provides an important reference for China and Belarus in promoting green economic development, and we should continue to pay attention to and promote the reduction of carbon intensity.

4. Results and Discussion

In the process of deepening the “Belt and Road” initiative, the concept of green development has become more popular and actively implemented in countries and regions along the route. With the help of US-SBM-DDF and Luenberger productivity index analysis, this paper deeply analyzes the current status and regional differences of low-carbon green development in 52 countries along the “Belt and Road”, and conducts empirical research on the socio-economic factors that affect their low-carbon green total factor productivity (TFP) growth. The research results not only fill some gaps in the research field of green “Belt and Road” construction, but also provide key policy inspiration for China and Belarus to promote green economic development under the background of “Belt and Road”.

The overall efficiency of low-carbon green development in countries along the route is poor, with significant differences among countries in the region, and only 25% of countries have reached the optimal level of development. This reflects that most countries face great challenges in the process of green economic transformation, and there are obvious gaps between different regions in terms of technology and resource allocation. The average annual decline in low-carbon green TFP in countries along the route was -0.0133, an increase of 0.35 percentage points compared with the traditional analysis framework. Pure efficiency improvement, pure technological progress and scale efficiency improvement are positive factors that promote TFP growth, while changes in technological scale have severely restricted its growth. This shows that in the pursuit of green development, the coordinated adaptation of technology and scale is crucial. Except for labor input, urbanization development and the square of economic development level, which have a positive effect on the growth of regional low-carbon green TFP, the other explanatory variables all have a negative effect. Moreover, there is a significant U-shaped relationship between overall economic growth and TFP in the countries along the route. This means that when the economy reaches a certain stage, the promotion of green development can effectively promote the improvement of TFP.

China and Belarus need to accelerate the transformation from the investment-driven "high-carbon" economic growth model to a low-carbon green sustainable model and improve technical efficiency. Increase corporate investment in scientific and technological innovation, especially in the research and development of clean production and energy-saving and carbon reduction technologies in the field of environmental protection, and fully release the positive driving force of technological progress. At the same time, optimize the input-output ratio of factors such as capital, labor, and energy, innovate the business management system and governance structure, and achieve efficient allocation of resources; re-examine their own geographical and resource advantages, break through the bottlenecks of domestic economic development and institutional quality, and promote the full release of the green technology spillover effect of trade openness between countries. Actively expand the trade field, tap new growth points, strengthen energy cooperation, optimize the energy structure, balance differences in resource endowments, and promote green development with the help of trade and resource cooperation; given that different factors have different mechanisms of action on low-carbon green development, the two countries should formulate precise improvement strategies based on the impact of their own economic variables on pure efficiency, pure technology, scale efficiency, technology scale, etc., to ensure scientific and reasonable decision-making and achieve targeted promotion of green economic development; as an important participant in the construction of the green "Belt and Road", China should strengthen the coordination of sustainable development goals and plans with Belarus, promote the docking of ecological and environmental protection policies and regulations, and jointly explore the formulation of green project construction and financing guidelines, technical standards, etc., to lead low-carbon green development in cooperation areas such as infrastructure and product trade.

5. Conclusion

Based on this, China and Belarus should accelerate the transformation from the investment-driven "high-carbon" model to a low-carbon, green and sustainable model. On the one hand, enterprises should increase their investment in scientific and technological innovation in the field of environmental protection; on the other hand, they should use their own geographical and resource advantages to break through development bottlenecks and release the green technology spillover effect of trade openness. In addition, the two countries should strengthen the coordination of sustainable development goals and plans, promote the docking of ecological and environmental protection policies and regulations, formulate green project construction, financing guidelines and technical standards, lead low-carbon green development in infrastructure, product trade and other fields, and contribute to the development of the green economy of the "Belt and Road".

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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