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The Direct and Indirect Impact of Green Bond Issuance on Enterprises'Carbon Emission Reduction —— Evidence from China

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Abstract

The issuance of green bonds plays an important role in promoting the optimization and upgrading of industrial structure, green transformation and sustainable economic development. This paper constructs a spatial weight matrix through multi-dimensional economic space to capture the spatial effects of short-term data, and makes an empirical study on the overall economic and environmental effects of China's green bond issuance using spatial panel Durbin model. The results show that in the case of data scarcity, the spatial weight matrix constructed by multi-dimensional economic space can capture spatial effects more accurately than the traditional spatial weight matrix. There is significant spatial heterogeneity among the carbon emissions of enterprises. The issuance of green bonds directly reduces the total carbon emissions. Every 100 million yuan of green bonds issued will directly reduce the carbon emissions of enterprises by 97.34 billion tons, which has a great role in promoting the sustainable development of the economy. However, due to the scarcity of data, the indirect impact of green bonds is not significant. In addition, the direct impact of production capacity and net coal consumption rate on total carbon emissions is positive, but interestingly, production capacity has a spatial spillover effect on carbon emissions, while net coal consumption rate has a spatial aggregation effect on carbon emissions.

Keywords: Green Bond; Spatial Panel Durbin Model; Carbon Emission; Spatial Agglomeration

JEL classification: C31F30 G15

1. Introduction

The greenhouse effect has aroused the close attention of the international community on greenhouse gas emissions, and the support in the field of energy conservation and emission reduction has been increasing. Green bonds emerged at the historic moment. Since the first

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green bond issued by the European Investment Bank in 2007, the scale of green bonds has expanded rapidly and become a new star in the financial field.

At present, most of the research on green bonds is from the perspective of investment, focusing on the liquidity, volatility and return of green bonds. For example, Linh Pham (2016) used the daily closing price data of S&P Green Bond Index from April 2010 to April 2015 to analyze the volatility of the green bond market, and found that the overall impact of the traditional bond market tends to spill over to the green bond market [1]. Juan C.Reboredo （2018）studied the common movement between green bond and financial market, and found that green bond market is coupled with corporate bond and bond market, but weak cooperation with stock and energy commodity market, and affected by price spillovers in fixed income market [2]. WulandariFebi et al.（2018）studied the impact of liquidity premium on yield spreads of green bonds, and found that the impact of volume decreases over time, which means that the liquidity risk of green bonds can now be neglected [3]. Britta Hachenberg and Dirk Schiereck（2018）found that the rating AA-BBB of green bonds and the entire sample trading were slightly tighter in their respective periods than the non-green bonds of the same issuer. In addition, the trading of financial and corporate green bonds is tenser than its comparable non-green bonds, while the trading of government-related bonds is slightly more extensive. The size, duration and currency of issuance have no significant influence on the pricing difference [4]. XiaoyanGao and Wenpeng Ji (2018) used the method of entropy to construct the financial evaluation index of green bond issuer to describe the issuer's financial ability comprehensively and objectively. Then, from the point of view of the characteristics of green bond issuer, the paper made an empirical study on the influencing factors of the formation of credit spreads of green bond issuance [5].

In addition, some scholars have discussed the impact of the issue of green bonds on the world's energy structure from a macro perspective. For example, SolveigGlomsrrd and Taoyuan Wei (2018) found that recent subscriptions by large banks and institutional investors have reached levels that could contribute significantly to the low-carbon transition. Green Finance reduced global coal consumption to 2.5% below BAU in 2030 and increased the global share of non-fossil energy power from 42% to 46%. 。 By 2030, green finance had reduced global carbon dioxide emissions comparable to the total emissions of the European Union and Japan in the past year [6].

China's green bond market has just been established, and it have taken shape since the relevant guidance and implementation measures were promulgated in 2017. At this stage, domestic research on green bonds mainly focuses on experience summary and policy formulation. For example, Jiayu Jin and Liyan Han (2016) summarized and analyzed 272 international green bonds issued from 2007 to 2015, analyzed the development trend and characteristics of green bonds in different economies and industries, and analyzed the risk characteristics of green bonds [7]. Xiaoying Zhan (2016) proposed that China should learn from the experience of green bond development in the international market, coordinate supervision, unify the scope of green project definition, accelerate the green certification and information disclosure system, introduce incentive policies, enhance the attractiveness of green bonds, improve the green financial system, and actively promote the development of green bonds to promote China's economic restructuring , the implementation of the concept of ecological civilization and sustainable low-carbon development [8].

In summary, the existing literature mostly studies green bonds from the perspective of investors or policymakers, and few articles on the impact of green bonds on the sustainable development of the world economy are also from a macro perspective. Because China's green bond market has just taken shape, its development time is short, and its data is seriously insufficient, which brings great difficulties to economic modeling. From the micro perspective, this paper studies the impact of green bond issuance on enterprise upgrading technology, energy saving and emission reduction, as well as the spatial effects on other enterprises. By constructing multi-dimensional economic space and integrating data of different frequencies, the problem of insufficient data is overcome. The structure of the article is divided into four parts, the first part is a brief introduction, the second part introduces the construction of spatial weight matrix and spatial panel Durbin model; the third part is the analysis of empirical results, and the fourth part is conclusion.

2. Materials and Methods

2.1 Spatial correlation test

In order to compare the performance of different spatial weighting matrices, we first set up three traditional spatial weighting matrices.

The first is the binary adjacency matrix:

$$Wa_{ij} = \begin{cases} 1 & i \text{ and j belong to the same province or adjacent provinces} \\ 0 & otehwise \end{cases} \quad (1)$$

The second is a threshold matrix based on geographical distance:

$$Wt_{ij} = \begin{cases} 1 & d_{ij}^{*} < 800 \\ 0 & otehwise \end{cases} \quad (2)$$

The third is the gravitational effect matrix based on geographic distance.

$$Wd_{ij} = \begin{cases} 1/d_{ij}^{*} & i \neq j \\ 0 & otehwise \end{cases} \quad (3)$$

d_{ij}^{*} is the geographical distance between the headquarters location of enterprise i and enterprise j since energy enterprises have branches in many provinces. As shown in Table 1, because of the scarcity of data and the sparsity of matrix, Moan's I Index cannot be calculated by using binary proximity matrix and threshold matrix, and Moan's I Index calculated by gravitational effect matrix is not significant. It is obvious that under the condition of insufficient data, it is difficult for traditional spatial weight matrix to capture the spatial effect of variables.

Table 1 Moan's I Index of Total Carbon Emissions under Traditional Matrix

	2016	2017	2018
Wa	NaN	NaN	NaN
	(NaN)	(NaN)	(NaN)
Wt	NaN	NaN	NaN
	(NaN)	(NaN)	(NaN)
Wd	-0.5835	-0.5521	-0.5592
	(-1.1012)	(-0.9629)	(-0.9943)

Note: The critical value of 5% significant level was -1.6449.

In this case, we refer to the method of Li LiLi et al. (2015) to construct the generalized multi-dimensional economic spatial weight matrix(GMESWM) [9].

$$\mathrm{Wgme}_{ij} = \frac{\overline{COP_i} * \overline{COP_j}}{\exp(\sqrt{1-|R_{ij}|^{d_{ij}}})} \quad (4)$$

$$\text{where,} \quad d_{ij} = \frac{d_{ij}^*}{max\{d_{ij}^* \mid j=1,2,\cdots\}}$$

$\overline{COP_i}$ indicates the average thermal power business proportion of the i'th enterprise in 16-18 years.It implies that the larger the proportion of thermal power business, the more external and internal pressure enterprises has to upgrade technology and equipment. At the same time, the proportion of thermal power business represents the company's business structure, and the companies with similar business structure have greater influence on each other.

d_{ij}^* indicates the geographical distance between enterprise i and enterprise j, while R_{ij} is the correlation coefficient between enterprise i and enterprise j calculated using the closing price data of enterprise stock for 16-18 years. In this way, not only the daily data and annual data are organically combined, but also the stock market and the securities market are combined, which greatly increases the richness of the data and helps the robustness of the results.

From Table 2, we can see that after using the newly constructed generalized multi-dimensional economic spatial weight matrix, Moan's I index has become significant, and the spatial effect has been effectively reflected. The Moan's I indexes from 2016 to 2018 are significantly negative, which shows that carbon emissions have obvious spatial heterogeneity.

Table 2 Moan's I Index of Total Carbon Emissions under GMESWM

	2016	2017	2018
Moran's I	-0.5619	-0.5749	-0.5926
Z(I)	-1.7295	-1.8279	-1.9614

Note: The critical value of 5% significant level was -1.6449.

2.2 Variable Selection

China's green bond market is beginning to take shape. By the end of 2018, only 22 green bonds (excluding medium-term bills) were issued, which came from 16 enterprises. As the disclosure of carbon emission information of Listed Companies in China is still in its infancy, most of the relevant rules are to encourage voluntary disclosure. Only enterprises that conduct carbon emission trading must disclose carbon emissions annually. In addition, because the disclosure standards are not uniform, some enterprises disclose the total carbon emissions, and some enterprises disclose the emission reduction. This paper mainly investigates the impact of the issuance of green bonds on corporate carbon emissions. Therefore, in order to unify the standards, financial and comprehensive enterprises were eventually eliminated, and only energy enterprises were selected to study (including four enterprises: CHINA LONGYUAN POWER GROUP CORPORATIO,HUADIAN FUXIN ENERGY CORPORATION LIMITED, CHINA POWER CLEAN ENERGY DEVELOPMENT COMPANY LIMITED, GUANGZHOU DEVELOPMENT GROUP INCORPORATED).We use Logarithmic data in the empirical study.

The amount of green bonds issued ($bond$). Because the funds raised by enterprises using green bonds cannot be used for equipment upgrading and technological transformation immediately, it will take a period of time, so bonds are considered as a factor affecting enterprises in their lifetime. The amount of green bonds is mostly less than 1 billion, so logarithmic processing is not used. Otherwise, in order to make the data meaningful, a large number of zero raw data need to be changed into 1, which will have a great impact on the results. The issuance of green bonds will inevitably promote enterprises to save energy and reduce emissions, and its coefficient should be negative.

Production capacity (PC). It refers to the total annual power generation of an enterprise. Its unit is 100 million kilowatt-hours. We use Logarithmic data in the empirical study. Obviously, there should be a positive correlation between production capacity and carbon emissions.

Net coal consumption rate ($NCCR$). That is, the standard coal consumed by enterprises for every kilowatt-hour of electricity production. This is also an important indicator to measure an enterprise's technical standards. The empirical research also uses the logarithmic data. The higher the value, the more backward the technology, so it should also be positively correlated with carbon emissions.

Among the data mentioned above, carbon emissions, the proportion of thermal power business, production capacity, and net coal consumption rate come from the annual reports of listed companies and social responsibility reports, while the data of green bonds come from WIND database.

2.3 Spatial Panel Durbin Model

In order to study the impact of the issuance of green bonds on enterprises, we use the spatial panel Durbin model, as shown in Formula (5):

$$CE_{it} = \rho W \cdot CE_t + \beta_1 bond_{it} + \beta_2 PC_{it} + \beta_3 NCCR_{it} + \lambda_1 W \cdot bond_{it} + \lambda_2 W \cdot BC_{it} + \lambda_3 W \cdot NCCR_{it} + \varepsilon_{it} \quad (5)$$

Where, CE_{it} indicated the total carbon emission of enterprise i in year t. $bond_{it}$ Indicated the total amount of green bonds issued by enterprises i that are still in circulation in year t. PC_{it} Indicated the natural logarithmic value of the annual power generation of enterprise i. $NCCR_{it}$ Indicated the natural logarithm value of net coal consumption rate of enterprise i in year t. And W we used were the four spatial weighting matrices that we established earlier.

3. Results

Now let's compare the results of SDM model using the four spatial weight matrices mentioned above. As shown in table 3:

Table 3 Regression results of SDM model under different weight matrices

	Wa	Wt	Wd	Wgme
$bond$	-0.01636	-0.01627	-0.03320*	-0.02696**
PC	6.43543**	6.80695***	0.11082	1.73746***
$NCCR$	-3.830846*	-4.12162**	5.82491***	2.97003***
$W \cdot bond$	-0.02552	-0.04757	0.04447**	-0.03236
$W \cdot PC$	2.09267	2.708363	2.59196	9.96951***
$W \cdot NCCR$	-2.17109	-2.73692	-6.76336	-11.05008***
ρ	-0.23607	-0.23607	-0.32896	-0.77100***

Note: ***, ** and * respectively refer to the tests passing 1%, 5% and 10% significance levels.

(1)The coefficient of the spatial lag of carbon emissions is not significant in the traditional spatial weight matrix model, which shows that the simple binary adjacency matrix, threshold matrix and gravitational effect matrix cannot accurately capture the spatial effect of carbon emissions in this special case.The spatial effect coefficient of GMESWM model is significantly negative at 1% significance level, which indicates that there is significant spatial heterogeneity among the total carbon emissions of enterprises.The areas with high carbon emissions tend to be the gathering place of energy and manufacturing enterprises. Local governments prefer economic benefits in the balance of environmental protection and economic benefits. They even adopt various preferential policies to attract industries with high carbon emissions, which lead to the reduction of carbon emissions around them.Therefore, there is a negative correlation between the carbon emissions of surrounding enterprises and that of local enterprises.

(2) The coefficient of green bond issuance is negative, which is consistent with our hypothesis. The coefficient of GMESWM model passes 5% significance level, which shows that the issuance of green bonds can promote energy enterprises to optimize their energy structure, thereby reducing the total carbon emissions. For every 100 million yuan issued, green bonds will directly reduce carbon emissions by 97.34 billion tons（$e^{-0.02696}$）. The coefficient of its spatial lag term is not significant, indicating that the indirect impact of green bond issuance on carbon emissions is limited. The main reason is that the data span is relatively short. In the short term, green bonds issued by one enterprise can hardly affect the production and development of other enterprises.

(3)Production capacity is positively correlated with carbon emissions, and the coefficient of PC in GMESWM model is positive at 1% significant level, which indicates that the larger the production capacity of enterprises, the more carbon dioxide emissions, which is consistent with the reality. The coefficient of its spatial lag term is positive at 1% significant level, which indicates that the production capacity of surrounding enterprises has a positive spatial effect on the carbon emissions of local enterprises. This is due to the particularity of the energy industry. The location of energy enterprises is often concentrated in resource-dominant areas. When the local energy development reaches saturation, the enterprises with large capacity will migrate to the surrounding resource-dominant areas, which will lead to higher carbon emissions in the surrounding areas.

(4)The coefficient of net coal consumption rate is positive at 1% significant level, which indicates that improving technology and reducing standard coal consumption per unit of power generation are important ways to reduce total carbon emissions.The coefficient of its spatial lag term is negative at 1% significant level, which indicates that there is a negative spatial effect on the carbon emissions of local enterprises.Clean energy accounts for a smaller proportion in areas with high net coal consumption rate around them.Therefore, similar to the situation in (1), the government favors economic benefits in the balance of environmental protection and economic benefits, thus attracting industries with high carbon emissions to the surrounding areas and objectively reducing carbon emissions in the region.

4. Discussion

By constructing a generalized multi-dimensional economic spatial weight matrix, we integrates data of different frequencies, and brings green bond market and stock market into the same economic space.From the micro point of view, this paper studies the impact of green bond issuance on enterprise upgrading technology, energy saving and emission reduction, as well as spatial effects on other enterprises by using the spatial panel Durbin model.We further analyze and refine the empirical results and draw the following conclusions.

In the case of data scarcity, compared with the traditional spatial weight matrix, the matrix constructed by multi-dimensional economic space can capture the spatial effect more accurately, reduce the estimation error and improve the scope of application of the model.

The issuance of green bonds directly reduces the total carbon emissions. For every 100 million yuan issued, green bonds will directly reduce carbon emissions by 97.34 billion tons （$e^{-0.02696}$）. However, because the use of funds takes a period of time, the short-term impact on other enterprises is limited, so its indirect impact is not obvious.There is significant spatial heterogeneity among the total carbon emissions of enterprises.In addition, the direct impact of production capacity and coal consumption on total carbon emissions is positive. But interestingly, the production capacity of other enterprises has a positive spatial effect on carbon emissions of local enterprises, while net coal consumption rate of other enterprises has a negative spatial effect on carbon emissions of local enterprises.

Due to the lack of sufficient data, the research results also have certain limitations. With the passage of time and the enrichment of data, the future research will have more attractive conclusions.

5. Conclusion

This paper constructs a spatial weight matrix through multi-dimensional economic space to capture the spatial effects of short-term data, and makes an empirical study on the overall economic and environmental effects of China's green bond issuance using spatial panel Durbin model. The results show that in the case of data scarcity, the spatial weight matrix constructed by multi-dimensional economic space can capture spatial effects more accurately than the traditional spatial weight matrix. There is significant spatial heterogeneity among the carbon emissions of enterprises. The issuance of green bonds directly reduces the total carbon emissions. Every 100 million yuan of green bonds issued will directly reduce the carbon emissions of enterprises by 97.34 billion tons, which has a great role in promoting the sustainable development of the economy. However, due to the scarcity of data, the indirect impact of green bonds is not significant. In addition, the direct impact of production capacity and net coal consumption rate on total carbon emissions is positive, but interestingly, production capacity has a spatial spillover effect on carbon emissions, while net coal consumption rate has a spatial aggregation effect on carbon emissions.This paper is of great significance for policy makers to realize the realistic role of green bond issuance and to adjust policies in time.

Conflicts of Interest

The authors declare no conflict of interest.

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