Does Climate Risk Have the Same Effect on Government Bond Yields as It Does on Non-government Bond Yields?

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***Abstract*—This paper uses time series data to analyze the impact of climate risk and other factors on the yields of government bonds and non-government bonds. The results show that the impact of climate risk on government bond yields is much greater than that on non-government bond yields. Issuance has an effect on both government bond yields and non-government bond yields, but has a smaller effect on government bond yields and a larger effect on non-government bond yields. Duration has a bigger effect on government bond yields than on non-government bonds. The main reason is that the maturity of non-government bonds is generally shorter, while the maturity of government bonds is relatively longer. Credit risk has a much bigger impact on non-government bond yields. Because government bonds have little credit risk, default rates are low. Non-government bond's credit risk is relatively large with high default risk. Whether government bonds are traded across markets or not has a big impact on government bonds.**

***Index Terms*—Climate risk, government bonds, non-government bonds, yields, Maturity**

I. INTRODUCTION

SCHOLARS at home and abroad have studied this problem.

Marcus Painter(2020) studies the impact of climate change on municipal bonds. Counties exposed to climate change will pay more in underwriting cost and initial returns when issuing long-term municipal bonds than counties not exposed to climate change.

Little research has been done on how long-term climate risk changes are priced in financial markets. Hong et al. (2019) analyzed drought caused by climate change and found that the market was not sufficiently responsive to the risk. However, Bansal et al. (2016) used temperature rise as a proxy variable of climate change and found that it had a negative impact on asset values, indicating that the market has a pricing on climate change. In the real estate market, Bernstein et al. (2019) found that houses exposed to rising sea level would be sold at a discount compared with houses not exposed to rising sea level.

The financial consequences of climate change come in four main forms: production risk, reputational risk, and regulatory/litigation risk. Hong et al.(2019) proved that the production risk caused by long-term drought would have a negative impact on the stock returns of companies in the food industry. Dell et al.(2012) found that rising temperature would reduce agricultural and industrial output. Chava (2014) proved that investors of companies excluded by environmental screening require higher capital costs. These firms face either reputational risk of being flagged as a climate change indicator or regulatory risk, as current output is negatively affected by future climate change related to regulation. Bernstein et al.(2019) showed that the physical risk caused by sea level rise has a negative impact on the housing price exposed to the risk. They then find that this effect is very small when the housing market is highly liquid. Our study goes one step further and shows that in liquid markets investors take the physical risks of climate change to asset trading into account and price these risks in their holdings.

Hallegatte et al.(2013) used altitude GIS for the first time to calculate population exposure per 50 cm "elevation" of current mean sea level. They convert the affected population into an affected asset using capital estimates for each resident. For the existing level of defence in coastal cities, we used the Linham, Green and Nichollas approaches.

Bond ratings affect municipal bond prices because investors rely on bond ratings to evaluate credit risk (Cornaggia et al., 2017). In addition, credit ratings have an important impact on the local economy.

Adelino et al.(2017) found that there was a positive correlation between local government expenditure, employment and bond grade.

To sum up, scholars have studied the yields and prices of corporate and municipal bonds and found that credit risk, downside risk, liquidity and climate change are important influencing factors. This paper intends to analyze the impact of climate risk on the yields of government bonds and non-government bonds based on the research of scholars.

II. DATA

We collected the yield data of Shanghai corporate bonds and municipal bonds from the GuoTaiAn database, excluding national bonds, policy bank bonds, central bank bills, financial bonds, government-backed institution bonds, ultra-short financing bonds, medium-term notes, short-term financing bonds, perpetual medium-term notes, SME

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collective notes, convertible bonds, etc. Finally, corporate bonds and municipal bonds with maturities of 2 to 15 years were selected. Short-term and ultra-short-term bonds and special bonds are excluded, because short-term bonds and special bonds do not have the characteristics of ordinary bonds, and the results are prone to be not objective.

We select data on corporate and government bonds issued from 2005 to 2019. Bonds are divided into three grades: AA, AA+ and AAA.

III. Variables

The variables selected in this paper include corporate bond yield, climate risk, bond issue size, maturity date, bond rating and whether there is cross-market trading.

The climate risk in this paper is based on the measurement method in Hallegatte(2013), and the ratio between the possible loss caused by sea level rise and local GDP.

IV. Descriptive statistical analysis

A. Yield analysis of government bonds and non-government bonds

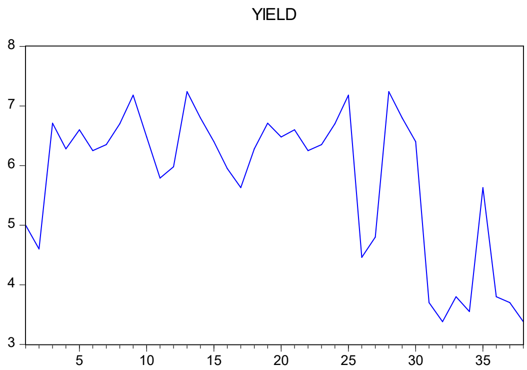

Figure 1 Government bond yields

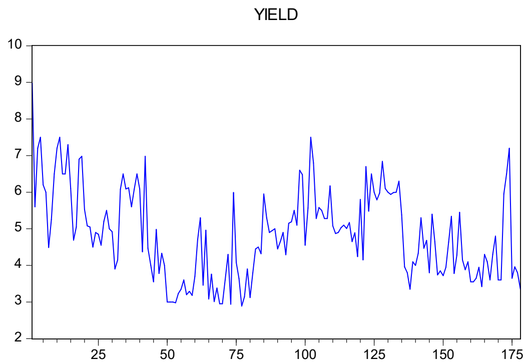

Figure 2 Non-municipal bond yields

As shown in the figure, the horizontal axis represents time and the vertical axis represents the rate of return, expressed in percentiles. During the sample period, yields of government bonds in figure 1 fluctuated between 3%-7% with relatively small fluctuations, while yields of non-government bonds in figure 2 fluctuated between 3%-9% with relatively large fluctuations. This is mainly because government bonds are relatively low risk and non-government bonds are relatively high risk.

B. Analysis of climate risks faced by government bonds and non-government bonds

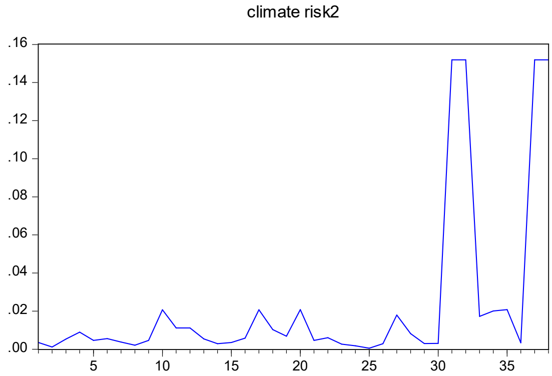

Figure 3 Climate risk for government bonds

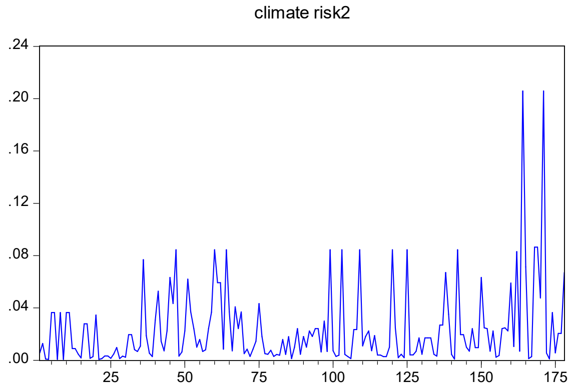

Figure 4 Climate risk to non-government bonds

As shown in Figure 3, the horizontal axis represents time and the vertical axis represents the rate of return, expressed in percentiles. The climate risk faced by government bonds fluctuates between 0.1% and 1.5%, and the fluctuation range is small. During the sample period, the time risk in the front is relatively small and the fluctuation is small, and the climate risk rises significantly with the global warming and climate anomaly, and the fluctuation becomes larger.

As shown in Figure 4, the horizontal axis represents time and the vertical axis represents the rate of return, expressed in percentiles. The climate risk faced by non-government bonds ranges from 0.1% to 2%, which is larger than that faced by government bonds, with relatively large fluctuations. During the sample period, the climate risk is relatively low and stable in most of the early period, but it increases sharply in the later period, which is closely related to the global warming and climate anomaly.

C. Descriptive statistical analysis

Table 1 and table 2 show the mean value, maximum value, minimum value and peak value of government bond yield, climate risk, returnable value, issuance, duration, bearish value, credit rating, market, etc. The comparison shows that the climate risk of government bonds is small, while that of non-government bonds is large. For other sequence values, the climate risk of government bonds is also relatively small, while that of non-government bonds is relatively large. Mainly because the government bond default risk is low, non-government bond risk is higher.

TABLE 1 DESCRIPTIVE STATISTICAL ANALYSIS OF GOVERNMENT BONDS

	Mean	Max	Min	S.D.	Skewness	Kurtosis	JB	P
yield	5.77	7.24	3.38	1.23	-0.81	2.25	5.05	0.08
risk	0.02	0.15	0.00	0.05	2.48	7.34	68.80	0.00
size	10.02	25.00	2.00	5.25	1.01	3.50	6.81	0.03
Maturity	6.03	10.00	3.00	1.62	-0.04	3.79	0.99	0.61
rating	2.24	3.00	1.00	0.85	-0.47	1.57	4.62	0.10
market	0.82	1.00	0.00	0.39	-1.63	3.65	17.49	0.00

TABLE 2 DESCRIPTIVE STATISTICAL ANALYSIS OF NON-GOVERNMENT BONDS

	Mean	Max	Min	S.D.	Skewness	Kurtosis	JB	P
yield	4.87	8.98	2.89	1.21	0.45	2.71	6.63	0.04
risk	4.46	7.32	1.58	1.28	-0.17	2.37	3.80	0.15
size	13.11	60.00	1.00	10.46	1.98	7.83	288.69	0.00
Maturity	4.74	8.00	2.00	1.14	0.01	3.47	1.63	0.44
rating	1.62	3.00	1.00	0.76	0.76	2.13	22.78	0.00
market	0.08	1.00	0.00	0.28	2.99	9.96	624.9	0.00

V. EMPIRICAL ANALYSIS

A. Model

In order to estimate the impact of climate risk change on government bond yields and non-government bond yields, the following models were developed.

$$yield = \beta_1 * \text{risk} + \beta_2 * size + \beta_3 * maturity + \beta_4 * rating + \beta_5 * market + e_t \tag{1}$$

In Formula (1), yield represents bond yield, risk represents climate risk, size represents issuance, maturity represents bond duration, rating represents credit rating, and market represents cross-market transaction.

Since some independent variables are correlated, we adopt stepwise regression analysis to eliminate irrelevant variables.

B. Analysis of empirical results

Impact analysis of climate risk

TABLE 3 ANALYSIS OF THE IMPACT OF CLIMATE RISK ON GOVERNMENT BOND YIELD

Variable	Coefficient	Std.	t-Statistic	Prob.
C	6.1808***	0.1719	35.9652	0.0000
CLIMATE_RISK	17.924***	3.4197	5.2413	0.0000

R-squared	0.4328	Mean dependent var	5.7666
Adjusted R-squared	0.4171	S.D. dependent var	1.2321
S.E. of regression	0.9407	Akaike info criterion	2.7669
Sum squared resid	31.858	Schwarz criterion	2.8530
Log likelihood	-50.570	Hannan-Quinn criter.	2.7975
F-statistic	27.47***	Durbin-Watson stat	1.3243
Prob(F-statistic)	0.0000		

TABLE 4 ANALYSIS OF THE IMPACT OF CLIMATE RISK ON NON-GOVERNMENT BONDS

Variable	Coefficient	Std.	t-Statistic	Prob.
C	5.0258***	0.1135	44.2921	0.0000
CLIMATE_RISK	6.7346**	2.9369	-2.2931	0.0230

R-squared	0.0290	Mean dependent var	4.8663
Adjusted R-squared	0.0235	S.D. dependent var	1.2101
S.E. of regression	1.1959	Akaike info criterion	3.2068
Sum squared resid	251.699	Schwarz criterion	3.2425
Log likelihood	-283.405	Hannan-Quinn criter.	3.2213
F-statistic	5.2585**	Durbin-Watson stat	0.7092
Prob(F-statistic)	0.0230		

As can be seen from table 3, the constant term is significant at the 1% confidence level, the impact of climate risk on the yield of government bonds is significant at the 1% confidence level, and the model is significant at the 1% confidence level, and climate risk can explain 43% of the change in the yield of government bonds. When climate risk changes, government bond yields move in the same direction.

It can be seen from table 4 that the constant term is significant at the confidence level of 1%, the impact of climate risk on the non-government bond yield is significant at the confidence level of 5%, and the model is significant at the confidence level of 5%. Climate change can explain 2.9% of the non-government bond yield. When climate risk changes, government bond yields move in the same direction.

Compared with the results of the above two tables, the impact of climate risk on the yield of government bonds is much greater than that of non-government bonds.

Analysis after adding circulation factor

TABLE 5 THE IMPACT OF ISSUANCE ON GOVERNMENT BOND RETURNS

Variable	Coefficient	Std.	t-Statistic	Prob.
C	6.7010***	0.3375	19.8530	0.0000
CLIMATE_RISK	18.3614***	3.3313	-5.5117	0.0000
ISSUE_SIZE	-0.0509*	0.0287	-1.7733	0.0849

R-squared	0.4796	Mean dependent var	5.7666
Adjusted R-squared	0.4498	S.D. dependent var	1.2321
S.E. of regression	0.9139	Akaike info criterion	2.7335
Sum squared resid	29.232	Schwarz criterion	2.8627
Log likelihood	-48.936	Hannan-Quinn criter.	2.7794
F-statistic	16.126***	Durbin-Watson stat	1.6306
Prob(F-statistic)	0.0000		

TABLE 6 THE IMPACT OF ISSUANCE ON THE RETURNS OF NON-GOVERNMENT BONDS

Variable	Coefficient	Std.	t-Statistic	Prob.
C	5.3982***	0.1404	38.446	0.0000
CLIMATE_RISK2	1.9152	3.0361	-0.6308	0.5290
ISSUE_SIZE	-0.0371***	0.0089	-4.1787	0.0000

R-squared	0.1171	Mean dependent var	4.8663
Adjusted R-squared	0.1070	S.D. dependent var	1.2102
S.E. of regression	1.1436	Akaike info criterion	3.1229
Sum squared resid	228.863	Schwarz criterion	3.1766
Log likelihood	-274.940	Hannan-Quinn criter.	3.1447
F-statistic	11.606***	Durbin-Watson stat	0.8761
Prob(F-statistic)	0.0000		

As can be seen from table 5, after the circulation factor is added, the constant term is significant at the 1% confidence level, climate risk is significant at the 1% confidence level, and circulation is significant at the 10% confidence level. R^2 increased from 43% to 48%. The model was significant at the 1% confidence level.

As can be seen from table 6, after the circulation factor is added, the constant term is significant at the 1% confidence level, while the climate risk is insignificant and the circulation is significant at the 1% confidence level. R^2 increased from 2.9% to 11.7%. It shows that issuance has a greater impact on non-government bond yield, while climate risk has a smaller impact on non-government bond yield.

Compared with the results in table 5 and table 6, the issuance has an impact on both government bond yield and non-government bond yield, but the impact on government bond yield is small, while the non-government bond yield is larger.

Analysis after adding the maturity

TABLE 7 INFLUENCE OF MATURITY ON GOVERNMENT BOND YIELD

Variable	Coefficient	Std.	t-Statistic	Prob.
C	4.1795***	0.4405	9.4875	0.0000
CLIMATE_RISK	23.2060***	2.3416	-9.9104	0.0000
ISSUE_SIZE	-0.0496**	0.0192	-2.5878	0.0141
MATURITY	0.4349***	0.0653	6.6633	0.0000
R-squared	0.7743	Mean dependent var		5.7666
Adjusted R-squared	0.7544	S.D. dependent var		1.2321
S.E. of regression	0.6106	Akaike info criterion		1.9506
Sum squared resid	12.677	Schwarz criterion		2.1230
Log likelihood	-33.062	Hannan-Quinn criter.		2.0120
F-statistic	38.881***	Durbin-Watson stat		1.7516
Prob(F-statistic)	0.0000			

TABLE 8 INFLUENCE OF MATURITY ON NON-GOVERNMENT BOND YIELD

Variable	Coefficient	Std.	t-Statistic	Prob.
C	5.4507***	0.4054	13.4465	0.0000
CLIMATE_RISK	7.1976**	2.9657	-2.4269	0.0162
MATURITY	-0.0873	0.0800	-1.0916	0.2765
R-squared	0.0356	Mean dependent var		4.8663
Adjusted R-squared	0.0246	S.D. dependent var		1.2102
S.E. of regression	1.1952	Akaike info criterion		3.2112
Sum squared resid	249.9966	Schwarz criterion		3.2649
Log likelihood	-282.8011	Hannan-Quinn criter.		3.2330
F-statistic	3.2279**	Durbin-Watson stat		0.7181
Prob(F-statistic)	0.0420			

As shown in table 7, after adding the duration factor, the constant term is significant at the 1% confidence level, climate risk is significant at the 1% confidence level, circulation is significant at the 5% confidence level, and duration is significant at the 1% confidence level. R^2 increased from 48% to 77%. The model was significant at the 1% confidence level. It shows that the duration has a great influence on the yield of government bonds and can explain a large part of the yield of government bonds.

As shown in table 8, after adding the duration factor, the constant term is significant at the 1% confidence level, while the climate risk is significant at the 5% confidence level, but the duration is not significant. R^2 is 3.5%. The model was significant at the 5% confidence level.

Compared with government bonds and non-government bonds, duration has a greater impact on government bond yields and a smaller impact on non-government bonds. The main reason is that the maturity of non-government bonds is generally shorter, while the maturity of government bonds is relatively longer.

Analysis after adding credit rating

As shown in table 9, the constant term is significant at 1% confidence level, climate risk is significant at 1% confidence level, circulation is not significant, duration is significant at 1% confidence level, and credit risk is significant at 5% confidence level. R2 increased from 77% to 80%. The model was significant at the 1% confidence level. It shows that credit risk has little effect on government bond yield. Eliminate circulation.

TABLE 9 INFLUENCE OF CREDIT RISK ON GOVERNMENT BOND YIELD

Variable	Coefficient	Std.	t-Statistic	Prob.
C	3.3856***	0.5643	6.0001	0.0000
CLIMATE_RISK	16.5871***	3.8547	-4.3031	0.0001
ISSUE_SIZE	-0.0169	0.0240	-0.7046	0.4860
MATURITY	0.3150***	0.0843	3.7345	0.0007
RATING	0.4630**	0.2199	2.1059	0.0429
R-squared	0.8010	Mean dependent var		5.7666
Adjusted R-squared	0.7769	S.D. dependent var		1.2321
S.E. of regression	0.5819	Akaike info criterion		1.8772
Sum squared resid	11.175	Schwarz criterion		2.0926
Log likelihood	-30.666	Hannan-Quinn criter.		1.9538
F-statistic	33.215***	Durbin-Watson stat		1.4027
Prob(F-statistic)	0.0000			

TABLE 10 INFLUENCE OF CREDIT RISK ON NON-GOVERNMENT BONDS

Variable	Coefficient	Std.	t-Statistic	Prob.
C	3.7394***	0.2249	16.6243	0.0000
CLIMATE_RISK	1.4736	2.7732	-0.5314	0.5958
RATING	0.7181***	0.1118	6.4228	0.0000
R-squared	0.2142	Mean dependent var		4.8663
Adjusted R-squared	0.2053	S.D. dependent var		1.2102
S.E. of regression	1.0788	Akaike info criterion		3.0064
Sum squared resid	203.6852	Schwarz criterion		3.0600
Log likelihood	-264.5676	Hannan-Quinn criter.		3.0281
F-statistic	23.8565***	Durbin-Watson stat		0.7257
Prob(F-statistic)	0.0000			

As shown in table 10, constant terms are significant at 1% confidence level, climate risk is not significant, and credit risk is significant at 1% confidence level. R^2 increased from 3.5% to 21%. The model was significant at the 1% confidence level. It shows that credit risk has great influence on non-government bond yield and is an important factor.

Compared with the yield of government bonds and non-government bonds, credit risk has a much bigger impact on the yield of non-government bonds. Because government bonds carry little credit risk, default rates are low. Non-government bond credit risk is relatively large, high default risk.

Analysis after adding market factors

TABLE 11 THE INFLUENCE OF MARKET FACTORS ON GOVERNMENT BOND YIELD

Variable	Coefficient	Std.	t-Statistic	Prob.
C	3.9318***	0.3037	12.9449	0.0000
CLIMATE_RISK	18.563***	2.2236	-8.3484	0.0000
MATURITY	0.0647	0.0622	1.0409	0.3055
RATING	0.2096	0.1257	1.6669	0.1050
MARKET	1.7225***	0.2697	6.3870	0.0000
R-squared	0.9097	Mean dependent var		5.7666
Adjusted R-squared	0.8987	S.D. dependent var		1.2321
S.E. of regression	0.3921	Akaike info criterion		1.0873
Sum squared resid	5.0728	Schwarz criterion		1.3028
Log likelihood	-15.659	Hannan-Quinn criter.		1.1640
F-statistic	83.099***	Durbin-Watson stat		1.0238
Prob(F-statistic)	0.0000			

As shown in table 11, constant term is significant at 1% confidence level, climate risk is significant at 1% confidence level, duration factor is not significant, credit risk is not significant, and market factor is significant at 1% confidence level. R^2 increased from 80% to 91%, and the model was significant at 1% confidence level. It indicates that whether cross-market trading has a significant impact on the yield of government bonds.As shown in table 12, the constant term is significant at the 1% confidence level and the climate risk is significant at the 5% confidence level. The cross-market transaction factor was not significant.

Compared with government bonds and non-government bonds, whether cross-market trading has a greater impact on government bonds.

TABLE 12 INFLUENCES OF MARKET FACTORS ON NON-GOVERNMENT BONDS

Variable	Coefficient	Std.	t-Statistic	Prob.
C	4.9995***	0.1173	42.6245	0.0000
CLIMATE_RISK	6.6506**	2.9400	-2.2621	0.0249
WHCRSMAK	0.2886	0.3230	0.8935	0.3728
R-squared	0.0334	Mean dependent var		4.8663
Adjusted R-squared	0.0224	S.D. dependent var		1.2102
S.E. of regression	1.1966	Akaike info criterion		3.2135
Sum squared resid	250.5558	Schwarz criterion		3.2671
Log likelihood	-283.0000	Hannan-Quinn criter.		3.2352
F-statistic	3.0255*	Durbin-Watson stat		0.7130
Prob(F-statistic)	0.0511			

Analysis after logarithm

TABLE 13 ANALYSIS OF GOVERNMENT BOND YIELD AFTER LOGARITHM

Variable	Coefficient	Std.	t-Statistic	Prob.
LN_CLIMATE_RISK	0.6831***	0.0468	-14.592	0.0000
LN_ISSUE_SIZE	-0.3532***	0.1127	3.1343	0.0035
MARKET	2.0721***	0.2137	9.6965	0.0000
R-squared	0.8145	Mean dependent var		5.7666
Adjusted R-squared	0.8039	S.D. dependent var		1.2321
S.E. of regression	0.5456	Akaike info criterion		1.7017
Sum squared resid	10.418	Schwarz criterion		1.8310
Log likelihood	-29.33	Hannan-Quinn criter.		1.7477
Durbin-Watson stat	1.1326			

TABLE 14 ANALYSIS OF NON-GOVERNMENT BOND YIELD AFTER LOGARITHM

Variable	Coefficient	Std.	t-Statistic	Prob.
C	3.8079***	0.3192	11.9297	0.0000
LN_CLIMATE_RISK	0.2376***	0.0689	-3.4497	0.0007
R-squared	0.0633	Mean dependent var		4.8663
Adjusted R-squared	0.0580	S.D. dependent var		1.2102
S.E. of regression	1.1745	Akaike info criterion		3.1708
Sum squared resid	242.80	Schwarz criterion		3.2066
Log likelihood	-280.20	Hannan-Quinn criter.		3.1853
F-statistic	11.9***	Durbin-Watson stat		0.7605
Prob(F-statistic)	0.0007			

As shown in table 13, after logarithm is taken, climate risk is significant at 1% confidence level, circulation is significant at 1% confidence level, whether cross-market transaction is significant at 1% confidence level, R^2 is 81%. Showing that climate risk, issuance and cross-market trading are the main influences on government bond yields, they explain 81% of government bond yields.

As shown in table 14, after logarithm is taken, constant term is significant at 1% confidence level, and climate risk is significant at 1% confidence level. R^2 is 6%. The model was significant at the 1% confidence level.

Compared with government bonds and non-government bonds, climate risks have a greater impact on government bonds. Climate risk also plays a role in non-government bonds, but it is not a major factor and explains only a small part of their yields.

VI. CONCLUSION

Through a comparative analysis on the impact of climate risk on the yields of government bonds and non-government bonds, this paper finds that the impact of climate risk on the yields of government bonds is much greater than that of non-government bonds. Issuance has an effect on both government bond yields and non-government bond yields, but has a smaller effect on government bond yields and a larger effect on non-government bond yields. Compared with government bonds and non-government bonds, duration has a greater impact on government bond yields and a smaller impact on non-government bonds. The main reason is that the maturity of non-government bonds is generally shorter, while the maturity of government bonds is relatively longer. Compared with the yield of government bonds and non-government bonds, credit risk has a much bigger impact on the yield of non-government bonds. Because government bonds carry little credit risk, default rates are low. Non-government bond credit risk is relatively large, high default risk. Compared with government bonds and non-government bonds, whether cross-market trading has a greater impact on government bonds.

After logarithmic analysis, it is found that climate risk has a greater impact on government bonds. Climate risk also plays a role in non-government bonds, but it is not a major factor and explains only a small part of their yields. The results of this paper provide reference for related research and policy makers.

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