Does Climate Risk Affect Corporate Bond Yield? Take Shanghai as an Example

Jiemin Huang

Abstract—**In this paper we collect data of corporate bonds and government bonds issued from 2005 to 2019 from CSMAR database.**

Firstly, we make a stepwise regression analysis and research on the impact of climate risk, selling back and cross-market transaction on corporate bond yield. The impact of climate risk on corporate bond yield is positive because if carbon dioxide emission is more, the earth will be warmer and sea levels will be higher, then companies will face more climate risks and corporate bond yields will increase. The impact from the selling back on corporate bond yield is negative because if the bond can be resold, the risk will be lower and the bond yield will decrease. The impact of cross-market transaction on corporate bond yields is positive because if corporate bonds cannot be traded, the liquidity of corporate bonds will be low, and the risk will increase, then corporate bond yield will increase.

Secondly, logarithmic regression analysis of climate risk factors shows that the climate risk is still significant and the model fits well. Selling back, cross-market trading and other factors are significant, and the pattern is more significant. Compared with the original model, it can better explain corporate bond yield.

Index Terms—**climate risk, selling back, cross market transaction, corporate bond, yield**

I. Introduction

SCHOLARS have conducted much research on the issue of how climate risk affect corporate bond yield. Marcus Painter (2020) studies the impact of climate change on municipal bonds. Regarding long-term underwriting fees and initial yields of municipal bonds issued by counties affected by climate change are more than counties not affected [1]. But this is only suitable for long-term bonds and regarding short-term municipal bonds the difference disappears. After strict standard of climate change was adopted in 2006, the difference in bond issuance costs between counties affected by climate risk and not affected increased.

A few people study how long-term climate risk is priced in financial markets. Hong et al. (2019) analyzes the drought caused by climate change and find that market does not respond adequately [2]. However, Bansal et al. (2016) take temperature rise as a proxy variable for climate change and find that its impact on asset value is negative and this indicates the market has priced climate change [3]. In real estate market, Bernstein et al. (2019) find that houses facing the risk of sea level rise will be sold at a discount compared to houses not facing the risk [4].

There are four kinds of financial consequences caused by climate change including production risk, reputation risk, regulatory risk and litigation risk. Hong et al. (2019) proves that the impact from production risks caused by long-term drought on the stock returns of food industry companies is negative [2]. Dell et al. (2012) find that high temperatures reduce the output of agriculture and industry [5]. Chava (2014) proves that investors demand a higher return of the companies facing climate risks [6]. These companies either face reputation risk of being labeled as climate change indicators or face regulatory risks because the output will be affected by future regulation on climate change. Bernstein et al. (2019) prove that the impact from risks caused by sea level rise on the prices of houses facing risks of sea level rise is negative [4]. Then, they find that if the liquidity of real estate market is good the impact from sea level rise will be very small. Our research goes further. In asset transactions investors will take the risks of climate change into consideration and these risks will be priced in the assets they hold.

Hallegatte et al. (2013) first use an altitude-based geographic information system to calculate the resident on the area whose altitude is 50 cm higher than the prior from the current average sea level [7]. With per capital of each resident and the value of the resident they get exposed assets. Credit rating of municipal bond affects its price because investors rely on them to assess credit risk (Cornaggia et al., 2017). In addition, the impact from credit ratings on local economy is very important [8]. Adelino et al. (2017) find that local government expenditure and employment positively correlate with bond ratings [9]. Other scholars also build models to study the climate [10] [11] [12].

In summary, scholars have conducted much research on yields and prices of corporate bonds and municipal bond. They find that credit risk, downside risk, liquidity and climate change are important influencing factors. This paper will analyze climate risk and its impact on corporate bond yield spreads based on their research.

II. Data

Excluding government bonds, policy bank bonds, central bank bills, financial bonds, bonds of government-backed institutions, ultra-short financing bonds, medium-term notes, short-term financing bonds, perpetual medium-term notes, collective notes of small and medium-sized enterprises,

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convertible bonds, etc, we get Shanghai's corporate bond and municipal bond yield data from the CSMAR database. After selection we get corporate bonds and municipal bonds with maturity from 2 to 15 years. And we exclude short-term, ultra-short-term bonds and special bonds because they do not have the characteristics of ordinary bonds and are easy to cause unobjective results.

The data of corporate bonds and government bonds issued from 2005 to 2019 are selected. These bonds are divided into three groups including AA, AA+ and AAA.

III. Variables Settings

The variables selected in this paper are corporate bond yield, climate risk, issue size, maturity, bond credit rating, put, redeemable(crdeem), selling back (crtsell) and cross-market transactions (market).

The climate risk in this paper is measured by the ratio between the possible loss caused by sea level rise and local GDP. This method is proposed by Hallegatte (2013).

In table 1, it's the climate risk of corporates we selected as sample, and Ls represents corporate code, and Cr represent the climate risk value. In this paper we measure climate risk of corporates with the ratio between total capital of the corporate and GDP of Shanghai. If climate risk happens the corporates in Shanghai will be destroyed.

TABLE 1 CLIMATE RISK OF CORPORATES

Ls	112061	112167	112193	112202	112315	112341
Cr	0.0055	0.0128	0.0009	0.0007	0.0365	0.0365
Ls	118422	118670	118734	122022	122023	122043
Cr	0.0365	0.0089	0.0089	0.0035	0.0048	0.0017
Ls	122136	122161	122183	122205	122223	122224
Cr	0.0346	0.0012	0.0007	0.0013	0.0032	0.0032
Ls	122338	122362	122464	122496	122525	122578
Cr	0.0031	0.0023	0.0196	0.0196	0.0053	0.0080
Ls	124190	124271	124344	124422	124433	124542
Cr	0.0055	0.0038	0.0021	0.0046	0.0207	0.0112
Ls	127092	127192	1280151	1280154	1280234	1280237
Cr	0.0058	0.0207	0.0769	0.0188	0.0103	0.0054
Ls	1280475	136009	136017	136024	136034	136085
Cr	0.0046	0.0528	0.0145	0.0071	0.0225	0.0635
Ls	136159	136177	136184	136198	136214	136236
Cr	0.0225	0.0621	0.0369	0.0242	0.0100	0.0159
Ls	136363	136402	136403	136404	136447	136459
Cr	0.0845	0.0592	0.0592	0.0084	0.0845	0.0369
Ls	136568	136581	136593	136666	136677	136698
Cr	0.0051	0.0084	0.0029	0.0084	0.0145	0.0434
Ls	136818	136887	1380087	1380173	1380263	1380354
Cr	0.0029	0.0044	0.0060	0.0026	0.0018	0.0005
Ls	143051	143119	143132	143165	143172	143196
Cr	0.0180	0.0013	0.0100	0.0242	0.0046	0.0181
Ls	143332	143371	143422	143435	143446	143451
Cr	0.0242	0.0063	0.0299	0.0067	0.0845	0.0072
Ls	143500	143514	143518	143519	143536	143538
Cr	0.0027	0.0013	0.0234	0.0234	0.0845	0.0109
Ls	143640	143674	143677	143740	143743	143878
Cr	0.0179	0.0039	0.0039	0.0027	0.0027	0.0100
Ls	145754	145756	1480068	1480129	1480171	1480242
Cr	0.0020	0.0845	0.0040	0.0040	0.0082	0.0029
Ls	150271	150435	150436	150499	151516	152040
Cr	0.0171	0.0171	0.0171	0.0046	0.0031	0.0269
Ls	155006	155026	155040	155043	155067	155068
Cr	0.0351	0.0044	0.0008	0.0845	0.0195	0.0195
Ls	155151	155188	155201	155254	155286	155336
Cr	0.0097	0.0634	0.0247	0.0242	0.0069	0.0225

IV. Research Hypothesis

(1) Hypothesis 1: Climate risk affects the yields of corporate bonds and municipal bonds

The emission of carbon dioxide makes the earth warmer and sea level higher. Then coastal cities face the risk of being submerged and the yields of corporate bonds and municipal bonds will be affected. If carbon dioxide continues to emit excessively, it will be warmer and sea levels will rise, then the yields of corporate bonds and municipal bonds in cities facing climate risk rise.

(2) Hypothesis 2: The impact from the issuance amount of corporate bonds and municipal bonds on their yields is negative.

The larger the number of bonds, the better the liquidity, the less liquidity risk the bonds face and the lower the yield. (3) Hypothesis 3: The maturity of corporate and municipal bonds has a negative effect on their yields.

The longer the maturity, the higher the risk of default and the higher the yields on corporate and municipal bonds. (4) Hypothesis 4: Bond credit rating affects corporate bond yield.

The higher the credit rating of corporate bonds and municipal bonds, the lower the default risk and the lower the yield. (5) Hypothesis 5: The bearish affects the yield of corporate bonds or municipal bonds.

If a corporate bond is bearish, its yield will be high.

(6) Hypothesis 6: The impact from selling back of corporate bonds or municipal bonds on their yield is negative.

If the bonds issued by a company can be sold and the loss caused by its default risk is lower, the bond yield will be relatively low.

(7) Hypothesis 7: Cross-market transactions affects the yields of corporate bonds and municipal bonds. Bonds with good liquidity have relatively low yields.

V. Descriptive Statistical Analysis

A. Analysis of corporate bond yield

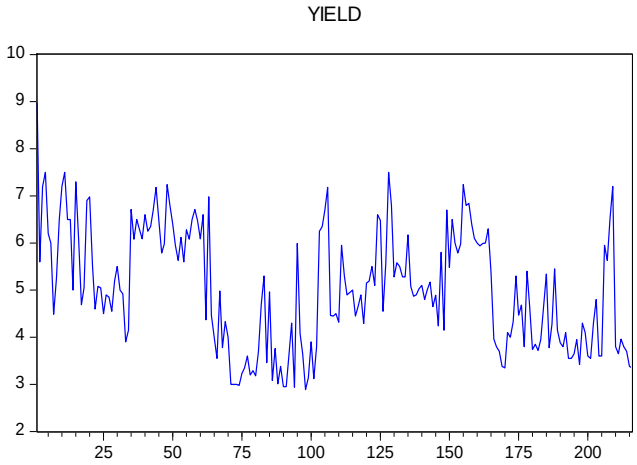

Figure.1 Corporate bond yield

In Figure 1, the horizontal axis represents company code and the vertical axis represents corporate bond yields. From above figure we find that the lowest corporate bond yield is 3 and the highest is 7.5, others are between 3 to 7.5.

B. Climate risk analysis

As it is shown in Figure 2, the horizontal axis represents company code and the vertical axis represents climate risk in %. From above figure we find that the highest climate risk is about 0.2% and the smallest is close to zero.

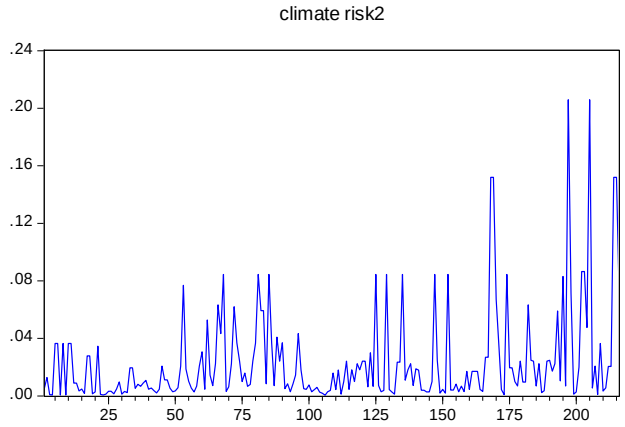

Figure. 2 The company faces climate risks

C. *Descriptive statistical analysis*

TABLE 2 DESCRIPTIVE STATISTICAL ANALYSIS OF EACH SEQUENCE

	Mean	Median	Max	Min	S.D.	Skewness	Kurtosis	JB	P
yield	5.02	4.97	8.98	2.89	1.26	0.24	2.22	7.574	0.02
climate risk	0.02	0.01	0.21	0.00	0.03	2.89	13.02	1204.0	0.00
deem	0.06	0.00	1.00	0.00	0.23	3.88	16.06	2076.9	0.00
sell	0.70	1.00	11.0	0.00	0.85	8.14	101.2	89121	0.00
Issue size	12.6	10.0	60.0	1.00	9.81	2.11	8.82	466.1	0.00
Maturity	4.97	5.00	10.0	2.00	1.32	0.39	4.10	16.14	0.00
Put	0.60	1.00	1.00	0.00	0.49	-0.42	1.17	36.27	0.00
rating	1.73	1.50	3.00	1.00	0.81	0.53	1.73	24.75	0.00
market	0.21	0.00	1.00	0.00	0.41	1.40	2.97	70.79	0.00

In Table 2 we find for yield the mean value is 5.0247, the median value is 4.9700, the maximum value is 8.9800, the minimum value is 2.8900, the standard deviation is 1.2590, the skewness is 0.2382, the kurtosis is 2.2160, the JB value is 7.5739 and the probability is 0.0227. We can conclude that corporate bond yield is significant at 5% confidence level.

For climate risk the mean value is 0.0236, median value is 0.0100, maximum value is 0.2059, minimum value is 0.0005, standard deviation is 0.0335, skewness is 2.8912, kurtosis is 13.017, Jarque-Bera value is 1204.0, probability value is 0.0000. We can conclude that climate risk is significant at 1% confidence level.

For redeemability mean value is 0.0556, median value is 0.0000, maximum value is 1.0000, minimum value is 0.0000, standard 0.2296, skewness 3.8806, kurtosis 16.059, Jarque-Bera value is 2076.9. We can conclude that redeemability is significant at 1% confidence level.

For selling back the mean value is 0.7037, the median value is 1.0000, the maximum value is 11.000, the minimum value is 0.0000, the standard deviation is 0.8492, the skewness is 8.1419, the kurtosis is 101.17, the Jarque-Bera value is 89121, the probability value is 0.0000.

We can conclude that selling back is significant at 1% confidence level.

For issuance size the mean is 12.569, the median is 10.000, the maximum is 60.000, the minimum is 1.0000, the standard deviation is 9.8127, the skewness is 2.1135, the kurtosis is 8.8238, the Jarque-Bera value is 466.05, and the probability value is 0.0000. We can conclude that issuance size is significant at 1% confidence level.

For maturity the mean value is 4.9676, the median value is 5.000, the maximum value is 10.000, the minimum value is 2.0000, the standard deviation is 1.3238, the skewness is 0.3851, the kurtosis is 4.0953, the Jarque-Bera value is 16.136 and the probability value is 0.0003. We can conclude that maturity is significant at 1% confidence level.

For put bearish the mean value is 0.6019, the median value is 1.0000, the maximum value is 1.0000, the minimum value is 0.0000, the standard deviation is 0.4907, the skewness -0.4161, the kurtosis 1.1732, the Jarque-Bera value is 36.270, the probability value is 0.0000. We can conclude that put bearish is significant at 1% confidence level.

For credit rating the mean value is 1.7269, the median is 1.5000, the maximum is 3.0000, the minimum is 1.0000, the standard deviation is 0.8095, the skewness is 0.5348, the kurtosis is 1.7326, the Jarque-Bera value is 24.752, the probability value is 0.0000. We can conclude that credit rating is significant at 1% confidence level.

For cross-market the mean is 0.2130, the median is 0.0000, the maximum is 1.0000, the minimum is 0.0000, the standard deviation is 0.4104, the skewness is 1.4022, the kurtosis is 2.9662, the Jarque-Bera value is 70.794, the probability value is 0.0000. We can conclude that cross-market is significant at 1% confidence level.

D. *Correlation analysis*

In Table 3 we find climate risk negatively correlate with redeemability and the correlation coefficient is -0.1014. It's positively correlated with issuance and the correlation coefficient is 0.2962, and positively correlated with bearish puts and the correlation coefficient is 0.1451 and negatively correlated with credit rating and the correlation coefficient is -0.3503.

Redeemability negatively correlates with issue size and correlation coefficient is -0.1105, negatively correlates with bearishness and correlation coefficient is -0.2982 and negatively correlates with cross-market transactions and the correlation coefficient is -0.1262.

Selling back positively correlates with bearishness and correlation coefficient is 0.5416 and negatively correlates with cross-markets and correlation coefficient is -0.2185.

Issuance is related to bearishness and the correlation coefficient is 0.1208. It negatively correlates with credit rating and the correlation coefficient is -0.2246.

The expiry date positively correlates with the credit rating with a correlation coefficient of 0.2999 and the expiry date is related cross-market and correlation coefficient is 0.5265.

Puts negatively correlates with credit ratings with a correlation coefficient of -0.1814 and negatively correlates with cross-markets and correlation coefficient is -0.2699.

The credit rating positively correlates with cross-market and the correlation coefficient is 0.3160.

From the perspective of variable correlation analysis, there is a correlation between multiple independent variables. In order to exclude the influence of correlation, we perform stepwise regression analysis.

TABLE 3 SEQUENCE CORRELATION ANALYSIS

	risk	deem	sell	Issue	maturity	put	rating	market
risk	1.00	-0.10	0.03	0.30	-0.01	0.15	-0.35	0.01
deem	-0.10	1.00	0.08	-0.11	0.01	-0.30	0.08	-0.13
sell	0.03	0.08	1.00	0.08	0.06	0.54	0.00	-0.22
Issue	0.30	-0.11	0.08	1.00	-0.01	0.12	-0.22	-0.04
maturity	-0.01	0.01	0.06	-0.01	1.00	0.09	0.30	0.53
put	0.15	-0.30	0.54	0.12	0.09	1.00	-0.18	-0.27
rating	-0.35	0.08	0.00	-0.22	0.30	-0.18	1.00	0.32
market	0.01	-0.13	-0.22	-0.04	0.53	-0.27	0.32	1.00

VI. MODEL ESTABLISHMENT AND ANALYSIS OF EMPIRICAL RESULTS

A. Building a model

In order to estimate the impact from climate risk changes on corporate bond yields, we establish the following model.

$$yield = \beta_1 * \text{climate risk} + \beta_2 * \ln(size) + \beta_3 * \ln(maturity) + \beta_4 * \ln(value) + \beta_5 * rating + \beta_6 * market + \beta_7 * deem + \beta_8 * sell + \beta_9 * put \quad (1)$$

According to the relevant literature of corporate bonds, we select the following variables, ln (issue size), ln(maturity), ln(value), bond credit rating, cross-market, redeemability, selling back and other variables as independent variables, and corporate bond yield spread as dependent variable.

Because of the correlations between some independent variables, we use stepwise regression analysis to exclude irrelevant variables.

B. Analysis of Empirical Results

Regression analysis with climate risk only

TABLE 4 THE IMPACT OF CLIMATE RISK FACTORS ON CORPORATE BOND YIELDS

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.2678***	0.1010	52.1340	0.0000
CLIMATE_RISK	-10.308***	2.4693	-4.1746	0.0000

R-squared	0.0753	Mean dependent var	5.0247
Adjusted R-squared	0.0710	S.D. dependent var	1.2590
S.E. of regression	1.2135	Akaike info criterion	3.2340
Sum squared resid	315.11	Schwarz criterion	3.2653
Log likelihood	-347.28	Hannan-Quinn criter.	3.2467
F-statistic	17.428	Durbin-Watson stat	0.7275
Prob(F-statistic)	0.0000		

The constant term is significant at 1% confidence level.

Add climate risk and selling back factors to the model for regression

TABLE 5 REGRESSION ANALYSIS WITH SELL

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.4555***	0.1192	45.7763	0.0000
CLIMATE_RISK	10.0978***	2.4302	4.1552	0.0000
SELL	-0.2738***	0.0959	-2.8545	0.0047

R-squared	0.1094	Mean dependent var	5.0247
Adjusted R-squared	0.1010	S.D. dependent var	1.2590
S.E. of regression	1.1934	Akaike info criterion	3.2058
Sum squared resid	303.50	Schwarz criterion	3.2526
Log likelihood	-343.22	Hannan-Quinn criter.	3.2247
F-statistic	13.079	Durbin-Watson stat	0.8365
Prob(F-statistic)	0.0000		

In table 5 we find that R^2=0.1094 and Prob(F-statistic) =0.0000. The model is significant at 1% confidence level. That's 10.9374% of the corporate bond yield can be explained by climate risk and selling back factors.

The constant term is significant at 1% confidence level.

The climate risk coefficient is 10.0978 which means that if climate risk changes by 1% the corporate bond yield will change by 10.0978% because if climate risk increases, corporate bonds yield will also increase. This indicates that it is significant at 1% confidence level. The null hypothesis that climate risk will affect the yield of corporate bonds is accepted.

The selling back coefficient is -0.2738 which means that if selling back changes by 1% the corporate bond yield will change by -0.2738% and selling back negatively correlates with the corporate bond yield spread if the bond can be sold, the risk will be low then bond yield will decrease. It is significant at 1% confidence level. The null hypothesis is accepted.

Add climate risk, sell, maturity to the model and perform regression analysis

In Table 6 on which maturity variable is added we can find that R^2=0.1281 and Prob(F-statistic) =0.0000. The model is significant at 1% confidence level.

The coefficient of constant term is 4.8154 which means that it is significant at 1% confidence level.

The coefficient of climate risk is 10.0575 which means that if climate risk changes by 1% corporate bond yield will change by 10.0575% and indicates that it is significant at 1% confidence level. The null hypothesis that climate risk affects corporate bond yield is accepted.

The coefficient of resale is -0.2855 which means that if the selling back changes by 1% the corporate bond yield will change by -0.2855% and selling back negatively correlates with the corporate bond yield because if the bond can be sold, the risk will be low, then the bond yield will decrease. This indicates that it is significant at 1% confidence level. The null hypothesis is accepted.

The coefficient of maximum maturity is 0.1303 which means

that the maximum maturity positively correlates with the corporate bond yield because if the maximum maturity date of the bond is larger, the default risk and liquidity risk faced by investors are higher, then the corporate bond yield should be higher. This indicates that it is significant at 1% confidence level. The null hypothesis is accepted.

TABLE 6 REGRESSION ANALYSIS AFTER ADDING CLIMATE RISK, SELL AND MATURITY FACTORS TO THE MODEL

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.8154***	0.3225	14.9317	0.0000
CLIMATE_RISK	10.0575***	2.4102	4.1728	0.0000
SELL	-0.2855**	0.0953	-2.9967	0.0031
MATURITY	0.1303**	0.0611	2.1334	0.0340

R-squared	0.1281	Mean dependent var	5.0247
Adjusted R-squared	0.1158	S.D. dependent var	1.2590
S.E. of regression	1.1839	Akaike info criterion	3.1938
Sum squared resid	297.12	Schwarz criterion	3.2563
Log likelihood	-340.93	Hannan-Quinn criter.	3.2190
F-statistic	10.382	Durbin-Watson stat	0.8740
Prob(F-statistic)	0.0000		

After adding climate risk, sell, maturity, and market to the model, perform regression analysis

For the analysis on which the factor of market is added in Table 7, we find that R^2 = 0.192593 and Prob (F-statistic) = 0.0000. The model is significant at 1% confidence level.

The constant term C=5.3347 and it is significant at 1% confidence level.

The coefficient of climate risk is 10.3211, which means that if climate risk changes by 1% corporate bond yield will change by 10.3211% because that if climate risk increases, the yield of corporate bonds will increase. This indicates that it is significant at 1% confidence level. The null hypothesis that climate risk affects the yield of corporate bonds is accepted.

The coefficient of resale is -0.1695 which means that if the selling back changes by 1% the corporate bond yield will change by -0.1695% and selling back negatively correlates with corporate bond yield. Because if the bond can be sold, the risk will be low then the bond yield will decrease. Also, this indicates that it is significant at 1% confidence level. The null hypothesis is accepted.

The coefficient of maximum maturity is -0.0305, which indicates that it is not significant, and the null hypothesis is rejected.

The coefficient of cross-market transaction is 0.9590, which means that if the cross-market transaction changes by 1%, the bond yield will change by 0.9590% and cross-market transaction positively correlates with corporate bond yield because that if the bond cannot be traded across the market, the bond liquidity will be reduced, then the risk will increase and bond yield will increase. This means that it is significant at 1% confidence level. The null hypothesis is accepted.

TABLE 7 EMPIRICAL ANALYSIS AFTER ADDING CLIMATE RISK, SELL, MATURITY, AND MARKET FACTORS TO THE MODEL

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.3347	0.3358	15.8864	0.0000
CLIMATE_RISK	10.3211	2.3258	4.4377	0.0000
SELL	-0.1695	0.0962	-1.7629	0.0794
MATURITY	-0.0305	0.0708	-0.4311	0.6669
MARKET	-0.9590	0.2336	-4.1056	0.0001

R-squared	0.1926	Mean dependent var	5.0247
Adjusted R-squared	0.1773	S.D. dependent var	1.2590
S.E. of regression	1.1419	Akaike info criterion	3.1262
Sum squared resid	275.14	Schwarz criterion	3.2043
Log likelihood	-332.63	Hannan-Quinn criter.	3.1577
F-statistic	12.583	Durbin-Watson stat	0.8898
Prob(F-statistic)	0.0000		

Eliminate insignificant maturity variables and perform regression analysis

TABLE 8 EMPIRICAL ANALYSIS OF CLIMATE RISK, SELL AND MARKET VARIABLES

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.2006	0.1263	41.179	0.0000
CLIMATE_RISK	10.299	2.3207	4.4379	0.0000
SELL	-0.1782	0.0939	-1.8983	0.0590
MARKET	-0.9032	0.1941	-4.6524	0.0000

R-squared	0.1919	Mean dependent var	5.0247
Adjusted R-squared	0.1804	S.D. dependent var	1.2590
S.E. of regression	1.1397	Akaike info criterion	3.1178
Sum squared resid	275.38	Schwarz criterion	3.1803
Log likelihood	-332.72	Hannan-Quinn criter.	3.1430
F-statistic	16.779	Durbin-Watson stat	0.8893
Prob(F-statistic)	0.0000		

From above empirical analysis in table 8 we find that R^2=0.1919 and Prob(F-statistic) = 0.0000, so the model is significant at 1% confidence level.

C=5.2006 and it is significant at 1% confidence level.

The coefficient of climate risk is 10.299, which means if climate risk changes by 1% the corporate bond yield will change by 10.299%. This indicates that it is significant at 1% confidence level. The null hypothesis that climate risk affects corporate bond yield is accepted.

The coefficient of selling back is -0.1782, which means that if selling back changes by 1% the corporate bond yield will change by -0.1782%. Because if the bond can be sold the risk will be reduced and the bond yield will decrease. This indicates that it is significant at 10% confidence level and it negatively correlates with the corporate bond yield. The null hypothesis is accepted.

The coefficient of cross-market transaction is -0.932, which means that if the cross-market transaction factor changes by

1% the bond yield will change by -0.932%, because if the bond cannot be traded across the market the liquidity of the bond will be reduced and the risk will increase, the bond yield will increase. This indicates that it is significant at 1% confidence level and it positively correlates with the corporate bond yield. The null hypothesis is accepted.

C. Regression analysis after taking the logarithm, removing the highly correlated variables ln (ISSUE_SIZE), RATING, PUT, and performing stepwise regression

Only ln (climate risk) variables

TABLE 9 REGRESSION ANALYSIS OF LN (CLIMATE RISK) VARIABLES

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.5568	0.2944	12.080	0.0000
ln(CLIMATE_RISK)	0.3245	0.0626	5.1851	0.0000
R-squared	0.1116	Mean dependent var		5.0247
Adjusted R-squared	0.1075	S.D. dependent var		1.2590
S.E. of regression	1.1894	Akaike info criterion		3.1940
Sum squared resid	302.74	Schwarz criterion		3.2252
Log likelihood	-342.95	Hannan-Quinn criter.		3.2066
F-statistic	26.885	Durbin-Watson stat		0.7687
Prob(F-statistic)	0.0000			

In above table we find that R^2=0.1116 and Prob(F-statistic) =0. 0000. The model is significant at 1% confidence level.
The constant term C=3.5568. It is significant at 1% confidence level.
The climate risk coefficient after logarithm is 0.3245, which means that if climate risk changes by 1% the corporate bond yield will change by 0.3245% and climate risk positively correlates with the corporate bond yield. This indicates that it is significant at 1% confidence level. The null hypothesis is accepted.
Compared with the regression analysis results in table 3, R^2 increases from 0.0753 to 0.1116, The model with logarithm is well fitted.

Empirical analysis of adding ln (climate risk) and ln (maturity) factors

In above table we find that R^2=0.1168, Prob(F-statistic) = 0.0000 and the model is significant at 1% confidence level.
The constant term C=3.0720, which means that it is significant at 1% confidence level.

The coefficient of climate risk after taking the logarithm is 0.3194, which means that if climate risk after taking the logarithm changes by 1% the corporate bond yield will change by 0.3194% and the climate risk after taking the logarithm positively correlates with corporate bond yield. This indicates that it is significant at 1% confidence level. The null hypothesis is accepted.
The ln(maturity) variable is not significant, and the null hypothesis is rejected. It is eliminated.

TABLE 10 REGRESSION ANALYSIS OF LN(CLIMATE RISK) AND LN(MATURITY) VARIABLES

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.0720	0.5222	5.8831	0.0000
LN_CLIMATE_RISK	0.3194	0.0627	5.0929	0.0000
LN_MATURITY	0.3245	0.2887	1.1238	0.2623
R-squared	0.1168	Mean dependent var		5.0247
Adjusted R-squared	0.1086	S.D. dependent var		1.2590
S.E. of regression	1.1887	Akaike info criterion		3.1973
Sum squared resid	300.96	Schwarz criterion		3.2442
Log likelihood	-342.31	Hannan-Quinn criter.		3.2163
F-statistic	14.091	Durbin-Watson stat		0.7797
Prob(F-statistic)	0.0000			

Empirical analysis of ln (climate risk) and deem factors

In above table we find that R^2=0.1127, Prob(F-statistic) =0.0000 and the model is significant at 1% confidence level.
The constant term C=3.5528 and it is significant at 1% confidence level.
The coefficient of climate risk after taking the logarithm is 0.3277, which means that if the logarithmic climate risk changes by 1% the corporate bond yield will change by 0.3277% and the logarithmic climate risk positively correlates with the corporate bond yield. This indicates that it is significant at 1% confidence level. The null hypothesis is accepted.
The redeemability variable is not significant, and the null hypothesis is rejected. It is eliminated.

TABLE 11 EMPIRICAL ANALYSIS RESULTS OF ADDING LN (CLIMATE RISK) AND DEEM FACTORS

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.5528	0.2950	12.042	0.0000
LN_CLIMATE_RISK	0.3277	0.0630	5.2022	0.0000
DEEM	-0.1847	0.3556	-0.5194	0.6040
R-squared	0.1127	Mean dependent var		5.0247
Adjusted R-squared	0.1044	S.D. dependent var		1.2590
S.E. of regression	1.1914	Akaike info criterion		3.2020
Sum squared resid	302.35	Schwarz criterion		3.2489
Log likelihood	-342.81	Hannan-Quinn criter.		3.2209
F-statistic	13.53	Durbin-Watson stat		0.7770
Prob(F-statistic)	0.0000			

Empirical analysis of adding ln (climate risk) and sell variables

TABLE 12 EMPIRICAL ANALYSIS OF ADDING LN (CLIMATE RISK) AND SELL VARIABLES

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.7759	0.2999	12.592	0.0000
LN_CLIMATE_RIS K	0.3175	0.0616	5.1518	0.0000
SELL	-0.2665	0.0941	-2.8326	0.0051
R-squared	0.1439	Mean dependent var		5.0247
Adjusted R-squared	0.1358	S.D. dependent var		1.2590
S.E. of regression	1.1703	Akaike info criterion		3.1663
Sum squared resid	291.75	Schwarz criterion		3.2131
Log likelihood	-338.96	Hannan-Quinn criter.		3.1852
F-statistic	17.896	Durbin-Watson stat		0.8804
Prob(F-statistic)	0.0000			

In table 12 we find that R^2=0.1439, Prob(F-statistic) = 0.0000 and the model is significant at 1% confidence level.
The constant term C=3.7759 and it is significant at 1% confidence level.
The climate risk coefficient after logarithm is 0.3175, This means that if the climate risk after logarithm changes by 1%, the corporate bond yield will change by 0.3175%, and the climate risk after logarithm is related to the corporate bond yield. This indicates that it is significant at 1% confidence level. The null hypothesis is accepted.

The coefficient of selling back is -0.2665, which means that if the selling back changes by 1% corporate bond yield will change by -0.2665% and selling back negatively correlates with the corporate bond yield because if the bond can be sold the risk will be low and bond yield will decrease. Also, this indicates that it is significant at 1% confidence level. The null hypothesis is accepted.
Compared with R^2=0.1094 in table 4 we can make the conclusion that the model fits better.

Regression analysis after adding ln (climate risk), selling back, and cross-market factors

In table 13 we find that R^2=0.2164, Prob(F-statistic) = 0.0000 and the model is significant at 1% confidence level.
The constant term C=3.5805 and it is significant at 1% confidence level.

The climate risk coefficient after logarithm is 0.3070, that is, the climate risk after logarithm changes by 1%, and the corporate bond yield changes by 0.3070%. The climate risk after logarithm is related to the corporate bond yield, because the climate risk increases, the corporate bond yield increases. This indicates that it is significant at 1% confidence level. The null hypothesis is accepted.
The coefficient of selling back is -0.1776, which means that if the selling back changes by 1% the corporate bond yield will change by -0.1776% and the selling back negatively correlates with the corporate bond yield because if the bond cannot be sold risk will increase, then the bond yield will increase. This indicates that it is significant at 1% confidence level. The null hypothesis is accepted.
The coefficient of cross-market transaction is -0.8473, which means that if the cross-market transaction changes by 1% the bond yield will change -0.8473% and the cross-market transaction positively correlates with corporate bond yield because if the bond cannot be traded across the market the liquidity will be reduced, then the risk and bond yield will increase. This indicates that it is significant at 1% confidence level.
Compared with R^2=0.1919 in Table 8 the model fits better.

TABLE 13 EMPIRICAL ANALYSIS OF ADDING LN (CLIMATE RISK), SELL, AND MARKET FACTORS

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.5805	0.2909	12.307	0.0000
LN_CLIMATE_RISK	0.3070	0.0592	5.1903	0.0000
SELL	-0.1776	0.0924	-1.9222	0.0559
MARKET	-0.8473	0.1913	-4.4294	0.0000
R-squared	0.2164	Mean dependent var		5.0247
Adjusted R-squared	0.2053	S.D. dependent var		1.2590
S.E. of regression	1.1223	Akaike info criterion		3.0870
Sum squared resid	267.03	Schwarz criterion		3.1495
Log likelihood	-329.40	Hannan-Quinn criter.		3.1123
F-statistic	19.513	Durbin-Watson stat		0.9101
Prob(F-statistic)	0.0000			

VII. CONCLUSION

This paper analyzes the impact from climate risk, selling back and cross-market transaction on corporate bond yield.
Firstly, we analyze the data through stepwise regression and get the results. The impact from climate risk on corporate bond yields is positive. If carbon dioxide emission is more, the earth become warmer, then sea level rise and climate risk faced by companies will be higher, so corporate bond yield will increase accordingly. If climate risk changes by 1% corporate bonds yield will change by 10.308%. The null hypothesis is accepted.
The impact from selling back on corporate bond yield is negative. If the bond can be sold, risk will be lower and bond yield will decrease. If selling back changes by 1% corporate bond yield changes by -0.2738%.
The impact from cross-market transaction on corporate bond yields is positive, so the null hypothesis is accepted. This is because if corporate bonds cannot be traded across markets, the liquidity of corporate bonds will be low, then the risk will increase, and corporate bond yield will increase. If the cross-market transaction factor changes by 1% the corporate bond yield will change by -0.932%.
Secondly, we take the logarithm of the climate risk, and then regressed the risk, and find that the climate risk after taking logarithm is still significant and the model fitted better. Selling back, cross-market transactions and other factors are all significant, and the model is more significant. Compared with the original model, it can better explain corporate bond yields.
Our conclusions are consistent with the scholars abroad that climate risk, selling back and cross-market transaction are important factors affecting corporate bond yields. Companies

should consider this when they issue bonds. For investors the factors including climate risk, selling back and cross-market transactions should be taken into consideration for good investment returns.

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