An Empirical Analysis of Volatility in China’s Green Bond Market

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Introduction

Motivation

What is green bond?

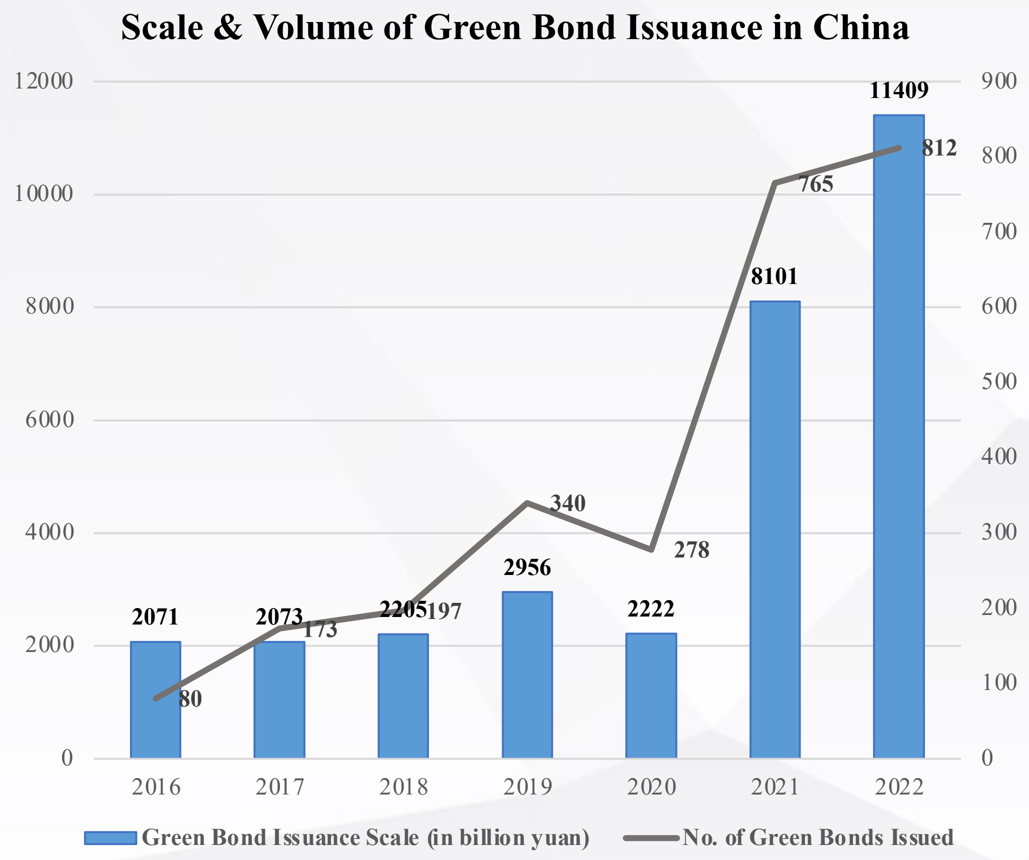
Green bond: a financial instrument to finance “green” and sustainable projects and provide investors with fixed-income payments.

Why care about the green bond market?

- A crucial financial instrument for tackling difficulties related to climate change and environmental issues;
- An fixed-income financial instrument that be contributed to the diversification of investor’s portfolios;
- An emerging and promising market, especially for China.

Research Questions

An Increasing Volume:



Data source: Wind

Key Questions:

- How does the volatility pattern of the Chinese green bond market perform, compared to the aggregate conventional Chinese bond market/equity market?
- Do the Chinese green bond market and China's overall bond market/equity market have any short- or long-term volatility transformation phenomenon?

Literature Review

Literature Review

Theories of volatility transformation:

- Monsoonal Effect (Masson, 1998);
  Spillover Effect (Kim & Lee, 2015);
  Contagion (Aloui & Nguyen, 2011; Desai, 2014; Mendoza & Quadrini, 2010);
  Herd Behavior (Bikhchandani & Sharma, 2000)

Methods of quantifying volatility:

- **Univariate GARCH Models:**
  Seminal ARCH model (Engle, 1983); Generalized ARCH (Bollerslev, 1986); GJR-GARCH (Glosten *et al.*, 1989); EGARCH (Nelson, 1990); NGARCH (Bera and Higgins, 1993); TGARCH (Zakoian, 1994)
- **Multivariate GARCH Models:**
  VEC-GARCH (Bollerslev, Engle and Wooldridge, 1988); CCC-GARCH (Bollerslev, 1990); BEKK-GARCH (Baba, Engle, Kraft and Kroner, 1991); DCC-GARCH (Engle, 2002)

Fixed-income & Equity Market & Green Financial Instrument Research:

- **Fixed-income & equity market research:**
  Campbell and Vuolteenaho (2004); Steeley (2006); Christiansen (2010), etc.
- **Green Financial Instrument Research:**
  Ortas and Movena (2013); Pham (2016); Climent and Soriano (2011); Nelson, Chang and Witte (2012); Tiwari *et al.* (2022); Khalfaoui, Jabeur, & Dogan (2022), etc.

Data

Description

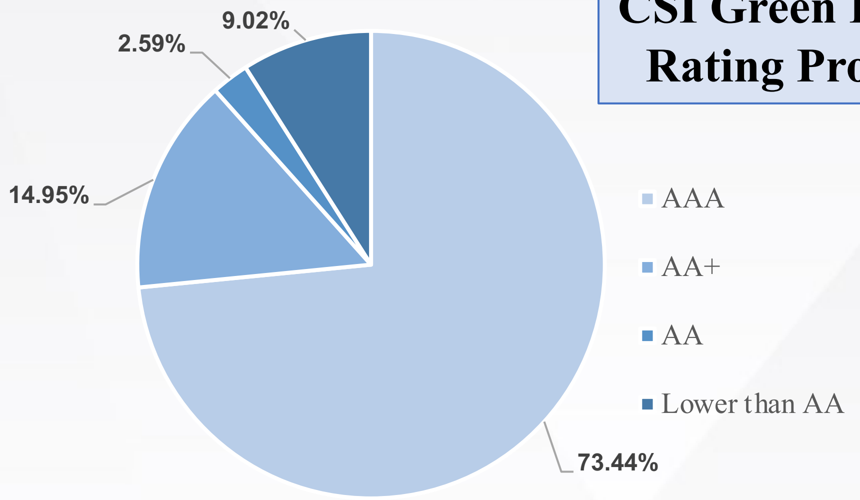
Three Sources: 05/31/2017 - 04/29/2022

- CSI Exchange Green Bond Index (*China Securities Index*): "labeled" green bond listed on Shanghai & Shenzhen Stock Exchange, excluding ABS, private-placement bond and equity-linked bond.

- S&P China Bond Index (*S&P Global*): daily return of 300 of the largest and most liquid firms from 24 industry groups of the global industry classification standard.

- S&P China A300 Index (*Standard & Poor Global*): government and corporate bonds denominated in the local currency of China.

CSI Green Bond Rating Profile



Data Source: China Securities Index

Descriptive Statistics

Descriptive Statistics of 3 Return Series

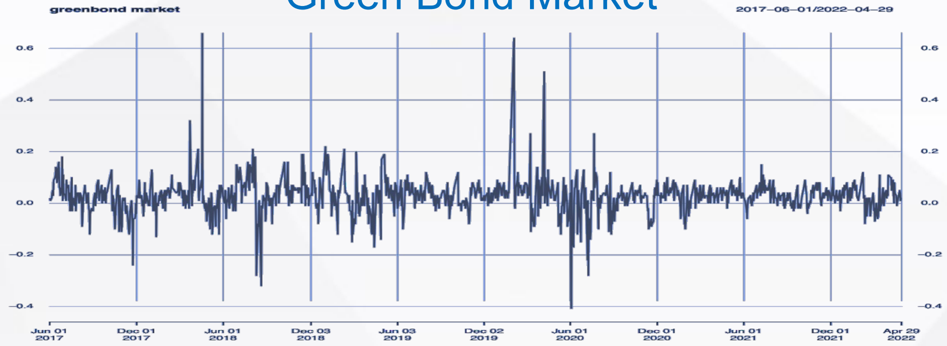
	GB Index	Aggregate Bond Index	A 300 Index
Mean	0.023972	0.021338	0.519316
Median	0.03	0.02	1.535
Maximum	0.66	0.69	204.69
Minimum	-0.41	-0.5	-273.55
Std. Dev.	0.067548	0.107095	46.50831
Skewness	0.90787	0.172266	-0.53987
Kurtosis	20.46776	5.926049	5.880188
Jarque-Bera	15626.59	470.1919	478.5854

ADF Test Results

	ADF test results
Returns on GB	-8.5357***
Returns on CB	-8.6535***
Returns on A300	-10.621***

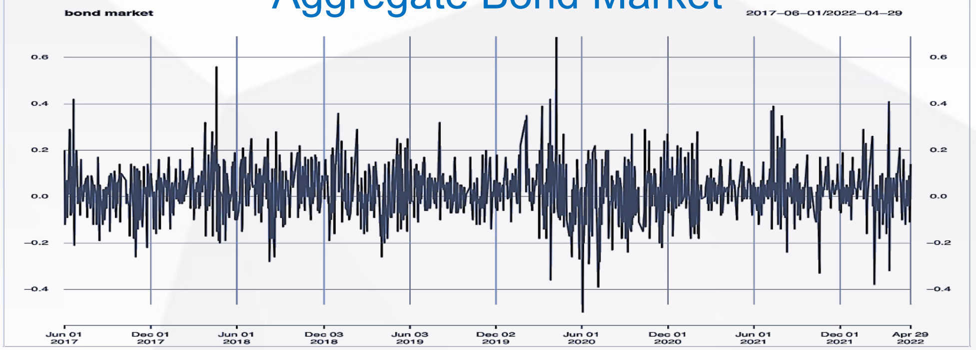
*Note: GB = green bond market; CB = conventional market; A300 = equity market; *p < 10%, ** p < 5%, *** p < 1%.*

Green Bond Market



Equity Market

Aggregate Bond Market



Econometric Specification

Baseline Model Specifications

Univariate GARCH Model Specification (address the question of how the volatility behaves)

$$Return_t = \sum_{h=1}^{r} \varphi_h Return_{t-h} + \sum_{k=1}^{s} \chi_k \varepsilon_{t-k} \, ,$$

$$h_{it} = a_0 + \sum_{p=1}^{P} a_i \varepsilon_{it-p}^2 + \sum_{q=1}^{Q} b_j \sigma_{it-q}^2, \text{ where } a_0 > 0; \;\; a_{\mathrm{i}} > 0 \; \forall i \in [1, p]; \;\; b_j > 0 \; \forall j \in [1, q]$$

- a_{I} and b_j represents the volatility clustering existence where one period of high volatility level is followed by another period of high volatility level;
- The lag terms *h* and *k* are determined by "*auto.arima*" functionality in R:

	GB return	**Bond market return**	**Equity market return**
ARIMA Structure	ARIMA(1,0,1)	ARIMA(5,0,3)	ARIMA(1,0,0)

For *p* & *q*, following most of the literatures applying GARCH model as analytical framework, I use GARCH(1,1).

Test for ARCH effect: Box-Ljung test of squared residuals:

	GB return	**Bond market return**	**Equity market return**
Q-statistics	21.112***	30.616***	66.46***

Baseline Model Extensions

Threshold Effect

$$Return_t = \sum_{h=1}^{r} \varphi_h Return_{t-h} + \sum_{k=1}^{s} \chi_k \varepsilon_{t-k},$$

$$h_{it} = a_0 + \sum_{p=1}^{P} a_i \varepsilon_{it-p}^2 + \sum_{q=1}^{Q} b_j \sigma_{it-q}^2 + \delta D_{threshold}\ \varepsilon_{it-p}^2,$$

$$\text{where } D_{threshold} = \begin{cases} 1, & if\ \varepsilon_{it-p} < 0 \\ 0, & if\ \varepsilon_{it-p} \geq 0 \end{cases}$$

Examine whether the return of 3 series responds more rapidly to positive or negative shocks

Covid-19's Impact

$$Return_t = \sum_{h=1}^{r} \varphi_h Return_{t-h} + \sum_{k=1}^{s} \chi_k \varepsilon_{t-k},$$

$$h_{it} = a_0 + \sum_{p=1}^{P} a_i \varepsilon_{it-p}^2 + \sum_{q=1}^{Q} b_j \sigma_{it-q}^2 + \lambda D_{pandemic},$$

$$\text{where } D_{threshold} = \begin{cases} 1, & if\ date < 12/01/2019 \\ 0, & if\ date \geq 12/01/2019 \end{cases}$$

Examine whether the return of 3 series become more volatile before/after the pandemic.

Half-life:

$$Half - life(days) = \frac{ln(0.5)}{ln(a_1 + b_1)}$$

Represents how many days each market takes to recover from the shock and return to half of its original volatility

Multivariate Model Specifications

Bivariate DCC-GARCH Model Specification (examine the existence of long-/short-term volatility transformation)

$$R_{Gt} = \mu_G + \varepsilon_{Gt}, \quad h_{Gt} = a_{0G} + a_{1G}\varepsilon_{Gt-1}^2 + b_{1G}h_{Gt-1},$$

$$R_{Mt} = \mu_M + \varepsilon_{Mt}, \quad h_{Mt} = a_{0M} + a_{1M}\varepsilon_{Mt-1}^2 + b_{1M}h_{Mt-1},$$

$$\varepsilon_t \left| I_{t-1} = \begin{bmatrix} \varepsilon_{Gt} \\ \varepsilon_{Mt} \end{bmatrix} \right| I_{t-1} \sim WN(0, H_t),$$

Conditional covariance matrix of z

Unconditional covariance matrix of z

$$(2)\ \mathbf{Q_T} = (1 - \alpha - \beta)\bar{\mathbf{R}} + \alpha z_{t-1} z_{t-1}' + \beta \mathbf{Q_{T-1}},\ (\mathbf{1})\ \bar{\mathbf{R}} = E[z_{t-1} z_{t-1}'],\ where\ z_t = \begin{bmatrix} \varepsilon_{Gt}/\sqrt{h_{Gt}} \\ \varepsilon_{Mt}/\sqrt{h_{Mt}} \end{bmatrix}$$

$$(4)\ \mathbf{\Sigma_t} = \mathbf{D_t} \times \mathbf{R_t} \times \mathbf{D_t} = \begin{bmatrix} \sigma_{gt}^2 & \sigma_{gmt} \\ \sigma_{mgt} & \sigma_{mt}^2 \end{bmatrix};\ \ (3)\ \mathbf{R_t} = diag(\mathbf{Q_T})^{-1/2} \times \mathbf{Q_T} \times diag(\mathbf{Q_T})^{-1/2};\ \mathbf{D_t} = \begin{bmatrix} \sqrt{h_{Gt}} & 0 \\ 0 & \sqrt{h_{Mt}} \end{bmatrix},$$

Conditional covariance matrix of two series

Conditional correlation matrix of two series

The parameters of interest, α and β, represent the level of volatility transformation between two markets in short- & long-term respectively.

Empirical Results

Baseline Result

Volatility clustering phenomenon

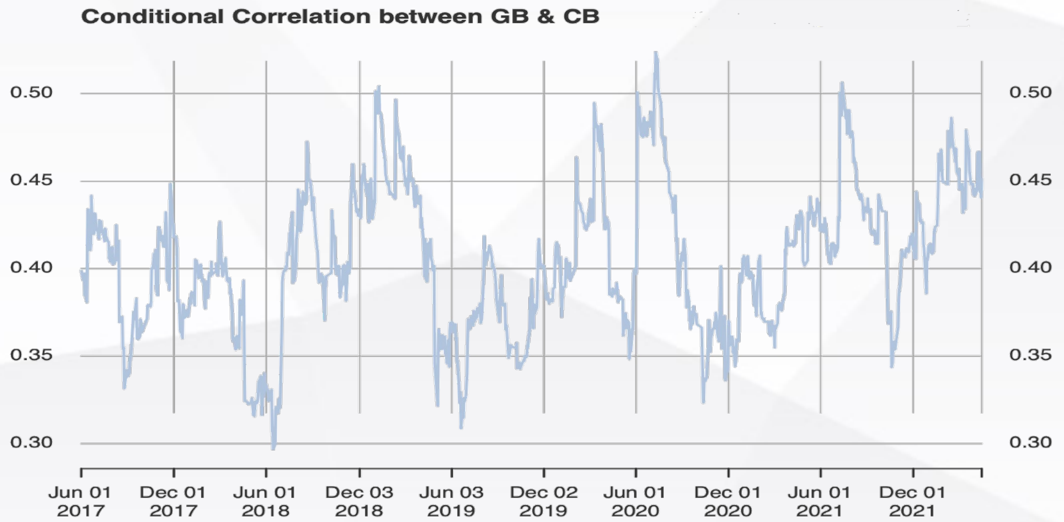
	GB returns	Bond market return	Equity market return
α_0	0.000115***	0.005721**	34.60248*
α_1	0.062198***	0.147723**	0.12849***
b_1	0.924123***	0.597723***	0.86842***
Persistence: $\alpha_1 + b_1$	0.986321	0.745446	0.99691
Half-life (Days)	50.325	2.360	223.973
Threshold effect (When it's negative shock, the dummy variable = 1)	-0.028337**	-0.017194	0.058595***
Covid-19 impact (After Covid =1, Before Covid = 0)	-0.000330*	-0.000643	0.000207**

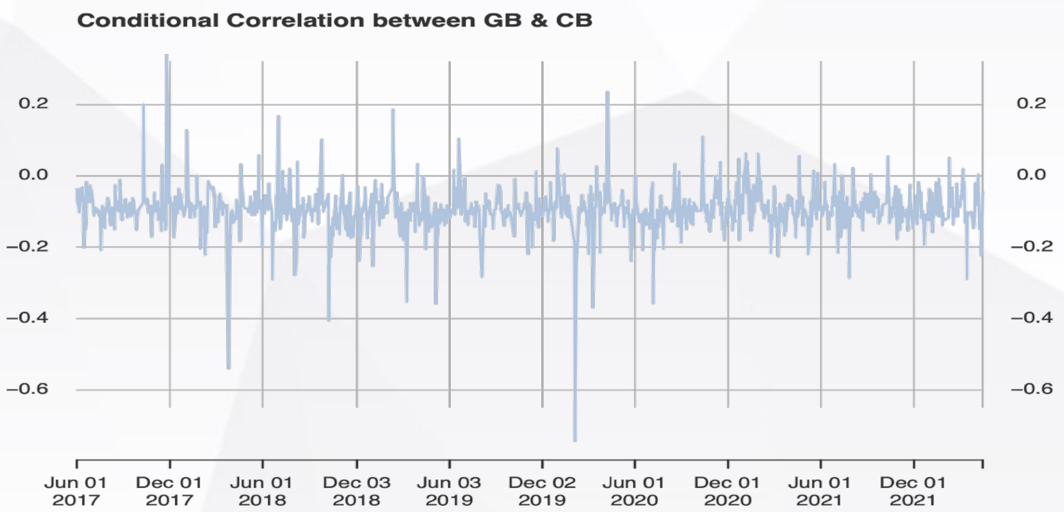
Bivariate Result Analysis

Volatility Transformation:

GB & CB				GB & Equity			
Parameter estimate: GB		Parameter estimate: CB		Parameter estimate: GB		Parameter estimate: Equity	
α_{0g}	0.000273	α_{0b}	0.000691**	α_{0g}	0.000273	α_{0e}	37.962883*
α_{1g}	0.141202*	α_{1b}	0.092199***	α_{1g}	0.141202*	α_{1e}	0.130569***
b_{1g}	0.827441***	b_{1b}	0.855476***	b_{1g}	0.827441***	b_{1e}	0.863876***
Estimates for the conditional covariance parameters				Estimates for the conditional covariance parameters			
α	0.011759			α	0.054674		
β	0.959064***			β	0.384216***		

Conditional Correlation:





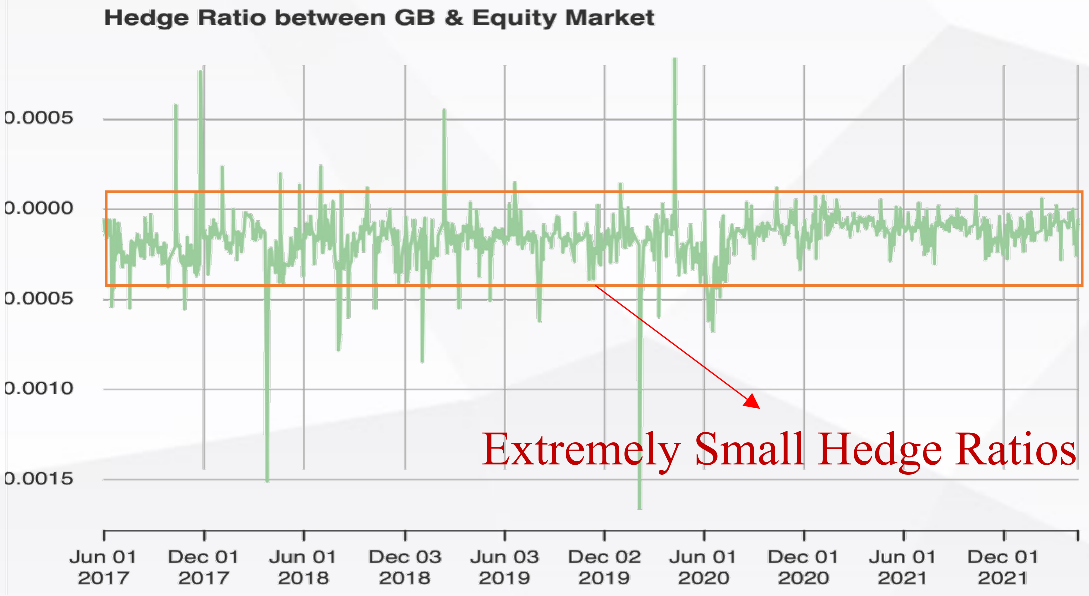
Further Discussion

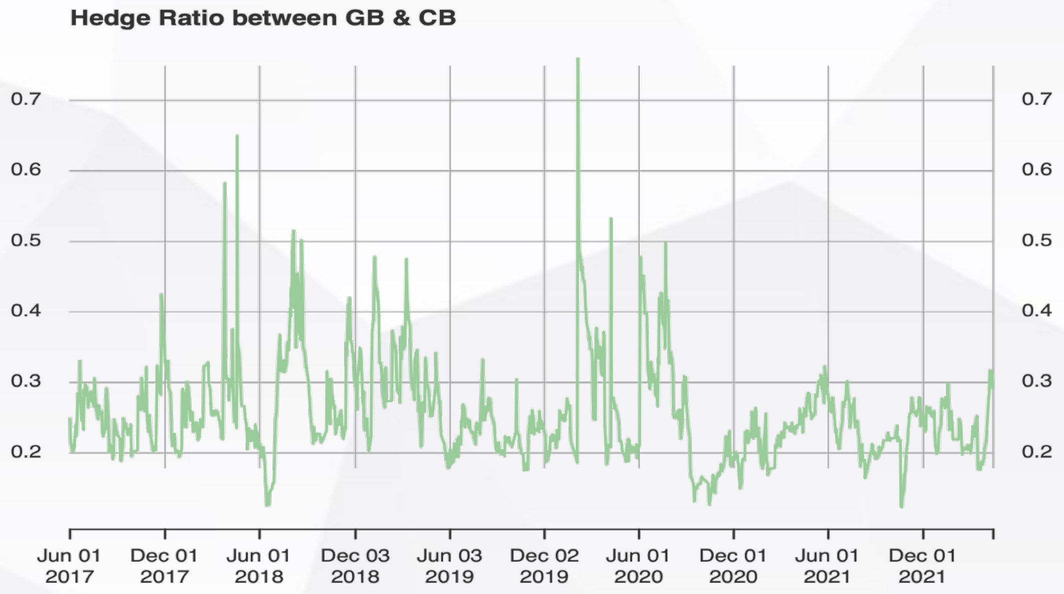
Why does there only exists long-term volatility transformation phenomenon?

In the short run, investors shall keep their green bond since:

- Green bond has policy funding support and relatively manageable risk.
- Most of the green bonds are highly rated and are high-quality assets.
- "Isolation" of the green bond market:

$$Optimal\ Hedge\ Ratio = \frac{\sigma_{gmt}}{\sigma_{mt}^2}$$





Further Discussion

Why does there only exists long-term volatility transformation phenomenon?

In the long run, long-term volatility transformation might be related to some structural shocks that change the ecology of the financial environment in equity or conventional bond market. For instance:

- Rating companies are less able to reveal credit risk.
- Inadequate regulation of the financial system.
- Non-market factors in local government bond issuance, leading to distorted market prices.

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深度关注丨东方金诚高管被查引出信用评级领域系列腐败案：量钱评级

来源：中央纪委国家监委网站 发布时间：2020–12–11 17:30 分享

News related to the causes of structural shock in the finance sector

Source: the Central Commission for Discipline Inspection of the Communist Party of China; Reuters

Conclusion

Conclusion

01 The Chinese green bond market's volatility is mainly determined by its own "experience" rather than "innovation" (shock);

02 The Chinese green bond market responds more rapidly to its positive shock, and during the period of Covid-19, the volatility of the green bond market became smaller;

03 There only exists significant long-term volatility transformation phenomenon between the green bond market and other two benchmark markets;

04 The weak connection between the green bond market and the equity market shows that green bonds could not provide a sufficient hedge protection against stock market.

05 More policy support and regulations should be implemented to stimulate social capital investment in the green bond market and enhance risk management capabilities.

Thank You For Your Listening & Invaluable Comments!