Adaptation Finance for Emerging Markets*

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ABSTRACT

A substantial investment gap exists in financing climate change adaptation in emerging markets. Governments could mobilize private capital through the green bond market to help close the gap. However, the relative cost of adaptation capital facing emerging markets remains unclear. To understand this, we analyze the green premium (Greenium) of 444 green bonds issued by governments and public agencies across 35 countries globally, spanning 17 currencies. Our results indicate that, among green bonds from emerging markets, the Greenium of adaptation bonds (green bonds whose use of proceeds includes climate change adaptation) is larger than that of non-adaptation bonds. The former is even larger if these adaptation bonds are from countries with higher physical risk exposure or stronger governance capacity. Notably, even among countries with above-median physical risk exposure, the Greenium of adaptation bonds from emerging markets is still larger than that from developed markets. Our results show the potential for emerging markets to mobilize more private capital in the green bond market to supplement public finance in supporting climate change adaptation.

KEYWORDS

Adaptation finance; Emerging market; Climate change; Green bond

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1. Introduction

According to the Global Risk Report 2024, climate change-related risks, particularly extreme weather events, are anticipated to be the top-ranked global risks in the coming decade (World Economic Forum, 2024). Climate change adaptation is increasingly urgent for reducing current and future climate-related losses by enhancing the coping capacity of the ecological, social, or economic systems. The demand for adaptation investments is growing (New et al., 2022), especially in resource-dependent and vulnerable regions (United Nations Framework Convention on Climate Change, 2015). Estimates for adaptation costs in emerging markets this decade range from US$215 billion to US$387 billion per year (UNEP, 2023).

However, climate finance has been prioritizing mitigation over adaptation globally (UNEP, 2021). As a result, the investment gap in adaptation finance is estimated to be 10-18 times larger than the international public capital flows to adaptation projects at present (UNEP, 2023). The shortage of adaptation finance is particularly concerning for emerging markets (Khan et al., 2020).

Given the inadequacy of public funding, governments are beginning to leverage private capital from the green bond market to help fill this gap. Green bonds are attractive to socially responsible investors due to their commitment to finance environmentally friendly projects contributing to climate change adaptation and mitigation. The green bond market has experienced substantial growth in recent years, with cumulative green bond issuances rising from US$100 billion in 2015 to over US$3 trillion in 2023 (Climate Bonds Initiative, 2024).

The additionality[1] of adaptation finance for emerging markets may appeal to climate-conscious investors. However, many emerging markets have been facing difficulties in raising capital from the financial market due to their poorly developed banking systems and weak regulatory frameworks (Berensmann et al., 2015). As such, little is understood about the relative cost of adaptation capital facing emerging markets. To address these research gaps, this study aims to answer the following research questions:

Research Question: Do projects dedicated to climate change adaptation proposed by emerging markets face a higher or lower cost of capital?

To address the above question, this study categorizes green bonds into two types: adaptation bonds (green bonds whose use of proceeds includes climate change adaptation) and non-adaptation bonds (green bonds whose use of proceeds does not include climate change adaptation). We focus on green bonds issued by governments and public agencies (public issuers) globally over the period 2014-2023 to explore the green bond premium of adaptation

[1] The term of "additionality" refers to directing capital toward green assets and projects that would not otherwise secure financing.

bonds. The green premium, i.e., the Greenium, is defined as the difference between the yield of a green bond and that of a comparable conventional bond (Agliardi & Agliardi, 2019). A larger Greenium means that a green bond faces a lower financing cost. Following Zerbib (2019), we generate a sample of 444 matched bond pairs covering 35 countries and regions and 17 currencies.

Our results indicate that the Greenium of adaptation bonds is 5.8 basis points (bps) larger if their public issuers are from emerging markets rather than developed markets. This means that emerging markets actually have a cost of capital advantage in financing adaptation compared to developed markets. Furthermore, we show that investors seem to be more enthusiastic about supporting climate change adaptation than other green projects in emerging markets. The Greenium of adaptation bonds is 9.5 bps larger than that of non-adaptation bonds for emerging markets. The differential is only 0.5 bps for developed markets.

To further understand whether public issuers with a stronger need for climate change adaptation actually incur a lower cost of adaptation capital, we examine how country-level physical risk exposure affects the Greenium conferred to adaptation bonds.

Our empirical analysis shows that the Greenium of adaptation bonds is 30.9 bps larger if they are issued by emerging markets with above-median rather than below-median physical risk exposure. Interestingly, even among countries with above-median physical risk exposure, the Greenium of adaptation bonds from emerging markets is still 18.0 bps larger than that from developed markets. Additionally, our results indicate that governance capacity can significantly reduce the cost of capital disadvantage of emerging markets.

This study makes the following three contributions. First, this paper innovatively reveals investor perceptions of climate change adaptation investments in emerging markets. To the best of our knowledge, this study is the first to examine the cost of financing climate change adaptation in different countries and physical risk exposure scenarios.

Second, our findings provide new insights into the determinants and inequalities of adaptation finance allocation. While existing literature suggests that climate vulnerability is not the primary driver of adaptation finance accessibility and allocation—instead emphasizing the role of institutional capacities, financial interests, and political considerations (Venner et al., 2024)—our results reveal a contrasting dynamic in the green bond market. Specifically, we demonstrate that investors take into account the additionality of adaptation bonds when conferring Greenium, as evidenced by the pricing of physical risk exposure.

The final contribution is that this study is essential to enhance the effectiveness of climate change adaptation efforts in emerging markets. Our results provide guidance for emerging markets to consider mobilizing more private capital in the green bond market to supplement public finance in supporting climate change adaptation. We also suggest governments of emerging markets build institutional strength to attract cross-border green capital flows.

The remainder of the paper is organized as follows: Section 2 provides a review of previous studies. Section 3 explains our hypothesis development. Section 4 describes the research design, including our data sources and sample selection process. Section 5 presents our regression models and discusses the results along with their implications for theory and practice. Finally, we conclude the paper in Section 6.

2. Literature review

Our paper is related to two strands of literature. First, it is related to the literature on the challenges of boosting international capital flows for sustainable investment from emerging markets. Barua and Aziz (2022) reveal that due to insufficient financial and economic capacity, emerging markets rely on overseas development assistance and public sources to promote green finance, with minimal private sector involvement. Hafner et al., (2019) identify a key barrier as the lack of information on climate change risks in emerging markets. Another significant factor is the inherent bias of international investors, who perceive risks in emerging markets that are not fully captured by credit ratings, leading to "unjustifiably" higher borrowing costs (Gbohoui et al., 2023). Similarly, Gadanecz et al. (2014) highlight exchange rate risks as a major determinant of local currency sovereign bond yields. Collectively, these studies emphasize that major challenges in scaling up sustainable investments in emerging markets.

Second, this paper is related to the literature on adaptation finance. Previous research has predominantly focused on the allocation of adaptation finance across nations, highlighting challenges faced by vulnerable regions. For instance, Garschagen and Doshi (2022) show many of the most vulnerable countries, particularly Least Developed Countries (LDCs) in Africa, struggle to access the Green Climate Fund, the largest climate change fund. Saunders (2019) finds a concave relationship between a country's climate vulnerability and the adaptation finance it receives, with diminishing and even negative returns to higher vulnerability. Other studies analyze barriers to acquiring and utilizing adaptation finance. Stadelmann et al. (2014) argue that the allocation mechanisms of the adaptation fund are overly simplistic and fail to address the needs of the most vulnerable countries. They also highlight challenges such as inconsistencies in ranking methodologies for vulnerable countries and the limited availability of funds.

Current studies on adaptation finance primarily focus on analyzing adaptation funds, overlooking other financing mechanisms such as private capital raised through the green bond market. To the best of our knowledge, this study is the first to examine the cost of financing climate change adaptation across countries, with a particular focus on emerging markets. Furthermore, we investigate two important sources of cost of capital for emerging markets:

physical risk exposure and governance capacity.

3. Hypotheses

The section motivates four research hypotheses to address our research questions.

The main focus of adaptation is to reduce the losses associated with the climate change. Goldsmith-Pinkham et al. (2023) show that the sea-level rise (SLR) exposure risk is priced in the municipal bond markets, implying that investors actively consider losses caused by physical risks and the potential benefits of adaptation. CISL (2016) further indicates that investing in adaptation can reduce investors' exposure to climate risks and enhance portfolio diversification. Additionally, Höchstädter and Scheck (2015) show that investors prioritizing environmental impact are willing to compromise on potential financial returns. Besides, CISL (2016) indicate that investing in adaptation can reduce investors' own exposure to climate risks and help further diversify the investment portfolio. Taken together, investors' willingness to promote adaptation investments may lead them to accept higher prices for adaptation bonds. Based on the aforementioned analysis, the first hypothesis is proposed:

Hypothesis 1: There exists a Greenium for the adaptation bonds.

Investing in green bonds issued by emerging markets poses a series of risks compared to investing in green bonds issued by developed countries. For instance, investors may encounter risks of higher political instability, greater currency fluctuations, and lower bond liquidity. These risks prompt investors to seek higher risk compensations when investing in green bonds from emerging markets. Accordingly, a second hypothesis is proposed for this paper:

Hypothesis 2: Green bonds from emerging markets suffer a green discount.

As discussed in Section 2, emerging markets require prioritized access to adaptation finance due to their disproportionately high climate risks and limited progress in building resilience compared to developed countries. In response, some developed countries are required to take the ethical responsibilities of financing climate adaptation efforts in emerging markets (Grasso, M., 2010; Khan et al., 2020; Ciplet et al. 2022). Consequently, even though investing in bonds issued by emerging markets may higher risks, investors' preference for investing adaptation actions may lead them to accept a lower risk premium for adaptation bonds. Therefore, we hypothesize:

Hypothesis 3: The Greenium of adaptation bonds is larger than that of non-adaptation bonds for emerging markets.

According to the Intergovernmental Panel on Climate Change (2021), regions with the least resources have the lowest capacity to adapt and are the most vulnerable to climate change impacts. This underscores the urgent need to implement adaptation bond projects in emerging markets facing high physical risks over those facing lower risks. Given the high demand and urgency for the execution of such bond projects, investors demonstrate increased preference in investing in them. These arguments lead to our last hypothesis:

Hypothesis 4: Physical risk exposure moderates the Greenium of adaptation bonds from emerging markets.

4. Research design and data

Our sample consists of global green bonds issued by public issuers over the period 2014-2023 together with conventional bonds with similar characteristics for matching the former.

4.1 Green bond data sources

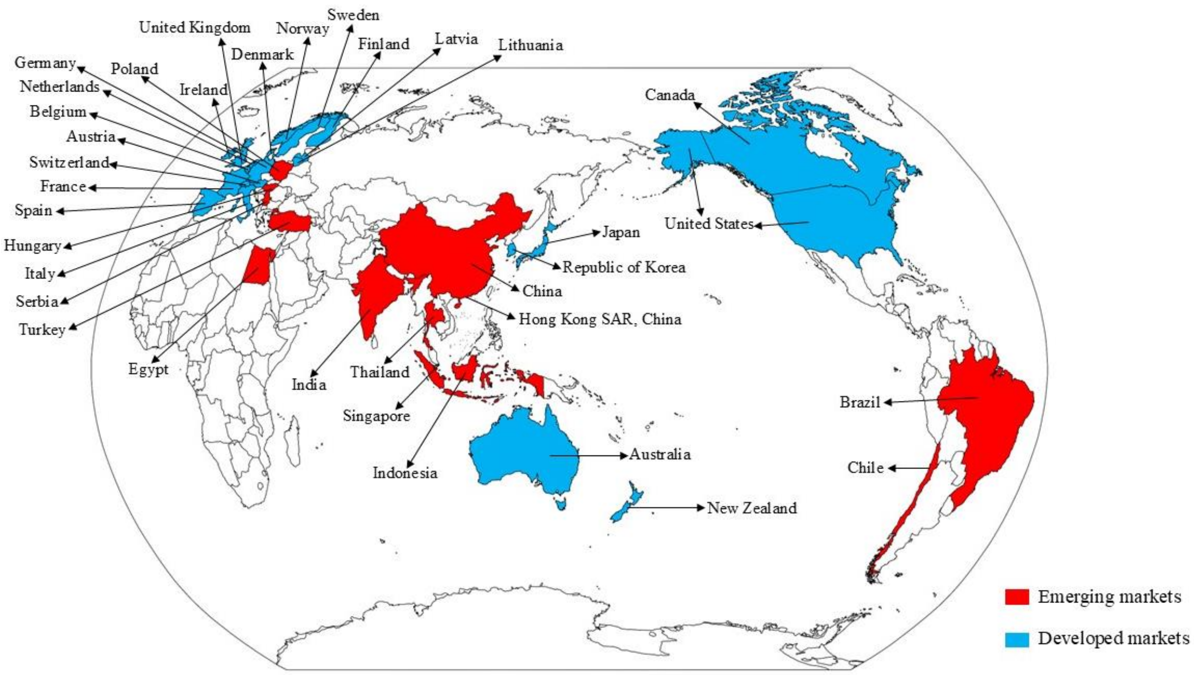
The green bond used in our sample is sourced from Bloomberg. All the green bonds issued from 2014 to 2023 are screened as follows: (i) Only bonds issued by public issuers, including agency, local authority, and sovereign, are included using the issuer's Bloomberg Industry Classification System to focus on the government bond market. This approach is motivated by the dominant role governments play as primary issuers in the adaptation bond market. (ii) Bonds without an International Securities Identification Number (ISIN) are excluded. (iii) Collateralized or option-embedded green bonds are excluded, referring to Lau et al. (2022), due to the lack of available collateral information and the practical challenge of finding matched bonds with identical option-embedded features.

4.2 Sample matching process

Building on existing literature (Zerbib, 2019; Bachelet et al., 2019; Hyun et al., 2020; Lau et al., 2022), this study estimated the Greenium through generating a sample of matched green and conventional bonds that are almost identical, except for the green label. Specifically, for each government green bond issued between 2014 and 2023, we search for a conventional bond from the same issuer, with the same currency, rating, and bond structure. The matched bonds should have close maturity dates, with a difference of no more than two years. The difference between the issue date and maturity date of the matched bonds must not exceed six years. The issuance amount of the matched conventional bond must be between one-fourth and four times the issuance amount of the green bond. After excluding samples with missing ask prices, bid prices, and yield data, we ultimately obtained 444 matched bond pairs covering 35 countries and regions and 17 currencies (see Figure 1).

Figure 1. The origin of public issuers in our sample

Source: compiled by the authors based on the definition of emerging and developed markets from the International Monetary Fund (IMF).



4.3 Data sources of key variables

(1) Bond-level variables

For these matched pairs, we retrieve from Bloomberg the daily observational data regarding ask prices, bid prices, and yields from the bond issuance date up to 29 February 2024. Data on the issuance amounts, currency, maturity, and use of proceeds' categories of the green bonds are also collected from Bloomberg. Yield spread, which is calculated as the difference between the ask yield of a green bond and that of its matched conventional bond, is winsorized at the 1st and 99th percentiles to mitigate the impact of outliers. The final sample includes 254,476 unbalanced bond-day observations.

The descriptive statistics of key variables within the sample of 444 green bonds and their matched conventional bonds can be found in Table 1. The statistics results show that the average yield spread for the full sample is 1.3 bps, which implies that the ask yields of green bonds are on average higher than those of their paired conventional bonds in our sample. The median yield spread of the matched bond pairs is 0.5 bps. In terms of bond characteristics, on average, green bonds are more liquid than their matched conventional bonds, as indicated by an average liquidity difference of -0.015. However, at the median level, the liquidity of green bonds does not differ from that of matched conventional bonds. Besides, the average issuance amount of green bonds is 1,024 million USD. Finally, the green bonds have maturities ranging from 3 months to a maximum of 100 years, illustrating substantial maturity diversity within our sample.

Table 1. Descriptive statistics of the 444 matched government bond pairs.

Table 1 presents the descriptive statistics for the 444 paired bonds in our sample, containing 254,476 unbalanced daily observations. The definition of variables can be found in Table 3.

Variable	Obs	Mean	SD	Min	Max	P50
Panel A: time-variant						
Yield Spread	254,476	0.013	0.166	-0.570	0.699	0.005
ΔLiquidity	254,476	-0.015	0.204	-5.697	3.974	0.000
Panel B: time-invariant						
Issue amount (bn USD)	444	1.024	3.334	0.003	37.530	0.204
Maturity (in years)	444	9.797	8.265	0.200	100.000	7.000

(2) Country-level variables

To understand the efficiency of adaptation capital allocation, we study whether the Greenium of adaptation bonds is positively correlated with their additionality. In other words, we are interested in whether public issuers with a stronger need for climate change adaptation actually incur a lower cost of adaptation capital. To do so, we use the exposure indicator from the Notre Dame Global Adaptation Initiative's (ND-GAIN) Country Index[2] to measure country-level physical risk exposure.

The ND-GAIN exposure indicator covers 182 countries and accesses the projected impact of climate change risks on six sectors (ecosystem services, food, human habitat, health, infrastructure and water) with higher values indicating greater exposure (Chen et al., 2023). Therefore, our study follows previous studies (Beirne et al., 2021; Cevik & Miryugin, 2023; Cevik & Jalles, 2022; Cheema-Fox et al., 2022; Jia & Li, 2020; Kling et al., 2021; Wen et al., 2023) that use data from the ND-GAIN index. Based on this, we categorize the country-level physical risk exposure of the issuers into above and below the global median, which remains constant over the sample period.

In the final sample of 444 bond pairs, 196 are adaptation bonds. Among these 196 adaptation bonds, 23 are from emerging markets, and 90 are from countries or regions with high physical risk exposure.

We also use the governance readiness indicator from the ND-GAIN Country Index to measure the governance capacity of each country. The ND-GAIN governance readiness indicator accesses the political stability, control of corruption, rule of law, and regulatory quality of a country. We categorize the governance capacity of the issuers' countries or regions into above

[2] https://gain.nd.edu/our-work/country-index/download-data/.

and below the global median for each year.

As expected, emerging markets have weaker governance capacities than developed markets on average. Within our sample, 100% of developed markets have above-median governance capacity; meanwhile, 54.5% of the adaptation bonds issued by emerging markets are from the ones with below-median governance capacity. Finally, countries or regions with high physical risk exposure tend to have below global median governance capacity (Table 2).

Table 2. Correlation Matrix.

Table 2 presents the Correlation analysis for the 444 paired bonds in our sample, containing 254,476 unbalanced daily observations. The definition of variables can be found in Table 3.

Variable	EM	Exposure	Governance
Exposure	0.124***		
Governance	-0.718***	-0.238***	
ΔLiquidity	-0.004**	0.073***	-0.059***

5. Regressions and Implications

This section presents the empirical estimation of our hypotheses proposed in section 3. Furthermore, policy implications will be discussed alongside the empirical results.

5.1 Adaptation bond premium

To examine Hypothesis 1 that whether adaptation bonds have a Greenium, we deploy an Ordinary Least Squares (OLS) regression model, as depicted in equation (1). The definitions and detailed descriptions of all variables are shown in Table 3.

$$Yield\ Spread_{i,t} = \beta_0 + \beta_1 Adaptation_j + Controls + \varepsilon_{i,t} \quad (1)$$

The dependent variable of this model is $Yield\ Spread_{i,t}$, i.e., the difference between the green bond yield and the conventional bond yield for the *i*th bond pair on trading day *t*. A more negative value of yield spread denotes a higher Greenium. The key variable $Adaptation_j$ equals 1 if the use of proceeds of green bond *j* of pair *i* includes adaptation project, and 0 otherwise. *Controls* includes control variables for the issuance amount and maturity of green bond *j*, difference in liquidity of the *i*th bond pair, and one-year lagged term of GD per capital and GDP growth of the countries or regions of pair *i*. Specifically, $\Delta Liquidity_{i,t}$ represents the difference in liquidity of the *i*th bond pair, defined as the difference between the bond liquidity of the green bond and that of its matched conventional bond. Following existing studies (Beber et al., 2009; Chen et al., 2007; Dick-Nielsen et al., 2012), we use the bid–ask spread (i.e., price bid minus price ask) as the proxy for the bond's liquidity indicator (Zerbib, 2019). We also control for differences across currencies and time (year). Finally, $\varepsilon_{i,t}$ is the error term.

Table 3. Definitions of variables.

Variable	Definition	Source
Dependent variable		
Yield spread	The difference (expressed in percentages) of the green bond ask yield over the matched conventional bond ask yield for the same trading date.	Bloomberg
Independent variables		
Adaptation	Equals 1 if the use of proceeds of a green bond includes funding adaptation project, and 0 otherwise.	Bloomberg
EM (Emerging markets)	Equals 1 if the issuer is from emerging markets, and 0 otherwise.	International Monetary Fund
Exposure	Equals 1 if the physical risk exposure of the issuer's country is severe compared to half of the countries globally, and 0 otherwise.	ND-GAIN Index
Governance	Equals 1 if the issuer's country or region has above-median governance capacity in year k-1, and 0 otherwise.	ND-GAIN Index
Control variables		
ΔLiquidity	The difference between the liquidity indicator of a green bond and its matched conventional bond.	Bloomberg
Issue amount	The natural logarithm of the issue amount of the green bond in millions of dollars.	Bloomberg
Maturity	The natural logarithm of the maturity of a bond (in years) plus one.	Bloomberg
GDP per capita	The natural logarithm of the GDP per capital of the issuer's country or region in year k-1.	World Bank
GDP growth	The annual percentage growth rate of GDP at market prices in constant local currency of the issuer's country or region in year k-1.	World Bank
Currency	The currency of the amount issued.	Bloomberg
Year	Year dummy variable.	Bloomberg

Table 4 presents the estimation results of regression model (1). When examining green bonds globally, the Greenium of adaptation bonds is 1.3 bps larger than that of non-adaptation bonds, and is statistically significant at the 5% level (column 3).

These findings support Hypothesis 1, demonstrating the existence of a Greenium for adaptation bonds. In the green bond market, investors exhibit a slightly higher preference for adaptation projects compared to non-adaptation projects. This reflects investors' acknowledgment of the importance of adaptation investments and their willingness to contribute to such initiatives.

Table 4. Adaptation bond and Greenium.

Table 4 reports the results of the OLS regression model (1) with the yield spread as the dependent variable. All the variables are defined in Table 3. Robust standard errors are reported. Standard errors are in parentheses. Significance levels: * p < 0.1, ** p < 0.05, *** p < 0.01.

	(1)	(2)	(3)
Adaptation	-0.001**	-0.001	-0.013***
	(0.001)	(0.001)	(0.001)
ΔLiquidity	0.016***	0.015***	0.009***
	(0.002)	(0.002)	(0.002)
Governance			-0.166***
			(0.003)
Ln(amount)	-0.007***	-0.008***	-0.009***
	(0.000)	(0.000)	(0.000)
Ln(maturity)	0.002***	0.002***	-0.001**
	(0.001)	(0.001)	(0.001)
Ln(GDP) lag		-0.007***	0.044***
		(0.001)	(0.001)
GDP growth lag		-0.001***	-0.001***
		(0.000)	(0.000)
Constant	-0.015***	0.061***	-0.324***
	(0.002)	(0.010)	(0.011)
Currency FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	252893	252893	252893
Adjusted R^2	0.055	0.055	0.068

5.2 Emerging markets and Greenium

To test Hypothesis 2 that green bonds issued by emerging markets suffer a green discount, we estimate the following regression model:

$$Yield\ Spread_{i,t} = \beta_0 + \beta_1 EM_i + Controls + \varepsilon_{i,t} \quad (2)$$

The key variable EM_i equals 1 if the issuer of the *i*th bond pair is from an emerging market, and 0 otherwise. Other variables are set in the same way as equation (1).

Table 5 presents the results of the regressions. The results in column (1) indicate a significant positive relationship between emerging markets and yield spread. The Greenium of green bonds is 1.9 bps smaller if their public issuers are from emerging markets rather than developed markets. In column (2), we add a control for GD per capital and GDP growth, the coefficient for emerging markets remains positive and highly significant. Column (3) controls for the governance capacity of the countries or regions where the public issuers are located, obtaining similar results.

These results indicate that emerging markets generally face a higher cost of capital when seeking funds for green projects, aligning with the literature.

Table 5. Emerging markets and Greenium.

Table 5 reports the results of the OLS regression model (2) with the yield spread as the dependent variable. All the variables are defined in Table 3. Robust standard errors are reported. Standard errors are in parentheses. Significance levels: * p < 0.1, ** p < 0.05, *** p < 0.01.

	(1)	(2)	(3)
EM	0.019***	0.033***	0.030***
	(0.002)	(0.003)	(0.003)
ΔLiquidity	0.015***	0.015***	0.009***
	(0.002)	(0.002)	(0.002)
Governance			-0.153***
			(0.003)
Ln(amount)	-0.008***	-0.008***	-0.009***
	(0.000)	(0.000)	(0.000)
Ln(maturity)	0.002***	0.002***	-0.002***
	(0.001)	(0.001)	(0.001)
Ln(GDP) lag		0.007***	0.052***
		(0.001)	(0.002)
GDP growth lag		-0.002***	-0.002***
		(0.000)	(0.000)
Constant	-0.015***	-0.084***	-0.423***
	(0.002)	(0.016)	(0.017)
Currency FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	252893	252893	252893
Adjusted R^2	0.055	0.056	0.068

5.3 Adaptation, emerging markets, and Greenium

We further test Hypothesis 3 to investigate the Greenium of adaptation bonds issued by public issuers from emerging markets. To do so, we add in an interaction term of $Adaptation_j$ and EM_i based on equations (1), as depicted below:

$$Yield\ Spread_{i,t} = \beta_0 + \beta_1 Adaptation_j + \beta_2 EM_i + \beta_3 Adaptation_j * EM_i + Controls + \varepsilon_{i,t} \quad (3)$$

Table 7 presents the estimation results. As depicted in column (3), the Greenium of non-adaptation green bonds is 3.2 bps smaller than if their public issuers are from emerging markets rather than developed markets.

Nevertheless, the picture reverses when we focus on adaptation bonds. The Greenium of adaptation bonds is 5.8 bps (-3.2+9.0) larger if their public issuers are from emerging markets rather than developed markets. This means that emerging markets actually have a cost of capital advantage in financing adaptation compared to developed markets.

Indeed, investors seem to be more enthusiastic about supporting climate change adaptation than other green projects in emerging markets. The Greenium of adaptation bonds is 9.5 bps (0.5+9.0) larger than that of non-adaptation green bonds for emerging markets. The differential is only 0.5 bps for developed markets.

Table 6. Adaptation, emerging markets, and Greenium.

Table 6 reports the results of the OLS regression model (3) with the yield spread as the dependent variable. All the variables are defined in Table 3. Robust standard errors are reported. Standard errors are in parentheses. Significance levels: * p < 0.1, ** p < 0.05, *** p < 0.01.

	(1)	(2)	(3)
Adaptation	0.001	0.001	-0.005***
	(0.001)	(0.001)	(0.001)
EM	0.030***	0.033***	0.032***
	(0.002)	(0.003)	(0.003)
EM*Adaptation	-0.023***	-0.021***	-0.090***
	(0.003)	(0.003)	(0.004)
ΔLiquidity	0.015***	0.015***	0.009***
	(0.002)	(0.002)	(0.002)
Governance			-0.204***
			(0.004)
Ln(amount)	-0.008***	-0.008***	-0.010***
	(0.000)	(0.000)	(0.000)
Ln(maturity)	0.002***	0.002***	-0.003***
	(0.001)	(0.001)	(0.001)
Ln(GDP) lag		0.001	0.045***
		(0.002)	(0.002)
GDP growth lag		-0.001***	-0.000*
		(0.000)	(0.000)
Constant	-0.014***	-0.026	-0.296***
	(0.002)	(0.017)	(0.018)
Currency FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	252893	252893	252893
Adjusted R^2	0.056	0.056	0.073

5.4 Emerging markets, exposure, and Greenium: Adaptation bond subsample

To test Hypothesis 4 whether the Greenium adaptation bonds issued by emerging markets is moderated by physical risk exposure, we estimate a regression model using a subsample in which the green bond within each pair is an adaptation bond:

$$Yield\ Spread_{i,t} = \beta_0 + \beta_1 Exposure_i + \beta_2 EM_i + \beta_3 Exposure_i * EM_i + Controls + \varepsilon_{i,t} \quad (4)$$

Table 7 presents the results of the regression model (4). As shown in column (3), the Greenium of adaptation bonds is 30.9 bps (-5.2+36.1) larger if they are issued by emerging markets with above-median rather than below-median physical risk exposure (see Figure 2). Interestingly, even among countries with above-median physical risk exposure, the Greenium of adaptation bonds from emerging markets is still 18.0 bps (-18.1+36.1) larger than that from developed markets (see Figure 3).

Lastly, our estimations show that governance capacity can significantly reduce the cost of capital disadvantage of emerging markets. Among green bonds from emerging markets, the Greenium of adaptation bonds is 7.4 bps larger if the governance capacity of the issuers' countries is above median rather than below median (column 3).

Table 7. Emerging markets, exposure, and Greenium: Adaptation bonds.

Table 7 reports the results of the OLS regression model (5) with the yield spread as the dependent variable. All the variables are defined in Table 3. Robust standard errors are reported. Standard errors are in parentheses. Significance levels: * p < 0.1, ** p < 0.05, *** p < 0.01.

Adaptation subsample	(1)	(2)	(3)
EM	0.238***	0.189***	0.181***
	(0.005)	(0.005)	(0.005)
Exposure	0.060***	0.054***	0.052***
	(0.002)	(0.002)	(0.002)
EM*Exposure	-0.340***	-0.340***	-0.361***
	(0.006)	(0.006)	(0.007)
ΔLiquidity	0.031***	0.028***	0.027***
	(0.003)	(0.003)	(0.003)
Governance			-0.074***
			(0.006)
Ln(amount)	-0.005***	-0.006***	-0.006***
	(0.000)	(0.000)	(0.000)
Ln(maturity)	-0.016***	-0.016***	-0.016***
	(0.001)	(0.001)	(0.001)
Ln(GDP) lag		-0.016***	-0.000
		(0.002)	(0.002)
GDP growth lag		0.007***	0.006***
		(0.000)	(0.000)
Constant	0.047***	0.228***	0.125***
	(0.003)	(0.027)	(0.025)

Currency FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	113665	113665	113665
Adjusted R^2	0.166	0.169	0.170

Figure 2. Yield spread distribution for adaptation bonds from emerging markets with different levels of physical risk exposure

Notes: Lower yield spread means larger Greenium, i.e., lower financing costs. In our sample, only 5 bonds are from emerging markets with below-median physical risk exposure.

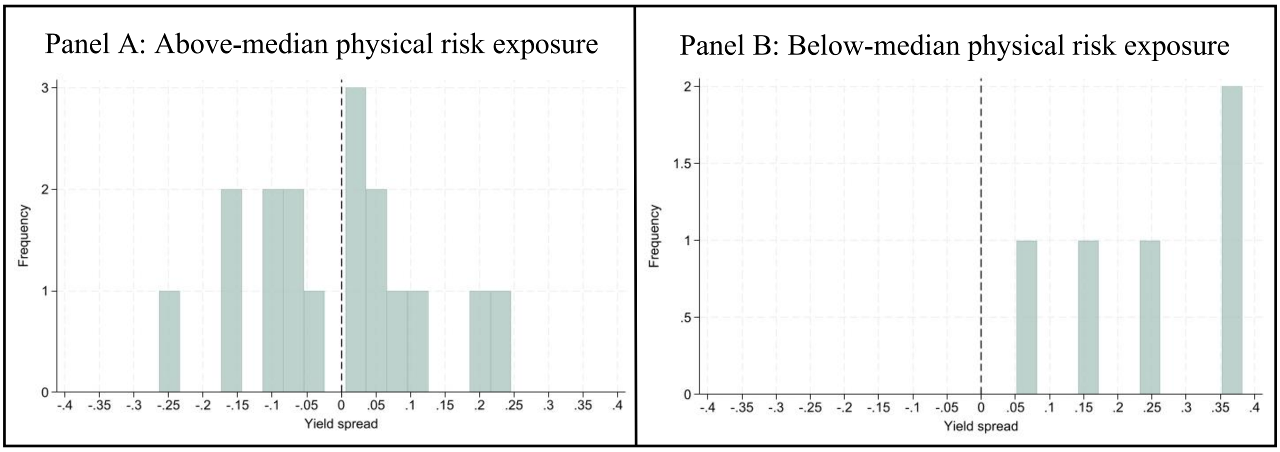
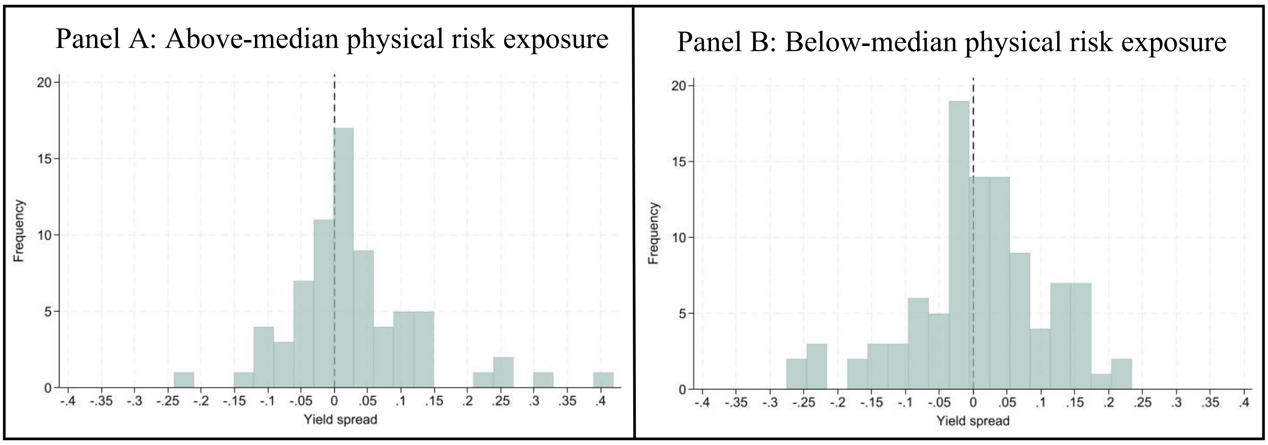


Figure 3. Yield spread distribution for adaptation bonds from developed markets with different levels of physical risk exposure.



6. Conclusions

By estimating the Greenium of adaptation bonds issued by governments and public agencies around the world, we show that emerging markets actually have a cost of capital advantage in financing climate change adaptation compared to developed markets. As such, emerging markets could consider mobilizing more private capital in the green bond market to supplement public finance in supporting climate change adaptation.

Attesting the efficiency of adaptation capital allocation, our research shows that investors actually take into account the additionality of adaptation bonds when conferring Greenium. In fact, even among countries with above-median physical risk exposure, the Greenium of adaptation bonds from emerging markets is still larger than that from developed markets.

Finally, we have shown that the cost of climate finance for emerging markets can be significantly lowered if they have higher governance capacity. This speaks to the importance of building institutional strength to attract cross-border green capital flows.

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