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THEMATIC BONDS: FINANCING NET-ZERO TRANSITION IN EMERGING MARKET AND DEVELOPING ECONOMIES

BY DR. GAUTAM JAIN

DECEMBER 2022

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Gautam joined the center after a long and fulfilling career in the financial industry where he covered emerging markets as a portfolio manager and strategist. He has worked at asset management firms and investment banks, including The Rohatyn Group, Barclays Capital, and Millennium Partners. He has helped manage emerging market local debt and hard-currency bond portfolios, encompassing currencies, interest rate instruments, and sovereign credits. He specialized in portfolio construction and asset allocation incorporating macroeconomic, policy, and political developments in emerging market and developing economies.

Gautam holds a Ph.D. in Operations Research from Columbia University. He also has an M.S. in Industrial Engineering from Iowa State University and a B.Tech. in Mechanical Engineering from the Indian Institute of Technology, Bombay. He is a CFA charter holder and a Cornell EMI Fellow. He has co-authored publications in the Journal of Derivatives, the Journal of Banking and Finance, the Journal of Applied Probability, and Probability in Engineering and Informational Science. He has also contributed chapters for the 2020 and 2021 Cornell EMI Annual Reports.

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EXECUTIVE SUMMARY

A significant gap exists globally between the financing needed and the current level of spending to meet net-zero goals. The problem is particularly acute for emerging market and developing economies (EMDE), as they face higher spending on the energy transition as a percentage of gross domestic product (GDP) and are likely to be affected more severely by climate change than advanced economies. Thematic bonds that target specific investment themes, including climate change mitigation, can help narrow the financing gap, but EMDE's share of the global thematic bond market remains small.

This report explains the urgency of raising financing for EMDE to address climate change and discusses the evolution of thematic bonds. It finds that the asset class has the potential to achieve significant further growth. As part of Columbia University's Financing the Energy Transition initiative, it offers policy recommendations to governments and development banks interested in increasing thematic bond issuances from these countries. Options to consider include addressing local currency risk using structured finance, adapting institutional frameworks such as Green Bond Principles (GBP) to national contexts, addressing accessibility issues in domestic markets, and providing tax incentives.

Other key takeaways from the report include the following:

- Even as the thematic bonds market has grown, the share of EMDE within it has plateaued at a low level. Excluding China, the total green bond issuance from EMDE has amounted to just 13 percent of global issuance to date and only 3 percent in local currencies.
- Headwinds to EMDE thematic bond issuances range from the costs and complexity of setting up a green bond framework for issuers to regulatory hurdles and local currency risk for investors.
- Green bonds trade with a premium and should, therefore, be very appealing to EMDE issuers and investors alike. The average premium across bonds analyzed in this study is seven basis points, with a premium observed 73 percent of the time in the historical secondary market trading of the green bonds in the sample.
- Other thematic bonds don't trade with a premium, but issuers could still benefit from issuing them because they attract a different and growing class of investors focused on environmental, social, and governance (ESG) metrics.

INTRODUCTION

Achieving net-zero emissions by the midcentury will require an unprecedented combination of technological advances, regulatory changes, and access to financing for low-carbon climate-resilient infrastructure. Financing the net-zero transition is a particularly urgent challenge facing emerging market and developing economies (EMDE).[1]

- **EMDE face disproportionately high physical and economic impacts of climate change.** While climate change affects the entire planet, emerging economies are likely to suffer disproportionately from rising temperatures and sea levels. Even under the United Nations' Intergovernmental Panel on Climate Change intermediate scenario where emissions peak in 2040, these countries are likely to see a sharp increase in days of extreme heat by the end of the century (Climate Impact Lab 2022; Jain 2022). The economic impact of climate change has also been shown to be more severe for EMDE (Pictet Asset Management 2020). Variable temperatures and rainfall patterns lead to lower crop yields in these countries where the agricultural sector contributes a higher share of GDP than in developed countries.[2] EMDE populations have poorer access than those living in developed countries to air-conditioning to deal with extreme heat, leading to higher mortality and morbidity rates. Moreover, a larger segment of EMDE populations is vulnerable to rising sea levels, flooding, and drought as they reside in water-stressed areas, including coastal regions (United Nations 2017).

- **There is a large energy transition-investment gap in emerging economies.** While the gap between investments needed for the transition versus the amount being spent is wide globally, it is particularly pressing in EMDE. The Organization for Economic Cooperation and Development estimates that an average of $6.9 trillion per year in global investments is required through 2030 for low-carbon infrastructure to meet climate objectives (Organization for Economic Cooperation and Development et al. 2018). For clean energy systems alone, the International Energy Agency estimates that, to reach the target of net-zero emissions by 2050, annual investments should rise to $5 trillion per year globally and $1 trillion per year for EMDE, excluding China by 2030 (International Energy Agency 2021a; International Energy Agency 2021b). Current spending is at a fraction of this pace, particularly in EMDE. In 2022, global spending on clean energy systems is expected to be $1.4 trillion (International Energy Agency 2022), or around 30 percent of the investments needed, while for EMDE, excluding China, it was $150 billion in 2020 (International Energy Agency 2021a), or 15 percent of what is needed.

  This investment gap looks starker in relation to the size of the economies of these countries. McKinsey & Company (2022) estimates that the spending on physical assets for energy and land-use systems under the net-zero 2050 scenario could be 4.2 percent to 6.5 percent of GDP in advanced economies and China compared to 9.2 percent to 21 percent of GDP for countries in Asia, Latin America, Sub-Saharan Africa, North Africa, the Middle East, and the Commonwealth of Independent States.

> EMDE face a "climate investment trap" (Ameli et al. 2021) whereby climate-related investments remain insufficient due to a set of chronic self-reinforcing mechanisms, such as an underdeveloped and illiquid financial system and elevated country risks, leading investors to shy away or lend only at prohibitively expensive rates. Deteriorating fiscal balances due to the pandemic and the higher cost of capital due to rising interest rates are posing significant additional hurdles for governments around the world to finance the net-zero transition.

The fixed-income market presents a potential path forward to finance at least part of the investments needed for low-carbon infrastructures. There is room in the bond market from both the supply and demand sides to support the funding of sustainability projects. On the supply side, global fixed-income markets are the largest among liquid asset classes at $127 trillion as of 2021 (SIFMA Research 2022). On the demand side, investment mandates based on environmental, social, and governance (ESG) criteria are growing rapidly. According to one estimate, professionally managed assets with ESG mandates already amounted to $46 trillion at the end of 2021 and are expected to expand to $80 trillion by 2024 (Foster 2022). Moreover, bond markets can provide long-term financing to match the life cycle of infrastructure projects, while bank lending tends to be more expensive, illiquid, and of shorter maturity (Organization for Economic Cooperation and Development 2021).

Thematic bonds, in particular, are a useful tool that targets specific investment themes such as climate change mitigation and Sustainable Development Goals (SDGs) proposed by the United Nations, offering a market-based solution to the formidable task of financing the net-zero transition. Within the thematic bond asset class, green bonds, whose proceeds are earmarked to finance environmental projects, are the most prevalent. By demonstrating that EMDE green bonds trade with a premium, this study makes the case that there is room for increasing their supply from these economies and proposes policy recommendations to do so.

Section 1 provides an overview of the types of thematic bonds in the market that can help address the net-zero challenge in EMDE. Section 2 elaborates on the growth of this asset class in recent years and finds that the share of EMDE within the asset class remains low. Section 3 describes the methodology of this study to estimate EMDE green bonds premium. It's a model preferred by portfolio managers who specialize in fixed-income relative-value trading as well as many central banks. Using that model, in section 4, this study establishes that EMDE green bonds trade with a premium and discusses how this benefits issuers as well as investors. The final section offers policy recommendations to national governments and international development finance institutions working toward raising the share of EMDE within thematic bonds to help countries meet the challenge of financing the net-zero transition.

1. AN OVERVIEW OF THEMATIC BONDS

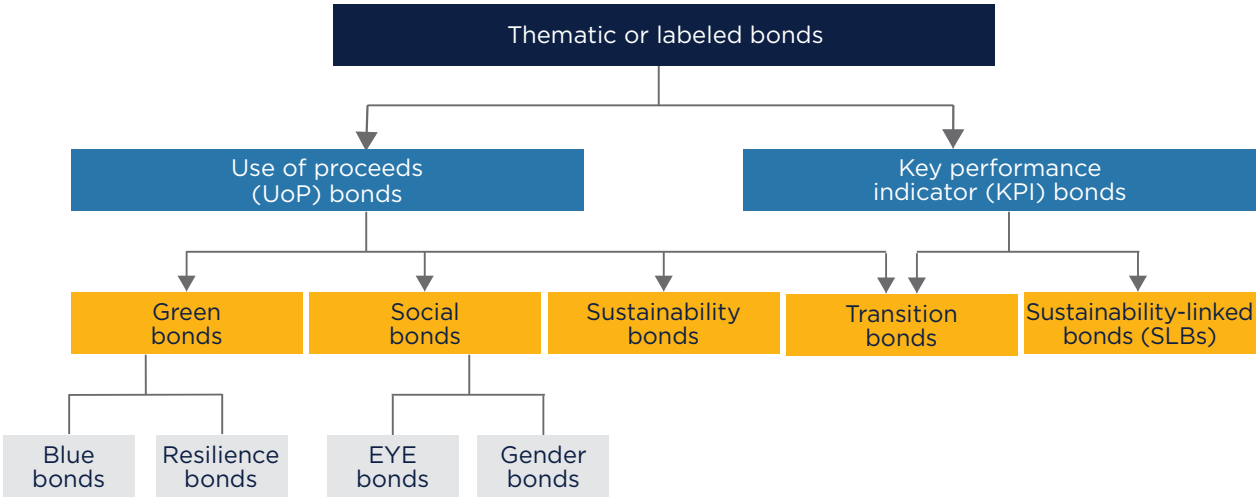
Thematic bonds, also referred to as labeled bonds,[3] are a recent financial innovation. The asset class originated in 2007 when the European Investment Bank issued a climate awareness bond. In 2008, the first green bond was issued by the World Bank in response to a request from a group of Swedish pension funds to find a way to invest in projects that helped the climate (World Bank 2019).

Although the first issuance was in 2008, lack of standardization remained a major hindrance to the development of the asset class. In 2014, the Green Bond Principles (GBP) were developed (International Capital Market Association 2022a) as a self-regulatory initiative designed to encourage transparency, disclosure, and integrity in the development of the market (Citigroup 2014). While these principles are not binding, they provide a harmonized set of guidelines for assigning, disclosing, managing, and reporting on the use of the proceeds from the issuance of a green bond. These principles addressed the risk of "greenwashing," at least to some extent, providing an impetus to the growth of the market for green bonds. As the demand and supply of green bonds increased, instruments with either different structures or objectives besides environmental sustainability were created, leading the asset class to expand beyond green bonds.

Broadly, thematic bonds can either be "Use of Proceeds" (UoP) type, which includes green, social, and sustainability bonds, or "Key Performance Indicator" (KPI) type, which includes sustainability-linked bonds. In addition, there are transition bonds that can either be UoP or KPI types of bonds (Figure 1).

- **UoP bonds:** As the name indicates, "Use of Proceeds" bonds differ from other fixed-income instruments in that the issuer of such bonds needs to specify how the capital being raised will be spent. The proceeds are thus ring-fenced or earmarked for projects that meet the specified purpose, such as climate sustainability or social issues
- **KPI bonds:** The proceeds of KPI bonds are not tied to any specific projects and there are no restrictions on how the proceeds are used as long as they meet prespecified goals, which in the energy transition context comprise sustainability or ESG objectives (Coldeweijer and Hsu 2021). Since the proceeds of KPI bonds are not ring-fenced, they are not subject to the same degree of scrutiny as UoP bonds. Therefore, to assure investors, their structures are typically designed to adjust the coupon rates upward or downward based on whether the prespecified objectives are met.

Figure 1: Types of sustainable bonds with subgroups



Note: This schematic is not comprehensive and attempts to include only those types of bonds that either have material amounts outstanding or are currently seen as potential areas of growth.

Source: Author's illustration.

The most prevalent UoP bonds are:

- **Green bonds:** The proceeds from green bonds are meant to be specifically utilized for eligible green projects with clear environmental benefits, including climate change mitigation and adaptation, nature and biodiversity conservation, and pollution control. To be aligned with GBP, the following core components need to be specified (International Capital Market Association 2022a):
  - Use of proceeds
  - Process for project evaluation and selection
  - Management of proceeds
  - Reporting

  GBP also recommends the establishment of green bond frameworks along with a pre-issuance second-party opinion and post-issuance third-party certifications to further assure investors. External reviews act as the fifth cornerstone for green bond issuance to add to the four components mentioned above. Several countries have developed green bond frameworks along these lines (Asian Development Bank 2021) with the European Union (EU) in the process of approving its own Green Bond Standard (EU GBS).[4]

  Projects covered by green bonds are usually targeted toward climate mitigation with financing for adaptation projects lagging. Resilience bonds were introduced as a

subset of green bonds with the specific goal of raising capital for climate adaptation and resilience investments (Climate Bonds Initiative et al. 2021). Similarly, at least until separate principles are released for them, blue bonds can be treated as a subset of green bonds with a focus on financing projects that contribute to ocean conservation, the health of the marine ecosystem, and coastal development (Inter-American Development Bank Invest and United Nations Global Compact 2021).

- **Social bonds:** The proceeds from social bonds are targeted toward addressing specific social issues by funding projects focused on basic infrastructure (e.g., clean drinking water, sanitation), affordable housing, food security, access to essential services (e.g., healthcare, education), employment, and equity. The Social Bond Principles (SBP) designed to achieve these outcomes mimic GBP (International Capital Market Association 2022b).

  Akin to green bonds, bonds targeting specific issues have sprouted in recent years as subsets of social bonds. Gender bonds fund projects to promote equal economic, business, and social opportunities for women by investing, for example, in women-led or women-founded businesses (Sacristán and Sentmat 2022). Similarly, EYE bonds direct funds toward education, youth, and employment (EYE) projects (Ryatt 2020). Other bonds under this category include health bonds, microfinance bonds, inclusive business bonds, and vaccine bonds.

- **Sustainability bonds:** There are instances when a social project can have environmental co-benefits or a green project can have social co-benefits. Moreover, sometimes it may be necessary to pool green and social projects together to meet a certain threshold in terms of the dollar amount for the bond being issued to finance them to reach a meaningful size. Sustainability bonds address such projects and should be aligned with the four core components of GBP and SBP cited above. Collectively, these core principles make up Sustainability Bond Guidelines (SBG) (International Capital Market Association 2021).

The most prevalent type of KPI bond is:

- **Sustainability-linked bonds:** As discussed earlier, the issuer of a sustainability-linked bond (SLB) commits explicitly to meeting certain environmental or social objectives, and the structure of the bond can vary depending on whether these predefined objectives are achieved or not. SLBs are therefore forward-looking performance-based instruments. International Capital Market Association (ICMA) has proposed Sustainability-Linked Bond Principles (SLBP) as a voluntary framework for issuers that has the following core components (International Capital Market Association 2020b):
  - Selection of KPIs along with the rationale for using the specific KPIs
  - Calibration of sustainability performance targets and the motivation behind them
  - Bond characteristics, including trigger events for changes in the bond structure
  - Regular reporting, preferably annual
  - Independent verification at least once a year

An important type of bond that can be either a UoP or a KPI is:

- **Transition bonds:** Since green bonds are designed to specifically finance projects that have already been deemed green, a hole is left for the financing of high greenhouse gas (GHG) emitting industries that want to transition to green.[5] AXA Investment Managers, an investor, first proposed the idea of transition bonds to fill this gap (Takatsuki and Foll 2019), which the ICMA followed by releasing its guidance for issuers of transition bonds (International Capital Market Association 2020a). However, the lack of a well-defined set of principles and no clear definition of which projects can classify as "transition" have led to confusion and disagreements even among companies providing second-party opinions.[6] Without further clarity in the definitions, there is a risk that this class of bonds—with the potential to finance the transition to net-zero emissions—may fail to gain traction.

2. EMDE'S LOW SHARE IN THE GROWING THEMATIC BOND MARKET

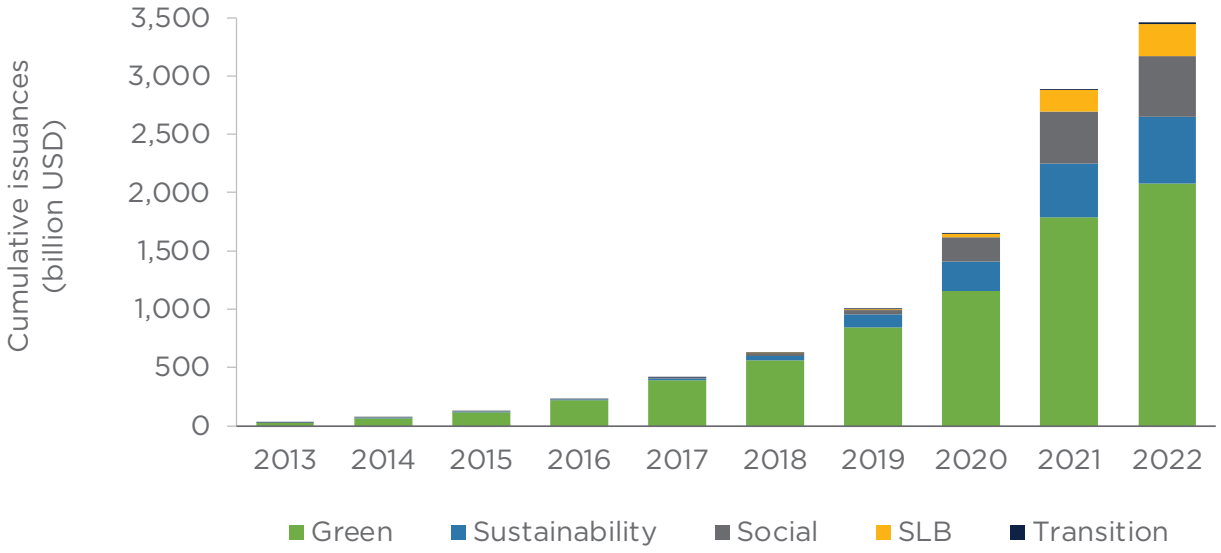
Growth of Thematic Bonds

In recent years, issuance has grown across all the main categories of thematic bonds (Figure 2). Total issuance for the asset class reached almost $3.5 trillion through July 2022 on the back of annual growth of 60 percent over the past five years.[7] In 2021 alone, $1.2 trillion of thematic bonds were issued, around three-quarters of which were meant for climate sustainability and low-carbon projects. Thematic bonds as an asset class will likely continue to grow with expectations as high as issuance of $5 trillion per year by 2025 (Climate Bonds Initiative 2021).

Making up 60 percent of the total, green bonds dominate among thematic bonds due to a combination of their first-mover advantage, the ease of identifying green projects as many countries are investing in renewable energy, and the lower perceived greenwashing risk that makes them appealing to investors. The popularity of green bonds also reflects the success of GBP as investors have come to rely on its key components, including the use of proceeds, second-party opinions, and third-party certifications. Although social and sustainability bonds are aligned with similar principles, it may be that investors either find it easier to quantify and measure the benefits of green projects in the form of lower GHG emissions (compared with the benefits from social projects) or they are simply prioritizing climate change as the most urgent issue.

While green bond markets have expanded at an annualized rate of almost 50 percent over the past five years, 2022 may turn out to be the first year with a small negative growth. At first glance, this is disappointing when compared to forecasts such as the Climate Bonds Initiative's projection of $1 trillion of issuance in 2022 (Climate Bonds Initiative 2021). However, in an environment of sharply rising global yields and high volatility of US rates, it's noteworthy that green bond and ESG funds have seen inflows even as conventional bond funds have experienced outflows (Duguid 2022).

Figure 2: Growth of the thematic bond market



Note: Data as of July 31, 2022.
Source: Bloomberg, Refinitiv.

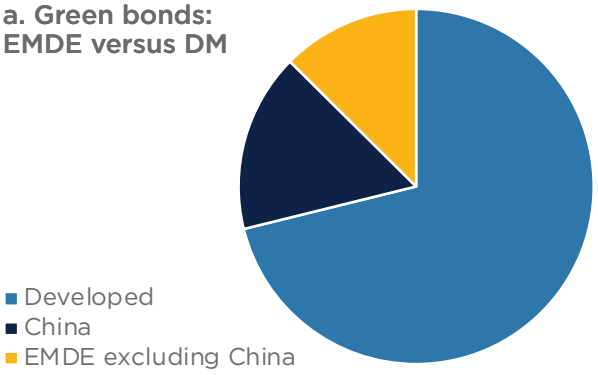
All indications are that the appetite for green bonds will remain strong. With the classification of nuclear energy as "green" under the EU taxonomy, the first EU nuclear green bond could be issued in the coming months (Ritchie and Martin 2022), following Canadaian Ontario Power Generation Inc.'s nuclear green bond issued in July (Duarte 2022). Similarly, on the heels of sovereign issuances by Poland, Chile, and South Korea, other nations including Singapore (Monetary Authority of Singapore 2022), India (Jena and Jain 2022), and Qatar (Mutua 2022) are contemplating or have announced their upcoming inaugural sovereign green bonds. The issuance of SLBs has also picked up in recent months. The flexibility provided by the structure of SLBs makes some issuers prefer these bonds. While issuers may have a proclivity to sell SLBs due to the fungibility of resources, investors continue to favor green bonds based on the issuance patterns, indicating a lower perceived greenwashing risk associated with green bonds.

EMDE's Low Share

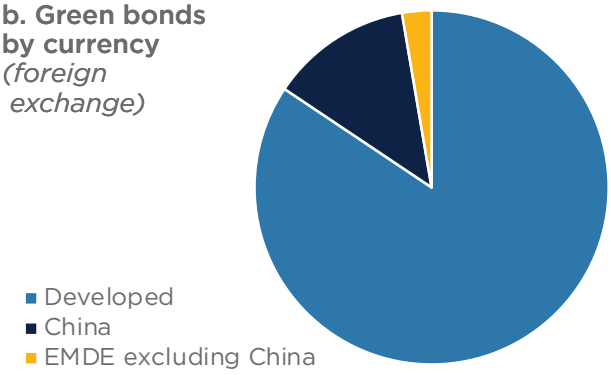
EMDE have benefited from the rapid increase in the thematic bond market. However, even as issuances from EMDE have grown, their share of the total has remained low (Figure 3). Excluding China, the total green bond issuance from EMDE has amounted to 13 percent of the global issuance to date (29 percent including China). The issuance in local currencies has been even smaller at 3 percent of the total. For social, sustainability, and sustainability-linked bonds, the EMDE share ranges from 15 percent to 22 percent (including China). The EMDE share of transition bonds is higher at 27 percent, but this is a small market.

Figure 3: EMDEs as a share of thematic bond issuances

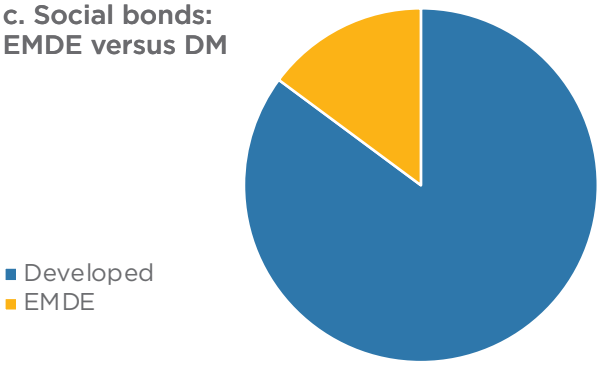
a. Green bonds: EMDE versus DM



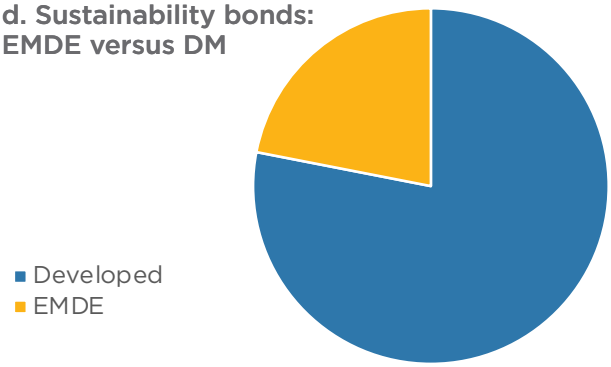
b. Green bonds by currency *(foreign exchange)*



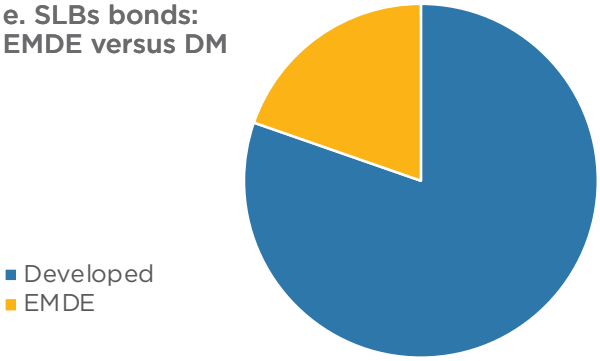
c. Social bonds: EMDE versus DM



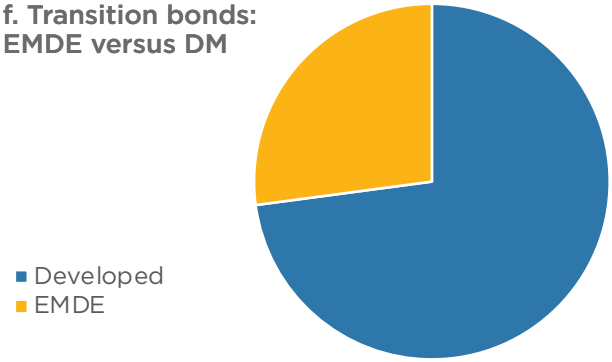
d. Sustainability bonds: EMDE versus DM



e. SLBs bonds: EMDE versus DM



f. Transition bonds: EMDE versus DM

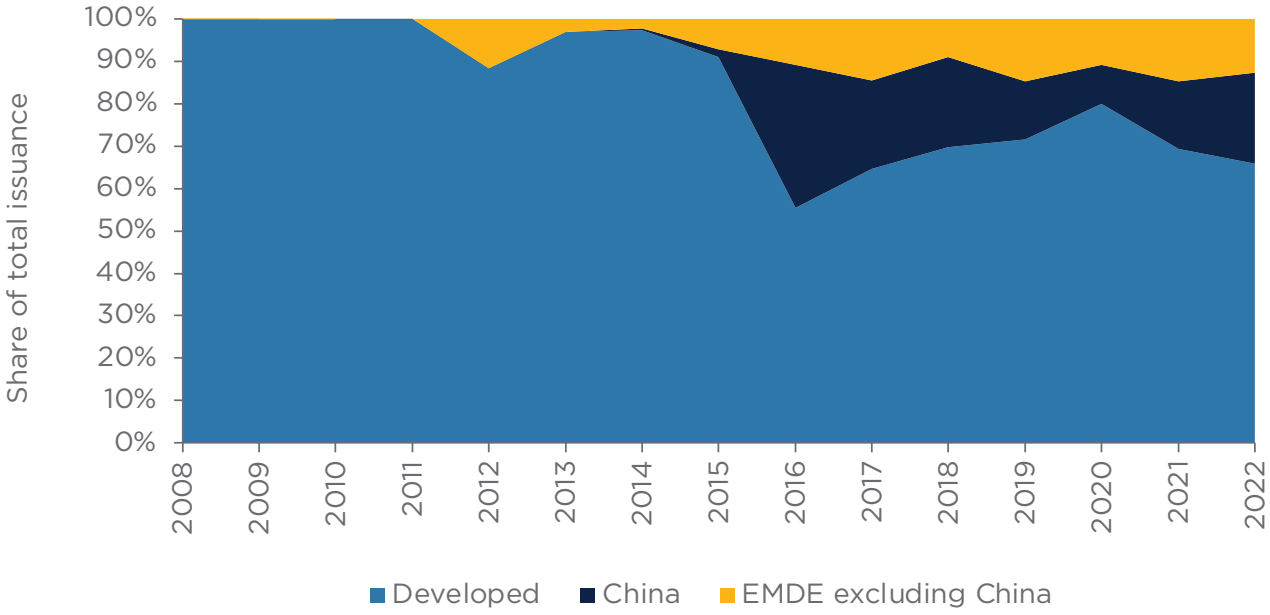


Note: DM refers to developed markets."Developed" includes multilateral development bank (MDB) issuances. Data as of July 31, 2022.

Source: Bloomberg, Refinitiv, author's calculations.

The share of EMDE in the global thematic bond market has not changed much with time. This is best exemplified by green bonds, which have been around the longest. With the notable exception of China (and Chile relative to the size of its debt market), the amount of issuances has been small, and the share for EMDE, excluding China, has plateaued in the 10–15 percent range of the total (Figure 4).

Figure 4: Share of EMDE (excluding China) in green bonds



Note: "Developed" includes MDB issuances. Data as of July 31, 2022.
Source: Bloomberg, Refinitiv, author's calculations.

Impediments to EMDE Issuances

While high indebtedness and elevated interest rates hinder bond issuances for some EMDE, for others the barriers are not insurmountable. As discussed below, EMDE thematic bond issuances are curtailed by a few supply-side issues and a mismatch between demand and supply when it comes to local currency bonds. Specifically, investors prefer to buy hard-currency bonds while EMDE have strong reasons for preferring to issue bonds in their local currencies.

As a result of the small share of EMDE bonds, the index coverage of emerging market green and other thematic bonds is small, especially in comparison with bonds issued by developed countries, and that in turn makes it harder for these countries to attract capital. The weight of emerging markets is just around 10 percent in the Bloomberg Barclays MSCI Global Green Bond index (Amundi Asset Management and International Finance Corporation 2022). JPMorgan Chase & Co. has a suite of ESG indices, or JESG, but they are not restricted to thematic bonds and are based on ESG scores of the components (JPMorgan Chase & Co. 2018). There are currently no dedicated indices for EMDE thematic bonds.

Impediments to EMDE thematic bonds issuances include the following:

- **Institutional complexity of setting up a green bond framework:** Chile stands out within EMDE for the variety and amounts of thematic bonds it has issued. Its issuances, denominated in both US dollars and Chilean pesos, amounted to $27 billion through July 2022, which is more than 70 percent of its outstanding external sovereign debt. In large part, that's because of its successful rollout and implementation of a green bond framework, which provides clear guidelines for the use of proceeds and definitions of green sectors and eligible green projects (Boitreaud et al. 2021). The country has since issued sovereign social, sustainability, and sustainability-linked bonds. An institutional framework like this is critical for the issuance of thematic bonds by governments and companies. But many struggle with the costs and complexities of establishing Green Bond Principles (or, equivalently, Social Bond Principles), adapted to a national context, as well as a taxonomy to assess sustainability projects that can be funded.

- **EMDE's reluctance to issue in hard currencies such as the US dollar or the euro:** Many emerging economies have suffered through balance sheet crises and weakening currencies—particularly in the 1980s and 1990s. They are well aware that if there are significant borrowings in foreign currency in the external market, a weakening currency increases the debt burden, leading to a vicious cycle with the domestic currency selling off and depreciating further. This is the "original sin" that EMDE try to avoid (Jeanne and Zettelmeyer 2002). But even if countries are not concerned about balance sheet crises, they may prefer to issue bonds in their own currencies to develop domestic debt markets. For now, almost the entirety of EMDE green bond issuances have been in US dollars or euros in response to investor demand (Figure 3), which is not ideal for EMDE and may be discouraging issuances.

- **Regulatory hurdles faced by foreign investors:** Accessing domestic markets customarily requires setting up a local account, which often can be an arduous endeavor, particularly in some emerging economies. In addition, many countries impose high taxes on interest income. Some may have capital controls in place, preventing access to the domestic market for foreign investors (Organization for Economic Cooperation and Development 2017). Such regulatory complexities can discourage foreign investors from buying EMDE local currency bonds.

- **Underdeveloped and illiquid domestic debt markets:** While taxation and regulatory complexity are common to capital markets in many countries, the problem is more complicated when the basic infrastructure for a domestic debt market to function is weak or insufficient, as in many least developed countries (UN Inter-Agency Task Force on Financing for Development 2021).

- **Perceived high monetary cost:** In addition to the indirect cost of setting up a thematic bond framework, there are nontrivial costs that UoP bonds entail for external reviews (Organization for Economic Cooperation and Development 2017), including second-party opinions and third-party certifications, which may discourage some issuers from pursuing this route unless they see equivalent savings.

As discussed in the next couple of sections, there are reasonable benefits—monetary and otherwise—that issuers can potentially derive from selling thematic bonds.

3. GREEN BOND PREMIUM IN EMDE: EXPANDING ON CURRENT LITERATURE

Select Literature Review

Before describing the methodology used in this study, it will be helpful to summarize findings from a select literature review on thematic bond premium. One literature review (MacAskill et al. 2021) finds that 56 percent of primary and 70 percent of secondary market studies confirm the existence of a green bond premium. Additionally, there appears to be strong evidence that investors reward green bonds when issuers appoint independent external reviewers (Simeth 2022; Dorfleitner et al. 2021; Hyun et al. 2021). External reviews can take the form of verifications, second-party opinions, and certifications from accredited third parties.

Studies in the literature are inconclusive on whether green bonds trade at a premium—sometimes referred to as "greenium." Methodological differences and analyses of disparate markets in different studies have contributed to this ambiguity. Most studies that have estimated green bond premiums have used either pairwise comparisons or econometric models with control variables to account for bond and issuer characteristics.

- **Pairwise comparisons:** These studies compare a green bond with a conventional bond from the same issuer with similar characteristics—most importantly, maturity. Frequently, a green bond's yield or spread is compared with the interpolated yield or spread of two conventional bonds to match the maturity of the green bond. Some studies, using different types of pairwise comparisons, estimate that green bonds trade with a premium (Dorfleitner et al. 2021; Partridge and Medda 2020; Löffler et al. 2021; Zerbib 2019), while others find no evidence of green bond premium in their analyses (Flammer 2021; Larcker and Watts 2020; Hyun et al. 2020).
- **Econometric models:** These studies typically use regression models with a host of control variables to sort out bonds from large databases that are most comparable to each green bond in the sample. The idea is to estimate the premium by regressing the yield or spread on various bond and issuer characteristics, such as maturity, ratings, sector, currency, etc. For example, a study by the US Federal Reserve, Caramichael and Rapp (2022), shows that, on average, green corporate bonds have a yield spread 8 basis points lower than conventional bonds in the primary market with the premium concentrated in large, investment-grade issuers in the banking sector and developed economies. But in an IMF study, Ando et al. (2022) obtain contrasting results as they find that green bonds from emerging market sovereigns trade with a premium of 12.5 and 49.3 basis points for euro- and dollar-denominated bonds, respectively, which are higher than the premium they find in advanced economies. The estimated premiums vary widely even among other studies that validate its presence (Koziol et al. 2022; Immel et al. 2021).

These variations can be partly explained by differences in the historical period and segment of the market analyzed—country, currency, rating (investment grade or high

yield), and sovereign, corporate, or municipal bonds. Above all, a significant differentiating factor affecting the findings is the methodology used to estimate green bond premiums. Both approaches have certain drawbacks when one considers how bonds can trade idiosyncratically based on a number of factors.

Studies based on pairwise comparisons compare a green bond with a conventional bond under the implicit assumption that the latter is trading at its "fair" yield. This assumption may often not hold for idiosyncratic reasons. For example, if a bond is included in an index that is popular as a benchmark, then it can trade at a lower yield than bonds of the same issuer not included in the index. Similarly, comparing green bonds with conventional bonds issued on the same day by the same issuer may seem reasonable, but it is plausible that investors may be seeking bonds of that particular maturity (typically, 10-year maturities are sought after). As such, both the green bond and the conventional bond that it's being compared to may be trading with a premium, but comparing one to the other will lead to the false conclusion that the green bond does not trade with a premium.

The regression modeling approach attempts to correct some of these limitations by using a large sample of conventional bonds to compare with green bonds, which minimizes the impact of each bond's unique and distinctive characteristics. But the considerable variations across different econometric studies show that the results are highly sensitive to model construction and the assumptions regarding the control variables to use. Moreover, some variables may be difficult to quantify and cannot be controlled even though they affect a bond or a credit. To complicate it further, bonds of a credit may temporarily trade idiosyncratically based on market developments and the macroeconomic environment, making it a non-trivial exercise to control for all such possibilities.

Applying the Practitioners' Model to EMDE

This study expands on the current literature by adopting an approach used by market participants, including portfolio managers who specialize in fixed-income relative-value trading, in evaluating if bonds are trading "rich" or "cheap" along the yield curve.[8] Such a model entails finding the best-fitting parametric curve to available bond yields using iterative optimization methods, and then bonds are judged to be "rich" or "cheap" by comparing their yields to the "fair" yield implied by the curve. In this class, the Nelson-Siegel model (Nelson and Siegel 1987) and the extension proposed by Svensson (1995)—known as the Nelson-Siegel-Svensson (NSS) model—are used extensively (Appendix 1). Central banks around the world also deploy these models, including the Bank of France, Deutsche Bundesbank, and the Swiss National Bank to name a few (Bank for International Settlements Papers 2005).

The NSS model was adapted for this analysis in the following way:

1. **Estimate the premium in a deterministic fashion as the difference between the observed yield of a green bond and its "fair" yield derived from the issuer's best-fitted yield (or spread) curve.** Once a curve is fitted across the yields (or spreads) of an entity's bonds, it is then used to compute the "fair" yield based on the duration of any given bond. If the "fair" yield of a bond is higher than its observed yield, then the bond is considered to be trading at a premium or trading "rich" to the curve, and vice versa.

2. **Analyze green bonds premium specifically for EMDE.** Except for the IMF study cited above, all others focused on either different segments of the market or did not differentiate for emerging markets. The estimate of the average premium in this study (section 4) differs from the findings of the IMF study, which uses a regression model.

3. **Adjust to a peculiarity specific to emerging market bonds whereby low-dollar priced emerging market bonds trade with a premium while high-dollar bonds trade with a discount.** As the probability of default is higher in emerging markets than in developed countries, investors are willing to pay a premium to incur a smaller loss in the event of a default. The loss suffered in the event of a default by a bond investor would be the difference between the price paid and its recovery value; the lower the purchase price, the lower the loss. As a result, the demand for low-dollar priced EMDE bonds tends to be greater than for high-priced bonds.[9] To address this specific idiosyncrasy, "DV01," or the dollar value of a basis point was used in this analysis, instead of duration when plotting the yield curve.[10] The DV01 of a bond corrects for the dollar-price issue since it incorporates the price and is, therefore, a better measure of its risk.

4. **Study social, sustainability, and sustainability-linked bonds, in addition to green bonds, to see if they trade at a premium or not.** Since these types of bonds are relatively new, there are few, if any, studies on the subject. Comparing and contrasting these bonds with green bonds in emerging markets leads to useful conclusions for policymakers.

To ensure the robustness of the analysis, only liquid emerging market sovereign and quasi-sovereign entities with enough bonds to fit a curve and with a reliable and long enough price history were included. The data set consists of the following:[11]

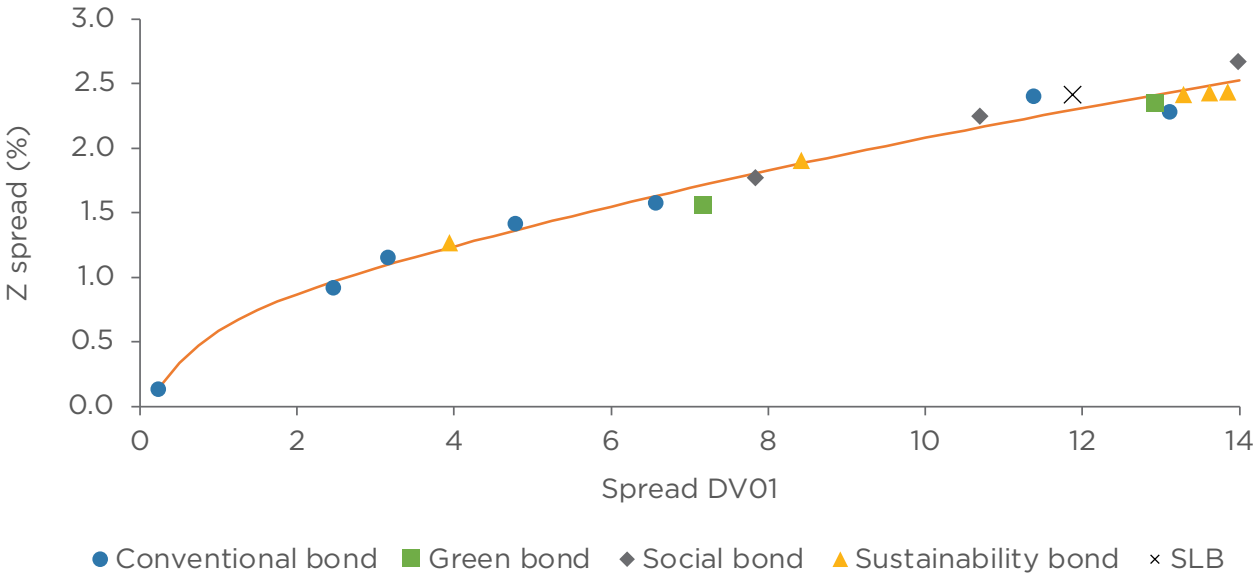
- Emerging market sovereigns and quasi-sovereigns[12] since these bonds are typically more liquid than corporate bonds.
- Curves with at least five bonds (including the green bond) outstanding. If there are fewer than five bonds on a curve, then it can suffer from the same shortcoming as the pairwise comparisons approach.
- A minimum size of $350 million (even if the bond is denominated in a different currency) for the thematic bond under analysis as a threshold for liquidity.
- Entities with at least six months (or 120 business days) of price, yield, and duration history available on Bloomberg for thematic bonds.[13]

To be able to use all bonds possible in the analysis, the approach had to adjust based on the currency as follows:

- For the hard-currency bonds, this analysis used "Z Spreads," which is the spread of a bond's yield over the swap curve in either the US or EU, depending on whether it is a dollar- or euro-denominated bond.[14]
- For local currency bonds, yields to maturity were used since they are a function of the macroeconomic dynamics of a country, particularly the monetary policy approach taken by the central bank.

As an illustration of the approach, the spread curve in Chile at a snapshot in time with an NSS model fitted to the country's US dollar bonds shows green bonds trading at a premium, unlike most other thematic bonds that trade fair or cheap to the curve (Figure 5). The NSS model is fitted historically for each day to the data set of thematic bonds described earlier. This resulted in a large sample of observations per bond, making the outcome statistically significant.

Figure 5: Chile's sovereign spread curve (USD) fitted using the Nelson-Siegel-Svensson model



Note: Data as of August 3, 2022.
Source: Bloomberg, author's calculations.

4. EMDE THEMATIC BOND PREMIUM AND ITS BENEFITS

As of July 2022, the full universe of green bonds issued by emerging market sovereigns and quasi-sovereigns amounted to $57 billion across 105 bonds, based on Bloomberg data. The constraints imposed by the chosen model resulted in a sample of 30 bonds amounting to $34 billion, or 60 percent of the total. The included bonds (Appendix 2) are diverse, comprising 10 EMDE spanning Latin America, Eastern Europe, the Middle East, and Asia, with denominations in five currencies. Fitting yield-DV01 curves, historically for each entity in the sample, led to nearly 15,000 total observations across all bonds, making the conclusions statistically significant.

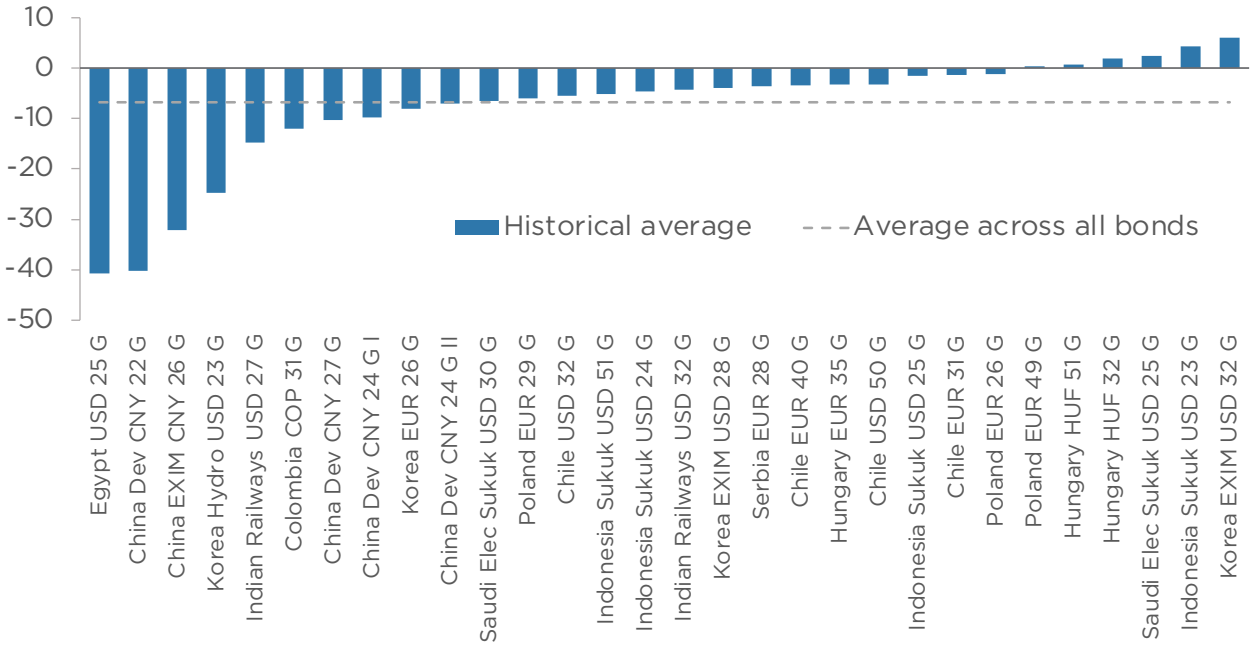
Do EMDE Green Bonds Trade with a Premium?

The results confirm that EMDE green bonds trade with a premium. The average premium across all the bonds is 7 basis points, with 24 out of 30 bonds in the sample trading with a premium in the secondary market on average (Figure 6, top). Specifically, a premium is seen in 73 percent of the total observations across all bonds. This analysis includes one-tailed t-tests (Stölzle and Gałkiewicz 2020), both at the bond level (Appendix 2, Table 1) and for the overall sample, to accept or reject the null hypothesis that the bonds don't trade with a premium.[15]

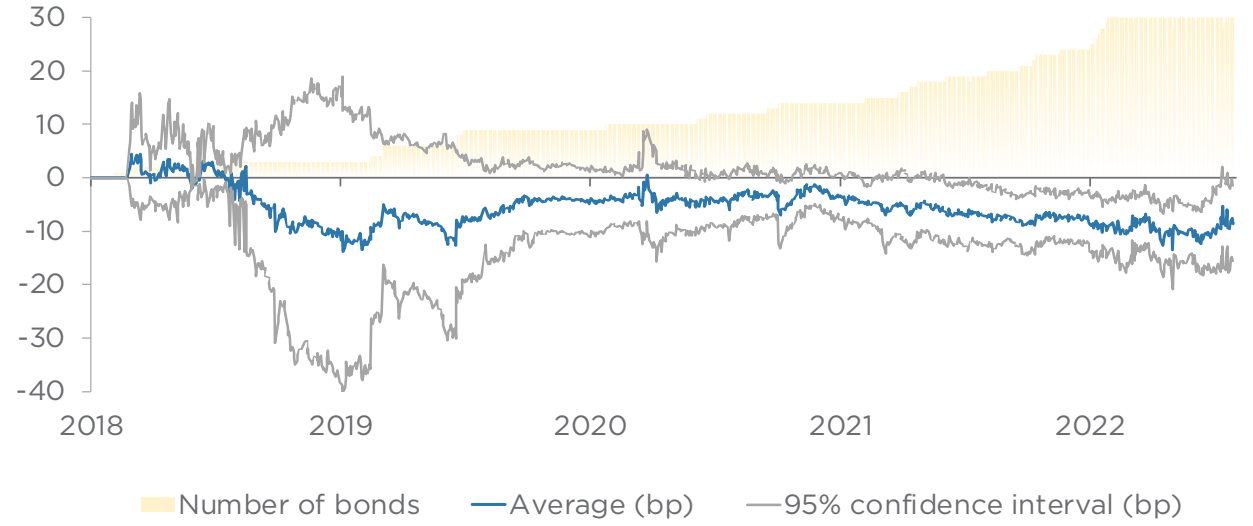
The null hypothesis is rejected for the overall sample (along with 24 out of 30 bonds) at the 0.01 significance level leading to the conclusion that green bonds in emerging market sovereigns and quasi-sovereigns have historically traded with a premium on average in the secondary market. Moreover, since 2021, as more bonds were issued, the confidence interval around the estimated premium narrowed, contributing to a more decisive conclusion. The premium increased during this period from close to flat to 9 basis points (the 95 percent confidence interval is 1 basis point to 16 basis points of premium) at the end of July 2022 (Figure 6, bottom).

Figure 6: EMDE sovereign and quasi-sovereign green bonds' premium

a. EMDE green bonds' premium/discount



b. EMDE green premium evolution



Note: A negative value signifies a premium. Data as of July 31, 2022.
Source: Bloomberg, author's calculations.

The gradual increase in the premium since early 2021 is likely explained by growing awareness among investors adapting to green bonds alongside an increase in assets benchmarked to green bond indices or directed toward green bonds because of ESG mandates. The supply of green bonds from emerging markets has increased since 2021 with more bonds getting added to the pool. But more pointed policies are needed to further expand the market as discussed in the final section of this report.

For EMDE green bonds, an argument can be made that increased issuance over time should eventually lead to the creation of EM-specific indices (Jain 2022), which in turn should mean more investments directed toward these indices. If so, then the premium can persist or potentially even increase.

Do Other Thematic EMDE Bonds Trade with a Premium?

To compare and contrast with green bonds, this study also analyzes the historical performance of other thematic bonds issued by EMDE by applying the same approach and assumptions to social, sustainability, and sustainability-linked bonds of emerging sovereigns and quasi-sovereigns.

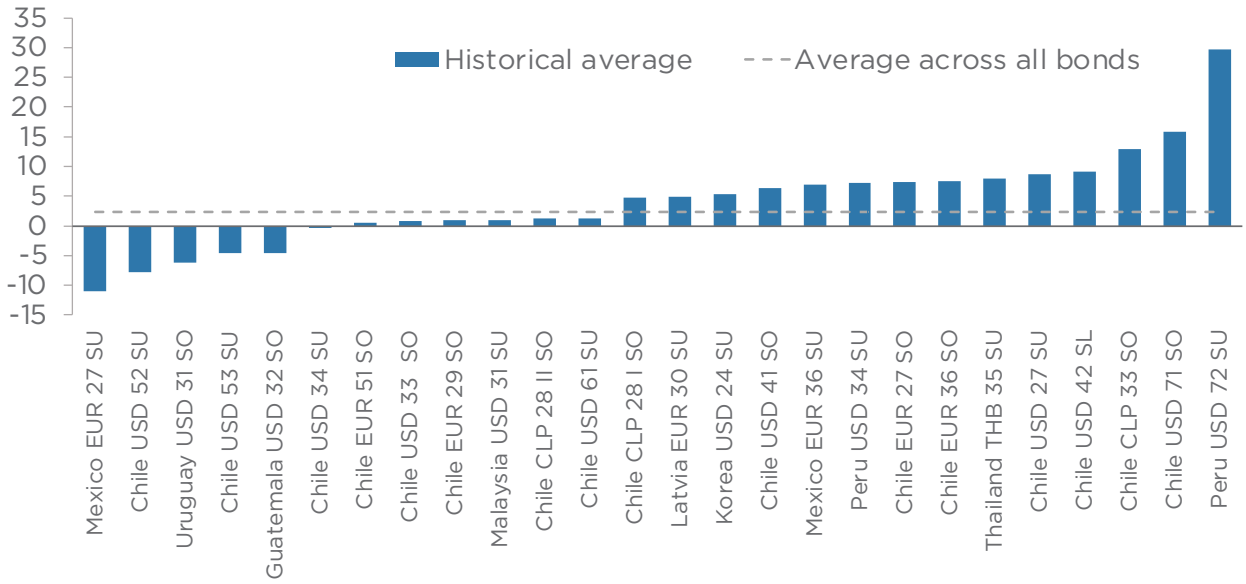
As of July 2022, the overall universe of emerging market sovereign and quasi-sovereign social, sustainability, and sustainability-linked bonds amounted to $88 billion across 261 bonds, based on Bloomberg data. Many social bonds are issued in small sizes for specific projects, making them too illiquid for this analysis. The constraints imposed in the analysis resulted in a sample of 26 bonds across nine countries from Latin America, Eastern Europe, and Asia in four currencies. Even though the number of bonds is small, the sample covers $41 billion or close to half of the total outstanding amount. The list of bonds (Appendix 2, Table 2) is dominated by Chile, a leader in issuing different types of thematic bonds.

The analysis shows that, unlike green bonds, social, sustainability, and sustainability-linked bonds in emerging markets, on average, don't trade with a premium. These bonds have traded with a discount of two basis points on average, with only 5 out of 26 bonds historically trading with a premium (Figure 7, top). A premium is observed in 37 percent of over 8,000 total observations across all bonds, and the conclusion is drawn that the null hypothesis of the one-tailed t-test that the bonds don't trade with a premium cannot be rejected (Appendix 2, Table 2).

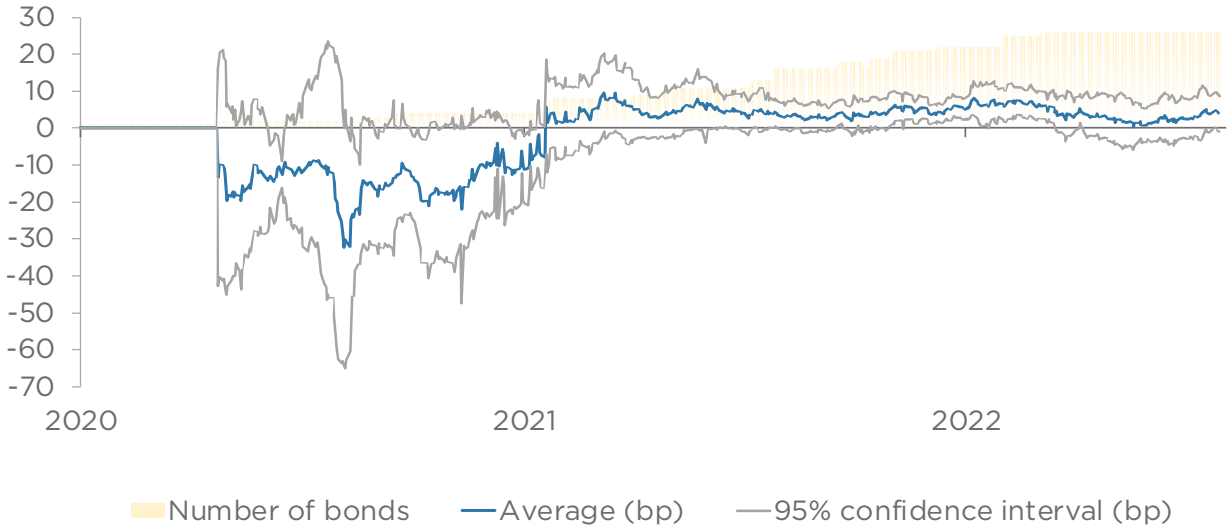
Moreover, since early 2021, the bonds collectively have not traded with a premium (Figure 7, bottom). In 2020, they had traded with a premium, but the sample size was small as is evident from the wide confidence interval during this period. Looking ahead, these bonds may trade with a premium as awareness grows, similar to green bonds. If specific indices are created for each category of thematic bonds, then their demand could grow, potentially leading to a premium. Regardless, these bonds will continue to help issuers access funding for specific projects (in the case of social and sustainability bonds) or to meet key sustainability or social targets (in the case of SLBs) and widen their pool of investors for borrowing.

Figure 7: EMDE social, sustainability, and sustainability-linked bonds' discount

a. EMDE social, sustainability, and sustainability-linked bonds' premium/discount



b. EMDE social, sustainability, and sustainability-linked bonds' premium evolution



Note: A negative value signifies a premium. SO refers to social bonds, SU to sustainability bonds, and SL to sustainability-linked bonds. Data as of July 31, 2022.

Source: Bloomberg, author's calculations.

A limitation of the approach used in this study is that it analyzed the premium in the secondary market but from an issuer's standpoint, whether a bond trades with a premium or not is more relevant in the primary market. The study refrained from analyzing bonds in the primary market for two reasons. First, the number of observations will be limited as it will be one per bond. Second, more importantly, correctly analyzing whether a bond was issued with a premium or discount needs the prices of all the bonds on the curve at the precise time of issuance. Using closing prices leads to inaccurate and misleading assessments since the curve adjusts pre-issuance and post-issuance based on how well or not the new bond is initially perceived and later received by investors.

Nevertheless, the green bond premium that this study demonstrated in secondary market trading is in line with anecdotal observations in the primary market. For example, the green bond issued by Colombia in pesos in late 2021 achieved a premium of seven basis points (Amundi Asset Management and International Finance Corporation 2022).

Benefits of the Green Bond Premium

EMDE green bonds premium is indicative of their demand overwhelming supply, leading to the bonds trading "rich" relative to other bonds of the same issuer, even though they are pari passu with each other (i.e., the bonds will be treated the same in the event of a default). Specifically, the strong investor appetite for green bonds along with their better risk-adjusted returns are important drivers behind the premium. Indeed, the advantages perceived by investors outweigh the overhang of buying a bond that trades expensive to the curve.

A consistent premium in EMDE green bonds is mutually beneficial to investors and issuers for reasons elaborated below.

Investors' Perspective

The strong investor demand for green bonds stems from:

1. **Increasing ESG mandates.** The number of funds with ESG mandates and those benchmarked to green bond indices is burgeoning. Green bonds that raise funding for low-carbon climate-resilient projects and regularly report on the progress, along with external reviews and certifications, are a good fit for most such funds as they need relatively less due diligence from investors. A recent survey (Climate Bonds Initiative 2022) reports that in the second half of 2022, two-thirds of the green bonds were allocated to investors who described themselves as green or socially responsible. Although EMDE bonds are at a disadvantage due to the low ESG scores for these countries and low allocations from ESG funds (International Monetary Fund 2022a), the green bond premium indicates that they are still benefiting from the proliferation of ESG mandates.

2. **Green bonds' value as signaling tools.** An investor survey found that the demand for green bonds can stem from reasons even when the expected financial benefits are not direct or explicit (Maltais and Nykvist 2020). Investments in green bonds can be a signaling tool for an asset manager by communicating their sustainability contributions to stakeholders and may even attract desired skilled employees to the company.

3. **Better risk-adjusted return.** Based on bid-offer spreads and trading volumes, green bonds may no longer be less liquid than conventional bonds (Febi et al. 2018). And even if there is a perceived lack of liquidity, it may not weigh on the performance of green bonds. Green bonds are typically bought by long-term investors such as pension funds (Doronzo et al. 2021; Flammer 2021) who do not respond to market fluctuations and may perform better during market upheavals. The smaller float of the bond may make it more difficult to borrow it in the repo market to short sell. This characteristic of the bond may lead some investors to prefer green bonds for their lower perceived mark-to-market risk and lower volatility, leading to better risk-adjusted returns.

Issuers' Perspective

The green bond premium could be an incentive and a catalyst for further issuances from EMDE. Along with investors, issuers benefit in the following ways:

1. **Cost savings.** The average green bond premium of seven basis points for emerging market bonds estimated in this study could help offset the costs associated with external reviews and certifications, even if issuers capture it only partially. Second-party opinion costs could be around 0.2–0.3 basis point for a EUR 1 billion bond issue (CICERO 2022) while validation by a certified auditor adds approximately 0.1 basis point (MacAskill et al. 2021). Although the post-issuance external reviews are less common, assuming these costs are borne annually, the combined costs of second-party opinions and third-party certifications should amount to around 0.5 basis point per year, far below the average premium observed in this study.

2. **Room for supply to grow.** With the demand remaining robust in the upcoming years, the supply can keep pace. While the supply of green bonds has increased in recent years, the total size of the market (around $2 trillion) is still a tiny fraction of the fixed-income market ($127 trillion). This "scarcity" value of green bonds is evident from the observed oversubscriptions of green bonds at the time of issue (Siswantoro 2018). In other words, there is significant room for green and other thematic bonds to be used for financing the net-zero transition.

3. **Improved credit outlook.** Issuing a green bond can potentially improve the long-term credit outlook of the issuer relative to those that issue only conventional bonds in the eyes of investors for the following reasons:

    - *Independent external reviews and periodic reporting, based on GBP, keep issuers focused on their environmental commitments*. According to the "green bonding hypothesis," a green bond acts as a commitment device with issuers who subject themselves to increased scrutiny following the issuance (Lu 2021). Failure to deliver on the green projects that an issuer pledged to could attract unnecessary media and investor attention, which may in turn lead to consequences, such as an exchange delisting the bond from its sustainable or green bond segment or portfolio managers exiting from investments related to the issuer.

    - *Increased spending on sustainable development based on the use of proceeds of green bonds may improve the long-term viability and, therefore, growth prospects*

of a company or sovereign. To be sure, there are concerns about "greenwashing" because investors cannot legally enforce the use of proceeds conditions laid out in the GBP. But external reviews can help to mitigate that risk. One empirical analysis shows issuers displaying a drop in carbon emissions after borrowing via green bonds with the reduction greater for issuers that engage in external reviews (Fatica and Panzica 2020).

Indeed, all the bonds—not just green bonds—of an issuer are likely to trade with a lower risk premium relative to industry peers with similar credit profiles except for borrowing in the green bond market because of the so-called "green halo" effect. All thematic UoP bonds, not just green bonds, could lower the risk perception of their issuers.

5. PATHWAYS TO INCREASING EMDE THEMATIC BOND ISSUANCES

With investors and issuers both benefiting from thematic bonds, and in particular green bonds, below are some steps federal governments and development banks can take to expand this market for EMDE. These are high-level recommendations intended to spur further research and policy discussions.

Policies for National Governments to Consider

Federal governments in emerging economies can play a more active role in boosting the domestic thematic bond market to finance sustainability projects that help meet their net-zero pledges. Below are some steps to consider:

- **Create an institutional thematic bond framework.** To enhance transparency and integrity in the thematic bond market, national governments need to develop green and social bond frameworks, along with delineating detailed taxonomies of projects that can fall under these categories, even if there is no intention to issue sovereign thematic bonds. Green Bond Principles and Social Bond Principles help to gain investor confidence, even if they are tweaked or adapted to a national context. A prescribed taxonomy helps both companies and investors identify projects that fall under sustainable or social activities, thus reducing the risk of greenwashing. Two tracks to consider when labeling a bond is the eligibility of projects and the integrity of the issuer's internal systems and controls (Asian Development Bank 2021). Implementing these steps may require the creation of joint committees consisting of government representatives from ministries covering finance, environment, energy or power, and transportation among other areas. Issuers report that the effort for labeling a bond is significant the first time but much easier for later issuances (Asian Development Bank 2021). An inaugural sovereign bond can act as a benchmark for domestic companies. But even if a country does not issue sovereign thematic bonds, creating frameworks and taxonomies will make it easier for its corporate and financial institutions to issue thematic bonds.
- **Realize savings using bond structure.** As discussed earlier, the actual cost of second-party opinions and third-party certifications can potentially be covered by the green bond premium. Capturing the entire premium in the primary issuance is difficult, though, since lowering the yield appreciably at issuance may reduce the bond's demand. As an alternative, issuers could embed changes to the bond structure, such as the step-down coupon feature Uruguay recently added to its first sovereign sustainability-linked bond (Inter-American Development Bank 2022). In other words, issue a green bond at a yield that matches a conventional bond with the same duration—with a step-down feature attached to the coupon that kicks in after each successful external review. On average, this should lead to a coupon lower than that of a similar conventional bond by the expected premium estimated to be in the 5–10 basis points range.

- **Consider green signaling benefits.** Even if the green bond–related additional expenses are not covered in full by the cost savings for an issuer, it still offers the possibility of attracting a new set of ESG-focused investors to help diversify the pool from which to borrow. The green signaling benefit of green bonds can potentially improve the credit profile of the issuer and therefore result in an overall lower issuance cost across all bonds.

- **Plan tax incentives.** Colombia is a recent example of a government stimulating demand for domestic bonds by lowering taxes on interest income (Medina and Jaramillo 2021). Policymakers should consider if lowering the withholding tax can increase investors' appetite for buying local bonds, as well as how to offset any loss of tax revenues. One approach to address this issue could be to introduce tax incentives specifically for holding green bonds. Lowering the tax rate on the coupons of a green bond has been shown to meaningfully increases its demand among investors (Agliardi and Agliardi 2019). The loss of the tax revenue can potentially be made up if the perceived credit risk of the issuer drops as a result of the green bond issuance, as discussed earlier, resulting in savings via a lower issuance cost.

- **Reduce regulatory complexities facing foreign investors.** Accessing domestic markets typically requires setting up a local account in addition to facing other, sometimes prohibitive, requirements. Such regulatory complexities can discourage foreign investors from buying domestic bonds. Alleviating the regulatory process is an obvious solution but may not be straightforward to implement for a government. A promising short-term solution adopted by several emerging countries—including Brazil (United States Securities and Exchange Commission 2007)—in the 2000s was to issue global bonds that were denominated in local currencies but settled in dollars or euros (including the coupon and principal payments) in an overseas clearing exchange (Jain 2022). A similar approach could be used for thematic bonds issued in local currencies if access to the domestic market is a bottleneck.

- **Issue benchmark-sized bonds to facilitate inclusion in indices.** Getting a bond added as a member of an index can help drive capital to a country. However, the index coverage of emerging market green bonds is small. Many criteria are important for a bond to be included in an index. Among the most common are the size of the bond, its accessibility by investors, and the credit ratings of the issuer. Achieving credit ratings above a threshold is particularly challenging for many EMDE. However, when that is not a binding constraint, the other criteria can be addressed. To reach a sufficient size to be included in an index, it may make sense to issue fewer bonds but with a wider coverage of projects. Even if there is no minimum bond amount requirement, if the bond size is insignificant relative to the size of all the bonds in the index, then investors are less likely to be interested in the bond and treat it as part of their tracking error with the index. Improving investor accessibility and reducing regulatory hurdles in the domestic bond market, as discussed earlier, also help with index inclusion.

  As the issuances of thematic bonds from EMDE pick up, their weight in global indices and the potential for dedicated indices should grow, leading to increased

demand. A virtuous cycle can then play out with EMDE bonds absorbed by investors benchmarked to green bond indices incentivizing more issuers to create green bond frameworks and borrow in the green segment of the fixed-income market, which in turn leads to an increase in the weight of EMDE in these indices.

Steps for Development Banks to Consider

Multilateral development banks (MDBs) and development finance institutions (DFIs) have been playing a critical role by lending directly to EMDE at favorable rates to lower the cost of capital for financing the net-zero transition. Since loans are not scalable, nor do they engage private investors, development banks may be able to make a bigger impact by enhancing ongoing efforts to help the EMDE thematic bond market grow. But doing so may require an increase in the institutions' risk appetite and ingenuity in tailoring solutions for specific countries.

- **Help create thematic bond frameworks.** Multilateral institutions such as the World Bank have helped countries set up green bond frameworks, including providing technical support for Seychelles's first blue sovereign bond and Egypt's inaugural green bond (Organization for Economic Cooperation and Development 2021). EMDE that cannot create such frameworks on their own would benefit tremendously from institutional counsel and guidance.

- **Facilitate growth of the market using blended financing and structured financing approaches.** On average, only a third of the resources that multilateral development banks commit to EMDE are currently matched by private capital (Li et al. 2022). One approach to address this is for national development banks and multilateral financial institutions to play an important role in increasing EMDE thematic bond issuances while helping emerging markets address deficiencies in their capital markets.

  First, there could be a ramp-up of efforts already underway, such as:

  - *Harmonizing the mandates, strategies, objectives, and operations of public development banks with SDGs* (Organization for Economic Cooperation and Development 2021), which would align incentives to encourage greater thematic bond issuances.

  - *Using a blended financing approach by providing credit enhancements* in the form of a guarantee on the principal or taking the first-loss tranche as they have the added benefit of attracting private funding (Organization for Economic Cooperation and Development 2021; International Monetary Fund 2022a). The way the guarantee is accounted for is important because if it is not treated very differently from a loan, then the institution's balance sheet is not being used effectively since the guarantee may never be used. It may be better to use a dynamic risk-adjusted approach that incorporates the changing probability of default of the credit receiving the guarantee, which may then free up part of the amount locked up for the guarantee to be used up for other purposes. Unless the balance sheet is leveraged while managing the related risks, the scale of this approach will be limited.

- *Providing technical assistance and buying local currency thematic bonds as anchoring investors* (Organization for Economic Cooperation and Development 2021). This encourages other private investors to participate as well, alongside the overall development of the domestic debt market. Depending on the amount bought as the anchoring investor (i.e., the ratio of private capital brought in over the institution's resources used), this approach may be a better utilization of the balance sheet.

Second, there is a need to consider new approaches, such as those focused on:

- *Addressing the local currency risk.* Multilateral development banks are helping to encourage local currency issuances. For example, the International Bank for Reconstruction and Development has issued sustainability bonds denominated in Rwandan franc, Kazakh tenge, and Georgian lari. They can go further by encouraging the involvement of foreign investors with an appetite for emerging market thematic bonds (Kim 2021) but who are wary of bearing the local currency risk. MDBs have an opportunity to conceptualize new, innovative approaches using structured finance to address the mismatch between the investor demand for hard-currency bonds and issuer preference to sell local currency bonds. For example, they can act as intermediaries so that issuers can sell green bonds in local currencies with a fixed coupon rate, while investors receive a fixed coupon rate in dollars or euros as if they invested in a hard-currency green bond. The multilateral institution, in such a structure, takes the currency risk but not the credit risk of the issuing sovereign or company. It can reduce currency risk by diversifying across many countries or by hedging it, where feasible. With an appropriate portfolio management approach, this could be cheaper than providing direct loans to emerging countries and a more effective use of an MDB's balance sheet. This is a way for institutions to help scale up and impact a greater number of green projects in EMDE while developing domestic markets and engaging foreign investors. With MDBs on average attracting only a fraction of private finance relative to their resources, there is a need for structured finance approaches like these to leverage their resources further.

CONCLUSION

This report highlights the urgent need for financing the low-carbon transition in EMDE and proposes a path forward by honing in on the thematic bond asset class, which has the potential to grow to become one of the key sources of this funding. It establishes that EMDE green bonds trade with a premium, making them particularly attractive to investors and issuers. Despite the premium, the share of EMDE within the thematic bond asset class remains low because of the institutional complexity of setting up thematic bond frameworks and underdeveloped and illiquid markets in some countries. More work needs to be done by policymakers to help grow the allocation of EMDE within thematic bonds. An important goal of future research should be to focus on more detailed recommendations for EMDE governments and development banks interested in boosting the EMDE thematic, and especially green bonds, market.

APPENDIX 1—YIELD CURVE MODELS

Models for fitting curves to yields of bonds with different maturities have evolved over the years from using simple polynomial splines (Moulin 2018). A theoretically appealing class of models is based on the principle of no arbitrage. Vasicek (1977), Cox et al. (1985), and Hull and White (1990) proposed some of the early models, which are among the most well known in this category. Unfortunately, these models have been shown to not perform well empirically and are difficult to estimate (Duffee 2002; Christensen et al. 2010).

As a result, another class of models has gained popularity as it allows for fitting realistic yield curves that are observable in practice. These models entail using optimization to find the best-fitting parametric curve to available bond yields. In this class, the Nelson-Siegel model (Nelson and Siegel 1987) and the extension proposed by Svensson (1995) are used extensively.

Splitting interest rate changes into orthogonal factors using Principal Component Analysis (PCA) demonstrates that the following factors explain almost the entirety of yield curve moves (Moulin 2018):

- The level of rates
- The slope or the differential between long-end and short-end rates
- The curvature explaining the shape of the slope
- Additional effects on the shape of the curvature

The appeal of the Nelson-Siegel-Svensson model arises from the fact that it attempts to capture all these factors. The model uses six parameters to define a smooth and well-behaved forward rate curve. The spot or zero rate curve can then be derived using its relationship with the forward rates. Mathematically, the instantaneous forward rate ($f(t)$) at time t can be defined as (Patrick 2015)

$$f(t) = \beta_1 + \beta_2 e^{-t/\gamma_1} + \beta_3 \left(-t/\gamma_1\right) e^{-t/\gamma_1} + \beta_3 \left(-t/\gamma_2\right) e^{-t/\gamma_2}$$

which when combined with

$$r(t) = \frac{1}{t}\int_0^t f(s)ds$$

helps derive the spot rate ($r(t)$) at time t as

$$r(t) = \beta_1 + \beta_2 \frac{1-e^{-t/\gamma_1}}{t/\gamma_1} + \beta_3 \left(\frac{1-e^{-t/\gamma_1}}{t/\gamma_1} - e^{-t/\gamma_1}\right) + \beta_4 \left(\frac{1-e^{-t/\gamma_2}}{t/\gamma_2} - e^{-t/\gamma_2}\right)$$

Each of the terms in the equation captures the four factors in the order mentioned above that help explain the yield curve moves dynamically. Setting $\beta_4 = 0$ in the above equations reduces it to the original Nelson-Siegel model. The six unknown parameters ($\beta_1, \beta_2, \beta_3, \beta_4, \gamma_1, \gamma_2$) are derived using a nonlinear optimization method to minimize the square of the difference between the modeled and actual yields along the curve.

APPENDIX 2—THEMATIC BOND PREMIUM ANALYSIS DETAILS

Table A-1: Characteristics, historical premia, and one-tailed t-tests for EMDE sovereign and quasi-sovereign green bonds

	Bond characteristics					Historical premium		Number of observations			One-tailed t-test	
	ISIN	Currency	Coupon	Maturity	Amount outstanding (USD mn)	Average	Standard deviation	Total days of data	Days with premium	% of days w/ premium	p value	Standard error
Chile EUR 31 G	XS1843433639	EUR	0.83	7/2/31	2,210	**-1**	5	806	546	**68%**	0.00***	0.17
Chile EUR 40 G	XS2108987517	EUR	1.25	1/29/40	1,397	**-3**	7	813	537	**66%**	0.00***	0.24
Chile USD 32 G	US168863DN50	USD	2.55	1/27/32	1,500	**-5**	6	656	598	**91%**	0.00***	0.23
Chile USD 50 G	US168863DL94	USD	3.50	1/25/50	2,318	**-3**	3	813	649	**80%**	0.00***	0.12
China Dev CNY 22 G	CND10002HWJ5	CNY	3.10	11/21/22	2,063	**-40**	16	340	340	**100%**	0.00***	0.88
China Dev CNY 24 G I	CND1000458V7	CNY	3.07	3/24/24	2,943	**-10**	8	351	307	**87%**	0.00***	0.43
China Dev CNY 24 G II	CND10004BRT3	CNY	2.28	7/29/24	1,549	**-7**	7	259	235	**91%**	0.00***	0.44
China Dev CNY 27 G	CND10004S2H3	CNY	2.45	1/21/27	2,346	**-10**	5	134	130	**97%**	0.00***	0.46
China EXIM CNY 26 G	CND10004QP63	CNY	2.48	12/28/26	1,727	**-32**	7	151	151	**100%**	0.00***	0.57
Colombia COP 31 G	COL17CT03797	COP	7.00	3/26/31	558	**-12**	9	140	132	**94%**	0.00***	0.77
Egypt USD 25 G	XS2241075014	USD	5.25	10/6/25	750	**-41**	17	472	464	**98%**	0.00***	0.79
Hungary EUR 35 G	XS2181689659	EUR	1.75	6/5/35	1,694	**-3**	7	562	435	**77%**	0.00***	0.30
Hungary HUF 32 G	HU0000405535	HUF	4.50	5/27/32	470	**2**	5	135	48	**36%**	1.00	0.45
Hungary HUF 51 G	HU0000404991	HUF	4.00	4/28/51	367	**1**	10	331	143	**43%**	0.89	0.53
Indian Railways USD 27 G	XS1733877762	USD	3.84	12/13/27	500	**-15**	8	386	374	**97%**	0.00***	0.39
Indian Railways USD 32 G	US45434M2H45	USD	3.57	1/21/32	500	**-4**	3	140	133	**95%**	0.00***	0.24
Indonesia Sukuk USD 23 G	US71567RAJ59	USD	3.75	3/1/23	750	**4**	5	1,155	228	**20%**	1.00	0.16
Indonesia Sukuk USD 24 G	US71567RAL06	USD	3.90	8/20/24	750	**-5**	5	902	764	**85%**	0.00***	0.18
Indonesia Sukuk USD 25 G	US71567RAN61	USD	2.30	6/23/25	750	**-2**	6	551	288	**52%**	0.00***	0.27
Indonesia Sukuk USD 51 G	US71567RAT32	USD	3.55	6/9/51	750	**-5**	2	301	301	**100%**	0.00***	0.09
Korea EUR 26 G	XS2376820259	EUR	0.00	10/15/26	812	**-8**	5	211	198	**94%**	0.00***	0.31
Korea EXIM USD 28 G	US30217G2C30	USD	1.75	10/19/28	750	**-4**	4	207	172	**83%**	0.00***	0.29
Korea EXIM USD 32 G	US302154DN61	USD	2.13	1/18/32	700	**6**	4	146	1	**1%**	1.00	0.30
Korea Hydro USD 23 G	USY4899GDC43	USD	3.75	7/25/23	600	**-25**	11	1,048	1,025	**98%**	0.00***	0.35
Poland EUR 26 G	XS1766612672	EUR	1.13	8/7/26	1,227	**-1**	3	1,171	828	**71%**	0.00***	0.08
Poland EUR 29 G	XS1958534528	EUR	1.00	3/7/29	1,684	**-6**	4	890	860	**97%**	0.00***	0.12
Poland EUR 49 G	XS1960361720	EUR	2.00	3/8/49	561	**0**	4	890	360	**40%**	1.00	0.13
Saudi Elec Sukuk USD 25 G	XS1960361721	USD	1.74	9/17/25	500	**2**	6	488	165	**34%**	1.00	0.26
Saudi Elec Sukuk USD 30 G	XS1960361722	USD	2.41	9/17/30	500	**-7**	6	181	156	**86%**	0.00***	0.44
Serbia EUR 28 G	XS2388561677	EUR	1.000	9/23/28	1,022	**-4**	3	224	207	**92%**	0.00***	0.22
Cumulative					**34,247**	**-7**	**13**	**14,854**	**10,775**	**73%**	**0.00*** **	**0.11**

*Note: A negative value signifies a premium. Bond classification is based on Bloomberg, which relies on self-reporting by issuers. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Data as of July 31, 2022.*

Source: Bloomberg, author's calculations.

Table A-2: Characteristics, historical premia, and one-tailed t-tests for EMDE sovereign and quasi-sovereign social, sustainability, and sustainability-linked bonds

	Bond characteristics					Historical premium		Number of observations			One-tailed t-test	
	ISIN	Currency	Coupon	Maturity	Amount outstanding (USD mn)	Average	Standard deviation	Total days of data	Days with premium	% of days w/ premium	p value	Standard error
Chile CLP 28 I SO	CL0002686989	CLP	5.00	10/1/28	2,046	**5**	18	275	128	**47%**	1.00	1.10
Chile CLP 28 II SO	CL0002642784	CLP	2.30	10/1/28	1,345	**1**	20	396	122	**31%**	0.90	0.99
Chile CLP 33 SO	CL0002642776	CLP	2.80	10/1/33	724	**13**	13	396	61	**15%**	1.00	0.64
Chile EUR 27 SO	XS2369244087	EUR	0.10	1/26/27	1,077	**7**	3	265	6	**2%**	1.00	0.20
Chile EUR 29 SO	XS2388560604	EUR	0.56	1/21/29	1,000	**1**	2	226	68	**30%**	1.00	0.15
Chile EUR 36 SO	XS2369244327	EUR	1.30	7/26/36	886	**7**	6	265	60	**23%**	1.00	0.36
Chile EUR 51 SO	XS2291692890	EUR	1.25	1/22/51	1,521	**0**	1	397	104	**26%**	1.00	0.03
Chile USD 27 SU	US168863DX33	USD	2.75	1/31/27	1,500	**9**	6	129	2	**2%**	1.00	0.49
Chile USD 33 SO	US168863DT21	USD	2.55	7/27/33	2,250	**1**	6	265	123	**46%**	0.98	0.36
Chile USD 34 SU	US168863DV76	USD	3.50	1/31/34	1,500	**0**	4	129	81	**63%**	0.19	0.35
Chile USD 41 SO	US168863DS48	USD	3.10	5/7/41	2,700	**6**	5	322	11	**3%**	1.00	0.26
Chile USD 42 SL	US168863DY16	USD	4.34	3/7/42	2,000	**9**	4	106	0	**0%**	1.00	0.39
Chile USD 52 SU	XS2327851874	USD	3.50	4/15/53	1,500	**-8**	4	129	124	**96%**	0.00***	0.37
Chile USD 53 SU	US168863DQ81	USD	3.10	1/22/61	2,000	**-5**	3	347	312	**90%**	0.00***	0.18
Chile USD 61 SU	US168863DU93	USD	3.25	9/21/71	1,000	**1**	3	396	131	**33%**	1.00	0.16
Chile USD 71 SO	US168863DW59	USD	4.00	1/31/52	1,000	**16**	6	227	0	**0%**	1.00	0.40
Guatemala USD 32 SO	USP5015VAK28	USD	5.38	4/24/32	500	**-5**	11	592	335	**57%**	0.00***	0.45
Korea USD 24 SU	US50064FAR55	USD	2.00	6/19/24	500	**5**	7	215	43	**20%**	1.00	0.45
Latvia EUR 30 SU	XS2420426038	EUR	0.25	1/23/30	678	**5**	4	168	12	**7%**	1.00	0.35
Malaysia USD 31 SU	USY57542AA32	USD	2.07	4/28/31	800	**1**	2	330	114	**35%**	1.00	0.10
Mexico EUR 27 SU	XS2135361686	EUR	1.35	9/18/27	890	**-11**	7	488	488	**100%**	0.00***	0.30
Mexico EUR 36 SU	XS2363910436	EUR	2.25	8/12/36	1,482	**7**	5	276	22	**8%**	1.00	0.29
Peru USD 34 SU	US715638DU38	USD	3.00	1/15/34	2,250	**7**	5	194	20	**10%**	1.00	0.38
Peru USD 72 SU	US715638DW93	USD	3.60	1/15/72	1,000	**30**	10	194	0	**0%**	1.00	0.69
Thailand THB 35 SU	TH062303FC01	THB	1.59	12/17/25	6,781	**8**	7	508	73	**14%**	1.00	0.32
Uruguay USD 31 SO	US917288BK78	USD	4.375	1/23/31	2,441	**-6**	17	922	608	**66%**	0.00***	0.55
Cumulative					**41,371**	**2**	**13**	**8,157**	**3,048**	**37%**	**1.00**	**0.14**

*Note: A negative value signifies a premium. Bond classification is based on Bloomberg, which relies on self-reporting by issuers. SO refers to social bonds, SU to sustainability bonds, and SL to sustainability-linked bonds. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Data as of July 31, 2022.*

Source: Bloomberg, author's calculations.

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NOTES

1. There is no official definition of an emerging market (Duttagupta and Pazarbasioglu 2021). The International Monetary Fund (IMF) World Economic Outlook (International Monetary Fund 2022b) defines 39 countries as advanced based on several factors including GDP per capita, the share of global trade, and integration into the global financial system. The rest of the countries are labeled emerging market and developing economies (EMDE). Since the analysis in this study focuses primarily on bonds, of the 39 economies labeled as "advanced" by the IMF, it includes Czechia, Hong Kong, Israel, Korea, Singapore, and Taiwan among EMDE because the bonds of these countries are typically covered by emerging market trading desks and debt capital market groups in investment banks. This report uses the terms "emerging markets," "emerging economies," and EMDE interchangeably.
2. On average, agriculture contributes 26.8 percent of GDP for low-income countries, 16.1 percent for lower-middle-income countries, 7.0 percent for upper-middle-income countries, and 1.3 percent for high-income countries (World Bank Data 2022).
3. These bonds are sometimes also referred to as GSSS bonds for green, social, sustainability, and sustainability-linked bonds. Given that the asset class is still growing, this study refrains from using this moniker as it appears restrictive (e.g., it excludes transition bonds).
4. The EU GBS will be aligned with the EU Taxonomy for environmentally sustainable finance (Cobat and Brisson-Félix 2022). Similar to the EU Taxonomy, EU GBS is likely to act as a benchmark for other countries that can then adapt them to their national contexts (Amundi Asset Management and International Finance Corporation 2022).
5. In the energy sector, for example, underinvestment in oil and gas due to a lack of access to debt financing increases the risk of these assets becoming stranded and new infrastructure not being built. This in turn may impair the supply of energy in the near term, leading to a potentially disruptive transition to net-zero emissions since there isn't sufficient renewable energy capacity as yet.
6. Webb (2022) cites the transition bonds issued by the Brazilian beef producer Marfrig and the Italian utility Snam as examples where external reviewers resorted to different standards to evaluate them.
7. The total outstanding amount is lower as some of the bonds have already matured.
8. Investors prefer to use yield versus duration curves—rather than yields versus maturities—since the duration is a better measure of a bond's risk or interest-rate sensitivity (Garbade 1996).
9. A more direct approach could have been to use an implied probability of default versus duration curve for the analysis. However, using yields or spreads instead of implied probabilities of default keeps the analysis intuitive. Moreover, when computing implied

probabilities of default, one has to make assumptions regarding the recovery value of a bond, which can vary across entities and add to the complication.

10. $$DV01 = -\frac{\Delta P}{10{,}000 * \Delta y} = \frac{P}{10{,}000}\left(-\frac{1}{P}\frac{\Delta P}{\Delta y}\right) = \frac{P*D}{10{,}000},$$

    where P is the price of a bond, y is its yield, and D is its modified duration.

11. Floaters and bonds trading at distressed levels are excluded from this study as these have specific characteristics that need to be analyzed separately.

12. These are federal government and agency bonds.

13. One reason for a bond's short price history could be that it was issued recently, and a bond's trading pattern immediately after issuance may differ from its eventual equilibrium behavior. If the bond was issued more than six months ago but the history on Bloomberg is sparse, then it is indicative that the bond is not liquid. In either case, it is better to not include the bond in the analysis.

14. These bonds trade on a spread basis as the US Treasury and the euro government bond yields tend to be major drivers of the yields for the dollar- and euro-denominated bonds, respectively.

15. The null hypothesis is H_0: $\boldsymbol{\mu}^* \geq 0$, where $\boldsymbol{\mu}^* = y - y^*$, y^* is the fair yield, and y is the observed yield of the green bond. The alternative hypothesis is H_a: $\boldsymbol{\mu}^* < 0$. Put simply, $\boldsymbol{\mu}^* \geq 0$ means that the bond does not trade with a premium.

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