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THE GREEN SIN: HOW EXCHANGE RATE VOLATILITY AND FINANCIAL OPENNESS AFFECT GREEN PREMIA

by Alessandro Moro* and Andrea Zaghini*

Abstract

We propose a model with mean-variance foreign investors who exhibit a convex disutility associated to brown bond holdings. The model predicts that bond green premia should be smaller in economies with a more closed financial account and highly volatile exchange rates. This happens because foreign intermediaries invest relatively less in such economies, and this lowers the marginal disutility of investing in polluting activities. We find strong empirical evidence in favor of this hypothesis using a global bond market dataset. Exchange rate volatility and financial account openness are thus able to explain the higher financing costs of green projects in emerging markets relative to advanced economies, especially when green bonds are denominated in local currency: a disadvantage that we can call the "green sin" of emerging economies.

JEL Classification: F21, F30, F31, G11, G12.
Keywords: green bonds, greenium, exchange rate volatility, financial openness, original sin.
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1 Introduction[1]

It is cheaper to finance climate-friendly projects via a green bond than via an otherwise identical conventional bond. Indeed, several studies suggest that the yield on green bonds is lower than that of equivalent non-green bonds: the negative spread being labeled as greenium. The larger the greenium the larger the cost advantage in favor of green bonds when financing green projects (Gianfrate and Peri, 2019; Zerbib, 2019; Fatica and Panzica, 2021; Fatica et al., 2021; Baker et al., 2022). This empirical evidence can be easily rationalized also from a theoretical perspective when assuming that investors have non-pecuniary environmental concerns (Krueger et al., 2020; Bolton and Kacperczyk, 2021; Giglio et al., 2021; Pastor et al., 2021; Baker et al., 2022).

However, there is still limited empirical evidence in the literature about the differences in green premia across markets and currencies. A theoretical justification of the main drivers of this cost heterogeneity is also missing. To the best of our knowledge, the present paper is the first attempt to fill these gaps. In particular, as a possible explanation of the differences in green premia across markets and currencies, we focus on how exchange rate volatility and financial openness affect foreign investors' decisions about green and non-green (brown) asset purchases.

To this aim, we first develop a partial-equilibrium model featuring foreign investors with mean-variance preferences and a convex disutility associated to brown asset holdings. According to the model, green premia should be smaller (less negative) in countries with more closed financial accounts and highly volatile exchange rates. The rationale being that since foreign investors tend to invest smaller amounts of their wealth in such economies, they care relatively less about the moral costs of investing in brown assets. Foreign investors might also face transaction costs discouraging them from diversifying the investment into multiple financial vehicles, including those specialized in the financing of green projects, when the size of the investment is small. In turn, the higher demand for brown bonds pushes their yield closer to the green one, narrowing the greenium.

We then find empirical evidence supporting the model implications using a global market dataset of bond placements in advanced and emerging markets economies. Over

[1]The views expressed in the paper are those of the authors and and do not involve the responsibility of the Bank of Italy. We thank two anonymous reviewers of the Bank of Italy's working paper series, Fabrizio Ferriani, Riccardo Settimo, Marco Taboga, Giovanni Furio Veronese, Marco Wilkens, and the participants at the first Elsevier Finance Conference in Rio de Janeiro for their insightful comments and suggestions.

the period 2014-2021, we estimate a greenium of -30 basis points in advanced economies and a premium close to zero in emerging markets, which are typically considered riskier by international investors. When taking into account currency and market characteristics, it emerges that the greenium is smaller when the exchange rate volatility is sizable and when there are stringent domestic restrictions on foreign financial flows – which are also a proxy for a weaker degree of institutional quality at large.

These results are relevant from a policy perspective. First, they help explaining why only a limited share of total investments goes to companies involved in carbon solutions in emerging markets (OECD, 2023; IMF, 2023; IEA, 2023). Indeed, these countries are characterized by more closed financial accounts, less developed institutional frameworks, and their currencies are more volatile in comparison to the hard currencies of advanced economies. Paralleling the literature on the "original sin" (Eichengreen and Hausmann, 1999; Eichengreen et al., 2005; Eichengreen et al., 2007; Bertaut et al., 2023),[2] the higher financing costs of green projects in emerging markets – especially when denominated in local currency – can be labeled as the "green sin" of such economies. Second, from a normative point of view, we suggest that a liberalization of the financial account coupled with an improvement in macroeconomic fundamentals, in particular a well-managed exchange rate, can help emerging market economies attracting foreign capital inflows and lowering the financing costs of domestic green activities. This is likely to represent a challenge for several emerging markets, given that the opening of the financial account might put pressure on the volatility of the exchange rate in countries with large foreign currency mismatches between assets and liabilities and shallow foreign exchange markets.[3] However, the joint and coordinated deployment of a large set of policy tools – including monetary, fiscal, macroprudential policy and foreign exchange interventions – can improve the trade-offs faced by emerging markets in dealing with the liberalization of their financial account (Adrian et al., 2021; IMF, 2023). Alternatively, the denomination in hard currencies, instead of local ones, could be useful for emerging markets in order to increase the attractiveness of their domestically issued green bonds.

It is important to stress that our paper does not pretend to detect the only expla-

[2]The "original sin" refers to the difficulties emerging markets face in issuing debt denominated in their local currencies.

[3]While Calderon and Kubota (2018) find a positive relationship between financial openness and exchange rate volatility, there is still no unanimous evidence on this result. For instance, Glick and Hutchison (2005) find that countries with less restrictive capital controls and more liberalized regimes appear to be less prone to currency crises.

nation behind the heterogeneity in green premia and the higher financing costs of green projects in emerging markets, but to highlight an unexplored channel in the literature. Other possible explanations might include additional macroeconomic and financial risks discouraging foreign investments, weaker green preferences of investors and less binding legal requirements for green bond issuance in emerging markets, or the lower commitment of policymakers to adopt sound climatic policies in these countries – especially, if green assets are perceived as a hedge against climate change risk, anticipating more stringent regulations in the future. However, even controlling for (some) of these alternative variables, our analysis shows that exchange rate volatility and financial openness remain important factors affecting green premia.

Our paper is strictly related to the empirical literature assessing the pricing of green bonds. The interest in the market assessment of green bonds is related to their special feature, according to which the proceeds of the placements are univocally linked to an underlying green project. The consistency of the projects to the global green framework is endorsed by the International Capital Market Association (ICMA), the institution providing the Green bond principles (ICMA, 2021), a list of high level categories for eligible green projects. Contributions in this literature can be classified according to the method of analysis employed: a regression approach (Ehlers and Packer, 2017; Kapraun et al., 2019; Tang and Zang, 2020; Fatica et al., 2021; Baker et al., 2022; Zaghini, 2023) and a propensity score matching approach (Gianfrate and Peri, 2019; Zerbib, 2019; Larcker and Watts, 2020; Fatica and Panzica, 2021; Flammer, 2021). According to the first method, bond yields are regressed on a green dummy, controlling for the bond maturity, amount issued, currency, rating, and all the other variables that might have a bearing on the bond yield; the coefficient attached to the green dummy represents the estimate of the greenium. According to the propensity score matching approach, instead, each green bond is matched to one or more conventional counterparts based on common characteristics and then the difference in yields is computed as a measure of the greenium. Contributions can additionally be classified as employing data from primary market placements or secondary market trades.[4]

Given that we are interested in assessing the reasons behind the heterogeneity in the

[4]For instance, Larcker and Watts (2020), Fatica et al. (2021), and Zaghini (2023) rely on primary market data, while Zerbib (2019), Tang and Zang (2020), and Flammer (2021) rely on secondary trade prices. At the same time there are also contributions dealing with both data sources (Gianfrate and Peri, 2019; Kapraun et al., 2019; Baker et al., 2022).

cost of financing green projects around the World, we focus on the different sources of risk that might influence bond yields via a regression approach. In addition, since the initial placement of the bond exactly defines the financing cost conditions for the issuer, we rely on the bond pricing on the primary market.[5]

The paper is also related to the theoretical literature that rationalize the existence of a negative greenium by introducing pro-environmental preferences in agents' utility function. In particular, Pastor et al. (2021) and Baker et al. (2022) introduce a non-pecuniary extra-benefit for green asset holdings in a mean-variance utility framework. In a DSGE environment, Ferrari and Nispi Landi (2022) add to standard consumption preferences a concave utility for green asset holdings and a convex disutility for brown asset holdings.[6] We improve on the quoted papers by taking a mixed approach. On the one hand, we adopt a mean-variance framework that allows us to capture the effects of exchange rate volatility; on the other hand, we include a convex disutility for brown bond holdings, in order to have a non-constant greenium that endogenously depends on the main variables of the model.

The paper also partially overlaps with the literature on the drivers of international capital flows, in particular with reference to the domestic country-specific features (pull factors) that are able to attract foreign financial flows (Eichengreen and Hausmann, 1999; Forbes and Warnock, 2012; Cerutti et al., 2019; Koepke, 2019; Bertaut et al., 2023; Ferriani et al., 2023). Focusing on the bond market, we document how the characteristics of two of the most relevant pull factors (the exchange rate volatility and the financial account openness) are able to influence not only the total amount invested in emerging market and developing economies, but also the portfolio choices of foreign investors between green and brows assets.

The rest of the paper is organized as follows. Section 2 describes our theoretical framework and shows some illustrative simulations. Section 3 discusses some stylized facts concerning the green bond market. Section 4 illustrates our estimates of the greenium as a function of exchange rate regimes, exchange rate volatility and financial ac-

[5]While secondary market prices and volatility affect prospective issuance and they can be thought of as the current market assessment of this issuance (Goldstein and Yang, 2017), they do not change the face value of the already issued bonds and thus the cost for the issuer.

[6]Since Sidrauski (1967) it has been increasingly common in the macroeconomic literature to include asset holdings in the utility function to rationalize the difference in yields between similar assets or justify positive holdings of an otherwise dominated asset (see Alpanda and Kabaca, 2020, for a recent example).

count closeness. Section 5 proposes meaningful robustness checks. Section 6 offers some concluding remarks and draws the policy implications.

2 Model

We propose a partial-equilibrium financial model for a small-open economy with three types of agents: foreign investors, domestic investors and domestic firms. There are two types of firms: brown firms that rely on a carbon-intensive technology to produce their output and green firms which employ a clean technology. Both types of firms issue bonds to finance their capital. Bonds issued by brown (green) firms are called brown (green) bonds. Both types of bond can be purchased by domestic as well as foreign investors. It is assumed that both resident and non-resident investors have a preference for investing in green activities. Foreign investors, unlike their domestic counterpart, face two additional challenges in their investment strategy. They are subject to exchange rate volatility and to a tax imposed by the government of the small-open economy, that may represent a capital control on foreign inflows.

Foreign investors. Foreign investors are non-resident financial intermediaries who, as in Adrian et al. (2021), intermediate cross-border financial flows, borrowing funds from the rest of the World and investing in the small open economy. The pool of foreign investors has mass one and there is no heterogeneity; hence, their behavior can be analyzed by looking at that of a representative agent. Furthermore, foreign investors have mean-variance preferences complemented by a quadratic non-pecuniary disutility associated to the brown investment.[7] In particular, they borrow an amount of funds I_f, expressed in foreign units, at the exogenous foreign gross rate R^* and invest a share q_f of the borrowed resources in brown bonds issued by domestic firms and $1 - q_f$ in green bonds. Brown bonds pay a rate of return equal to r_b, while the remuneration of green bonds is denoted with r_g. The remuneration of these domestic financial activities is taxed at a rate τ. Hence, foreign investors choose the optimal level of investment and the share invested in brown activities, maximizing the following utility function:

$$U_f = \mathrm{E}\left[\left(\frac{e'}{e}R_f - R^*\right) I_f\right] - \frac{\gamma}{2}\mathrm{Var}\left[\left(\frac{e'}{e}R_f - R^*\right) I_f\right] - \frac{\delta}{2}\left(q_f I_f\right)^2, \tag{1}$$

[7]Without consequences on the model implications, investors might feature a concave utility in the green investment.

where $R_f = 1 + (1-\tau)[q_f r_b + (1-q_f) r_g]$ denotes the gross return from the investment in the small open-economy, while e and e' represent the current and future value of the exchange rate, respectively. The exchange rate is expressed in terms of foreign currency per domestic currency, so that an increase of e denotes an appreciation of the domestic currency. Parameters γ and δ measure the degree of risk-aversion and the preference toward green investments, respectively. The only source of randomness in (1) is given by the future value of the exchange rate: it is assumed that e' has mean μ_e and standard deviation σ_e.

The assumption about the disutility of the brown investment introduced as a convex function of the outstanding amount of the brown investment $q_f I_f$ (in contrast, for instance, to the share of the brown investment q_f) implies that the larger the investment in a given market, the higher the marginal disutility of increasing the brown share. A possible justification for this functional form relies on a rational inattention argument (Mackowiak at al., 2023). When investors devote a small amount of their wealth to a country, they pay little attention on how this investment is partitioned between green and brown activities. Conversely, if the amount invested is significant, they start caring also about the partition. Another possible argument in favor of the disutility specification relies on the size of the transaction costs: if the amount invested is large, it could be more reasonable to split it between different financial vehicles (investment funds, ETFs, etc.), including those specialized in green investments, even though high transactions costs have to be paid. Conversely, if the investment is small, transaction costs might induce to choose a single financial vehicle, probably the one with the best risk-return profile without considering environmental issues.

Differentiating the objective function (1) with respect to I_f, it is possible to obtain the following equation:

$$\left(\frac{\mu_e}{e} R_f - R^*\right) - \left(\gamma \frac{\sigma_e^2}{e^2} R_f^2 + \delta q_f^2\right) I_f = 0, \qquad (2)$$

while the first order condition (FOC) with respect to q_f yields:

$$(1-\tau)\left(\frac{\mu_e}{e} - \gamma \frac{\sigma_e^2}{e^2} R_f I_f\right)(r_b - r_g) - \delta q_f I_f = 0. \qquad (3)$$

The intuition behind these equations is the following. From equation (2), a higher exchange rate volatility σ_e (or a higher inflow tax τ, which reduces the return R_f) leads to a lower foreign investment I_f. The contraction of foreign inflows reduces the marginal cost of investing in polluting activities $\delta q_f I_f$ in equation (3). Hence, foreign investors increase the share invested in brown assets q_f. The higher relative foreign demand for brown bonds tends to make the greenium $r_g - r_b$ less negative.

Domestic investors. There is also a mass one of resident investors who have an endowment I_d that can be invested in financial activities. For simplicity, it is assumed that domestic investors have a strong home bias and invest a share q_d in domestic brown bonds and a complement share $1 - q_d$ in domestic green assets: this simplifying assumption is supported by the evidence in Coeurdacier and Rey (2013) on the role of home bias in investment choices, especially in emerging markets; furthermore, it allows to better highlight the mechanism related to the behavior of foreign investors that we aim to test in the econometric section. Similarly to foreign investors, domestic households also exhibit a preference for the green investment, specified as a quadratic cost in the brown investment with a weight equal to δ. It is also assumed that domestic investors own domestic firms and the revenues of the inflow tax are rebated to them through a lump-sum transfer. Hence, domestic investors choose the share invested in brown activities, maximizing the following utility function:

$$U_d = \left[1 + q_d r_b + (1 - q_d)\, r_g\right] I_d + T + \Pi_b + \Pi_g - \frac{\delta}{2}\left(q_d I_d\right)^2, \tag{4}$$

where $T = \tau I_f e^{-1}\left[q_f r_b + (1 - q_f)\, r_g\right]$ is the lump-sum transfer from the government, while Π_b and Π_g are firms' profits in the brown and green sector, respectively. The maximization of (4) gives the following FOC:

$$(r_b - r_g) - \delta q_d I_d = 0. \tag{5}$$

Domestic firms. It is assumed that there is a mass θ of firms in the brown sector and $1 - \theta$ in the green sector. Firms in sector $j \in \{b, g\}$ issue bonds to finance their capital k_j, which is assumed to be the only productive input. Firms produce their output (y_j) according to a decreasing return to scale technology: $y_j = \phi_j k_j^\alpha$, where ϕ_j measures the productivity in sector j (capturing all the other productive factors non explicitly modeled). The profits in each sector j can be written as $\Pi_j = \phi_j k_j^\alpha - k_j r_j$. The profit maximization yields the following demand for capital:

$$r_j = \alpha \phi_j k_j^{\alpha-1}. \tag{6}$$

Table 1: Model parameters

Parameter	Meaning	Value
$R^* - 1$	foreign interest rate	0.01
α	capital in production parameter	0.33
ϕ_b	brown sector productivity parameter	0.15
ϕ_g	green sector productivity parameter	0.15
θ	size of the brown sector	0.80
δ	weight of brown investment disutility	0.0045
e	current exchange rate	1.02
μ_e	expected value of future exchange rate	1
I_d	domestic households' wealth	1
γ	foreign investors' risk-aversion	1, 2, 3
σ_e	exchange rate volatility	0, 0.01, ... , 0.05
τ	inflow tax rate	0, 0.01, ... , 0.05

For simplicity, we have assumed that bonds are issued only by firms, excluding the issuance from the government and the financial sector, and that brown (green) firms can issue only brown (green) bonds. However, these simplifications are not as restrictive as they appear: in fact, equation (6) can be assumed as a reduced-form for the aggregate demand of brown and green capital in the small-open economy, without affecting the results of the model.

Market clearing. Market clears when the demand of capital in the two productive sectors equal the supply of funds from domestic and foreign investors:

$$\begin{aligned} \theta k_b &= q_d I_d + q_f I_f / e, \\ (1-\theta)\, k_g &= (1-q_d)\, I_d + (1-q_f)\, I_f / e. \end{aligned} \tag{7}$$

Given that the model is not susceptible to a closed-form solution, we solve numerically the system of non-linear equations represented by the FOCs of foreign and domestic investors, the firms' capital demands and the market clearing conditions.[8]

Table 1 illustrates the values chosen for model parameters in the numerical exercise. The exogenous interest rate $R^* - 1$ assumes a standard value equal to 1 per cent (Adrian et al., 2021). Analogously, a standard value of 0.33 is assigned to the capital share in production α. The productivity parameters are assumed equal in the two sectors

[8] Even though it is possible to find a closed-form solution for the amount invested by foreign investors in brown and green activities, these expressions are non-linear in bond yields making the overall model not susceptible to a closed-form solution.

($\phi_b = \phi_g$) to better highlight the role of demand-driven factors and a value of 0.15 is chosen for these parameters (as in Mendoza et al., 2009), which implies a interest rate on green and brown bonds around 3 per cent. The weight of the disutility associated to brown investments δ is calibrated to have a negative greenium equal to -30 basis points, which is within the range of the empirical estimates in the literature (Ehlers and Packer, 2017; Gianfrate and Peri, 2019; Zerbib, 2019; Kapraun et al., 2019; Larcker and Watts, 2020; Tang and Zang, 2020; Fatica et al. 2021; Baker et al., 2022; Zaghini, 2023). It is not easy to estimate the size of the productive brown sector, given the absence of a clear empirical definition of brown production: we select a value of θ, close to 80%, that is consistent with the estimate in Georgeson and Maslin (2019). The domestic households' wealth is normalized to one. The expected value of the future exchange rate μ_e is assumed equal to one, while the current value e is calibrated to have a ratio between foreign investments over total investments close to 40 per cent, as in Aoki et al. (2016) and Ghironi and Ozhan (2020). We simulate the model for different values of risk-aversion γ, exchange rate volatility σ_e and inflow tax rate τ: in particular, γ ranges from 1 to 3, as typically assumed in mean-variance optimization (Liu and Xu, 2010), while σ_e and τ vary in the $[0; 0.05]$ range.[9]

Figure 1 shows how the increase in the exchange rate volatility affects the equilibrium of the model, for different degrees of foreign investors' risk aversion and assuming $\tau = 0$. A higher exchange rate volatility reduces foreign investments in the small open economy, which has become riskier for foreign investors. The lower overall investment induces foreign investors to increase the share invested in the brown sector because the marginal disutility of increasing the share of brown assets is lower. The yield on both brown and green bond increases as a result of the lower foreign investment, but the higher relative foreign demand for domestic brown bonds leads to a smaller increase in their yield compared to that of green bonds, which implies a smaller greenium in absolute level (i.e., a less negative greenium). The reduced greenium induces domestic investors to increase the share of green bonds in their portfolio. A higher risk-aversion of foreign investors amplifies the impact of a volatile exchange rate because more risk-averse investors reduce capital inflows to a larger extent as they suffer greater losses from the increase in uncertainty.

Figure 2 shows the effects of a higher inflow tax keeping fixed the exchange rate volatility at $\sigma_e = 0.03$. Since more stringent capital controls induce a lower level of

[9]For the exchange rate volatility, we estimate the upper bound of the range considering the third quartile of its empirical distribution in the International Financial Statistics database.

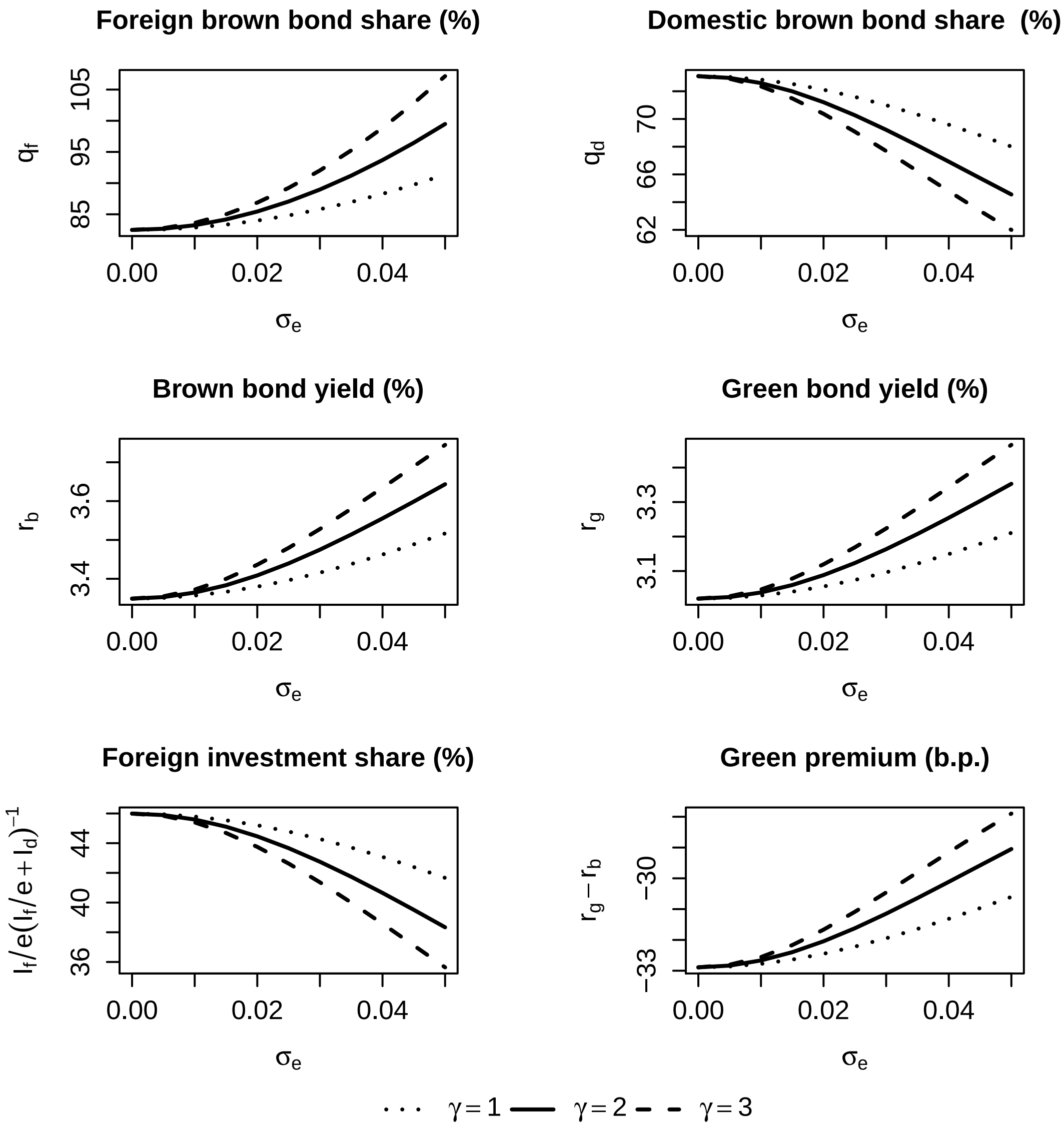

Figure 1: Effects of a higher exchange rate volatility on the brown bond share of foreign and domestic investors, on foreign inflows in the domestic economy, on the green and brown bond yield, and on the greenium

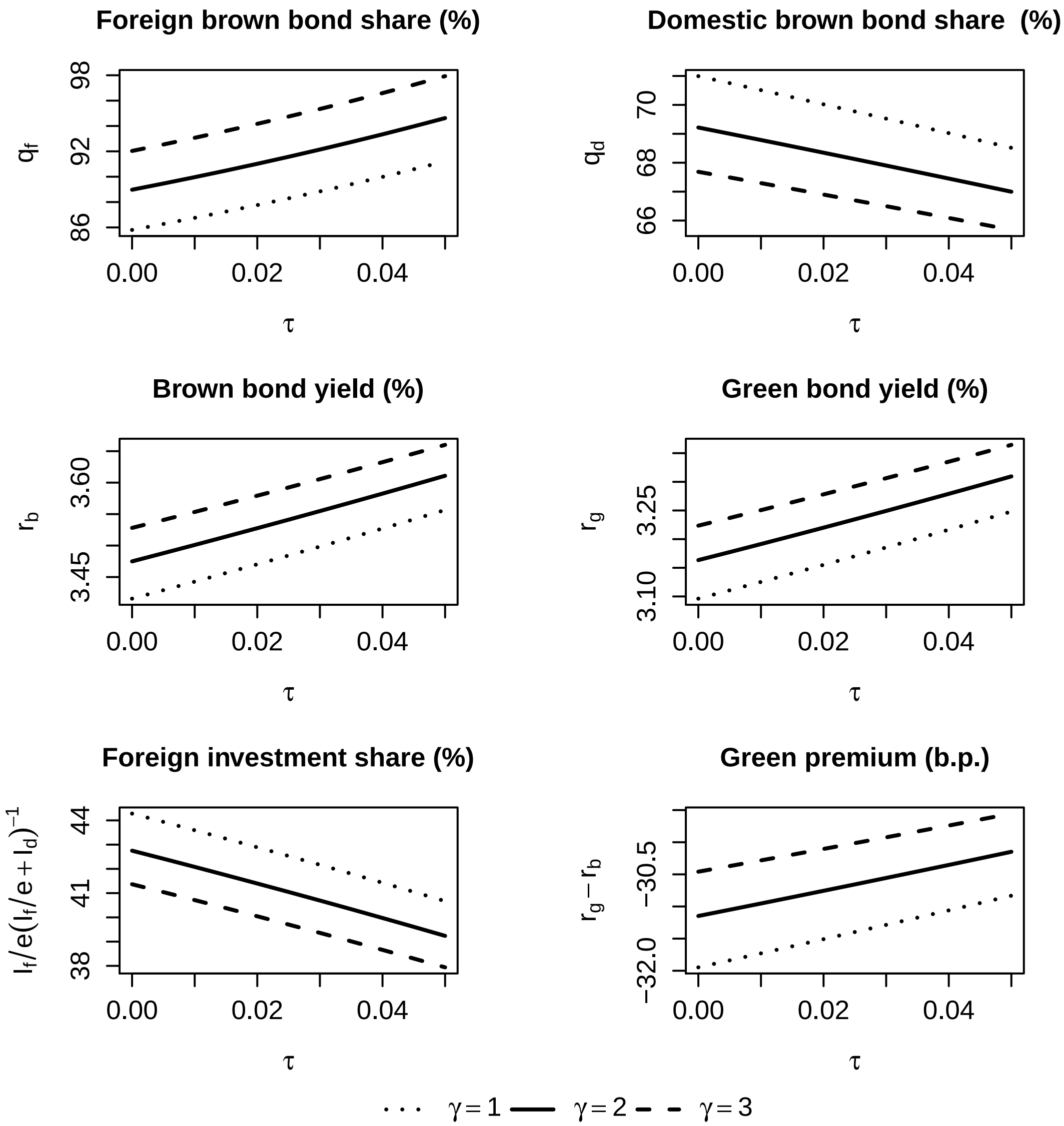

Figure 2: Effects of a higher inflow tax on the brown bond share of foreign and domestic investors, on foreign inflows in the domestic economy, on the green and brown bond yield, and on the greenium

foreign investments in the small open economy, a higher inflow tax also leads to a less negative greenium for the same reasoning described above. However, in this case, a higher foreign investors' risk-aversion simply moves up the curves without any interaction effect.

3 Green bond markets

In order to empirically test the model implications, we collect information on bond placements by merging three data providers: Dealogic DCM Analytics, Refinitiv Datastream and Bloomberg. Over the 8-year period from January 2014 to December 2021, we end up with a dataset of 203,341 brown and green bonds issued in 36 advanced economies (AEs), 33 emerging market economies (EMEs), and 9 low-income countries (LICs). Our dataset provides comprehensive coverage of the green bond market, capturing around 89 per cent of the green bond issuance recorded in the Climate Bonds Initiative database.

For each new bond placed we have the following information from Dealogic DCM Analytics: the pricing date; a green label that identifies green bonds; the rating; the maturity, measured in years to maturity; the amount issued (in US billion); the currency in which the bond is denominated; the frequency of the coupon; the interest rate type (fixed, floating, variable). In addition, Dealogic DCM Analytics provides dummies identifying collateralized, subordinate, and callable bonds. At the issuer level we have: the rating; the nationality; the country of incorporation; the business sector description at the 2-digit SIC code level; the ultimate parent name, nationality and business sector. The annualized yield to maturity at issuance is instead sourced from Refinitiv Datastream and Bloomberg.

Note that, as a general rule, the market where the bond is issued can be anywhere in the World, regardless of the nationality of the issuer. Each bond is uniquely identified by the alphanumeric ISIN code (International Security Identification Number). An ISIN identifies the economy where the bond is issued by adding a two-character country code, based on the coding ISO 3166, at the beginning of the code number. Thus it is always possible to identify the market where the bond has been issued. For instance, Lojas Americanas SA, the Brazilian chain of retail stores, has placed bonds, over the period under analysis, in the domestic Brazilian market as well as in the United States. Brazilian bonds are identified by the two letters "BR", while those issued in the United States by "US". The market of placement determines the contract law the seller and the buyer have to abide by.

Table 2: Nationality of the issuer vs market of issuance

	Market of issuance			
Issuer's nationality	AEs	EMEs	LICs	Total
	Absolute frequencies			
AEs	176,068	44	1	176,113
EMEs	10,529	15,879	2	26,410
LICs	723	51	44	818
Total	187,320	15,974	47	203,341
	Relative frequencies (%, by row)			
AEs	100	0	0	100
EMEs	40	60	0	100
LICs	88	6	5	100
Total	92	8	0	100
	Relative frequencies (%, by column)			
AEs	94	0	2	87
EMEs	6	99	4	13
LICs	0	0	94	0
Total	100	100	100	100

Notes: the table reports the distribution, in absolute and relative terms, of bonds, by market of issuance and nationality of the issuer, grouped in Advanced Economies (AEs), Emerging Market Economies (EMEs), and Low-Income Countries (LICs). Bonds placed in global markets, during the 2014-2021 period.

Table 2 shows the absolute number and the frequency of the bonds in our dataset by nationality of the issuer and market of placement. By looking at the nationality of the issuer (middle panel) we have that issuers from AEs place their bonds almost exclusively in AE markets (99.97%), just 45 bonds are placed in EME or LIC markets. More heterogeneous is the placement activity by EME issuers: a share of 60% of bonds remains in the EME markets while 40% goes to AE markets. Issuers from LICs place their bonds only marginally in EME and LIC markets (6% and 5%, respectively), the placement activity being concentrated in AE markets (88%).

Focusing instead on the markets of placement we have that they are strongly characterized by the "domestic" issuance (lower panel). Between 94% and 99% of the placements are due by issuers from the same group. This circumstance is of great relevance for the analysis. Since we are investigating how the exchange rate features (regime and volatility) and the policy decisions about maintaining free access of foreign financial flows affect the domestic market prices, looking at the nationality of the issuer would be a mis-

Table 3: Size of the green bond market

	Brown		Green	
	Frequency	Issuance (USD bill.)	Frequency	Issuance (USD bill.)
AEs	181,625	88,530	5,695	1,460
	97%	98%	3%	2%
EMEs	15,247	2,047	727	153
	95%	93%	5%	7%
LICs	46	3	1	0
	98%	99%	2%	1%
Total	196,918	90,580	6,423	1,613
	97%	98%	3%	2%

Notes: the table reports the distribution of bonds placed in Advanced Economies (AEs), Emerging Market Economies (EMEs) and Low-Income Countries (LICs), and the amount issued (USD billions) in these three groups during the 2014-2021 period, distinguishing between green and brown bonds. Issuance refers to the total amount issued over the 2014-2021 period. The size of green and brown bond markets is computed both in terms of their relative share in the number of bonds and in terms of their relative share in issuance.

take. Consider for instance the case of EMEs. If we were to analyze the effects of the above-mentioned characteristics on the bond placements by EME issuers instead of bond placement in the EME markets, we would also consider over 10,000 additional bonds placed and priced in AE markets, that most likely do not share the same features about capital controls and the exchange rate framework.

The size of the green segment is around 2% of global issuance (Table 3). However, this figure masks a substantial heterogeneity across economies: in fact, if the share of the green market in terms of issuance is 2% in AEs, its weight increases to 7% in EMEs.

The greatest issuance of green bonds happens in the European market, which comprises in our definition the European bond market (ISIN codes that start with "XS") and the bonds issued by EU institutions (Table 4). In terms of outstanding amounts, the United States are the second market in which green bonds are issued, even though the share of green bond issuance over total issuance (green share) is substantially low. On the contrary, the green share of the Swedish market stands out among AEs, being the only one above 10%. In EMEs, the Chinese market has the lion share of green bond issuance and its figures alone can explain the greater relevance of green emissions in EMEs compared to AEs, as noted from Table 3. Thailand is the second largest issuer of green

Table 4: Major issuers of green bonds

Country	green bond issuance (USD bill.)	green share (%)
Advanced Economies (AEs)		
Europe (XS+EU inst.)	590.0	4.7
USA	397.5	0.8
France	133.4	4.4
Germany	63.6	2.4
Canada	30.3	1.3
Japan	25.8	0.3
Australia	25.7	3.0
Sweden	25.7	11.5
UK	22.3	2.0
Italy	16.7	0.9
Emerging Market Economies (EMEs)		
China	141.2	20.7
Thailand	6.8	3.3
Malaysia	1.3	10.8
Mexico	0.8	2.8
India	0.7	0.3
Brazil	0.4	5.9

Notes: the table reports the issuance of green bonds in USD billions during the 2014-2021 period and the green share, defined as the ratio between the issuance of green bonds and the total issuance during the overall period analyzed, by major issuer countries in Advanced Economies (AEs) and Emerging Market Economies (EMEs). Europe comprises the bonds placed in the European bond market (ISIN codes that start with "XS") and the bonds issued by EU institutions. Issuance refers to the total amount issued over the 2014-2021 period.

bonds among EMEs, and Malaysia stands out for a green share close to 11%. The other emerging markets are far below in terms of green bond issuance.

The relevance of these economies in the issuance of green bonds is reflected in the currencies in which green bonds are denominated: among the currencies of AEs, the euro, the US dollar, and the Swedish krona are the most used currencies of denomination, while the Chinese renminbi and the Thai baht are the preferred EME currencies for green bond denomination (Table 5).

The characteristics of green and brown bonds are reported in Table 6. As for the cost of issuance, green bonds pay on average a return which is 28 basis points lower than that of brown bonds. While there are no statistically significant differences in the

Table 5: Major currencies of green bonds

	Brown		Green	
Currency	Frequency	Issuance (USD bill.)	Frequency	Issuance (USD bill.)
Advanced Economies (AEs)				
EUR	24,078	16,989	1,232	685
	12%	19%	19%	42%
USD	98,603	53,300	2,296	488
	50%	59%	36%	30%
SEK	3,597	316	781	68
	2%	0%	12%	4%
GBP	3,129	2,258	86	57
	2%	2%	1%	4%
Other	46,254	15,413	992	150
	23%	17%	15%	9%
Emerging Market Economies (EMEs)				
CNY	3,945	685	549	147
	2%	1%	9%	9%
THB	2,977	198	45	7
	2%	0%	1%	0%
INR	2,725	248	84	2
	1%	0%	1%	0%
BRL	630	27	36	1
	0%	0%	1%	0%
Other	10,869	1,143	321	8
	6%	1%	5%	0%
Total	196,918	90,580	6,423	1,613

Notes: the table reports the distribution of bonds and the issuance (in USD billion) during the 2014-2021 period, by major currencies of denomination, distinguishing between green and brown bonds and currencies of Advanced Economies (AEs) and those of Emerging Market Economies (EMEs). Issuance refers to the total amount issued over the 2014-2021 period. Relative frequency are calculated by column. Notation: EUR = euro, USD = US dollar, SEK = Swedish krona, GBP = British pound sterling, CNY = Chinese renminbi, THB = Thai baht, INR = Indian rupee, BRL = Brazilian real.

Table 6: Brown and green bond characteristics

Variables	Brown	Green	Difference
yield (%)	2.794	2.515	-0.279*
	(0.136)	(0.107)	(0.163)
maturity (year)	9.364	9.329	-0.035
	(0.458)	(0.297)	(0.533)
amount issued (USD bill.)	0.460	0.251	-0.209*
	(0.123)	(0.018)	(0.123)
investment grade bonds (%)	90.959	88.946	-2.013
	(1.055)	(2.129)	(2.335)
collateralized bonds (%)	19.550	12.222	-7.328***
	(2.145)	(1.573)	(2.641)
subordinate bond (%)	8.644	3.036	-5.608***
	(0.995)	(0.623)	(1.190)
callable bond	0.761	1.152	0.391*
	(0.097)	(0.219)	(0.234)

Notes: the table reports sample averages of the main characteristics of green and brown bonds and the differences between the two groups. The number of observations is 203,341. Bonds placed in global markets, during the 2014-2021 period. Cluster-robust standard errors at issuer level are shown in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

average maturity and investment grade frequency between the two types of bonds, the amount issued of green bonds is lower than that of brown bonds. Moreover, there are less collateralized and subordinate bonds with a green label; conversely, callable bonds are more frequent among green bonds. This heterogeneity confirms the importance of controlling for bond characteristics, as well as for issuer and sector characteristics, when estimating the greenium (Fatica et al., 2021).

4 Econometric analysis

Relying on the dataset described in the previous section, we estimate the following specification:

$$yield_{b,c,m,n,t} = \alpha + green_b * (\beta + \gamma X_{c,m}) + \delta Z_b + \theta_{m,t} + \lambda_{c,n,t} + \varepsilon_{b,c,m,n,t}, \qquad (8)$$

where *yield* is the annualized yield to maturity at issuance on bond b, denominated in currency c, issued in market m by an issuer resident in country n at time t. The variable *green* is a dummy that takes value one for green bonds, and zero otherwise. The vector Z contains the bond and issuer characteristics: maturity (measured in years to maturity), amount issued in USD billions, the frequency of coupon, the interest rate type (fixed, floating, variable), a dummy for collateralized bonds, a dummy for subordinate bonds, a dummy for callable bonds, the rating of the bond, the rating of the issuer,[10] issuer's sector-specific fixed effects. With θ we denote time varying and market-specific fixed effects capturing all the macroeconomic and financial factors that are likely to affect bond yields at the market of issuance level, while λ indicates time varying fixed effects taking into account the currency of denomination and its interaction with the nationality of the issuer. Equation (8) is estimated with Ordinary Least Squares; standard errors are clustered at the issuer level.

The assumption underlying our econometric model is that conditioning on a rich set of bond, issuer and sector characteristics, and macroeconomic and financial factors, that vary over time and across currency of denomination, market of issuance and nationality of the issuer, the remaining difference between a green and a conventional bond defines the greenium:

$$greenium_{c,m} = \beta + \gamma X_{c,m}. \tag{9}$$

We further assume that the greenium changes reflecting a vector X of variables describing the characteristics of the market m where the bond is placed and those of the currency c in which the bond is denominated.

Table 7 reports a first set of regressions considering in X dummies for the different income groups (advanced and emerging market economies, according to the IMF World Economic Outlook and World Bank income classification)[11] and for the alternative exchange rate regimes (exchange rate pegs versus freely floating exchange rate regimes, based on the classification of Ilzetzki et al., 2019). The first column shows that globally (i.e., considering all markets and exchange rate arrangements) the greenium estimate

[10] The rating of the bond (issuer) is first linearized between 1 (CC/Ca) and 20 (AAA/Aaa), so that, when the same bond (issuer) receives more than one assessment from Moody's, Fitch and Standard&Poors, they can be averaged. Then, the average is transformed into a set of dummy variables.

[11] Given that the only low income country issuing green bonds is Nigeria, we are not able to identify a dummy for this income group which is absorbed by model fixed effects.

is negative and statistically significant with an absolute value of 28 basis points. The value is relevant also from an economic point of view: considering that the unconditional sample mean of all yields stands at 2.79 per cent, the greenium estimate represents a 10 per cent discount on the cost of financing green projects.

The second column compares the greenium in AEs (the baseline) with that in EMEs. Regression results show that bonds issued in AEs have a statistically significant negative greenium of 30 basis points. At the same time, the relative disadvantage of issuing green bonds in EMEs amounts to 28 basis points, suggesting a negligible greenium of 2 basis points, not statistically different from zero.

The third column distinguishes emerging markets according to the exchange rate regime.[12] While a disadvantage persists in both regimes, the difference is relevant. EMEs with an exchange rate peg are worse off by 23 basis points with respect to AEs; in turn, this implies a greenium of around 7 basis points. EMEs with a freely floating exchange rate face an even larger disadvantage: the 34 basis points difference in the cost of placing green bonds makes the greenium entirely disappearing, if not turning it into positive values.

The reported evidence is fully consistent with our theoretical predictions. Since EMEs are usually characterized by more closed financial accounts and are perceived as a riskier asset class, they should have a smaller (less negative) greenium in comparison to AEs. Moreover, since foreign investors face larger exchange rate risks in emerging economies with a freely floating exchange rate regime, the greenium should be smaller there than in markets with exchange rate pegs.

However, some caution should be paid in analyzing the effects of the different exchange rate regimes. In fact, as shown in the fourth column, the larger greenium detected in fixed exchange rate regimes is mainly driven by China. The other pegs exhibit much smaller green premia.

In order to directly test the implications of our model and assess the effect of the exchange rate volatility and the financial account closeness, in Table 8 we show the estimates of the interaction of the green dummy with these two variables. The exchange rate volatility for each currency c is measured as the standard deviation of $\Delta \ln(e_{c,t})$, where $e_{c,t}$ is the exchange rate between currency c and the US dollar in month t (average value in month t, taken from the IMF International Financial Statistics), as in Kenen and

[12]Since most advanced economies have a freely floating exchange rate regime, the interaction between the dummy for this income group and those for different exchange rate arrangements looses relevance.

Table 7: Exchange rate regimes and the greenium

Variables	(1) bond yield	(2) bond yield	(3) bond yield	(4) bond yield
green	-0.283***	-0.301***	-0.301***	-0.301***
	(0.044)	(0.046)	(0.046)	(0.046)
green * EME		0.282***		
		(0.109)		
green * EME peg			0.227**	
			(0.106)	
green * China				0.221**
				(0.108)
green * EME peg (ex. China)				0.416
				(0.368)
green * EME floater			0.338*	0.338*
			(0.176)	(0.176)
Observations	196,772	196,772	196,772	196,772
Adjusted R-squared	0.818	0.818	0.818	0.818

Notes: the table reports the coefficients of the regression in which the dependent variable is the yield at issuance on bonds placed during the 2014-2021 period in global markets. The independent variables shown are: a dummy variable tracking green bonds, its interaction with the dummy denoting Emerging Market Economies (EMEs), the interaction with the dummies indicating EMEs with freely floating exchange rate regimes, and the interaction with the dummies indicating EMEs with fixed exchange rate regimes (also distinguishing between China and the other pegs). Ordinary Least Squares estimates. Cluster-robust standard errors at issuer level are displayed in parentheses. Significance levels: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 8: Exchange rate volatility, financial closeness, bond inflows and the greenium

Variables	(1) bond yield	(2) bond yield	(3) bond yield	(4) bond yield
green	-0.379***	-0.305***	-0.399***	-0.686***
	(0.076)	(0.047)	(0.079)	(0.183)
green * exchange rate volatility	0.539**		0.531**	
	(0.265)		(0.264)	
green * financial closeness		0.366***	0.357***	
		(0.129)	(0.127)	
green * low bond inflows				0.644***
				(0.249)
Observations	196,772	196,760	196,760	195,407
Adjusted R-squared	0.818	0.818	0.818	0.818

Notes: the table reports the coefficients of the regression in which the dependent variable is the yield at issuance on bonds placed during the 2014-2021 period in global markets. The independent variables shown are: a dummy variable tracking green bonds, its interaction with the exchange rate volatility indicator (with respect to the US dollar), the interaction with the financial account closeness indicator (based on Chinn-Ito, 2006), and the interaction with the indicator of low foreign bond inflows. Ordinary Least Squares estimates. Cluster-robust standard errors at issuer level are displayed in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Rodrik (1986), Rose (2000), and Rose and Engel (2002). The financial account closeness indicator for each market m is defined as the complement to one of the Chinn-Ito *de iure* index of financial account openness (Chinn and Ito, 2006). Moreover, in order to test the supposed mechanism of transmission of the effects of these two factors on the greenium through the lower participation of foreign investors, we also construct the interaction of the green dummy with a indicator of low foreign penetration. This indicator is equal for each market m to the opposite of the average ratio of bond inflows over GDP (taken from the IMF International Financial Statistics). For comparability purposes, the exchange rate volatility and the low foreign bond inflows measures are re-scaled to vary between zero and one. Table 9 shows some summary statistics of these measures together with other risk indicators used in the following Robustness section.

In the first column of Table 8 the coefficient estimating the effect of the exchange rate volatility is positive and statistically significant, indicating a dampening effect on the greenium. At the median value of the distribution, the estimated effect reduces the greenium by 18 basis points, leaving it negative at around 20 basis points. In order to have a greenium close to zero, a value above the top 5 per cent of the distribution is needed. In other words, only countries with very high exchange rate volatility do not show a negative greenium. The second column reports that also a more closed financial account leads to a lower greenium. The effect is somewhat similar: at the median value the greenium is 21 basis points. The combined effect is reported in the third column. Both sign and magnitude are confirmed for each coefficient. The fourth column shows that countries with a lower level of foreign bond inflows relative to their GDP have a smaller greenium.

The reported empirical evidence based on a very large and heterogeneous set of bonds is thus fully in line with the predictions of the theoretical model: higher currency volatility and more stringent financial constraints determine a reduction of the greenium due to a minor attractiveness of the domestic market for foreign investors. This in turn implies that in many countries a large part of, when not all, the advantage in issuing green bonds when financing climate friendly projects is lost. In other words, there seems to be a "green sin" situation burdening especially emerging markets: residents of such economies are less able to issue debt in domestic currency to finance local green projects and thus they are doomed to pay higher interest rates and lag behind in the transition process. Before drawing possible policy implications, in the next section we perform some robustness checks of the results.

Table 9: Summary statistics of risk indicators

Index	Obs.	1st Quartile	Mean	Median	3rd Quartile	Std. Dev.
Exchange rate volatility (w.r.t. USD)	103	0.209	0.338	0.329	0.443	0.180
Exchange rate volatility (w.r.t. SDR)	103	0.073	0.226	0.179	0.321	0.186
Financial account closeness (Chinn-Ito, 2006)	76	0.000	0.340	0.270	0.672	0.348
Capital inflow restrictions (Fernandez et al., 2016)	64	0.000	0.277	0.045	0.534	0.336
Low bond inflows	65	0.687	0.753	0.796	0.909	0.211
Regulatory Uncertainty	76	0.140	0.459	0.472	0.729	0.304
Real GDP volatility	77	0.070	0.141	0.108	0.165	0.134
Debt-to-GDP ratio	77	0.163	0.261	0.227	0.344	0.159
Climate risk (ND-GAIN index)	73	0.260	0.501	0.537	0.714	0.271

Notes: the table reports summary statistics of the different risk indicators. The exchange rate volatility for each currency c is measured as the standard deviation of $\Delta \ln (e_{c,t})$, where $e_{c,t}$ is the exchange rate between currency c and the US dollar (or the SDR basket) in month t (average value in month t, taken from the IMF International Financial Statistics). The financial account closeness indicator for each market m is defined as the complement to one of the Chinn-Ito index of financial account openness (Chinn and Ito, 2006) or the Fernandez's index (Fernandez et al., 2016) of bond inflow restrictions. The low foreign bond inflows measure is equal for each market m to the opposite of the ratio of yearly bond inflows over GDP (taken from the IMF International Financial Statistics). The regulatory uncertainty index is constructed for each market m considering the opposite of the rule of law indicator (Worldwide Governance Indicators database). Real GDP volatility is calculated for each market m as the standard deviation of y-o-y real GDP variations (World Economic Outlook database). The ratio between public debt and GDP for each market m is taken from the World Economic Outlook database. The climate risk indicator is measured for each market m as the opposite of the ND-GAIN index of the University of Notre Dame. All these indicators are computed as standard deviations or averages over the 2000-2021 period, and re-scaled to vary between zero and one

5 Robustness

Table 10 displays the results of some robustness checks. First, we show how results are affected by changing the variable used to measure the volatility of exchange rates and the financial account closeness. In particular, in the first column the volatility of the exchange rate is measured considering the exchange rate of currency c with respect to a broader set of currencies: those included in the SDR basket (sourced from the International Financial Statistics).[13] In the second column we retain the exchange rate volatility measured considering the US dollar, but we include the Fernandez's index (Fernandez et al., 2016) of bond inflow restrictions instead of the financial closeness indicator constructed from the Chinn-Ito index. In the third column we replace the financial closeness variable with a broader indicator - that we call regulatory uncertainty - constructed considering the opposite of the rule of law index,[14] capturing the general attractiveness of an economy for investments. All these new indicators are re-scaled between zero and one. Overall, the signs and significance of the exchange rate volatility and financial account closeness are confirmed, no matter how they are measured.

In order to check also for a possible role of the sovereign and supranational issuance in determining the results of our investigation, in the fourth column we report the results of the estimation when the sample is reduced to corporate bonds only.[15] In other words, we exclude all the bonds placed by sovereigns, local authorities and multinational development banks, that amount to just less than 30,000 placements. When relying on this reduced sample, the effect of financial closeness remains statistically significant, while that of the exchange rate looses significance. The lower significance of the coefficient associated to the exchange rate volatility can be explained considering that corporate bonds are issued in a smaller number of currencies, typically the hard currencies of AEs.

[13]The SDR basker comprises five currencies: the US dollar, the euro, the Chinese renminbi, the Japanese yen, and the British pound sterling.

[14]Rule of law is one of the Worldwide Governance Indicators developed by the World Bank and it captures the degree of economic agents confidence in the rules of a given society, in particular the quality of contract enforcement, the respect of property rights, the trust in police and courts, as well as the likelihood of crime and violence.

[15]The empirical literature on the sovereign greenium suggests that it might be of a smaller magnitude than that arising from corporate issuance (Doronzo et al., 2021; Ando et al., 2022; Grzegorczyk and Wolff, 2022; Bolton et al., 2022). At the same time, Fatica et al. (2021) report evidence that the greenium of supranational institutions might be larger.

Table 10: Robustness

Variables	(1) SDR	(2) Capital controls	(3) Regulatory Unc.	(4) Corporate bonds	(5) Other risks
green	-0.382***	-0.393***	-0.511***	-0.380***	-0.658***
	(0.071)	(0.079)	(0.093)	(0.089)	(0.138)
green * exchange rate volatility	0.906**	0.550**	0.595**	0.328	0.591**
	(0.449)	(0.266)	(0.264)	(0.310)	(0.251)
green * financial closeness	0.360***	0.241**	0.735***	0.408***	0.164
	(0.127)	(0.120)	(0.200)	(0.136)	(0.234)
green * GDP volatility					-0.414
					(2.275)
green * debt/GDP					0.284*
					(0.156)
green * climate risk					0.695
					(0.566)
Observations	196,760	196,363	196,669	170,045	194,198
Adjusted R-squared	0.818	0.818	0.818	0.790	0.818

Notes: the table reports the coefficients of the regression in which the dependent variable is the yield at issuance on bonds placed during the 2014-2021 period in global markets. The independent variables shown are: a dummy variable tracking green bonds, its interaction with the exchange rate volatility indicator (with respect to the US dollar or the SDR basket); the interaction with the financial account closeness indicator (based on Chinn-Ito, 2006;) or the bond inflow restriction index (Fernandez et al., 2016); the interaction with the regulatory uncertainty index (based on the rule of law indicator); the interaction with real GDP volatility; the interaction with the debt-to-GDP ratio; the interaction with the climate risk indicator (based on the ND-GAIN index). Ordinary Least Squares estimates. Cluster-robust standard errors at issuer level are displayed in parentheses. Significance levels: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

In the fifth column we test whether the effects of the exchange rate volatility and financial account closeness remain statistically significant even controlling for a richer set of possible determinants of the greenium. The set includes standard measures of risk and volatility: overall macroeconomic risk, measured as the standard deviation of y-o-y real GDP variations (World Economic Outlook database); fiscal vulnerability, defined as the ratio between public debt and GDP (World Economic Outlook database); climate risk, measured as the opposite of the ND-GAIN index of the University of Notre Dame. This index captures both the vulnerability to climate change and the commitment and capacity to take adaptation measures, including sound climate policies and credible green investments.[16] For comparability purposes, all these indicators are re-scaled to vary between zero and one. Results show that the coefficient associated to the exchange rate volatility remains statistically significant even considering these additional risk measures. It is interesting to note that the new risk indicators do not increase the overall goodness-of-fit of the model and they are generally not statistically significant.

Also this additional empirical evidence confirms the role of the currency volatility and the financial openness in shaping the cost of green bonds with respect to conventional bonds, and, in turn, the reduced attractiveness of emerging markets green projects relative to advanced economies.

6 Concluding remarks

Taking stock of the current context in which the transition towards a carbon free economy is undergoing in almost all the World, we analyze how the cost of financing climate friendly projects are affected by international economy characteristics, such as exchange rate volatility and financial account openness. Structural country features have been traditionally analyzed in the context of international capital flows between advanced and emerging economies (Eichengreen and Hausmann 1999, Forbes and Warnock, 2012; Cerutti et al., 2019; Koepke, 2019; Bertaut et al. 2023), but we are the first to focus on the financing of green projects. Indeed, the possibility of a situation in which emerging economies might be already lagging behind in the green transition because of a lack in

[16]The ND-GAIN index measures the ability of a country to adapt to climate change. It is composed of two key dimensions of adaptation: vulnerability and readiness. Vulnerability refers to a country's exposure and sensitivity to the negative effects of climate change. Readiness measures a country's ability to leverage investments and convert them to adaptation actions. A higher value of the index indicates a higher ability of adaptation.

the ability of attracting foreign investment has been recently flagged by some of the most prominent supranational institutions (OECD, 2023; IMF, 2023; IEA, 2023). We show that high exchange rate volatility and strict constraints on capital inflows might act as a "green sin" for many emerging economies, jeopardizing the international financing of their green transition.

While in general it is difficult to track down capital flows directly aimed at financing the fight against climate change (both domestically and internationally), this is not true for green bonds. They are a special class of fixed income securities: the proceeds of the placement are earmarked to finance green projects only. We thus focus on the pricing of green bonds at issuance (i.e, on the primary market), that is the moment in which the cost conditions are set, once and for all, for the issuing institution. In this way we can compare the cost of green vs brown bonds and analyze the country-specific characteristics that have a bearing on the pricing mechanism.

First, we develop a theoretical model with mean-variance foreign investors who exhibit pro-environmental preferences. According to the model, green premia should be smaller (less negative) in countries with a more closed financial account and unstable exchange rates. This occurs because foreign investors invest relatively less in such economies and the moral cost of holding a large share of brown assets is much more limited. In turn, the higher relative demand for brown bonds pushes their yield closer to the green one, narrowing the greenium. This foreign investors' behavior can be justified relying on a rational inattention argument: when their exposure to a given market is small, they care relatively less about the partition of their investment between green and brown assets. In addition, the same behavior may be driven by the existence of transaction costs that induce them to simply choose the financial vehicle with the best risk-return profile (in our case, a brown vehicle).

Second, we empirically test the model predictions. By relying on a large dataset on global bond market issuance, we show that the greenium is affected by the exchange rate volatility of the currency in which the bond is denominated and the financial account closeness of the market in which the bond is issued. In particular, the higher the exchange rate volatility and the more stringent the restrictions imposed on cross-border financial flows, the lower the greenium. Given that emerging markets exhibit more closed financial accounts and their currencies are more volatile than those of advanced countries, our empirical evidence can explain why emerging markets face significant challenges in attracting private capital towards green projects.

From a policy perspective, the results of the analysis suggest that interventions aimed at the liberalization of the financial account could help emerging economies in attracting foreign capital inflows to finance the transition towards a low-carbon economy. This must be coupled with an improvement in their institutional framework and macroeconomic fundamentals. In particular, a well-managed exchange rate could help emerging market economies attracting foreign capital inflows in the domestic green bond market and lowering the financing costs of domestic green projects. A possible alternative to encourage foreign capital inflows, at least in an early phase, would be the issuance of green bonds denominated in hard currencies.

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