An option pricing approach for sustainability-linked bonds

Anthropocene Fixed Income Institute Discussion Paper

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Based on a novel pricing approach, this paper suggests that Sustainability–Linked Bonds (SLBs) should target credible and robust KPIs with material financial impact (front-loading, coupon step-up sizes) in order to achieve incentivizing cost-of-capital differences compared to traditional bonds.

Linking bond coupons to an issuer's sustainability performance became a popular market development in 2021. But despite the rapid growth of SLBs,[1] market criticism on current structures has been centered around two issues: (1) setting appropriate ambition for performance indicators and associated targets; and (2) setting the appropriate value of the coupon step up and its time horizon. Both these issues should affect the pricing of an SLB, but in different ways. So far, most studies have focused on evaluating a joint spread premium of factors (1) and (2), which we argue is difficult, even intractable.

This paper develops a pricing approach based on Black-Scholes' model to calculate the fair-value option of the coupon-step ups, to confront issue (2) above. In order to derive prices in this framework, we need to have KPIs for which we can derive inference about probabilities that they will be achieved. We define SLBs with such KPIs as Step-Up Priceable (SUP) in contrast to Step-Up Non-priceable (SUN) where more qualitative approaches need to be used. Through this, we illustrate how the optionality component of the total premium is related to the size and timing of the coupon step-up as well as the ambition level of the sustainability targets.

The analysis points out that an issuer can access a significantly lower yield/spread/higher total greenium if the negative incentives for non-performance are bigger and more front-loaded, and if sustainability targets are ambitious. We apply and showcase the approach in two cases of recently issued SLBs.

Please consider this a discussion paper to further the understanding of SLBs; we invite readers to contact the authors for comment and feedback. The final section highlights areas to develop further.

[1] SLB issuance totaled USD130.2bn in volume with 271 deals in 2021, see Climate Bonds Initiative, 31 Jan 2022.

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1. Introduction

Sustainability-Linked Bonds (SLBs) are one of the newest entrants to an increasingly active sustainable finance sector. SLBs are structured as fixed-coupon bonds where coupons increase by an amount called a coupon step-up at some stage during the bond's life shall one or several sustainability metrics (Key Performance Indicators - KPIs) are not met. In this way SLBs contrast from green bonds in that SLBs will target sustainability targets across an issuer's whole balance sheet, whereas green bonds finance a specific part of the balance sheet.[2]

With USD133bn[3] worth of issuance in 2021 alone, the SLB market has been poised with growth whilst being regularly called out over greenwashing concerns. Corporate issuers have largely dominated this market, seeing the opportunity to lower borrowing costs (in the form of "greeniums"[4]) as well as the issuances being markers of broader strategic sustainability alignments ("signalling"). Investor appetite for the product has been high.[5] Given the relatively quick growth, academic studies on the pricing dynamics is still in its infancy.[6]

Although there are no governing bodies regulating the way SLBs are structured yet, they usually aim to meet ICMA's SLB Principles requirements[7] which try to ensure a certain level of relevance and ambition on the SLBs' sustainability targets. However, ICMA's SLB Principles being general in nature, leaves it up to market participants' interpretation resulting in a diversity of opinions on how ambitious targets need to be in order to qualify as a an SLB.

Leaving aside the topic around whether the SLB targets in themselves are relevant or not to achieving an issuer's energy transition or other material sustainability targets,[8] market practitioners often reflect upon the potential risk to having the coupon step-up backloaded in the final years' of the bond, with fairly small step-up values (0.1-0.5%), as seems to be the current market standard.[9] One can question if the combination of just a few coupons that step-up before maturity as well as low step-up values in those coupons even generate financially materials incentives at all. The counter-argument to this is that an issuer carries an outsized reputational risk if the coupons actually step up.[10] However, the market appears to have reduced its sensitivity to non-calls in recent years.

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[2] There is a debate about the fungibility of money on balance sheet, and whether green bonds should have some requirements on the issuer level as a whole or not, see e.g. "How green bonds are (not) supposed to work", AFII, 25 Nov 2020.
[3] As per the Bloomberg database.
[4] See "What's in a Greenium: An Analysis of Pricing Methodologies and Discourse in the Green Bond Market", C. Harrison, C. Partridge and A. Tripathy, The Journal of Environmental Investing 10(1), 2020.
[5] "Sustainability-linked bonds – their potential to promote issuers' transition to net-zero emissions and future research directions", G. Vulturius, A. Maltais and K. Forsbacka, Journal of Sustainable Finance & Investment, Feb 2022.
[6] One of few examples is "Spread Analysis of the Sustainability-Linked Bonds Tied to an Issuer's Greenhouse Gases Emissions Reduction Target", M. Liberadzki, P. Jaworski, K. Liberadzki, MDPI Energies 2021, 14(23).
[7] "Sustainability-Linked Bond Principles", ICMA, June 2020.
[8] As an example "Enbridge oil sands SLB – participation trophy alert", AFII, 23 Jun 2021, reflects upon one SLB and its multitude of conditionalities and whether those are material or not.
[9] See "How companies can lower the bar in sustainability bond binge", Reuters, 15 Dec 2021.
[10] An analogy to this would be the reputational risk seen for banks not calling subordinated bonds, c.f. "Deutsche Bank non-call on sub-bond hits debt market", Reuters, 17 Dec 2008.

Coupon step-ups are not new: it has been a common investor protection measure in hybrid/subordinated bonds, where investors usually get a coupon step-up if the issuer is downgraded below investment grade. Lando and Mortensen (2004)[11] study this in the context of European telecom bonds.

This papers explores how to price the pure financial value of the coupon step-up, in order to better understand the all-in spread differential between an SLB and a traditional equivalent bond. If the option value is high, investors should accept a higher price on the bond (and a lower yield/spread) which then would explain a spread differential versus the vanilla bond curve. We argue that the true greenium (by which we understand the value that an investor ascribes to the bond due to its positive impact potential), should be the difference between the SLB bond spread and the vanilla bond curve adjusted for the option value inherent in the SLB. A brief discussion on premia in new issue bond settings is available in the Addendum.

Not accounting for the option value in an SLB may lead to assumptions that issuers are taking advantage of investors demand, as too great a greenium means investors are overpaying for the non-pecuniary features of the bond. Our experience of markets is that the investor collective would usually not subject itself to such a systematic loss of value, and the optionality value addition would go some way toward explaining why some studies have found SLBs to be more expensive than expected.

In order to price the step-up, we apply a Black-Scholes' options-based pricing method where the underlying dynamics of the probability that the coupon will step-up are explicitly modelled. Therefore it is natural to define coupon step-up probabilities in terms of drift and volatility terminology. But important to note, this volatility does not relate to the underlying security volatility itself (as it does when we price e.g. an equity vanilla call option), but instead with regards to the volatility around the sustainability targets. This means that deciding on specific aspects around the law-of-motion for the sustainability targets becomes crucial in order to price the option value.

It follows that, in order for the pricing approach to work, the considered SLB must have a reasonably well understood conditionality. Following this, we propose splitting the SLB universe into two categories: step-up priceable (SUP) and step-up non-priceable (SUN). We discuss ways to parameterize and infer parameters in the SUN context and implications of that. For example, if we believe a relevant target is to reduce CO_2e emissions by 5% per annum for a certain segment of companies, then this implies a similar trend ('drift') that the issuer of the SLB should outperform in order to contribute positively in terms of CO_2e reductions. In the final section of the paper, we implement the pricing approach on two recently issued SLBs and discuss how other assumptions and settings of ambition levels, as well as parameterization of timing of conditionality and coupon size could have affected the actual pricing.

[11] "On the Pricing of Step-Up Bonds in the European Telecom Sector", D. Lando and A. Mortensen (2004), Copenhagen Business School/SSRN.

The core contribution in this paper is to show how an SLB structure can be used to lower cost-of-capital for issuers through adjusting various parameters of the conditionality that then translates into optional value of the bond. An issuer with an ambitious target, a high-coupon step-up and a long pay-out time of the step-ups can achieve substantially lower cost-of-capital, even without subsidized financing from investors via "greeniums". These results would suggest a different market structure than today's low SLB premiums (with little effect on cost-of-capital) combined with too modest sustainability ambitions, small coupon increases and backloaded pay-outs. From an academic standpoint, in order to decide on "greenium", one needs to establish the optionality premium first, which this paper attempts to solve. We also highlight the need for parsimonious KPIs, with at least some historical data, in order to use the option premium argument when seeking to reduce cost of capital.

We acknowledge our model has limitations and we would encourage further research on these topics. From a mathematical standpoint, we do not include default probabilities such that we account for varying default paths if coupon steps-up happen or do not happen. In order to establish laws-of-motion and from there infer coupon step-up probabilities, we make a few assumptions that certainly can be challenged. We recognize the exploratory aspect of our approach in the context of sustainable bonds and expect subsequent iterations of our model as we gather market feedback.

1.1 Model specification

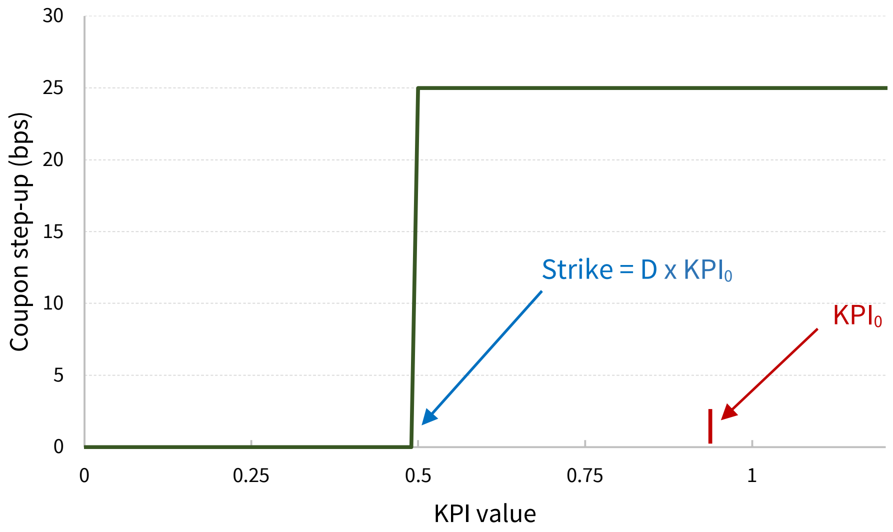
Consider a sustainability-linked bond that promises to pay coupons C_t at future times $0 < t_1 < \cdots < t_n$ and a principal N at maturity t_n. However, if a predefined Sustainability Performance Target (SPT) is not met at a specified date $t_\tau < t_n$, the SLB will pay additional coupons CSU_t (Coupon Step-Ups) between time t_τ and t_n.

The SPT is set up as a condition on one or several KPIs set against a defined baseline, D. For the purpose of the below model, we will consider that the SPT is linked to only one metric called KPI_t and that the SPT is met if $KPI_t < D \cdot KPI_0$ with $D < 1$. For example, if KPI_t refers to carbon emissions and the conditionality would be on a 25% emissions reduction by the measurement date τ, we would set $D = 0.75$.

Note that we define the SPT in the negative, i.e. the option is only called when the SPT is not met, in line with market practice. Also, in line with market practice, the option is of European knock-in style meaning that if it gets triggered on time t_τ, it does not reset, even if the company performs in line or better with the SPT after t_τ. As the SPT is based on an improvement of the KPI between t_0 and t_τ, the option is in-the-money at the time the SLB is issued.

An investor buying an SLB is thus long an ITM European binary call option observed at time t_τ, of maturity t_n and strike KPI_0 paying a stream of coupons between t_τ and the bond's maturity t_n.

Figure 1. Pay-out of an SLB which pays a 25bps coupon step-up if the KPI does not improve by more than 50% at the defined observation date. (European binary call option – Strike = 50%).



Therefore, an investor buying a SLB is effectively buying a "traditional" fixed-rate bond (SLB_0^1) and a binary option (SLB_0^2)called if the SPT is not met. Thus, we have:

$$SLB_0 = SLB_0^1 + SLB_0^2 \tag{1}$$

where

$$SLB_0^1 = PV\left(\sum_{t=1}^{n} C_t + N\right) \tag{2}$$

$$SLB_0^2 = \mathbb{E}\left[\sum_{t=\tau}^{n} 1_{\{KPI_\tau \geq \mathrm{D} \cdot KPI_0\}} \times CSU_t\right] \tag{3}$$

We assume that, under the no-arbitrage hypothesis, the value of a SLB_0^1 is equal to the discounted value of the future cash flows it is expected to generate:

$$SLB_0^1 = \left(\sum_{t=1}^{n} \frac{C_t}{B(O,t)} + \frac{N}{B(O,n)}\right) \tag{4}$$

For the purpose of this paper, we do not specify the dynamics of interest rates and assume they are deterministic. Therefore, we can express the discount factor as $B(O,t) = e^{-r_t t}$, with r_t being the risk-free interest rate at time *t*. Note that we assume here that we operate in a market without default risk: we will return to this further below.

Assuming $CSU_t$and KPI_t are independent, we can write SLB_0^2 in the following form:

$$SLB_0^2 = \mathbb{E}\left[1_{\{KPI_\tau \geq D \cdot KPI_0\}}\right] \cdot \mathbb{E}\left[\sum_{t=\tau}^{n} CSU_t\right] \tag{5}$$

The equation simply specifies that the value of the binary option is the expectation that the SPT will be met multiplied by the discounted value of the coupon step-up cash stream if the option triggers. Equation (*6*) can be reduced to a simpler expression:

$$SLB_0^2 = \mathbb{E}\left[1_{\{KPI_\tau \geq D \cdot KPI_0\}}\right] \cdot \sum_{t=\tau}^{n} \frac{CSU_t}{B(O,t)} \tag{6}$$

Breaking down the SLB pricing so far, we can see that at the core of the pricing is a measure of the probability that the SPT will trigger, $\mathbb{E}\left[1_{\{KPI_\tau \geq D \times KPI_0\}}\right]$.

But first it is useful to refine current arguments around what is a greenium in an SLB. Normally, a greenium is commonly understood as the yield/spread differential between a labelled bond and a real or hypothetical non-labelled/vanilla bond. If a green bond trades at a z-spread of 100bp and an interpolated curve for vanilla bonds for the same issuer would suggest it should trade at 102bp, we call this differential a 2bp greenium.[12] This number is generally interpreted as the excess willingness of investors to pay for a labelled bond as it achieves some sort of non-pecuniary motive.

From Equation (1), however, we note that in the SLB structure, the differential in spreads should be disassembled in terms of the traditional greenium as well as the option value inherent in the coupon structure. Just comparing the SLB spread with a vanilla bond spread is difficult unless the optionality is accounted for. Therefore, there are two components in the SLB pricing: first, a purely arbitrage-based condition that the investor is willing to pay in order for the optionality of higher coupons, and second, any additional premium the investor is willing to pay in order to achieve some broader 'good' as per SPT.

1.2 Coupon step-up probabilities

Returning to the probability measure that the SLB step-up will be triggered, $\mathbb{E}\left[1_{\{KPI_\tau \geq D \times KPI_0\}}\right]$, we note that in order to price the optionality and thus the SLB at all, one needs to define some sort of hypothesis on the dynamics of the KPIs in order to define a range of outcomes and their likelihood. This is not a trivial task, and we think it is useful to establish that some SLBs will be **priceable** (in cases where one can derive some meaningful hypothesis on probabilities) and some will be **non-priceable** (lacking a good understanding of what could drive probabilities). Such a classification allows investors to make the distinction between weak or robust KPIs of an SLB structure KPIs , and therefore should be a key input into the investment (sizing) decision.

To illustrate this discussion around construction of probabilistic measures, let us now turn to the application of this structure to an area which is ubiquitous in SLBs: carbon emissions. A standard construct is to relate the issuer's emissions to some threshold reduction level at time t_τ. If the emissions reduction is not met, the coupon steps up.

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[12] Note that greenium is defined in the positive on behalf of the labelled bonds, i.e. it reflects how much lower the spread is for the labelled bond versus the vanilla bond. A negative greenium suggests that the green bond would trade at a wider/higher spread than the comparable vanilla bond. Refer to the Addendum for an overview of various premiums in new issue bond pricing.

To derive likelihood that the SPT will trigger and thus price the structure appropriately, we suggest the following framework to think about how the KPI will evolve:

1. The issuer's own current emissions ('relative position', marked as blue dots in Figures 2-4).
2. The issuer's sector emissions and emissions trend ('exogenous trend', CE^{SECT}) that are exogenously given, for example by standards such as the Science Based Targets Initiative (SBTI).
3. The issuer's own emissions trend ('deterministic trend', CE^{*}, see Figure 4). A special case of this is where we make no assumptions on this, i.e. that trend growth is zero, CE^{0}, as in Figure 2 and 3.
4. The distributional properties of the KPI as depicted by the titled probability density functions (blue, yellow) in the figures. We will assume that these are normal distributions with varying volatility.

Let us first look at a scenario as illustrated in Figure 2 where we make an assumption that there is no endogenous carbon reduction trend for the company. If left un-incentivized, the company's carbon emissions would follow a completely stochastic process with zero emissions reductions expectation. If we at the same time, assume that the carbon emissions process that the CSU is linked to is also a zero expectation random process, it is trivial to see that the value of the binary option is simply a proportion of the discounted future cash flow value. It is heads or tails if you actually get access to the stepped-up coupons. However, as illustrated in Figure 2, there will be some probability distribution (blue) around that zero increase level CE^{0}.

Figure 2. Evolution of SLB KPI over time: No carbon emission increase, no endogenous trend.

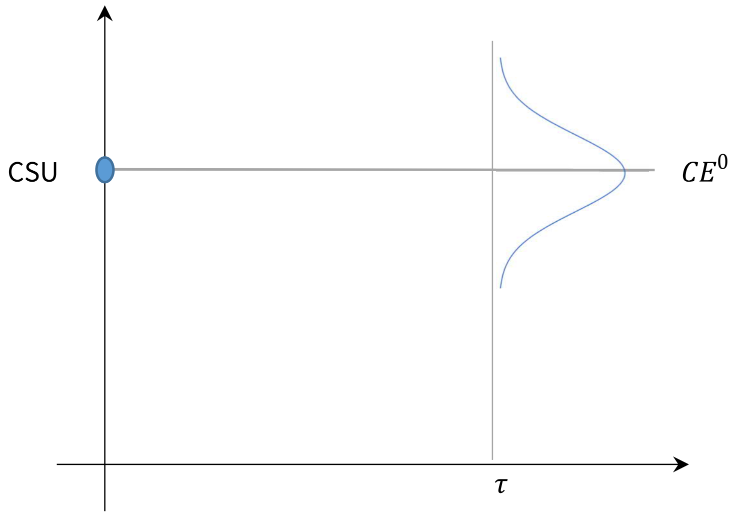
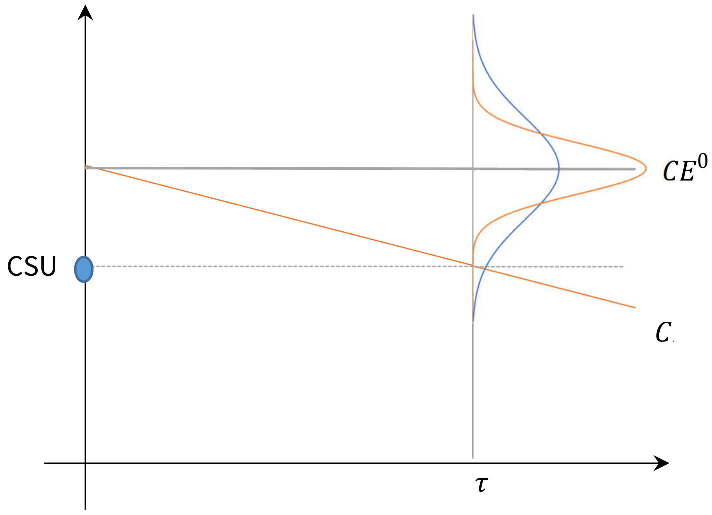


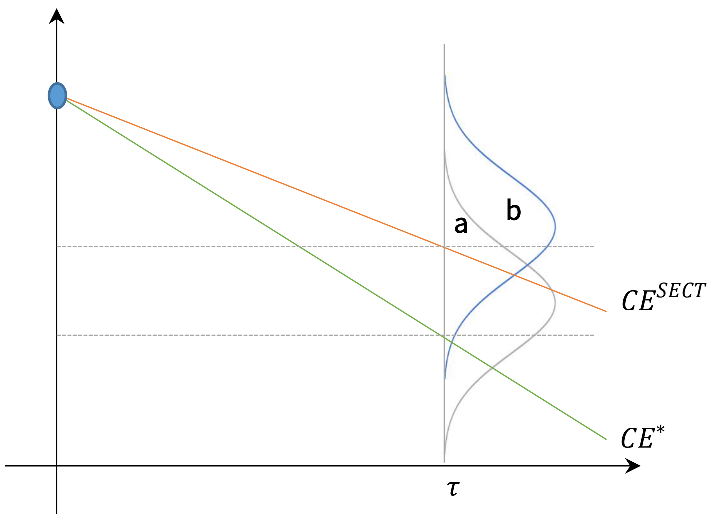
Figure 3. Zero ambition, sector carbon decrease trend: how higher volatility (blue pdf) makes the option value lower.



Finally, we look at a third scenario, Figure 4 where the ambition is linked to a sector decrease in carbon emissions (say 5% per annum). However, the company is deemed to have an even more ambitious reduction trajectory CE^* if it determines to pursue that. If the investor agrees to strike the sustainability condition at the sector trend, the company can "arbitrage" the premium they have been paid (corresponding to **a+b**): if they achieve the trajectory CE^*, the premium **b** that they have received has been an overcompensation on behalf of investors.

We believe this is an interesting conclusion: if investors are driven by scientific targets such that they know what the company should achieve on average in order to be sustainability-aligned, but the issuer is more ambitious than that (recognizing that there will be cost associated with that ambition), then there is an excess optionality premium that accrues to the benefit of the issuer.

Figure 4. High ambition, sector carbon decrease trend: how higher volatility and ambitious trend makes the option value lower.



Two key factors come out of the application of the model:

1. Setting the baseline trend (the exogenous trend). A more aggressive peer trend (steeper sectoral CO2 emissions reduction pathways) decreases the probability that the SPT will not be triggered/the option will knock-in, and thus reduces the arbitrage value of the SLB. An additional outcome of the model is that the SLB price does not depend on the baseline, only on the level of CO2 emissions at the time the SLB is being issued. Thus, there are no "rational" reasons for issuers setting baselines far in the past other than for marketing purposes.
2. Deciding on the discretionary capacity of the company to affect activities such that the company's emissions converge towards the trend. This is the "volatility" in the model. We can also interpret this number as a measure of the investor's belief that the company has means to actually stay below the SPT. This is an important point: A high belief that the company could reach the target (= a high volatility factor) implies, ceteris paribus, a lower value for the investor of the potential coupon step-ups: the investor simply does not expect the step-ups to be paid out.

To formalize the above, the KPI is defined as the company's carbon emissions CE_τ at time τ, and CE_0 is the emission at the time zero, i.e. at issuance of the bond.[13] Thus,

$$SLB_0^2 = \mathbb{E}\left[1_{\{CE_\tau \geq D \cdot CE_0\}}\right] \cdot \sum_{t=\tau}^{n} \frac{CSU_t}{B(O,t)} \tag{7}$$

Let us now more specifically define the dynamics of the hypothetical process driving whether the sustainability condition will be met or not, i.e. how do we specify CE_t in order to evaluate $\mathbb{E}\left[1_{\{CE_\tau \geq CE_0\}}\right]$? We let carbon emissions be described by a geometric Brownian motion, satisfying the following differential equation:

$$\frac{dCE_t}{CE_t} = \delta dt + \sigma dW_t$$

where δ (the "drift") is the general trend that the company needs to catch up to in terms of its sustainability target. This parameter essentially guides on what the company needs to outperform on, in order to not have to pay out stepped up coupons. We discuss more specific measures below.

The parameter σ provides the volatility metric of this stochastic process. In our framework, we see this reflecting two dimensions: Firstly, the magnitude of the stochastics affecting the company in terms of normal random events (e.g. changes in demand, production techniques based on raw materials etc); and secondly the capacity for the company to influence the evolution of the sustainability factor themselves. We can also interpret this number as a measure of the investor's confidence that the company has means to actually meet the SPT. This is an important point worth repeating: a high confidence that the company could reach the target (= a high volatility factor) implies, ceteris paribus, a lower probability for the investor that the coupon step-up will be paid out.

[13] We will return to more specific metrics around carbon emissions below.

Example: consider a thermal coal issuer issuing an SLB with a condition to cut thermal coal production by 50% in five years. The investor considers it very unlikely that the issuer will meet the condition as it would mean a fundamental change of the current business model, and thus a high probability that they will receive the coupon step up. This optionality is thus more valuable to the investor than if the issuer was more likely to reach the KPI. Taking this to the next step, the thermal coal issuer could thus extract a higher premium/lower cost-of-capital for setting an ambitious target than if they were less ambitious. Note the potential for different views on the volatility/probability factor if you are an investor or issuer.

Using the closed form of the Black-Scholes formula for binary options pricing[14] and the law of motion in (7) , the price of the SC coupon stream SLB_0^2 can then be expressed as:

$$SLB_0^2 = \phi(d_2) \cdot \sum_{t=\tau}^{n} \frac{CSU_t}{B(O,t)} \qquad (8)$$

with:

- ϕ the cumulative distribution function
- $d_2 = d_1 - \sigma\sqrt{t_\tau},\ \ d_1 = \frac{ln\left(\frac{CE_0}{D}\right) + \left(\delta + \frac{\sigma^2}{2}\right) \cdot t_\tau}{\sigma\sqrt{t_\tau}}$,
- D being the option's strike price

In the language of option pricing, the investor is buying a (binary) European call option where the process governing the payout is not based on the underlying asset price itself, but another stochastic process. The SLB's issuer, from this perspective, is selling the call option and collecting the premium. Combining current emissions, drift parameters and volatility, as well as call dates, defines how far in- or out-of-the-money the option is on issuance date, with commensurate effect on the price of the option/SLB.

Under the hypothesis that there is no arbitrage in the bond markets and that investors are not assigning non-pecuniary effects of their investments, the price of a SLB should be equal to the price of a "traditional" bond issued on the same day and with the same maturity, paying fixed coupons C_t' between t_1 and t_n. Thus, we can write:

$$SLB_0 = \underbrace{\left(\sum_{t=1}^{n} \frac{C_t}{B(O,t)} + \frac{N}{B(O,n)}\right)}_{\text{Traditional bond component}} + \underbrace{\phi(d_2) \times \sum_{t=\tau}^{n} \frac{CSU_t}{B(O,t)}}_{\text{Coupon step-up premium}} = \left(\sum_{t=1}^{n} \frac{C_t'}{B(O,t)} + \frac{N}{B(O,n)}\right) \qquad (9)$$

This equation tells us that in the absence of non-financial considerations from investors (i.e. pure value-based greenium and new issue premium – see addendum), the spread between C_t and C_t' should be a function of the SLB's embedded option price adjusted for discount factors:

[14] *Options, Futures, and Other Derivatives*- John C. Hull

$$\sum_{t=0}^{n} \frac{C_t' - C_t}{B(O,t)} = \phi(d_2) \cdot \sum_{t=\tau}^{n} \frac{CSU_t}{B(O,t)} \tag{10}$$

It should be noted that all else equal, the relationship between the coupon step-up and the option price is linear according to the above equation.

1.3 Parameter calibration

As discussed in the previous section, the price of the option embedded in the SLB, depends on the calibration of two parameters: the drift and the volatility of the KPI. The direct way to calibrate the option parameters would be to look at the historical data of the KPIs and from that data make inference of the dynamics of the KPI.

Put more simply, in order to forecast how likely it is that the KPI will achieve the SLB condition, we need to have some idea about the dynamics of the KPI such that we can generate a forecasting model for it. This requires the KPI to be (1) measurable, and (2) have actual time-series data for those measurements. This is expressed in ICMA's "Voluntary Process Guidelines for Issuing Sustainability-Linked Bonds" (June, 2020) explicitly as "The KPIs should be: […] measurable or quantifiable on a consistent methodological basis […]".[15]

For the purpose of our methodology, an SLB with KPIs that fulfil conditions (1) and (2) above is defined as a **step-up priceable (SUP)**-SLB, simply meaning that we can infer some sort of probability distribution for the likelihood of a coupon step-up. SLBs where no or little such inference that can be made, we define as **step-up non-priceable (SUN)**.

This is not to make a distinction of the quality of either category's non-financial impact: a SUN-SLB may have much greater non-financial impact (as hence more implicit value for investors looking for that) than a SUP-SLB and thus deserve a greater premium. What we are highlighting is a SUN-SLB just has to be priced differently than the SUP-SLB. The advantage of the SUP is that under our methodology this can be partially priced, which should lead to a lower uncertainty premium, ceteris paribus, in the SUP-SLB versus the SUN-SLB.

Under the assumption that we are working with a SUP-SLB, and assuming a law-of-motion as of Equation (7), we now turn to discussing how to calibrate the drift and volatility parameters.

Drift - δ

The drift parameter can be interpreted as an acceptable trend factor, such as the minimal rate of KPI improvement as required by some robust benchmark. For example, in the context of carbon emissions, a macro target such as the reduction in absolute emissions needed per annum to align with the Paris Agreement could be considered such as drift. According to the Intergovernmental Panel on Climate Change (IPCC),[16] limiting global warming to below 2°C requires a decline of 25%

[15] We also note the added condition with respect to benchmarks: "[…] able to be benchmarked, i.e. as much as possible using an external reference or definitions to facilitate the assessment of the SPT's level of ambition." which is relevant in the context of our earlier discussion around ambition levels.

[16] "Special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways", IPCC, 2018.

from 2010 levels by 2030 (-2.84% p.a.) whereas the 1.5°C scenario entails a decline of 45% (-5.80% p.a.).

Clearly the required reduction in emissions to achieve these targets differs between sectors and industries, but until these are more widely available - as baseline on a portfolio level - the macro target should fit an investor trying to align a diversified portfolio with Paris targets.

Other, more specific ways to calibrate the drift rely on issuance-level analysis based for example on the below parameters:

- Historical data
- Science-based targets
- Peers-based comparison
- Issuer's own declared sustainability targets
- Climate scenarios
- Regulatory requirements

This clearly highlights the need for further research into relevant drift terms, but the advantage of specifying into a single drift term is that it becomes in some form comparable across SLBs such that investors can have a first go at ambition levels built into the comparables.

Volatility - σ

In order to account for the capacity of the issuer to influence its carbon emissions, we can express the volatility as follows:

$$\sigma = \sigma_i \cdot \beta$$

where:

- σ_i is the carbon emissions' intrinsic volatility calculated based on the issuer's historical data (i.e. historical volatility).σ_i
- β is a measure of magnitude of the issuer's capacity to influence its carbon emissions.

we recognize the complexity to calibrate the β parameter as it depends on the investors' appreciation of the issuer's sustainability profile. Where no strong such views exist, one can/should simply set $\beta = 1$.

If one decides to apply β adjustments, an issuer perceived as unlikely to improve its carbon emissions profile (for example, an issuer without a credible transition plan or management team) would get a β <1, whereas an issuer whose management is fully committed to transition to a low carbon production process would get a β>1. In terms of our earlier discussion around a divergence between investors' perception of probabilities to reach targets versus the issuer's belief, this would manifest itself through varying values of β. if we assume that investors have a belief β and the issuer has its own β^*such that $\beta < \beta^*$, then by necessity investors' volatility assumption will be lower than the issuer's, $\sigma < \sigma^*$, implying that the issuer can harvest an excess SLB premium.

1.4 Multiple KPIs

So far, we have focused on SLBs with Carbon Emissions as the only KPI but many SLBs depend on more than one KPI. As an example, Enbridge has issued in 2021 an SLB linked to carbon emissions, workforce diversity and percentage of women on the board.[17] Although integrating multiple KPIs can be perceived by the market as the issuer's commitment to its sustainability strategy across the company, we want to bring our readers' attention to the resulting increased pricing complexity, where the distinction between SUP and SUN-SLBs is also important.

If we consider an SLB dependent on two KPIs, Equation (3) becomes:

$$SLB_0^2 = \mathbb{E}\left[\sum_{t=\tau}^{n} 1_{\{KPI_\tau^1 \geq \mathrm{D}\cdot KPI_0^1\}} \cdot 1_{\{KPI_\tau^2 \geq \mathrm{G}\cdot KPI_0^2\}} \times CSU_t\right] \tag{11}$$

To estimate the value of SLB_0^2, we now need to consider that either KPI^1 and KPI^2 are independent or be able to model their correlation. Regarding independence, studies show that even if the KPIs belong to different ESG segments, the correlation is likely to be high. A 2020 study evaluates the average correlation between the E and S factors at 0.79 for S&P500 companies.[18] In the second case where correlation exists, we need to explicitly model it. In a bivariate case, this is straightforward if one has sufficient data, and slightly more complicated once one considers three or more KPIs that are not easily measured or supported with quality data. In general, given the issues with availability of data, we would opine that it is hard enough to define the dynamics of one time-series in the ESG context, let alone the interdependence between several, thus making it hard to define such instruments as SUP-SLBs.

Having said that, investors and issuers could consider having one core priceable KPI in their structure that is step-up priceable, and then adding others as good measure, but not be expected to derive a premium for them. Alternatively, we view positively an SLB paying several step-ups, each one depending on a different KPI as it removes the need for modeling the correlation between KPIs.

[17] "Enbridge oil sands SLB - participation trophy alert", AFII, 23 Jun 2021.

[18] "Does environmental, social and governance performance influence economic performance?," K. Cek and S. Z. Eyupoglu, Journal of Business Economics and Management 21(4):1165-1184, 2020.

2. Empirical applications

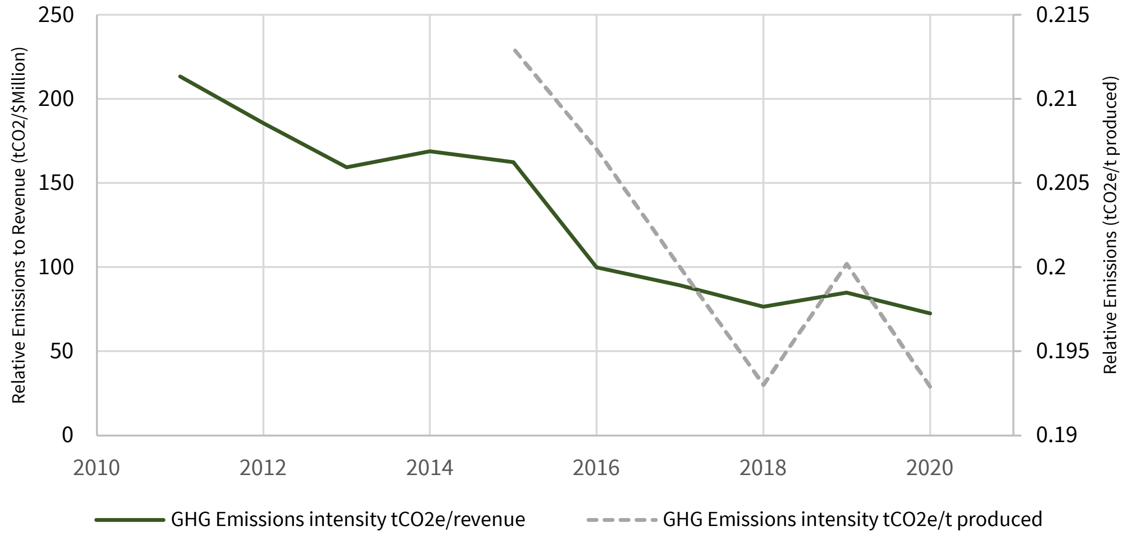
2.1 SUZANO 3.75% 01/15/31

Brazilian paper company Suzano entered the SLB market as early as 2020, raising approximately $2.75 billion through four transactions.[19] Suzano estimates the greenium of its 09/14 SLB issuance at 15 basis points compared to a non-SLB bond.[20]

The Suzano 3.75% SLB's sustainability condition is linked to emissions intensity relative to the output produced, which is a common KPI in the space. Notably, the KPI upon which the SC is based is averaged over two years rather than being a snapshot. From a technical standpoint, this lowers volatility of the KPI. However, we deem this effect small, and consider the sustainability condition only observed for the year 2025. Our readers will notice that averaging data collected on predetermined observation dates results in a lower volatility hence a reduced option price (an "Asian" option in the world of derivatives trading).

Issuer: Suzano (Ticker: SUZANO)
Issue size: USD1.25bn
ISIN: US86964WAJ18
Issue date: 10 September 2020
Maturity date: 15 January 2031
Coupon: 3.75% with a 0.25% step-up if the company does not meet its "sustainability condition"
Sustainability condition: a reduction of Greenhouse Gas Emissions Intensity to 0.190 tCO2e/ton produced or less by the end of 2025, equivalent to at least an estimated 10.9% reduction as measured against the 2015 baseline year, calculated by taking the average of the tCO2e/ton produced for the years 2024 and 2025.

Figure 5. Suzano's carbon emissions relative to revenue vs tons produced. Source: Bloomberg, Suzano, AFII.



[19] SUZANO 3.75 01/31 (US86964WAJ18, USD1.25bn), SUZANO 3.125 01/32 (US86964WAK80, USD1bn), SUZANO 2.5 09/28 (US86964WAL63, USD500mn). Note that the KPIs for the 3.125 and 2.5 were focused on female representation and industrial water usage rather than the GHG emissions target in the 3.75 bond.
[20] "Suzano: Sustainable bonds, rather than loans, is where the greenium is", Environmental Finance, 2021 (1).

As a reminder, we evaluate the volatility as follows$\sigma = \sigma_i \cdot \beta$ with σ_i as the historical volatility of the KPI and β as a potential adjustment factor.

Obtaining KPI volatility in this case is not straightforward as we only have six historical data points for the intensity of carbon emissions relative to the tons of pulp and paper produced, as illustrated in Figure 5Figure 5. Arguably, this is a small sample size to have a strong inference on the volatility parameter even if it is still more than for most SLBs. As an alternative, we proceed by using the intensity per sales (rather than production) as a proxy as that dataset provides us with eleven data points and seem fairly correlated with the intensity per tons produced. It should be noted that the quality of our approximation depends on the stability of Suzano's products prices.[21] Using the CO2e/t proxy, we estimate the historical volatility such that $\sigma_i = 16.56\%$.

According to the SPO[22], Suzano's transition plan seems to be in line with peers whereas its Bloomberg ESG Disclosure data score is above the sector's median, such that we see little need to do any β-adjustment. Thus, we have:

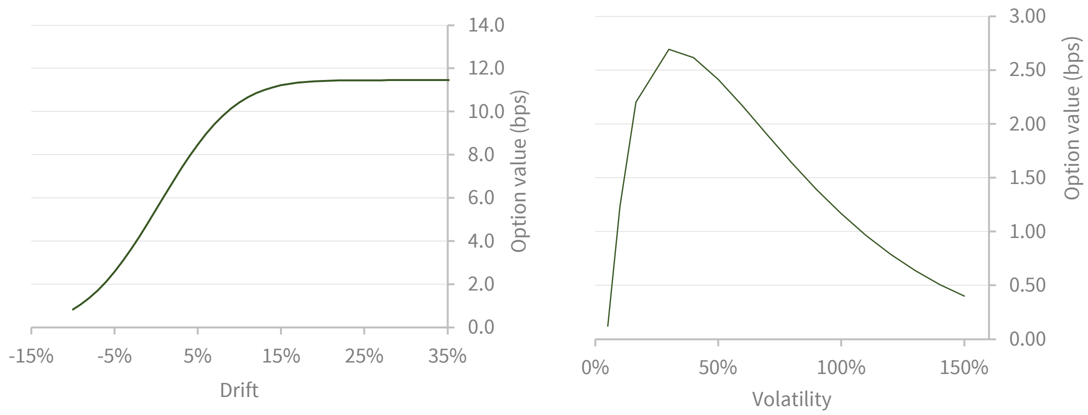
$$\sigma = 16.56\% \cdot 1 = 16.56\%$$

Using this, we calculate the option value in the SLB based on various drift parameters:

- IPCC 1.5 degrees (-5.80% p.a.): 2.20bps
- IPCC 2 degrees (-2.84% p.a.): 3.71bps
- Historical drift (-1.96% p.a.): 4.23bps

This illustrates the optionality effect quite clearly: depending on the assumed ambition level, the option premium value (that accrues to the issuer) changes between 2.2-4.2bps. If Suzano were to continue decarbonizing as it has done historically, the likelihood is high that the company would not meet its SLB condition, which leads to a high valuation of the coupon step-up option. We illustrate this drift sensitivity in Figure 6 (left). Note that once the drift becomes "high", the option value converges to the value of the (discounted) coupon step-up payments, almost 12bps.

Figure 6. (Left) Sensitivity of Suzano SLB optionality to the drift parameter; (Right) Sensitivity to the volatility estimate.



[21] An important point when measuring carbon intensity as CO2e/sales is whether sales revenue is inflation-adjusted or not. If sales are considered in nominal terms, the intensity will deflate in the same pace as inflation with compounding effects.

[22] Suzano Secondary Party Opinion (SPO) – ISS

Looking at the sensitivity of the model's parameter, we can observe on Figure 6 (right) that the option price is a bell-shaped function of the volatility which is somewhat intuitive: the bigger the potential movements in carbon intensity the higher the probability to meet the SPT but as the drift is far in the negative territory, too small movements (i.e. volatility) around the trend increase the probability to meet the SPT.

Using these inputs and applying Equation (9)-(10), we find that the premium in as measured solely by the inherent value of the coupon step-up for Suzano's SLB should have been 2.2 basis points. If we take the stated number of total greenium of 15bp at face value, then we would deconstruct this as 12.8bp of non-pecuniary greenium and 2.2bp of optionality value.

The key take-aways from this example:

- **Parsimony and data-availability**: Having appropriate and accurate data is crucial for calibrating the option price. If we assume that investors will require an uncertainty premium when lacking data on the dynamics of the KPI, it is actually in the interest for the issuer to provide data-sets for the investors to calibrate on. Our experience, to be formally published in later work, is that such data-provisioning is unusual to say the least.
- **Baseline behavior/drift assumptions:** differing assumptions on the counterfactual ("if the company were not to issue an SLB, what would its KPI trajectory have been?") clearly has an important effect when quantifying the option value. Again, if the issuer can present a solid case for its counterfactual, it does remove uncertainty premiums. Also, similar to how market participants assumed recovery values as given in CDS pricing, one could imagine standards develop whereby, for example, KPIs are gauged versus IPCC 2-degree target pathways.

2.2 REPSM 0.375% 07/06/29

Oil multinational Repsol launched its first SLB in June 2021, raising EUR1.25bn over an 8yr and a 12yr tranche. Our study focuses on the 8y tranche, which offered investors a 25bps step-up in 2027-29 if the company did not achieve a 12% carbon intensity reduction by 2025.[23]

Issuer: Repsol (Ticker: REPSM)
Issue size: EUR650mn
ISIN: XS2361358299
Issue date: 29 June 2021
Maturity date: 6 July 2029
Coupon: 0.375% with a 0.25% step-up if the company does not meet its "sustainability condition"
Sustainability condition: reduction in Repsol's carbon intensity indicator of 12% by 2025

For the purpose of their SLB, Repsol designed its own methodology for calculating their carbon intensity (CII – Carbon Intensity Indicator) which "measures the CO2e emissions for every unit of energy that the company makes available to society".[24] From a pure pricing standpoint, the internal definition poses several issues: (1) the company did not – to our knowledge – make historical data publicly available on the evolution of this KPI, thus making probabilistic inference only possible through proxy; (2) translating science-based goals in terms of SPT expectations (and subsequently defining the drift) might prove highly complex.

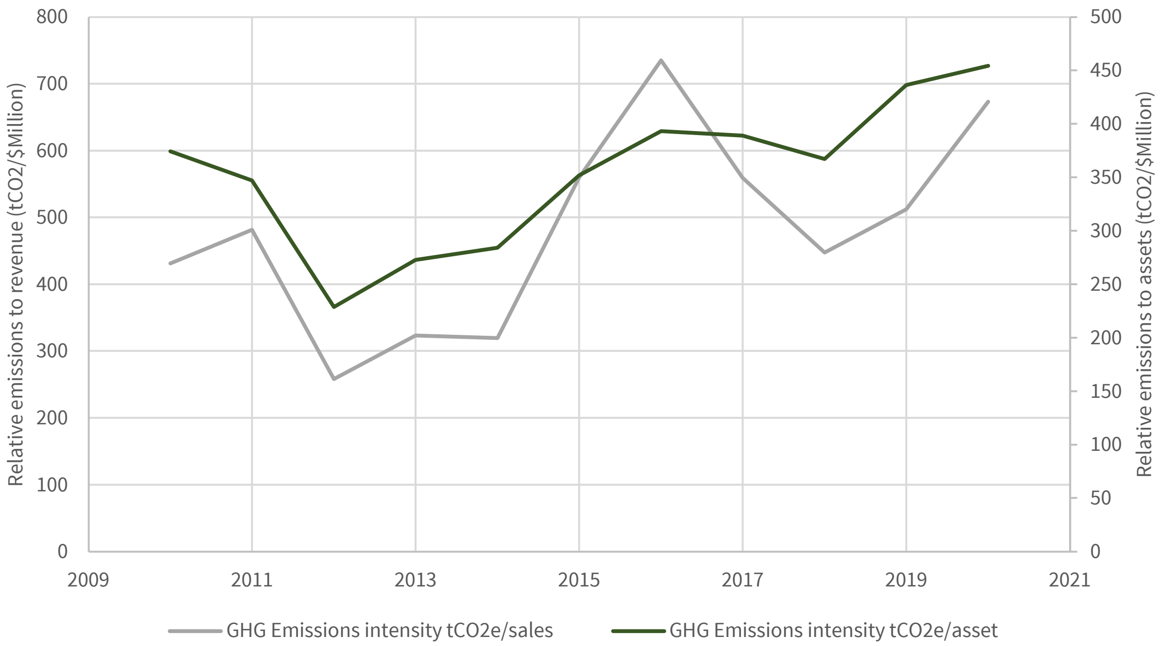
[23] In contrast, the 12yr bond, REPSM 0.875 07/2033 (XS2361358299), had a step-up of 37.5bps per annum in 2032-33 if the carbon intensity KPI had not declined by 25% by 2030.
[24] "Repsol Carbon Intensity Indicator - definition," Company presentation material, accessed 14 Mar 2022.

As previously discussed in the paper, we would likely define this type as a step-up non-priceable (SUN) SLB where investors are not provided with enough information or structure to price the optionality of the bond, hence removing optionality value and increasing the cost-of-capital accessible for the issuer.

However, we still find it useful to evaluate also this SLB out of a proxy KPI perspective. Coming back to our statistics estimates, after reviewing of the KPI definition, we believe "Carbon Emissions relative to Revenue"[25] to be an acceptable proxy. Repsol's Carbon Intensity Indicator's measures the company's CO2 equivalent emissions (numerator) relative to energy obtained through their products (denominator) which is directly linked to the amount of products sold by the company with the drawback that carbon emissions relative to revenue are calculated in nominal terms. Collecting data for the proxy as per Figure 7, we evaluate the historical volatility at 32.2%.

Using the IPCC target 1.5 drift (-5.80%) and a beta parameter of 1, we obtain a valuation of the optionality of 3.3bps. Note that the issuer compared the future values to a 2016 baseline. This may be useful optically – a 12% reduction from 2016 may sound bigger than e.g. a 5% reduction from 2018 – however in terms of the pricing model, only the latest data is relevant in terms of deciding how likely it is that the step-up condition will (not) be met.

Figure 7. Repsol's carbon intensity relative to revenue and assets. Sources: Bloomberg, AFII



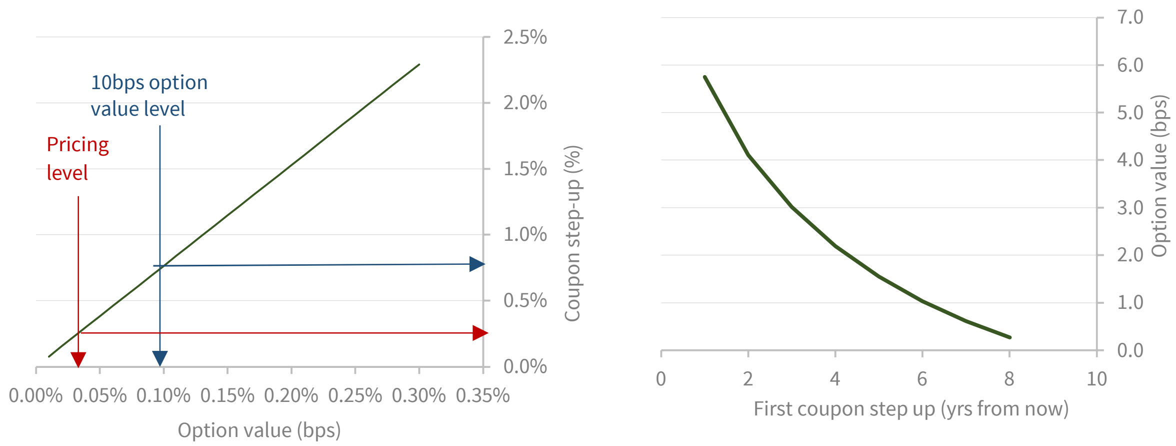
Our first sensitivity analysis with regards to this structure is to look at how sensitive the option value of the SLB would be with respect to more ambitious coupon step-ups. We illustrate this in

[25] Source: Bloomberg. Definition: Total greenhouse gas (GHG) if available, else total carbon dioxide (CO2) intensity calculated as metric tonnes of greenhouse gases, if available, else CO2 emitted per million of sales revenue in the company's reporting currency.

left-hand panel of Figure 8. For example, holding the other parameters of the model constant, we can see that in order to get to a 10bp option value premium, the coupon step-up should have been 76bps instead of 25bps (shown as the blue arrow relationship in the graph). This illustrates how the issuer can target a certain all-in-greenium of the SLB by adjusting the size of the coupon. Although it might seem trivial, it may be of some importance when deciding on the structure of an SLB to understand that higher coupon step-ups generate lower cost-of-capital for the issuer in an almost mechanical, linear way.

In the right-hand panel of Figure 8, we look at the impact of the first coupon step-up date on the option value. Intuitively, the option value is increasing as the length of the time-period when the step-up is being paid increases. Ceteris paribus, a structure that starts paying coupon step-ups on dates closer to the issue date is more valuable than one that does so at a later date. Nonetheless, our readers will observe that the relationship is not linear. As time passes, the probability to reach the target increases which in other terms lead to a lower probability the SLB will pay the coupon step-up.

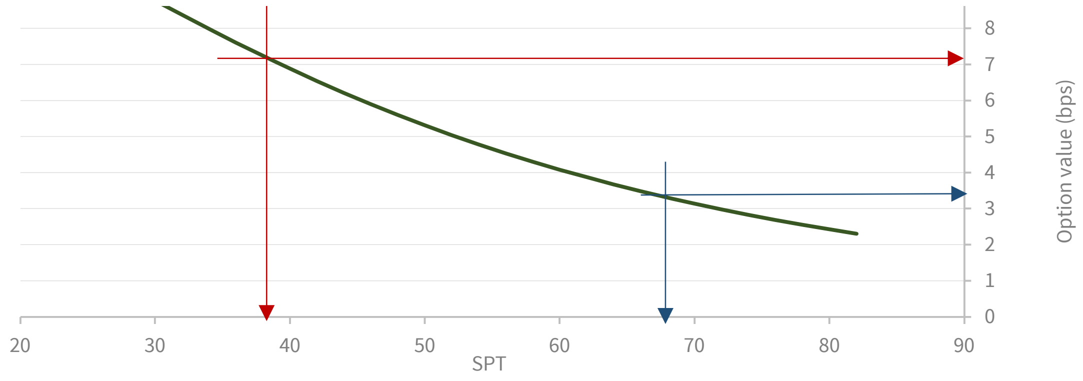
Figure 8. (Left) Coupon step-up as a function of the option value; (Right) Option value as a function of the timing of the coupon step-up. Source: AFII, Bloomberg.



Another application of the model is to calculate the option value as a function of the sustainability performance target (SPT). As observed in Figure 9, the theoretical option value of Repsol's SLB would have more than doubled had the SPT been set at 38.85 g CO2e/MJ (red lines) instead of 68.4 g CO2e/MJ (blue lines), i.e. a 50% carbon intensity reduction compared to the 2016 baseline. From a optionality standpoint, a more ambitious SPT entails an option that is even more "in-the-money" and subsequently priced higher. Indeed, in the 2021 Sustainability Report, Repsol announced an absolute Scope 1 + Scope 2 emission reduction targets of 55% to 2030,[26] which – if adhered to and applied in an SLB framework – would have allowed the issuer to reap that 10bps option premium. Add to this a reduction of uncertainty premium, as from a statistical angle such a target would have been much easier to generate data for as well as to measure going forward.

[26] "Repsol increases its targets for renewable generation and emission reductions", Company press-release, 5 Oct 2021.

Figure 9. Option value in the Repsol case as a function of the SPT. Source: AFII, Bloomberg



Key takeaways from our Repsol example are as follows:

- **Structural parameters:** We show how the interaction between the option premium and the structural parameters (coupon step-up size, timing of CSU) can be tuned to achieve, for example, a particular coupon size. It is clear that these decisions are quite material for the size of the option premium and hence the all-in-greenium the issuer can access.
- **KPI construction and condition ambition:** the Repsol SLB has what appears to be an over-engineered KPI making probabilistic inference hard in our view. Using an alternative, however, we show how ambition-level again can drive quite different magnitudes of the option value and all-in-greenium.

3. End notes and suggestions for further research

The size of coupon step-ups, the timing of when they happen and the probability that it will happen are three factors that are crucial to determine in order to price the optionality value in a sustainability linked bond. For market participants, we believe that being able to have a decent amount of inference on the last factor, probabilities, is important in order to reduce risk-premiums on this novel type of bond. Thus, it would seem to be in the interest of issuers of SLBs to actually provide more robust and transparent data and metrics in these structures than what is the case currently in the market. We believe, from an investor perspective, that segmenting SLBs coming to market as step-up priceable (SUP) or step-up non-priceable (SUN) is useful to direct efforts in terms of analysis and potentially investment activity.

Moreover, we believe the proposed pricing approach should provide issuers with a stronger argument as to why SLB targets should be ambitious as it does link ambition levels to actual lowering cost of capital. The analogy with convertible bonds is not far-fetched: convertibles have lower coupons than traditional bonds due to the equity conversion optionality. If investors deem that optionality valuable, they will accept significantly lower coupons on the bond component. In the context of transition companies, which often is touted as the key domain for issuing SLBs, "selling" optionality around transition plans, will drive significantly lower cost-of-capital only if the targets are indeed ambitious.

In the empirical examples that we have shown in this paper, some of the SLB option premiums might have seen modest, as bonds still have been relatively short, but it is worth reminding that the maximum size of the premium grows in line with the full discounted cash flows of the step-up. Longer bonds will start showing magnitudes that are substantially bigger. Building structures such as 5x15s, i.e. a five year condition and fifteen year maturity, will be an interesting application that also should align well with the long-term commitments of energy transition projects.

This paper is presented in a "Consultation paper" format and we invite readers to contact the authors for comments and critique. We recognize some of the short-falls of the current approach where more research is needed:

Integration of default risk

In this first version of the pricing approach, we do not model default probabilities. The probability that the bond will be repaid (and that coupons will be paid) is correlated to the level of spread that the bond is trading at. Given that the coupon step-up increases spreads, one should expect that the value of the option is decreased, as it is less likely that the step-up coupon stream will be paid in full compared to the non step-up. The differential will be increasing in step-up size. Add to this any correlation between the failing to miss a sustainability target and underlying default probabilities as well: studies show that a company which poorly manages its sustainability risks is more likely to underperform overall.[27] We intend to model default probabilities in a future extension to the current approach.

[27] "Are Sustainable Companies More Likely to Default? Evidence from the Dynamics between Credit and ESG Ratings?", A. Aslan, L. Poppe and P. Posch, MDPI (2021).

Effects on duration/YTM

Investors looking to buy SLBs should be warry of the effects the optionality of the coupon step-up could have on the bond's duration and convexity and the substantial impact on their portfolio's total risk assessment. Our approach of inferring probability metrics for the sustainability conditions being achieved should be helpful in such calculations.

Parameter calibration

Pricing SLBs requires both observable and latent variables as an input. Observable variables such as coupon or maturity are directly observed whereas latent variables (namely drift, beta and volatility) require mathematical models and/or investors' judgement to be estimated. The use of latent variables is not new to the financial sphere and is inherent to option pricing. The disclosure of ESG data being relatively recent in the financial markets' history, it is not surprising to see many issuers coming in the market with SLBs that belong to the "SUN" segment of the SLB market. As time passes and regulators and investors push for increased data quality and disclosure, we should see the proportion of "SUN" SLB decreasing to the benefit of "SUP" SLBs.

We introduced in this paper a simple methodology for evaluating the KPI's volatility based on both historical data and investors' own appreciation of the issuer's sustainability profile (the "beta"). However, there might not be enough of the KPI's historical data to perform meaningful statistics calculations hence why small sample techniques (econometric approaches, structural mathematical modelling) in this context could be a promising direction for future research. The beta parameter on the other hand cannot be observed. An idea for objectifying its calibration is to create a decision tree based, for example, on the quality of data disclosed and the belief in the issuer's transition plan.

Advanced coupon step-up structures

As has been briefly touched upon, most SLBs in the market currently have several KPIs, and further research is needed in terms of understanding how to price the optionality in such cases. As argued, a high correlation between KPIs will reduce the additional optin value by each KPI compared to when it has been applied individually. This effect is often used in pricing structured products such as auto-call baskets, and not in a way that we deem in benefit to the end investor.

Furthermore, we have only considered a one-time knock-in type of SLB structure. There could be many variations to this, which could have meaningful impacts in terms of driving sustainability impacts: for example, having multiple, additional step-ups if conditions are not met, or having step-downs if they are. Having good inference on the law-of-motion for the KPIs becomes more and more important as the coupon structure becomes more complex.

4. Appendix: Decomposing risk premiums in labelled bonds

We illustrate this in *Figure 10* where we also add a new issue premium component. In the example, we assume that a secondary market bond would trade at point A ("Fair value") at a spread of 54bp. However, a new issue bond would have to offer a new issue premium (NIP) of 11bp, landing it at 65bp (point B). Hypothetically, a new issue green bond would be issued at 60bp (point D), meaning that the real greenium in a green bond would be (B-A)-(D-A) = (65-54) - (60-54) = 5bp when accounting for the inherent new issue premium. [28]

Now, if we assume that the optionality component in a coupon-step up bond would be worth 5bp for the investor, we would get a standard bond pricing with step-up optionality at 49bp (C), excluding NIP. If we define an SLB as a green bond with a coupon step-up, that SLB would then price with both the greenium (13bp) and the option premium(5bp) at 47bp (E) in fair value terms. However, given that is it a new issue, we need to add the NIP:

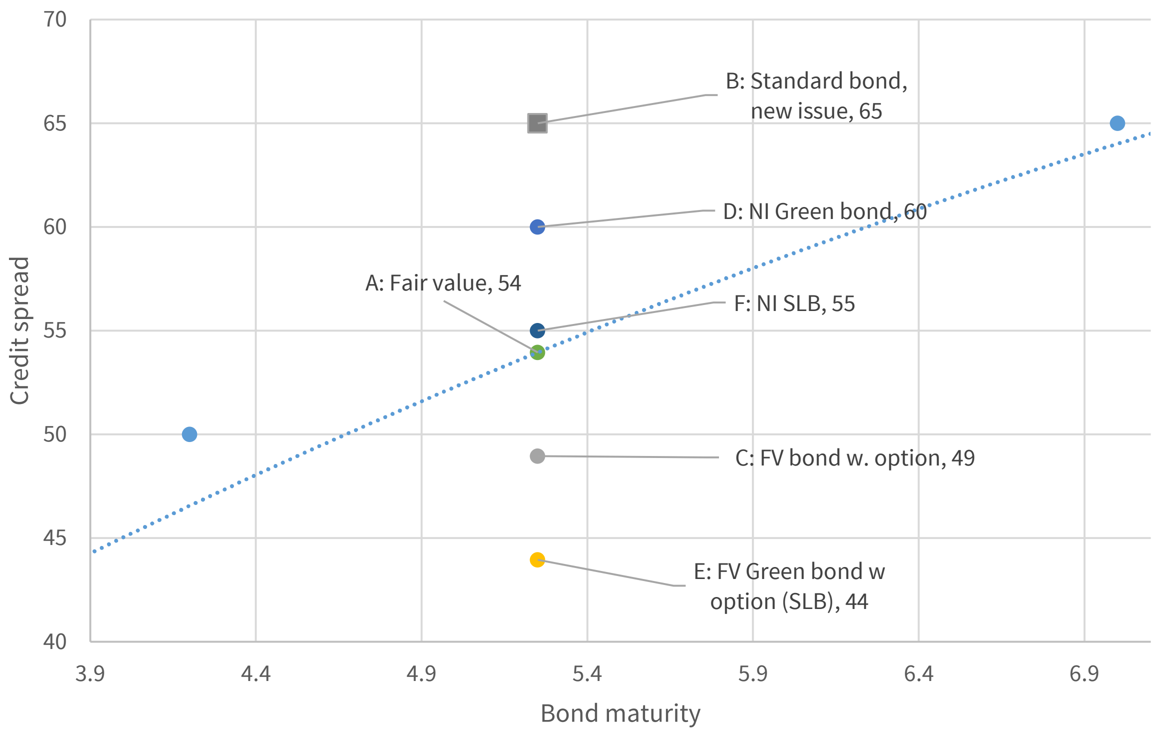
SLB NI spread = Bond fair value + new issue premium – optionality value – greenium =

F= A + (B-A) – (A-C) – (B-D) ⇔ F= B-A-C-D

⇔ D=B-A-C-F which is the expression to get the greenium in the SLB, accounting for NIP and optionality in it.

We note that the NIP (B-A) can be inferred from cross-sectional analysis of the market.[29]

Figure 10. Deconstructing a 'greenium' in an SLB.



[28] There are more factors to add here, such as a liquidity premium, but we believe that to some extent should be factored into the model that provides the fair-value spread.
[29] New issue premia across the market can be found through analysis similar bonds being issued in a similar time-period and with similar bond features.

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