Transition linkers

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Abstract

This paper introduces a novel financial instrument, called the transition linker: a sovereign bond which allows investors to hedge risky asset return correlation with national progress on the energy transition. Transition linkers share similarities with inflation-linked bonds, convertible bonds, and other performance-linked debt instruments. Their defining feature is a coupon rate that adjusts in steps depending on whether the issuing country meets, exceeds, or falls short of its externally committed decarbonisation targets. We demonstrate how transition linkers can play a key role in asset allocation under the hypothesis that unsuccessful energy transitions could lead to lower or more volatile returns on risky assets. At the same time, the linker provides cost-of-capital incentives for the issuer (the government) to generate policies that increase the transition likelihood. The paper develops a pricing approach for transition linkers and discusses various structural implementations to accommodate traditional mainstream fixed income books and analyses hypothetical transition linker formats for Japan, Australia and Mexico.

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1 Introduction

The energy transition theme is front of mind among large global investors and policymakers. There is, however, a substantial disconnect between investment exposures and the success or failure of policymaking. An asset owner may hold an investment hypothesis that market-wide risky asset returns will be lower and/or more volatile in case of a failed energy transition but have few ways to hedge the portfolio accordingly. At the same time, while governments may want to transition their economies the long-term financial benefits of doing so may come in conflict with short-term electoral considerations.

In many ways, this problem is similar to that of inflation. Consider a pension fund that is invested in both equities and government bonds in their domestic market. If the government runs an inflationary policy, nominal risky asset returns may go up but remain flat or even fall in real terms, while bond portfolios will likely fall in real value. If the risk of an inflationary policy is high, investors require a higher interest rate on the government bond – everything else equal – than if a lower inflation pathway is credibly committed to, see Thedéen (2004). This has led to the development of the inflation linker market, where investors receive higher returns to compensate for inflation. This provides investors with a hedge against perceived suboptimal policy, while at the same time reducing incentives for governments to run that policy; for examples, see Velandia-Rubiano et al. (2022).

With a similar hedge/policy approach, this paper proposes a transition-linked bond. The transition linker is similar to an inflation linker, but rather than using a price index as target variable, the transition linker would use a government's committed carbon reduction target(s). If targets are not met, the coupon level of the bond adjusts, providing investors with a hedge against suboptimal transition performance and governments with an incentive to achieve their transition goals.

In a broader structural perspective, the transition linker is a performance-linked bond. This we define as a bond where the coupon or the nominal (effectively the lifetime yield of the bond) is dependent upon the performance of a set or implied target. Performance-linked bonds span a large spectrum: for example, the earlier mentioned inflation linkers as well as convertible bonds, corporate hybrids, financial hybrid capital, catastrophe bonds, and more recently sustainability-linked bonds (SLBs).

Specific to the transition linker, the decarbonisation target is externally committed to and, in some cases, verified against the issuing country's Nationally Determined Contributions (NDCs). This provides a clear metric for which there will be a continuous supply of data and new information. In order to capture a distribution of outcomes around the decarbonisation target, we structure the transition linker as a bond plus option structure with multiple strikes and coupon adjustments based on outperformance or underperformance vis-a-vis the decarbonisation target. Given that NDCs are committed to at five-year intervals, e.g. 2030, 2035 and so on, transition linkers could be issued at maturity points well in line with traditional government bond issuance. Moreover, by connecting transition linkers to NDCs, issuers do not need to make any more commitments to target variables, a point which has previously made for complicated discussions between treasuries and governments in labelled bond issuances, see Cheng et al (2022).

As we will show in the following sections, the transition linker combines the technical mechanism of an inflation-linked bond, offering a hedge against adverse outcomes and creating incentives for the issuer to mitigate those risks, with an enhanced SLB structure that incorporates broader target-setting capabilities. We expand beyond the characteristics of these instruments by incorporating multiple strikes on one single target variable and introducing an incremental coupon adjustment, as well as having the target variable set exogenously.[2] As such, it leverages the idea of pricing performance-links as options struck on some variable such as equity price, inflation, credit rating, or in this case decarbonisation. From a pricing perspective, the transition linker can also be described as a convertible bond, but with a binary rather than continuous call option.

This paper makes a clear distinction between performance-linked and sustainability-linked, as the term "sustainability" has become an expression of non-pecuniary features of bonds which complicates adoption from a fundamental standpoint as it may suggest a deviation from fiduciary duties. Instead, we treat the transition linker as a general performance-linked structure where outcomes that influence investors' risky-asset returns/risks correlate with coupon adjustments. These adjustments are triggered by missing/outperforming targets, thus providing a compensation for increases/decreases in risk. This avoids the negative language frequently used in discussions

[2]Similar ideas have been partially implemented in earlier SLB structures, however, the transition linker is novel in the combination of multiple strikes and a singular performance target.

around SLBs, when pre-determined coupon adjustments based on nonperformance are often called 'penalties.' In a performance-linked bond, a coupon adjustment is just the execution of an ex ante financial agreement to which both parties have willingly agreed and which should have provided a balanced risk-return exchange for both parties. Going back to the inflation linker, if inflation has run too high, making the cost of the inflation-linked debt higher for the government, this is rarely called a 'penalty' paid to investors.

A number of approaches to tying bond performance to carbon emissions have been proposed: Dahlen et al. (2024) is similar in nature but uses the green bond format and links coupon levels to the carbon emissions of a particular project. Another (unpublished) proposal from Bob Litterman suggests bonds linked directly to an aggregate of a carbon price index, similar to how the transition linker is discussed in this paper, see Global Capital (2023). One can even find earlier variations of the idea, see Mainelli and Onstwedder (2009). The approach in this paper differs in that it relates carbon emissions targets to transition and inherent economic risk therein, and leverages upon traditional bond formats that have widespread adoption in the market.

This paper is structured as follows: the first section of the paper analyses a simple portfolio optimisation under the assumption that the risky (equity) asset underperforms in case of an unsuccessful transition. Like the inflation linker, it is straightforward to show that a transition linker, which increases coupon payments in case of missing targets, reduces correlation between the risky asset and the bond. The investor thus ends up with a higher potential portfolio Sharpe ratio. By extension, the investor could accept a slightly lower yield/higher volatility on the transition linker while still being able to construct a superior portfolio to one without a transition linker.

We then proceed to look at the pricing of performance-linked bonds generally, starting out with a discussion on how inflation linkers can be used to derive market expected rates of inflation and the general inflation linker market structure. We also explore the convertible bond structure, pricing bonds plus call options. The option pricing approach is central to understanding the pricing of discrete target-linked bonds, for which we then describe a general pricing model. This leads into analysis of a probabilistic approach to assessing the likelihood that a sovereign achieves its transition targets, a critical factor in pricing transition linkers. By measuring the price-differential between two similar, or ideally identical, bonds from a sovereign issuer, where one is standard and one has optionality linked to transition success or failure, we show that it is possible to derive a measure of implied probability of

climate transition success.

The next section looks at technical design considerations to accommodate wider uptake of transition linkers in traditional mainstream fixed income books, given that it may be slow to change investment mandates in fixed income when it comes to transition investing, and some labelled debt instruments may not fit well into pre-existing mandates leading to slower adoption rates.

We propose to use the twin bond format used in inflation-linked bonds (ILBs) as well as for a few green bonds; we also propose to use the 'greenback' definition - to have an option value of at least 1%/$1 of the bond price - to set coupon steps and payout periods, and to use NDCs – government commitments under the Paris Agreement and updated and tracked on a global scale – as transition proxy targets. We also propose two alternative transition linker formats, one with a lower coupon than the equivalent government bond, a premium transition linker; and one with a similar coupon, a zero-cost transition linker.

The final section of the paper analyses a hypothetical transition linker structure for the Japanese sovereign. Japan has both a sizable inflation linker market as well as a defined transition strategy and bonds tied to it, the so-called GX use-of-proceeds bonds. This makes the country a natural candidate for transition-linked bond issuance.

The transition linker serves a number of purposes. By applying a fully priceable structure, investors, governments, and the general public alike can derive market implied probabilities on whether future transition targets are likely to being met or not, allowing for better planning of capital expenditure and other economic activities. For investors, a transition linker could be an important instrument to hedge lower returns on risky assets in a non-transition scenario. For governments/issuers, the transition linker is a way to achieve lower cost-of-capital for credible, ambitious transition policies and investments, and a way for investors to incentivize transition policies without becoming political. By having a structure similar to other tradeable bond types, the transition linker could be implemented quickly, in size, and with normal bond liquidity considerations.

2 Portfolio benefits of transition linkers

Do future transition risk scenarios matter enough for investors to find it useful to hedge transition risk? One of the main arguments for a transition-linked bond would be that, similar to the idea behind an inflation-linked bond, it can be used to hedge future risk scenarios for the portfolio. In this section, we look at what value (if any) a transition linker could have in a portfolio context, under the assumption that investors expect returns under a non-transition scenario to be lower than if transition is successful.

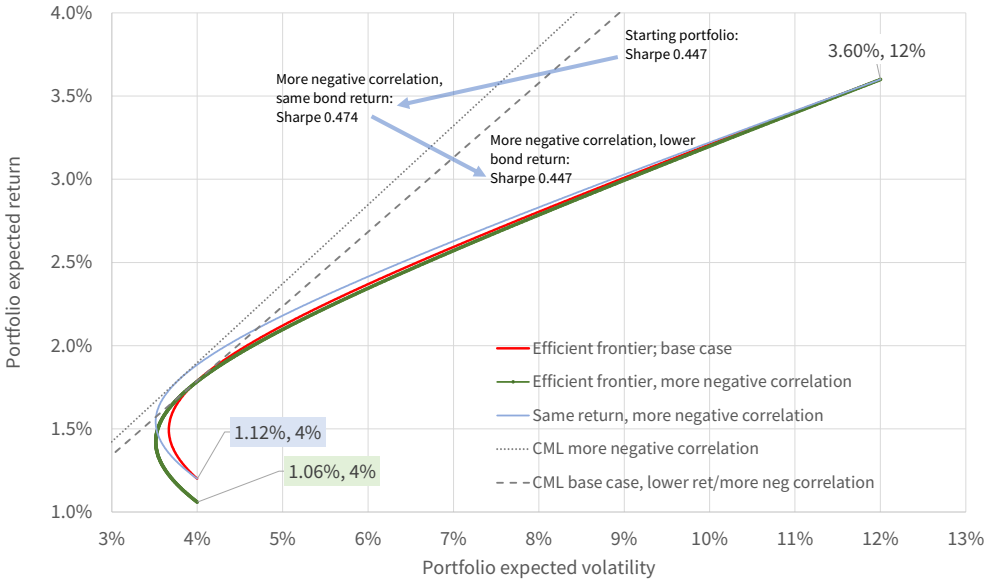
Is an assumption of broader portfolio performance correlated with transition success credible? A number of theoretical studies support this, e.g. Pang and Shrimali (2024) and Carbone et al. (2021), but there is also a robust supply of reports from asset owners and -managers aligned with it. Norges Bank Investment Management (2025) conducts an analysis specifically on their US equity portfolio and projects a 19% permanent loss of capital in a high-temperature rise scenario. GIC, the Singaporean sovereign wealth fund, projects that these scenarios are becoming more likely (GIC/World Economic Forum, 2025). A recent scenario study by Ortec discussed in Environmental Finance (2026) shows more near-term (2030) equity drawdowns of 15-20% in USD/EUR listed equities in a delayed transition scenario. Moreover, the study projects substantial government bond credit risk deterioration in such scenarios, also motivating why investors could be looking for loan rate variation contingents on transition progress.

Indeed, there can even be a legal argument for investors to look for hedging alternatives: "If an asset owner or investment manager concludes, or on the available evidence ought to conclude, that one or more sustainability factors poses a material risk to its ability to achieve its financial investment objectives, it will generally have a legal obligation to consider what, if anything, it can do to mitigate that risk (using some or all of investment powers, stewardship, policy engagement or otherwise) and to act accordingly." Freshfields et al. (2021). For an integrated theoretical perspective on transmission channels in transition processes, see Semienuk et al (2021).

In order to analyse the implications of this in a simple portfolio context, we assume a two-asset portfolio where one asset is an equity, and one asset is a government bond, as illustrated in Figure 1.[3] We assume an expected

[3]One could consider this in the context of a bond-only portfolio. Monnin et al. (2024), for example, discuss sovereign bond portfolios and the transition from a central bank perspective, where the choice will be within a sovereign bond portfolio.

Figure 1: Efficient frontiers in the bond-equity model with and without transition, assuming a -0.1 correlation (base) and a -0.2 correlation (more negative).



Sharpe ratio of 0.3 for both assets, and an expected volatility for the equity/bond of 12% and 4% respectively, meaning an expected return of 3.6% on the equity and 1.2% on the bond. We furthermore assume a slightly negative bond-equity correlation of -0.1, see for example Brixton et al. (2023). Simple portfolio optimisation of this set-up generates the efficient frontier in Figure 1 ("base case", red) with a maximum portfolio Sharpe ratio of 0.447.

In the next step, we ask what happens if the bond instrument would be slightly more negatively correlated with the equity asset? This would be the case for a transition linker, where the coupon is higher/lower if transition targets are met, and the expected return on the risk equity asset is expected to move in the opposite direction. In correlation terms, the equity asset return has negative correlation with the transition (a successful transition generates higher returns), and the bond asset has a positive return correlation as the coupon will be higher in the unsuccessful scenario. Analogously, if transition targets are met, the bond return goes down, similar to the results of Bolton and Kacperczyk (2023). First, we evaluate this by simply adjusting our portfolio optimisation using a correlation of -0.2 instead, as graphed in Figure 1 ("more negative correlation", blue). Naturally, this portfolio will outperform the first one at every point on the efficient frontier, with an expected Sharpe ratio of 0.474.

This suggests that the investor should be willing to accept a slightly lower return in the case of the more negatively correlated asset, the linker. To phrase it in investor language: how much lower a Sharpe ratio could the investor accept if they got a more negatively correlated bond (which would be the case in a transition-linked structure) and still be as well off as with the initial portfolio? Numerical optimisation yields the result in Figure 1 green frontier, where – holding everything else fixed – the expected Sharpe ratio on the bond is 0.265 (versus 0.3 in the original case). Translating this into expected returns, the investor would be as happy to hold the portfolio with a bond with 1.06% return (versus 1.2%) and -0.2 in correlation, effectively being able to pay 14bps for the hedge capacity.

These numbers are coarse estimates of bond and equity returns as well as volatilities and correlation, but still illustrate the point that adding a little bit of negative correlation is valuable in terms of total portfolio performance. Indeed, if an investor's hypothesis holds that an unsuccessful energy transition would lower equity portfolio returns (equalling a negative correlation assumption), then investing in transition linkers with the inverse return expectation is simply a way to optimise portfolio performance. This point is

trivial from a theoretical standpoint, but arguably one that is rarely considered when it comes to considering the relationship between traditional instruments and labelled bonds.

3 The universe of performance-linked bonds

As noted in the introduction, the family of bonds where coupons are linked to some outside variable is large. The main forms are described in Table 1.

In the context of sovereign bonds, there are fewer types of performance-linked instruments in evidence. The prevalent forms are the inflation linkers and the SLB format. Hybrids and convertibles depend on equity performance links, which are not available to sovereign issuers. In a recent paper, Cormack and Macrina (2024) introduce the notion of sovereign climate convertible (S-CloCo), where the equity conversion happens through investors receiving stakes in a sovereign wealth fund. SLBs in the sovereign format have gained some traction, with a few noteworthy issuances by Chile, Uruguay, Thailand, and more recently Slovenia with a unique structure.[4]

The tabulated list is not exhaustive. Volz (2020) surveys state contingent debt financing solutions for governments, and adding to this should be a relatively new bond type called outcome bonds that mix clear features of the SLB instrument with concessionary elements, usually with nature-linked performance targets.

We will discuss the sizable inflation linker market in the next subsection and following on from this, we will discuss convertible bonds due to some option pricing features that are useful as context to think about transition linkers.

3.1 Inflation linkers

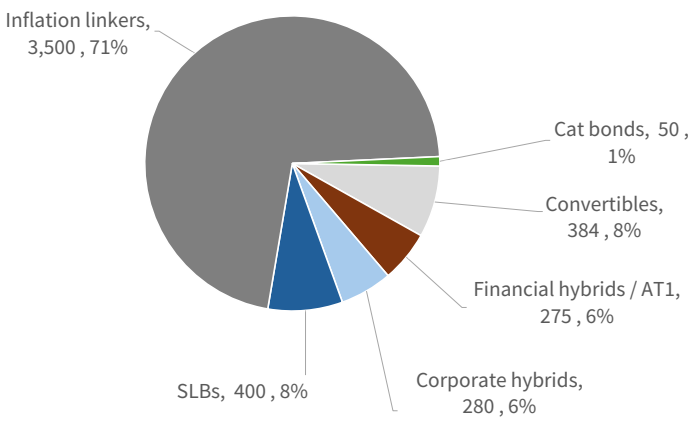
Inflation-linked bonds (ILBs) are instruments that allow investors to get a real (inflation adjusted) rather than a nominal return. As explained in the prior section, inflation linkers can be quite effective portfolio hedging tools in

[4]Slovenia's SLB has a single performance target focused on absolute emissions and a dual step-up/step-down structure. See Anthropocene Fixed Income Institute (2025) for a comprehensive analysis of that bond.

Table 1: Performance-linked bonds.

Type	Market cap	Description
Inflation linkers	4,000bn	Inflation linkers are bonds that pay the real interest rate for a certain maturity, by increasing the notional of the bond (and thus reducing the yield for a given coupon) based on an inflation index. The performance target in inflation linkers is continuous based on inflation indexes, and resets at discrete dates during the life of the bonds. Given positive inflation prevailing, inflation linkers price higher lower prices/lower yields than equivalent vanilla bonds (EVBs) and outperform is realized inflation is higher than expected inflation. If we assume that high inflation is negative for risk asset real returns, inflation linkers are short risk.
Convertible bonds	384bn	Convertible bonds can be viewed as performance-linked because they have a fixed coupon until a strike date, when they can be converted into equity and arguably become perpetual, variable coupon bonds. Given their potential equity upside, convertibles price with coupons below that of an EVB. The performance target in the convertible is simply the equity strike price where the bond converts, at a singular date. The convertible bond outperforms when the underlying equity outperforms: it is a long risk product, with the issuer selling a call option.
Corporate hybrids	280bn	Corporate hybrids are bonds that are called or step-up their coupon based on issuer decisions. However, as subordinated debt, companies will generally call hybrids if they lose their equity treatment status. Essentially, hybrids are performance-linked bonds tied to the credit quality of the underlying company. Companies issue hybrids as a cheap source of loss-absorbing equity capital. Given the potential conversion to equity in a downside scenario, and loss-absorbing status, corporate hybrids price with lower prices/higher yields than an EVB. Corporate hybrids outperform when companies perform: they are long risk, and the issuer buys a put option.
Financial hybrids	275bn	Financial hybrids, including instruments such as Contingent Convertibles (CoCos) and Additional Tier 1 (AT1) bonds, have played an important role in recapitalising the banking system following the Global Financial Crisis. A plethora of conditions exist in the financial hybrids family. Often, conversion is tied to some sort of level of Tier 1 capital meaningful to the ongoing viability of the institution. A conversion to equity or an outright write-down is triggered if this performance target is missed. Given the downside write-down or equity risk in an adverse scenario, financial hybrids price with lower prices/higher yields than those without the performance target. They outperform when markets are good: they are long risk, and the issuer is again buying a put option.
Catastrophe bonds	50bn	Catastrophe bonds, or cat bonds, have performance targets based on specific physical events, which if they occur, increase risk and potentially decrease returns for investors. Without going into the specifics, cat bonds have often been seen from a portfolio allocation perspective to be uncorrelated to other risk assets, which is interesting in terms of the argument in the previous section. Cat bonds can be seen as investors selling call options, with a capped upside (the premium) and 100% downside.
Sustainability-linked bonds	400bn	Sustainability-linked bonds (SLBs), where the coupon is discretely tied to a number of performance targets. This makes the format extremely, perhaps too, flexible. As SLBs can be of step-up or step-down type, the initial price/yield will be fully dependent upon the structure. And given the multiplicity of performance targets, it can be impossible to tell whether the SLB is long or short risk. In a step-up SLB, the issuer is selling a binary call option on a future stream of cash flows (the step-up coupons), and analogously, the investor is buying a binary call.

Figure 2: Sizes of sub-segments of the USD5trn linked bond market. Amounts in USDbn and percentages in terms of total performance-linked bond market cap. Estimates from various sources.



terms of real return portfolio optimisation. The equity asset has a nominal return, but the end investor is really interested in the real return of that asset. If a bond asset then has a more negative correlation than a nominal bond, then it makes sense for the investor to buy that negatively correlated asset in order to achieve a higher real return risk-ratio.

In an ILB, the investor receives the real interest rate (defined as nominal interest rate minus inflation). As hinted in the section on simple portfolio analysis, inflation linkers can be viewed as a way for investors to reduce correlation between their bonds and equity holdings. As shown in Chiang and Chen (2023), correlation between aggregate equity markets and inflation is negative.

From a technical standpoint, ILBs operate by increasing the principal value of the bond by a pre-defined measure of inflation, such as CPI. Coupon payments are fixed in percentage terms, but based on the inflation-adjusted principal value, meaning that dollar payments differ over the life of the bond. Given an expectation of positive inflation over time, the yield on an ILB should be below that of a nominal bond. The difference between the two is referred to as the "break-even inflation rate." The relationship can be de-

duced from the so-called Fisher equation.

$$(1+i) = (1+r)(1+\pi) \tag{1}$$

where i is the nominal interest rate, r is the real rate and π is the inflation rate. This is often approximated as

$$i = r + \pi \tag{2}$$

Assuming we have two bonds, one which is in nominal terms, and one that is in real terms, we can simply rearrange to get implied inflation $\pi = i - r$. This means that given market-observed i and r, one can derive a market-implied inflation rate π^* simply as:

$$\pi^* = i - r + \epsilon \tag{3}$$

where the residual term ϵ includes an inflation risk premium and a liquidity premium likely such that the break-even inflation rate only approximates the expected inflation rate. There is a substantial body of research on the premiums besides the break-even rate, see D'Amico et al (2009) for an overview and introduction. See Garcia and van Rixtel (2007) for an analysis of how this market-implied inflation rate can be used for informational purposes by central banks and other policymakers.

JPMorgan Chase (2022) provide an overview of the market environment around inflation-linked securities. Currently, there is around USD4.2trn of liquid (defined as at least USD250mn issued) government linkers, with an annual issuance of around USD400mn per annum, Figure 3. Notably, 2024 saw the biggest amount of issuance with over $700bn issued.

Figure 3: Annual inflation linker issuance, 1985-2025. 2025 is year to date (26 August). Source: Bloomberg.

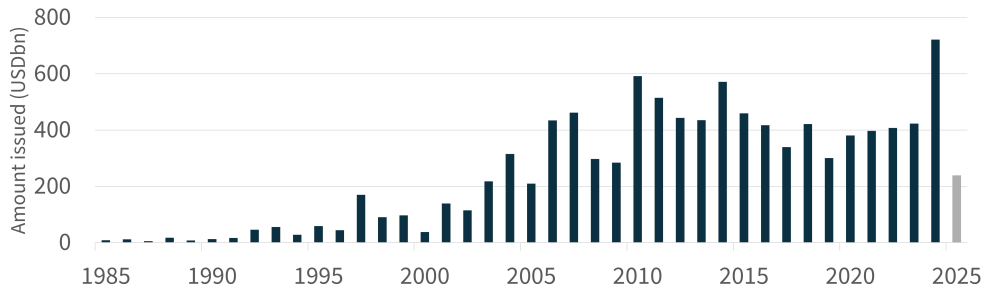


Table 2: Significant sovereign issuers of inflation linkers, in USD bn.

Country	Nominal bonds	Linker bonds	Linkers %	GDP (% global)	Emissions (% global)
United States	19,258	1,629	8.5%	25.3%	12.6%
United Kingdom	2,559	595	23.2%	3.0%	0.9%
Brazil	1,129	291	25.8%	1.9%	1.2%
France	2,658	267	10.0%	2.7%	0.8%
Italy	2,481	256	10.3%	2.0%	0.8%
Japan	9,614	93	0.9%	4.2%	2.8%
Spain	1,345	91	6.7%	1.4%	0.7%
Germany	1,389	80	5.8%	4.0%	1.8%
Argentina	128	76	58.9%	0.6%	0.5%
Israel	103	64	62.6%	0.5%	0.2%
SUM	32,186	3,729		45.9%	22.2%

The main inflation-linked markets are in highly developed markets, some of which are quite crucial also in terms of the energy transition, see Table 2. The proportion of linkers to the total domestic government bond markets vary widely, between 5% to 25% for the bigger markets.

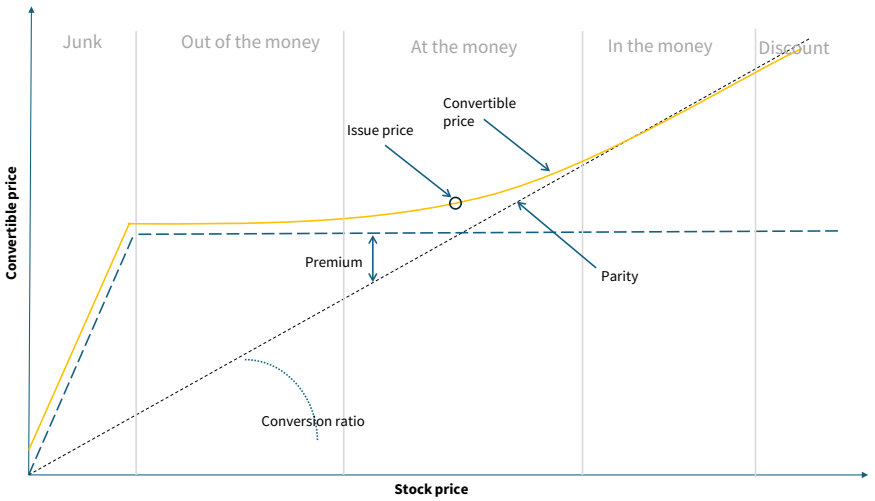
A number of factors have led to the relative success of the inflation linker market. Of course, it solves a portfolio optimisation problem for investors seeking real rather than nominal returns, but as Norges Bank Investment Management (2012) points out, the bonds serve an important purpose as an incentive for the issuer to contain inflation. A simple way for an indebted government to deflate a debt load is to generate inflation such that the nominal debt burden shrinks as a ratio to GDP. As investors understand this, they require additional risk-premiums on government bonds where this is likely to happen. If a government signals a commitment to not inflate away debt, then the risk-premium on nominal bonds goes down. Inflation linkers become a way to formally commit to non-inflationary debt management, and anchor investor expectations on inflation losses in their government bond portfolios.

In a similar way, a government today might face higher risk-premiums on all type of bonds if investors perceive their commitment to transition as loose. This is especially true in a time where the energy transition has become something of a political ideology statement in the non-corporate world. A transition linker product can thus help to firm up the credibility of the commitment.

3.2 Convertible bonds

A convertible bond is a bond where the initial bond converts into equity (shares) if a pre-determined price is achieved at a likewise pre-determined date, see Figure 4. As such, the performance bogey in the convertible is the share price of the issuer, which make convertibles slightly more complex as the performance metric is directly in connection with the bond itself, through the capital structure.

Figure 4: Convertible bond payoff profile and terminology.



The traditional way to model a convertible is to view it as a bond with an attached equity call option. This is an approach that we will also use for pricing the transition linker. The pricing dynamics between the stock price (the performance variable) and the convertible price is illustrated in Figure 4. The convertible trades similar to a traditional bond as long as the underlying stock price is far out-of-the-money vis-a-vis the strike/conversion price. It starts pricing more and more like an equity as the stock price gets closer to the strike. If one views the stock price as essentially the sum of all discounted future earnings of the company, the relationship between the convertible and the performance target bonds where the value is the discounted cash flows of the coupon variation, is fairly clear.

Convertible bonds may not appear as impressive as inflation-linked bonds in terms of issuance sizes, but it should be kept in mind that convertibles are generally issued by smaller companies, in contrast to the large sovereign issuers that dominate the inflation linker space. In this sense, convertibles and SLBs are more closely related, see Erlandsson and Richardson (2022). One important structural difference between the convertible and the inflation linker as well as the sustainability-linked bond is that there is no issue in terms of data quality and measurement error of the performance variable. The stock price is directly measurable with high precision.

3.3 Performance target bonds

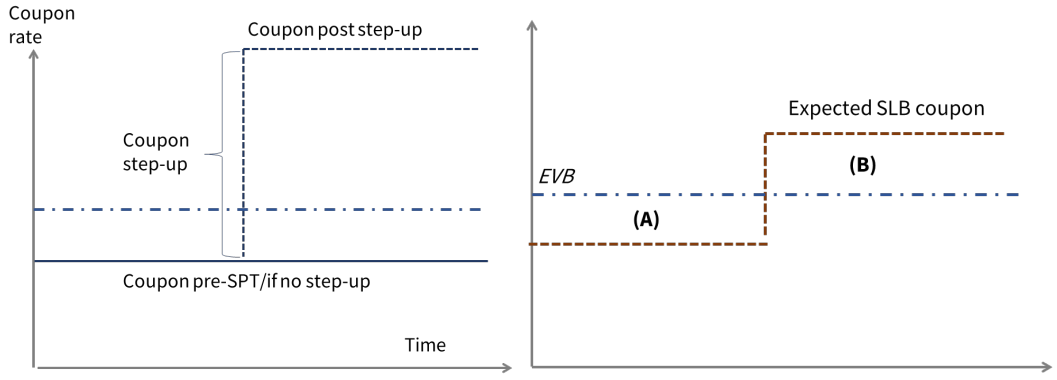
Performance target bonds are structures where payoffs depend on a discrete target rather than linking performance to a whole range of outcomes. A sustainability-linked bond is a performance target bond, a convertible is a mixture, and an inflation linker is not a performance target bond. Below, we describe a highly stylized model of a bond structure where the coupon rate is tied to the achievement of some general performance target (PT). In the context of the transition, this target could be a country's NDC carbon emission targets, used as a proxy for its energy transition. For simplicity of translating the notation between performance target bonds and transition linkers, below we use the notation TL interchangeably with the general performance target bond.

To start our analysis, we will use the pricing framework from Erlandsson and Richardson (2024), which was originally introduced in Mielnik and Erlandsson (2022) and Erlandsson et al. (2022). This approach considers the performance target bond to consist of a plain bond and an option on a future cash flow as represented by the coupon step. Similar option pricing approaches have been proposed in Resendiz and Shrimali (2024) and Feldhütter et al. (2024). The model will use a coupon step-up structure, which is commonly used in SLBs, meaning a higher coupon will apply if the issuer misses the PT. It can be mathematically described as follows:

$$\sum_{i=0}^{t-1} \Phi_i \cdot \left(C^{EVB} - C^{TL}\right) = \pi_1 \cdot \sum_{i=t}^{T} \Phi_i \cdot \left(C^{TL*} - C^{EVB}\right) - \pi_2 \cdot \sum_{i=t}^{T} \Phi_i \cdot \left(C^{EVB} - C^{TL}\right) \tag{4}$$

where Φ_i is the discount factor for time i (which runs from $0 \ldots t \ldots T$ where t is the step date and T is the maturity date), and where C^{EVB} and C^{TL} is the equivalent vanilla bond (EVB) coupon and the TL fixed coupon i. C^{TL*} indicates the TL coupon when it has stepped up. The probability to step is denoted π_1 with the non-step probability $\pi_2 = 1 - \pi_1$. The left-hand side of Equation 4 is our (A) in Figure 5 (right), and the right-hand side (B).

Figure 5: Liquid (Call options structure of a step-up bond: (left) the coupon level in the step or no-step up case, (right) the expected step structure coupon/the probability weighted average of the step and no-step up coupon levels.



Naturally, the issuer will not sell this option without compensation. Therefore, we note that the coupon on the TL bond will be necessarily lower than that of an EVB. This is illustrated in Figure 5(right) the expected value (probability multiplied by the discounted value of the cash flows) of the option (B) should be equal in value to the reduced coupon flow in the early life of the bond (A).

All variables in the pricing model in Equation (4) are deterministic except the probability for the cash flow to pay out. This is central to the idea of a transition linker: by observing the pricing we should be able to back-out the implied probability to step, π_1. Rearranging Equation (4) , we get:

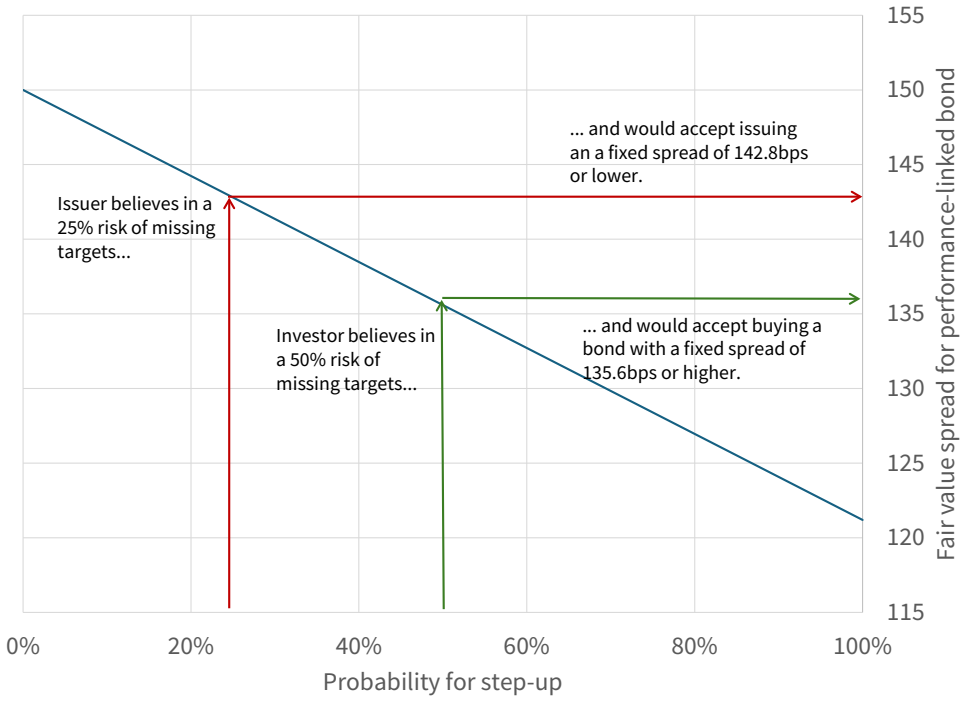
$$\pi_1 = \frac{\left[\sum_{i=t}^{T} \Phi_i \cdot \left(C^{EVB} - C^{TL}\right)\right] + \left[\sum_{i=0}^{t-1} \Phi_i \cdot \left(C^{EVB} - C^{TL}\right)\right]}{\left[\sum_{i=t}^{T} \Phi_i \cdot \left(C^{TL*} - C^{EVB}\right)\right] + \left[\sum_{i=t}^{T} \Phi_i \cdot \left(C^{EVB} - C^{TL}\right)\right]} \tag{5}$$

Although Equation (5) may seem unwieldy, the practical implementation of it is straightforward. If we know the price of the transition-linked bond

(observed in markets) and have an EVB price, we can observe the yield differential between the two and compare it to the coupon differential in the event the performance condition would be activated, and by backing that out discern the likelihood that this will happen.

The pricing equation can also be expressed in spread terms[5] which allows us to conduct a simple analysis: what is the fair value spread for the initial coupon of the performance-linked bond, given a certain belief of the probability to hit the target? This is trivial to calculate in the case of a single target, describing the almost linear relationship in Figure 6.

Figure 6: Liquid (Illustrating how different views on probabilities to hit/miss PTs can drive the performance-linked bond transaction).



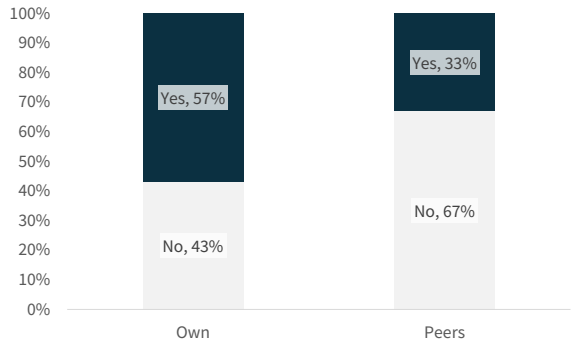
If we assume that there are heterogenous beliefs around the probability of achieving the performance target held by the issuer and the investor, we can

[5]For purposes of this analysis, consider the spread as a differential between an underlying government bond and the actually issued bonds, which applies in cases of non-government issuances. The same logic holds in sovereign issuances as well.

see that an investment exchange can happen that is 'good' for both sides. As illustrated in Figure 6, the issuer may express a high probability of hitting the performance target (25% of missing it) and see fair-value spread at 143bps, whereas the investor may think it is 50-50, implying a fair-value spread of 135.6bps. This means that in the interval [135.6,142.8] bps a trade should happen: the issuer would get cheaper funding than they believe is fair, and the investor would be buying a cheaper option than what is their estimated fair value.

How likely is it that an investor will believe the issuer is less likely to miss a target than the issuer themselves expects? As an indication, consider survey evidence by Bloomberg in 2023, where 250 CEOs of large corporations were asked whether they believed their own organisation would hit net-zero targets or not: 57% responded Yes. When asked if they thought their peers would achieve net-zero targets, only 37% believed that was the case. see Figure 7. This suggests that the CEOs would on average accept fairly small compensation for selling the step-up option (as they believe they would hit their own targets), and be willing to buy the step-up options on their peers at greater value (as they believe peers unlikely to meet targets).

Figure 7: "Will you/your peers hit their net-zero targets?" Illustrating diversity of estimated probabilities: corporates believe they will themselves hit net-zero targets, but that their peers will not. Source: Bloomberg Intelligence, sample of 250 large-cap corporates.



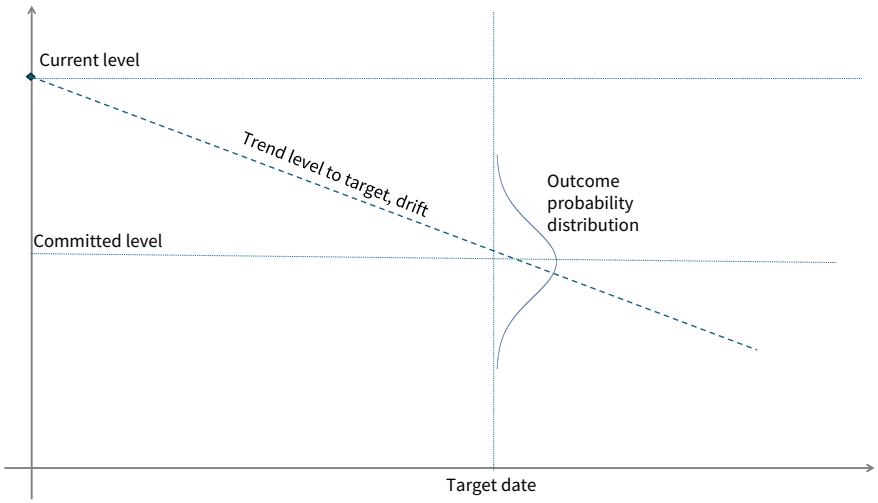
4 Transition linker structures

Given these various forms of linked bonds, it is useful to define formally what the transition linker is. In its core form, the transition linker has a

single performance target variable with a number to strike levels that can vary the coupon rate post the trigger date in a number of discrete steps. The coupon rate is thus somewhat less flexible than in a convertible bond, but more flexible than in a traditional SLB. With a single target variable in mind, and with that target variable being tied to exogenous commitments, the transition linker reflects the non-discretionary type of dynamics of achieving performance in convertibles and inflation linkers. The transition linker is mainly intended for sovereign purposes, similar to inflation-linked bonds. The underlying variable is targeted through policy, but is also subject to stochastic factors that affect investors and issuers alike.

The key concept wrapped in our analysis of transition is reflected in Figure 8: an issuer starts at an initial point t_0 and is projecting a (linear or otherwise) trend of carbon emissions decrease, to reach a target ('Commitment level') according to NDCs at the target date τ. The probability distribution projected for time τ, shown as the vertical bell-shape curve, represents the distribution of possible outcomes given the information set at time t_0. Using this information, we can derive probabilities and thus price expected coupon flows that would come out in case transition targets are not fulfilled.

Figure 8: Conceptual view of forward probability distribution.



The above logic can be applied to the design of performance-linked structures with multiple strikes, and even to securities where the negative and positive option premiums balance out. For earlier examples of multiple strikes attached to one and the same KPI, see Anthropocene Fixed Income Institute

(2024a), or Loughran and Wallen (2024).

Here we consider two possibilities of structuring a transition linker, noting that one could of course extend the analysis to a case with continuous payouts based on how far the target the actual outcome is. From a practical standpoint, having discrete strikes is likely to reduce the reliability on precise data, as minor variations that will not have an impact on whether a strike is hit or missed will not have to be contested. With the continuous case, every 0.01% of variation will matter in terms of financial value, which may cause the data provisioning to become excessively expensive and raise litigation risks and costs. Instead, we look at two main forms: pricing with a premium, and pricing without ('zero cost').

4.1 Premium transition linker

Taking the perspective that the linker is predominantly used as a hedge for unsuccessful energy transition scenarios and follow-on lower performance in other asset returns, the premium transition linker structures strike levels above targets and with coupon step-ups.

An example is provided in Table 3 and Figure 9, setting strikes for step-ups at +5% and +15% of the target respectively. This means that the issuer will be selling upside options, and collect a premium, whereas the investor pays a premium for downside (transition) performance protection. The strike levels here are indicative and should in real cases be calibrated to the estimated volatility levels of the transition target variable.

Figure 9: Hypothetical trend and strikes for premium transition linker.

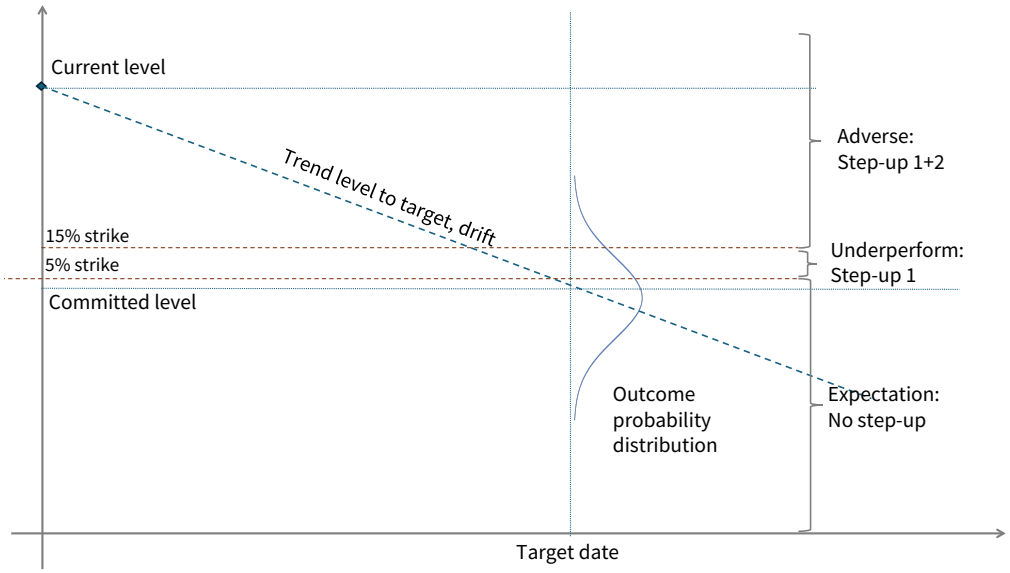


Table 3: Strike structure for premium transition linker.

Scenario	Strike level versus target	Coupon effect
Expectation	$[-100\%, 0\%]$	No coupon adjustment
Underperformance	$(0\%, 15\%]$	Step-up
Adverse	$(15\%, \dots)$	Additional step-up

4.2 Zero cost transition linker

From an investor and issuer perspective alike, being able to start with a zero premium structure might be the more feasible option. To illustrate this, we propose a balanced structure tied to the target with both step-up and step-downs with two strikes each, see Table 3 and Figure 9. In the range of -5% to +5% of emissions relative to the target, the coupon does not adjust. This means that small variations versus the target are ironed out. However, outside the target range, coupons start to adjust, with a further strike 15% outside, such that the structure continues to price incremental out/underperformance also when the relatively tight NDC range has been surpassed.

Slovenia's issuance of a decarbonisation target SLB in June-2025 was structured along the lines of this, with a step-up for a missed target, and a step-down (called a 'stretch target') for outperformance. However, AFII (2025) analysed the structure and did not see the targets as probable, removing some of the symmetry required to have it truly zero-cost. The motivation for the 'stretch' target was interesting, in context of transition linkers, as it was perceived that the issuer needed to see both upside as well as downside for the target level.

Figure 10: Hypothetical trend and strikes for zero cost transition linker.

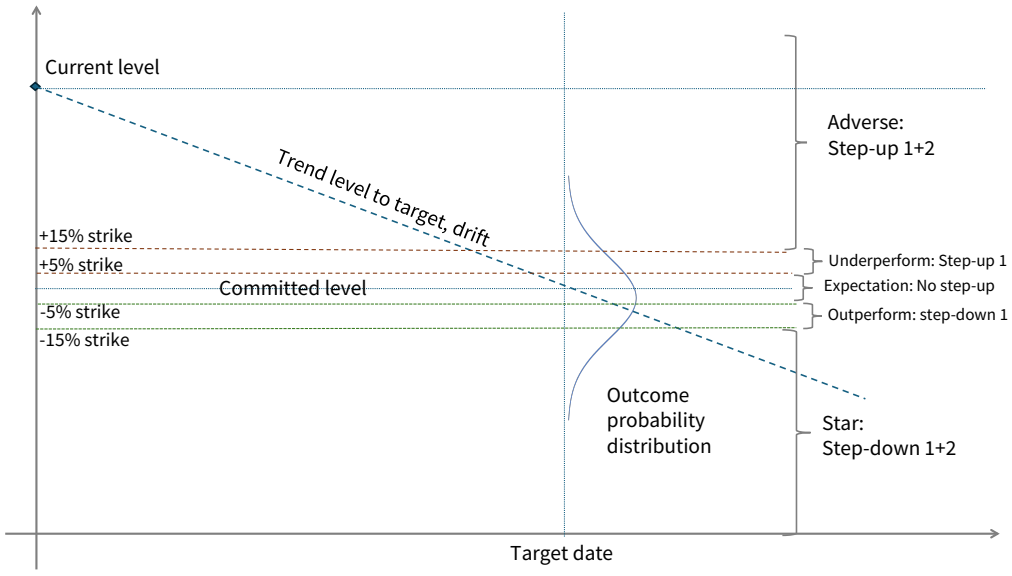


Table 4: Strike structure for zero cost transition linker. Source: AFII.

Scenario	Strike level versus target	Coupon effect
Strong	$\leq -15\%$	Step-downs 1+2
Outperformance	$(-15\%, -5\%)$	Step-down 1
Expectation	$[-5\%, 5\%]$	No coupon adjustment
Underperformance	$(+5\%, +15\%)$	Step-up 1
Adverse	$\geq +15\%$	Step-up 1+2

4.3 Pricing of transition linkers

The pricing framework in the previous section is useful for demonstrating why performance-linked bonds are essentially all about probabilities. However, it says little about how to derive those probabilities. The Black-Scholes pricing framework is a way to use an assumption about a forward probability distribution to derive probabilities that the underlying variable will hit certain strike prices, as reflected in the pricing framework proposed by Mielnik and Erlandsson (2022) reproduced in the Appendix.

It can be useful, however, to also apply a rule-of-thumb in terms of understanding transition linker pricing. First, estimate the discounted value of the coupon step-ups in the structure, which is essentially the coupon step-up multiplied by the number of years it pays out, and present-value that number. Second, assess the probability that that coupon stream will be paid out. The price differential between the EVB and the transition linker will simply be the product of these two numbers. Note that due to having a single target variable, a rule-of-thumb like this can be applied, and also that this avoids any assessment of non-financial greeniums, which in terms should support practical applicability. The next section continues to discuss features of the transition linker such that it would be straightforward to use in a market deployment.

Table 5: German Bunds in green twin format, pricing as of 12 Sep 2025. Green bonds denoted by *. Source: Bloomberg, AFII.

ISIN	Coupon (%)	Maturity date	Size (EURbn)	Yield (%)	Greenium (%)
DE0001102507	0.00	15/08/2030	33.5	2.250	
*DE0001030708	0.00	15/08/2030	11.0	2.245	-0.005
DE000BU2Z007	2.30	15/02/2033	38.3	2.503	
*DE000BU3Z005	2.30	15/02/2033	12.0	2.499	-0.004
DE0001102481	0.00	15/08/2050	44.5	3.241	
*DE0001030724	0.00	15/08/2050	12.8	3.226	-0.015
DE0001102614	1.80	15/08/2053	33.5	3.261	
*DE0001030757	1.80	15/08/2053	12	3.253	-0.008

5 Structural considerations for transition linkers

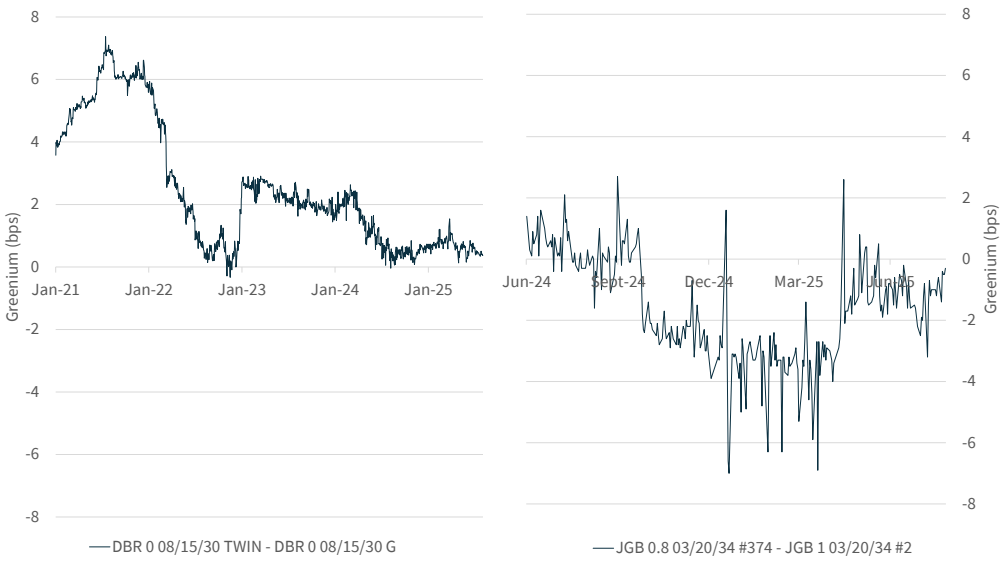
In many cases, performance-linked bonds have failed to take off not due to the inherent logic of the concept, but because of practical considerations. This is especially true in the SLB space, where the critique has sometimes been substantial in terms of targets and financial materiality. In this section, we discuss a number structural features that would enable the transition linker to circumvent some of the main issues with SLBs.

5.1 Twin bond structure

The first recommendation is important in terms of potential adoption for a transition linker. As studied in Erlandsson (2020), the structural features of bonds are manifold, and it can become quite difficult to compare relatively small premiums ('greeniums', and in this case option premiums) even where there are minor structural differences. Issuing a transition linker somewhere on the maturity curve where there are few other bonds, requiring interpolations of an equivalent vanilla bond yield/spread, can introduce substantial measurement errors in terms of calculating the option value. Thus, the recommendation is to issue the transition linker paired with a traditional bond. A useful precedent here is the German twin-Bund structure, introduced in 2020, which has since proliferated in a number of issuances, see Table 5. Greeniums, in the table ranging between 0.4 to 1.5 basis points, are possible to extract with high precision through this.

The twin Bund form gives a fairly precise estimate of the greenium, and

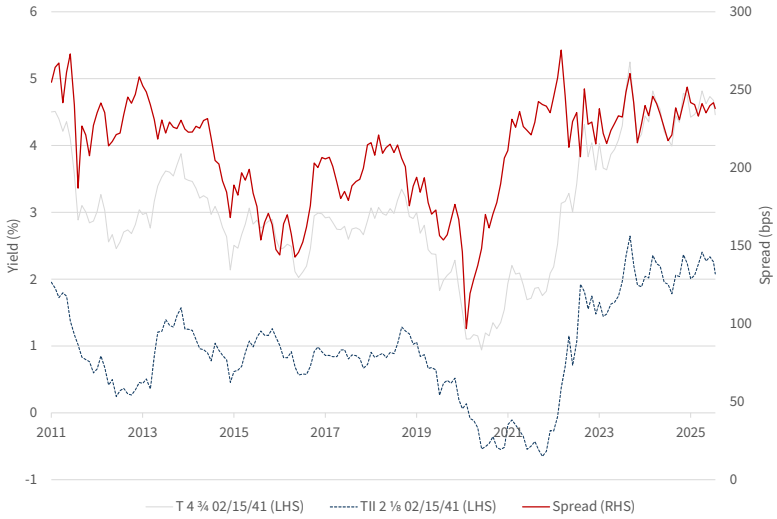
Figure 11: 'Greeniums' in German and Japan twin-bond structures. Source: Bloomberg.



with a high exchangeability, the liquidity premium should be near zero. Still, historically we have been able to see quite substantial variations in the green bund greenium, varying from 2bps on issuance, up to a high of 7bps in 2021 and down to flat or even negative in late 2022, see Figure 11. Given that the greenium arguably represents a non-pecuniary value and that the Bund trades at a low yield, the variations thereof are fairly large.

The similarity with the inflation linker is quite clear. Inflation linkers are often issued at the same maturity point as the nominal bonds. For example, consider the old 30yr US Treasury UST 4.75 02/2041 and the linker TII 2.125 02/2041, Figure 12. The average yield differential is around 1.75%-2% between the nominal bond and the linker. It should be noted that the transition linker would have a coupon struck much closer to its twin bond compared to most inflation linkers, meaning that it would actually be more 'twin-like' than an inflation linker.

Figure 12: Yield differential, 'inflation protection value', between the nominal and inflation linked 30y (old, off-the-run) Treasury. Source: Bloomberg.



5.2 Coupon calibration

The magnitude of the option premium 'traded' in the transition structure will be directly proportional to the size of the coupon variations and how long they are paid out for. A recurrent question in the SLB market has been how to calibrate coupon step sizes and payout maturities in order for the structure to be material. On the one hand, one can argue that the payment needs to be material from the perspective of the issuer in order to provide a sufficient incentive. This type of perspective is fraught with uncertainties, however, as some analysts seem to disregard two simple facts: first, the coupon step should reasonably be analysed as applying across the whole debt structure of the issuer as it is the marginal cost of debt; and second, the coupon step should be related to the credit spread rather than the yield/absolute coupon of the issuer. On this last point, for an issuer with a credit spread of 50bps, having a coupon step-up of 12.5bps may sound minor, but in % terms of their credit spread, it is actually substantial. This also implies that for high-grade sovereign issuers of transition linkers, the coupon step level does not need to be outsized, as the credit spread effectively is near-zero.

However, measurement errors are important to consider. These are an-

Table 6: Coupon setting using $1 criteria. USD AA-rating discount curve as of 29 October 2024. Assumption of 50% probability of step. *Step-up* is the step-up required for making the option worth $1, *Fixed discount* the corresponding reduction of the initial coupon, *Bp delta* the basis point change in the option premium for one basis point increase in the coupon step-up.

	Option value				
Coupon step	3s5s	5s7s	3s7s	5s10	7s10s
0	.00	.00	.00	.00	.00
.125	.103	.095	.198	.127	.222
.25	.207	.189	.396	.254	.443
.375	.310	.284	.594	.381	.665
.50	.413	.379	.792	.507	.886
.625	.517	.474	.990	.634	1.108
.750	.620	.568	1.188	.761	1.329
.875	.723	.663	1.386	.888	1.551
1.0	.827	.758	1.584	1.015	1.772
1.25	1.034	.947	1.981	1.268	2.216
1.50	1.240	1.136	2.377	1.522	2.659
2.0	1.654	1.515	3.169	2.030	3.545
Step-up	120.9	63.1	63.1	98.5	56.4
Fixed discount	-10.1	-16.5	-16.5	-14.5	-12.2
Bp delta	.827	.758	1.584	1.015	1.772

other reason to prefer slightly more sizeable option premiums. As the transition spread differential may come down to a few basis points, and the market may trade with some bid-offer, having too low a premium will simply make the differential oscillate within the bid-offer, making any inference on expected transition impossible. Anthropocene Fixed Income Institute (2023) proposes a simple rule-of-thumb for sizing the option premium, namely, to size parameters such that the option premium is worth $1 in bond price terms, assuming a 50% probability that the option will pay out. Table 6 and 7 illustrate how coupon steps need to adjust to account for different maturity schedules in the TLB. The longest payouts, the 5s10s (target date 5 years from now, and a full 10yr maturity of the bond) mechanically offer the biggest payouts, by merit of paying out coupon steps for longer. In the yen example, a 5s10s structure with a 41.8bps (third row from bottom) step-up would meet the $1 criteria, and such a bond would have its starting coupon set at 13.3bps (penultimate row) below that of an EVB.

Table 7: Coupon setting using 1%/$1 criteria. Yen A-rating discount curve as of 29 October 2024. Assumption of 50% probability of step.

	Option value				
Coupon step	3s5s	3s7s	5s7s	5s10	7s10s
0	.00	.00	.00	.00	.00
.125	.123	.244	.121	.299	.178
.250	.245	.487	.242	.598	.356
.375	.368	.731	.363	.898	.534
.50	.490	.975	.484	1.197	.712
.625	.613	1.218	.605	1.496	.891
.750	.735	1.462	.726	1.795	1.069
.875	.858	1.705	.848	2.094	1.247
1.0	.981	1.949	.969	2.393	1.425
1.250	1.226	2.436	1.211	2.992	1.781
1.50	1.471	2.924	1.453	3.590	2.137
2.0	1.961	3.898	1.937	4.787	2.850
Step-up	102.0	51.3	103.2	41.8	70.2
Fixed discount	-10.7	-15.3	-7.6	-13.3	-7.9
Bp delta	.981	1.949	.969	2.393	1.425

Another consideration is how to avoid coupons going negative if one uses a linker with step-down features. Similarly to inflation linkers, such situations can be handled by issuing the bond at a premium above par and re-striking the starting coupon higher as compensation. An alternative approach goes back to the portfolio optimisation exercise in earlier sections. If one can calibrate the expected returns and correlation in a transition/transition linker scenario spectrum, then it is also possible – as is done in that section – to see how much lower the expected return is on the bond. This can be translated into the coupon discount on the transition linker.

5.3 Selection of transition performance indicators

A key obstacle in prevailing performance-linked markets such as SLBs has been the selection of KPIs. As part of the Paris Agreement, governments have committed to various decarbonisation targets, as enshrined in their Nationally Determined Contributions (NDCs) and we monitor the release of 2035 targets. Based on the latest update of the Climate Watch NDC Tracker (as of 30 Aug 2025), only 30 countries have submitted new NDCs so far, cover-

ing 21% of global emissions, but further progress is expected in the coming months.[6] Looking at recent market transactions, NDCs form the basis for the coupon structure in Slovenia's successful SLB issuance, see Anthropocene Fixed Income Institute (2025) for an analysis. Although not as frequently updated or as certain as inflation numbers, NDC progress is possible to track. For example, Umulisa et al. (2023) provide a tracking tool. The NDCs also have the advantage of being the actual commitments of sovereigns, making it reasonable to expect that they can enter into other (financial) commitments based on them, see Environmental Finance (2025). Finally, the five-year cycle of NDC targets aligns well with bond market maturity considerations.

It should be noted that the pricing of transition linkers can also provide useful information for revising and updating NDC targets. If the transition linkers are deeply in the money (meaning they indicate no step-ups), it suggests that targets credibly could be revised further downwards, and that new, more ambitious targets would allow the issuer to sell new linkers at a level such that outperformance versus targets reduces cost-of-debt.

One disadvantage of NDCs is that they do not adjust for the Scope 3 emissions of countries that are fossil fuel exporters, and thus may not be as well correlated to transition outcomes as wished for by investors. An overview of transition risks from this perspective is available in Americo et al. (2023). For example, the NDC target of Australia may seem reasonable on a domestic emissions level, but when adding exported emissions through the trade of coal and gas, the numbers are much less accommodating. From a portfolio allocation perspective, it is likely that the investment hypothesis of lower returns in a non-transition scenario also includes a failure to transition fossil fuel extraction industries. Thus, we would suggest that transition targets are set as NDCs plus fossil fuel exports for significant fossil fuel producing nations, but allow this issue to be the topic for future research.

5.4 Observation dates and final maturities

A key design question in terms of the transition linker will be the timing of the observation and step-up date relative to the final maturity date. As discussed in the coupon calibration section, this is a question directly linked to coupon size, and the size of the total premium being sought.

[6] An alternative source for NDC tracking is Bloomberg New Energy Finance's BNEF Theme: Setting 2035 Targets to Get on Track for Net Zero

It would, of course, not be impossible to mimic the structure of an inflation linker. The nominal of the bond could change depending on whether the PT is met or not, instead of a coupon adjustment applying. However, we believe that this is likely to generate more operational issues than a coupon adjustment.[7] Also, one pattern of issuance in the performance-linked space (for example, see HOLNSC 0.5% 04/2031, ISIN: XS2261215011), has been to backload the coupon step to be larger and paid out as one lump sum at maturity. Slovenia's issuance in June-2025, based on 2030 emissions targets, was structured to pay coupon variation only for the ultimate coupon.

In order to avoid a whole new array of targets being set, it should be practical to tie the step dates and maturities to the NDC timings, which run on a five-year cycle. Currently, the 2030 targets are the 'near-term', and there are expectations that 2035 targets will be committed to during the COP30 cycle. A reasonable transition linker structure would thus have a 2030 target and step-up date, with a 2035 ultimate maturity. Five years is far out enough to provide incentives to the issuer, and a reasonable amount of volatility around the target to make pricing meaningful. The ten-year maturity would be in line with standard bond issuance and provide enough of cumulative value to serve as a hedge. Note that the transition linker would, post-step date, in effect become a standard bond, as the coupon by that time is fixed. Having said this, one can argue that a linker that has stepped up actually becomes an active hedge, along the lines of the discussion in the portfolio optimisation section.

6 Case studies

In this section, we provide the case studies of hypothetical transition linker structures for Japan, Australia and Mexico respectively. The Japan study develops the structure looking both at a premium and a zero-cost calibration whereas the two latter cases use asymmetric up and down-side strikes in a similar vein to the bond issuance of Slovenia in 2025. We also highlight a number of other proposals with similar analytics.

[7] 'Mainstream' money manager mandates generally are capable of handling other types of coupon variable debt like corporate hybrids, SLBs, and floating rate notes, whereas inflation linkers are broadly speaking not included in traditional mandates.

Table 8: Japan inflation-linked, transition, and nominal bonds. Pricing as of 12 Sep 2025. Source: Bloomberg, AFII.

ISIN	Type	Coupon	Maturity	Size(bn)	Yield (%)	EVB sprd(bps)
JP1120291Q59	ILB	0.01%	10/03/2034	919.4	-0.048	-149.9
JP1480021Q54	GX	1.00%	20/03/2034	699.6	1.493	1.7
JP1103741Q44	EVB	0.80%	20/03/2034	8608.4	1.471	

6.1 Japan transition linker

Japan is both an issuer of inflation-linked bonds, albeit in relatively modest sizes relative to the total amount of Japan Government Bonds (JGBs) outstanding, and an issuer with a clearly defined transition plan. Japan also has transition targets, and has issued bonds to raise capital in order to achieve them. The most recent 10yr inflation linker (JP1120291Q59, issued in auction in May, 2024) was issued with a 0.005% coupon and with a substantial premium, resulting in an issue yield of -0.544% and with a maturity of 10 March 2034. As illustrated in Table 8, the linker is currently trading with a spread of -129.6bps to the vanilla JGB (JP1103741Q44). Also, at that point of the curve, we have the GX transition bond (JP1480021Q54) trading with a 2 bps spread differential (negative 'greenium' - the labelled bond is lower in valuation than the non-labelled) to the standard JGB. The GX bond is a use-of-proceeds bond, meaning that it has a commitment to deploy raised capital to certain assets or activities, but offering no differentiation in terms of financial features to the standard JGB. This suggest that there is investor participation in both 'linked' instruments as well as the transition theme at the 10yr point on the JGB curve.[8]

For context on NDCs and transition, Japan's emission targets are illustrated in Figure 13, highlighting the reduction of CO_2 emissions to 2030 by -42/-46%, see Anthropocene Fixed Income Institute (2024a) for a further discussion.[9] For purposes of the below calculations, we have assumed a target of 816.3MT CO_2e emissions in 2030 (-42% from 1407.3MT emissions in the peak year 2013), with the latest observation being 1086.1MT for 2023.[10]

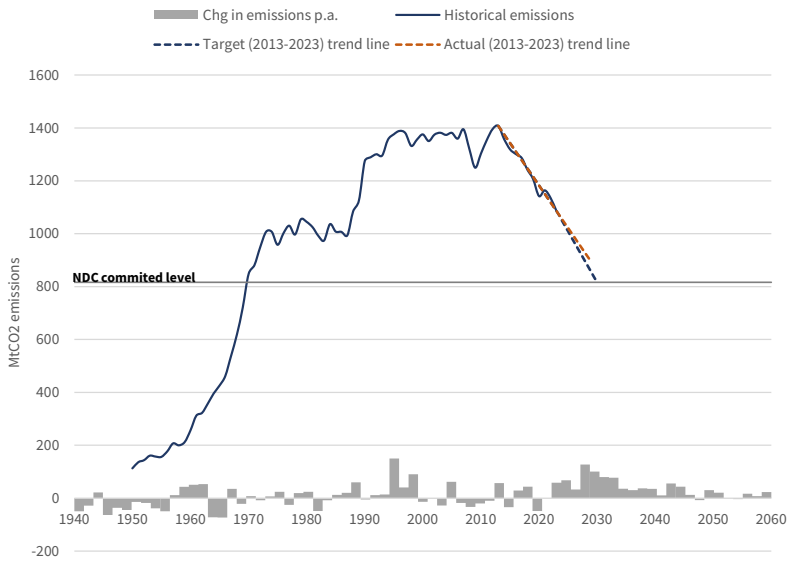
[8]Having said this, one should also recognise that some Japanese investors consider bonds with step-features as structured investments, with adverse capital- and risk treatment, which has led to many SLBs in Japan having been issued with non-pecuniary step features, rather than coupon payments, see Erlandsson and Richardson (2024).

[9]The 46% nets Land Use, Land-Use Change and Forestry (LULUCF) with greenhouse gas emissions, which is a contested approach. Without LULUCF, the targets is at -42%.

[10]Time-series data is based on the data disclosed by the National Institute for Environmental Studies, NIES, linked here, with an extrapolation for 2023 based on fossil fuel

Japan has been able to reduce emissions by 2.59% per annum since 2013, compared to a required rate for reaching the targets of 3.20%. For purposes of pricing the structure, using the notation discussed in the Appendix, we thus assume 2.59% as the drift δ and set the volatility σ using the full sample data to 6.49% per annum.

Figure 13: Japan carbon emissions and current NDC targets. Sources: Global Carbon Budget, National Institute for Environmental Studies, author's calculations.



6.1.1 JGB premium transition linker

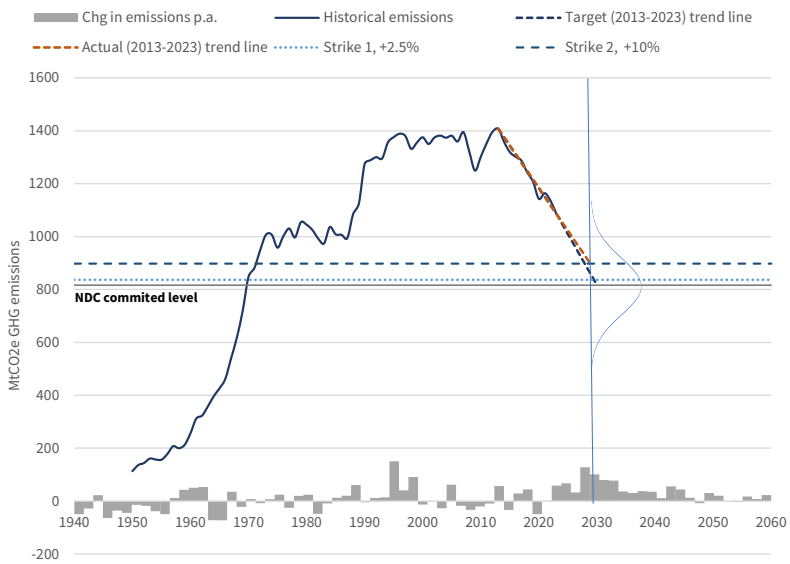
Given the relatively low volatility in Japan's emissions numbers, we tighten the premium linker performance targets relative to the illustrative levels, setting the underperformance level at 2.5% (837MT) above the stated 2030 target, and the adverse scenario at 10% (898MT). We price both strikes with an associated coupon step-up of 0.25%, such that an adverse transition scenario would increase the coupon by a total of 0.5%. The 25bps coupon step-up is seen as fairly standard in the SLB market for corporate issuers, but

based CO_2 emissions reductions in 2023 of -4.3% as indicated by Global Carbon Budget (2024), here .

would be considered fairly large for a high-grade sovereign. The size of the step-up should also be related to the absolute level of yields: the benchmark JGB trades at the time of writing at around 1.47%, so a coupon step up to a level of 2% (for two step-ups) is substantial.

By applying the pricing model in the Appendix, we arrive at a pricing of the premium transition linker as per Table 9. The total option value is clearly short of one dollar, the 'greenback' level, at 72.9 basis points, which would translate into a 8.5bps "running" equivalent. From an initial pricing angle, the 8.5bps is the reduction in the coupon expected when pricing a new bond. Referring back to prevailing JGB levels in Table 8, we would thus expect the premium transition linker to price with a yield/coupon close of 1.47%-0.085%= 1.395%. Effectively, the investor would pay around 8-9bps for the hedge as discussed in the second section, and the issuers (the government) would crystallise this if transition targets are met.

Figure 14: Premium transition linker strike structure; Japan.



6.1.2 JGB zero cost transition linker

In order to create a near-zero cost linker, we re-strike the option structure to have steps at +/-2.5% and +/-10% respectively, with step-ups for higher

Table 9: Japan premium transition linker proposed structure. +0.25% coupon step for each target.

JGB premium transition linker		
Start date:	First accrual date:	Final maturity:
18 Oct 2024	20 Mar 2031	20 Mar 2034
Probability for target 1 (+2.5%): 54%		Value of strike 1: 43bps upfront, 5.0bps running
Probability for target 2 (+10%): 38%		Value of strike 2: 30bps upfront, 3.5bps running
Total value of transition strikes: 72.9bps upfront, 8.5bps running		

outcomes and step-downs for lower (better) outcomes. As the model indicates a slightly higher probability that the issuer will miss the target than not (54% as indicated above), in order to achieve a zero-cost structure where the strikes are symmetric, we need to adjust the coupon steps such that they are asymmetric. We set the coupon step-ups to be 0.2% for each missed strike on the upside (higher emissions than committed) and to -0.34% for the downside (lower emissions than anticipated). In this way, we can achieve a structure that has approximately zero expected value at inception, and thus could price as 'zero-cost'. Table 10 provides the pricing of the structure.

In this structure, there is no value exchange at the inception of the trade, but as time progresses, an adjustment of value will happen as the issuer either under- or outperforms versus target. So the structure would still be able to provide data on market implied beliefs in the issuer meeting transition targets, even if there would be no direct cost-of-capital effect for the issuer. Over time, however, the zero-cost linker would provide incentives for the issuer to perform better across a broader spectrum of outcomes compared to the premium linker. This may be an important feature: to have added incentives to decarbonize even when targets have been met, especially if there are technological advances that facilitate a partially faster decarbonisation.

Figure 15: Zero cost transition linker strike structure; Japan.

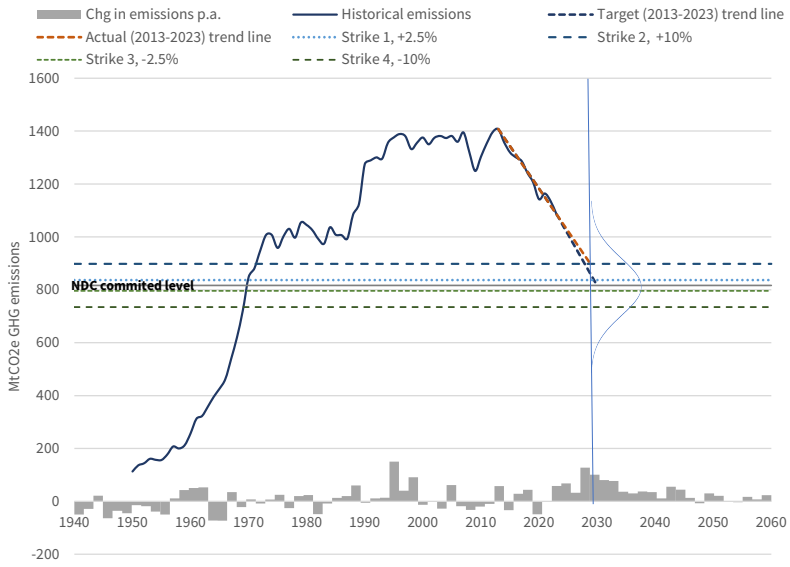


Table 10: Japan zero cost transition linker proposed structure. +0.2% coupon step-up each on missing the +2.5%/+10% targets, -0.34% coupon step-down each on overachieving versus targets -2.5%/-10%. Pricing 6 Mar 2025.

JGB zero cost linker		
Start date:	First accrual date:	Final maturity:
6 Mar 2025	20 Mar 2031	20 Mar 2034
Probability for target 1 (+2.5%): 54%		Value 1: 34bps upfront, 4.0bps running
Probability for target 2 (+10%): 38%		Value 2: 24bps upfront, 2.8bps running
Probability for target 3 (-2.5%): 35%		Value 3: -37bps upfront, -4.3bps running
Probability for target 4 (-10%): 19%		Value 4: -21bps upfront, -2.4bps running
Total value of transition strikes: 0.1bps upfront, 0.00bps running		

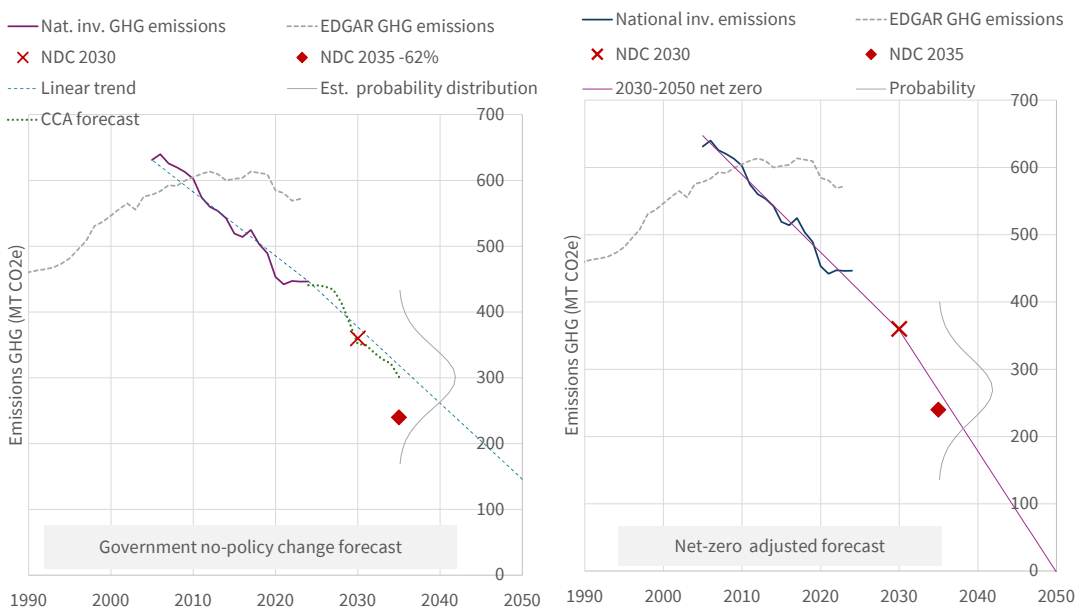
6.2 Australia

Australia's 2030 NDC target is 360MT of emissions, marked with an x in Figure 16. This is almost exactly an interpolation of the trend in carbon reduction in Australia between 2005 (the base year) and 2024, based on the national inventory data. This NDC is marginally lower than a simple extrapolation of Australia's emissions reduction over 2005-2024 (dashed lined in Figure 16).

The 2035 NDC (marked as a diammond) at 240MT implies an increase in the pace of reduction compared to the historical trend. Taking this trend and its historical volatility (2.4%), we can create a probability distribution of emissions in 2035. This is shown by the vertical bell-shape in the left-hand panel of Figure 16. The bell-shape is centred around the spot forecast of 300MT. Only a small tail of the distribution has emissions below the 240MT NDC. In other words, the probability of achieving the 2035 NDC is fairly small — just 10% — based on this approach. If we take the government's own forecast per the Climate Change Authority (dotted green line, left panel), the spot forecast is 301MT and we get a similarly small (9%) probability of hitting the NDC.

These probabilities may be perceived as too slight to be credible. To achieve an alternative and somewhat more favourable probability distribution, we first assume that Australia will meet the 2030 target of 360MT, and then proceed on a linear trend to net-zero by 2050 (blue line in Figure 16). Curiously, this would imply an exact 5% reduction per annum between 2030 and 2050, based on 2030 emissions (i.e. a 17MT reduction every year). On this trend, we get a spot forecast for 2035 of 270MT (the vertical peak of

Figure 16: Estimated forward probability distribution of Australia 2035 NDC achievement based on linear trend from emissions reduction 2005-2024. Source: EDGAR, Australian government, Author's calculations.



the bell shape in right hand panel of Figure 2), still well above the NDC commitment of 240MT but at least in the realm of possibility as projected by the forward probability distribution. Based on this naïve forecast model, the probability to achieve 240MT or less in 2035 is approximately 26%.

To be clear, these forecasts are based on statistical analysis only that should of course be complemented by fundamental analysis. After all, emissions could come in lower based on planned, but not currently disclosed, policies as well as technical innovations and a faster-than assumed adoption of electrification technologies, such as EVs. On the flipside, there could be policies that push in the opposite direction and increase emissions.

To continue to price the structure, we rely on the Black-Scholes type of model described above. We estimate the model-required drift δ and volatility σ by converting the absolute value reductions shown in Figure 16 into their log-normal equivalents. This results in $\delta = -4.5\%$ and $\sigma = 5.2\%$. We also assume the more optimistic projection for achieving the NDC, assuming a 26% current (spot) probability of meeting the targets.

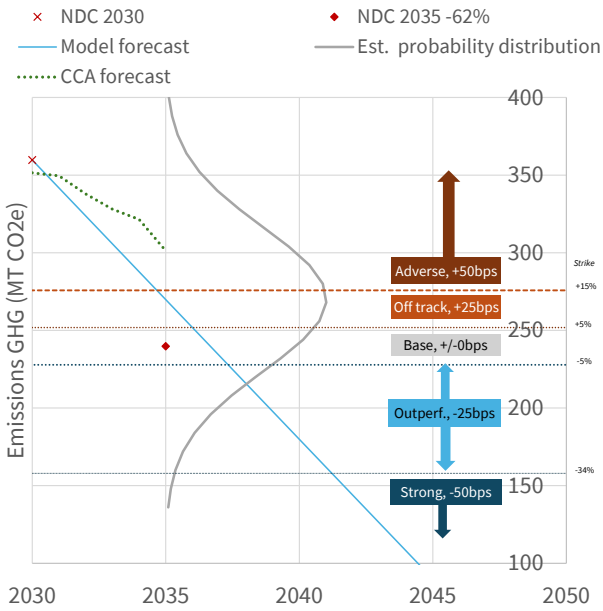
Armed with this and the model, we price a transition linker premium structure as per Table 1. We define the 'Strong' scenario as emissions below 158MT, or equivalent to -76% below the baseline year, which is the lower point of Australia's NDC range (62-75% reduction). We set 'Outperform' as reducing 5% (to 228MT) more than the assumed 240MT target. On the flipside, 'Off track' pricing applies if emissions exceed the target by 5% (252MT) and 'Adverse' pricing if emissions come in at 15% above (276MT).

Table 11 provides details on the likelihood of each scenario occurring based on the forecast referenced in the previous section, and the associated valuations of expected cash flows in terms of their 'option' value.

Table 11: Linker thresholds

	Strong	**Outperformance**	**Off track**	**Adverse**
Strike level coupon step	−0.25%	−0.25%	+0.25%	+0.25%
Full coupon step	−0.50%	−0.25%	+0.25%	+0.50%
Strike (%) vs NDC target	−34%	−5%	+5%	+15%
Absolute strike (Mt)	158	228	252	276
Implied probability	0.1%	16.8%	64.8%	44.1%
Upfront value	−0.001%	−0.114%	0.441%	0.300%
Running value (bps)	−0.01	−1.01	3.90	2.65

Figure 17: Australia transition linker strike structure.



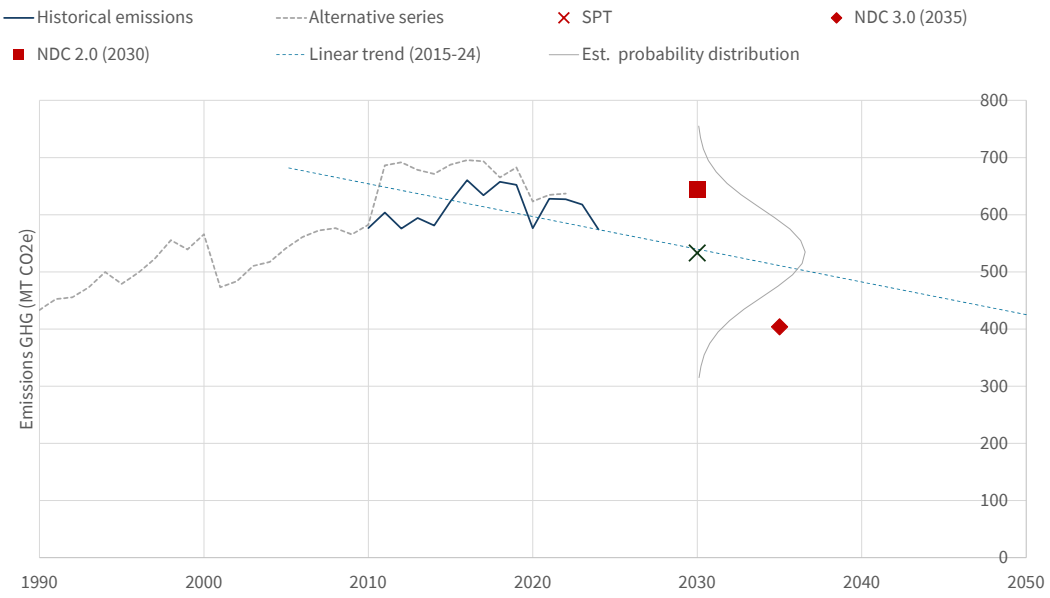
These option strikes are jointly valued at 0.63% upfront/5.5bps running, with the step-ups being valued at 0.74%/6.6bps and the step-downs at -0.12%/-1.0bps, respectively. These are priced off of the ACGB AUD2.75 05/41-bond structure copy. The asymmetry between the step-ups and step-downs stem from the low assessed probability that the target will actually be met. There is a 17% estimated probability of one or two step-downs, compared to a 65% chance of any step-up. This leaves an 18% probability that the coupon will remain unchanged. These probabilities are shown in the ranges in Figure 17.

This means that, compared to the baseline 2.75% bond, the transition linker would price with a yield 5.5bps tighter/0.63% higher price than a traditional instrument, based on our assumptions. To go back to basics: this would mean that the government would be able to issue at a substantially lower cost-of-capital that is retained if they achieve the NDC. On the flipside, investors could rationally buy the lower coupon bond as their mathematical expectation would be to recover the initially lower coupon with a later higher coupon stream. Any non-pecuniary benefits in terms of driving incentives for lower emissions would be additional to this. It is important to note that this is not a wholly hypothetical structure but the one suggested in the Slovenia issuance referred to above.

6.3 Mexico

Mexico's historical emissions and targets are illustrated in Figure 18. The solid line shows the GHG emissions time series which the framework SPT is based on, and the dotted line the longer historical time series we have used in earlier work. Earlier interpretations of NDC 2.0 language, where Mexico expressed emissions as % versus BAU, saw 644 MtCO2e emissions in 2030 as the unconditional target, which in turn makes the SPT of 533 MtCO2e look like an ambitious one. The latest data point in a comparable series show 574 MtCO2e of emissions in 2024. A recent UNDP opinion on the framework confirms the ambition level.

Figure 18: Mexico GHG emissions 1990-2024, SPT target and 2030/2035 NDCs, and estimated probability distribution for emissions outcome based on statistical analysis. Source: Government of Mexico, UNDP, UNFCCC.



The explicit SPT is ideal for building a transition linked bond structure, using the SPT as central point for designing step-up and step-down strike levels in terms of emissions and coupon variations. Moreover, Mexico be-

ing a frequent issuer in € markets with a batch of maturities across the 2030-2040 part of the curve provides good support in terms of building twin bond formats. We propose a structure based on MEX €5.125% 05/2037 (XS2991917613) bond and with four strike levels and coupon steps of 25 basis points each: two on outperformance, leading to a maximum coupon reduction of 50bps, and two on underperformance, generating a potential coupon increase of up to 50bps. We calibrate the observation and coupon step date to end of 2033, allowing for adjusted coupons in 2034-2037. This structure is represented in Table **??** below.

Some summary points on the pricing:

- ◇ The full structure prices at -3bps versus the secondary curve, as the step-ups are estimated to be more likely to happen than the step-downs, thus providing an expected financial advantage to investors.
- ◇ The equivalent bond price difference is €0.37 (compared to a bond price of EUR100).
- ◇ The step-downs are valued at -6.2bps versus the step-ups at 9.3bps respectively.

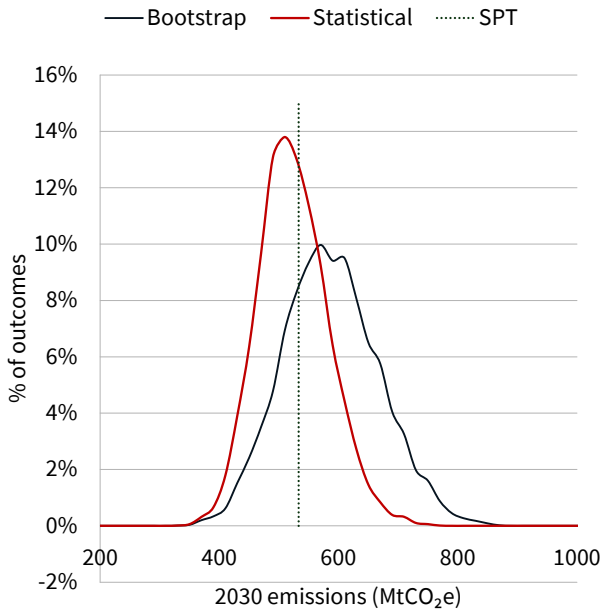
Table 12: Transition linker structure for Mexico based on 2030 emissions SPT and the MEX €5.125 05/2037 bond. Pricing based on data from 2 April 2026, with a hypothetical bond pricing date of 10 April 2026.

	Strong	**Outperformance**	**Underperformance**	**Adverse**
Coupon step	-0.25%	-0.25%	0.25%	0.25%
Strike (%) vs target	-15.0%	-5.0%	0.0%	10.0%
Absolute strike MT	453	506	533	586
Implied probability	15.3%	37.1%	50.4%	27.9%
Upfront value	-0.221%	-0.536%	0.728%	0.403%
Running value (bps)	-1.82	-4.40	5.97	3.31
Option values	**Down+Up**	**Down only**	**Up only**	
Upfront	0.37%	-0.758%	1.131%	
Running value (bps)	3.06	-6.22	9.28	

Core to the above pricing is the assumption around the distribution of outcomes, i.e. the likelihood that an investor (as well as the issuer) will be facing a certain amount of step-ups or step-downs. Our analysis is based on

an interpolation of the emission reduction trend between 2015-2024 and historical volatility. As an alternative, consider Figure 19, where a bootstrapped probability distribution[11] is also shown in dark blue. This distribution indicates a substantially higher likelihood (more mass to the right of the SPT vertical line) of emissions coming in higher than the SPT, or equivalently, a higher likelihood of step-ups. Applying the bootstrapped distribution would suggest a higher value of the transition linked structure above, thus illustrating that there could definitely be a diversity of opinion about the true value for the bond.

Figure 19: Alternative probability distributions for Mexico 2030 emissions vis-à-vis the SPT. The bootstrap distribution is based on a Monte Carlo simulation with 10,000 iterations with draws based on the historical emissions data.



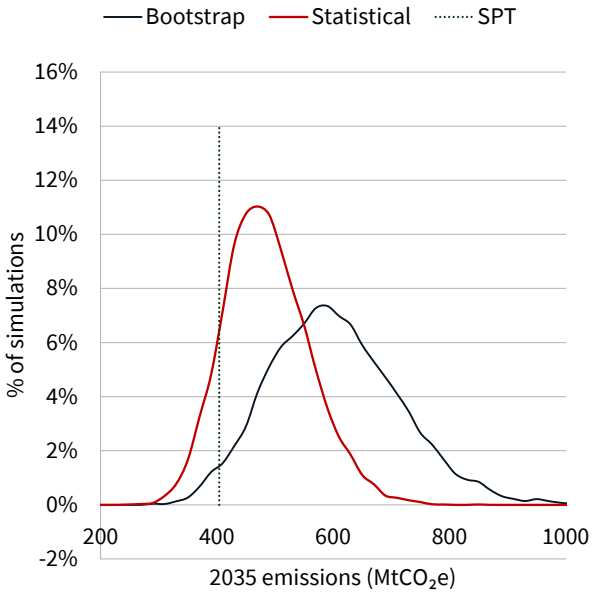
As part of the NDC 3.0 process, Mexico has also submitted a 2035 absolute emission target with an upper bound of 404 MtCO2e (-174 MtCO2e,

[11]The bootstrap method generates time-series by randomly drawing changes in emissions from the historical time-series and then generate new cumulative emission time-series. By repeating this process (in our case, 10 000 iterations), an probability distribution such as one in the graph can be generated. The bootstrap approach has the advantage of being agnostic on the underlying distribution and thus has capacity to better reflect non-normality such as excess kurtosis and skewness.

-30% from 2024). As illustrated by the red diamond in Figure 18 above, this commitment looks substantially more ambitious than the 2030 target. It implies an average annual emissions reduction of 3.14% from the baseline year.

Further quantitative analysis, see Figure 20, where the lion's share of the probability distributions is located to the right of the NDC/SPT level, indicating a high probability that the target will not be achieved. Or equivalently, the target is one that is not easily achieved looking at historical data, but will require substantial efforts/ambition on behalf of the sovereign.

Figure 20: Alternative probability distributions for Mexico 2035 emissions vis-à-vis the SPT. The bootstrap distribution is based on a Monte Carlo simulation with 10,000 iterations with draws based on the historical emissions data.



6.4 Additional case studies

David and Erlandsson (2025) provide further case studies on Latin America, specifically the Mexico (using older NDC targets than above) and Chile sovereign transition linker structures. Germany, France and Italy structures are modelled in Malinconico and Jakobsson (2025). As mentioned above, the Slovenia issuance, SLOREP €3.125% 07/2035 (ISIN SI0002105052) is a

format nearly identical to the transition linker structure, except that is has a single up and down strike. However, the important feature of the Slovenia bond is a single decarbonisation target, and the multiple strike structure.

7 Conclusion

This paper has proposed bond structures similar to inflation-linked bonds that allow investors to use their fixed income books to hedge portfolios against unsuccessful energy transitions. The focus has been on sovereigns, as there is evidence that policies implemented on the sovereign level may be the most important factor in allowing other risky assets to transition.

The proposed structure(s) would be easily deployed within the current market from a practical standpoint, as they share many features with the USD3.5trn inflation linker bond class. They also have the advantage of deriving value from financial outcomes and can be well motivated from a portfolio allocations perspective, thus hopefully avoiding critique for being non-pecuniary and non-aligned with fiduciary duty. The suggested target variable, carbon emissions as measured under NDCs, allow the target data to be provided independently of the bond structure, and for commitments to be verified by other parties rather than investors, solving some of the data and ambition level concerns in sustainability-linked bonds.

For issuers of transition linkers, there are several advantages. First of all, successful achievement of targets will lead to lower cost-of-debt than in the vanilla debt case. More ambitious targets will further lower that cost. Second, transition linkers will provide a much more timely and objective measurement of the credibility of transition plans. This could help mitigate an ever-present critique of transition measures. Thirdly, transition linkers can be highly standardised and are general corporate proceed type of bonds, avoiding costly and time-consuming programs to track bond proceeds and impacts.

Transition linkers could play an important role in responding to an asset owner conundrum: expectations on risky asset returns are lower in a non-transitioning world, policies for avoiding this are best devised by governments, and investors currently use very little of their formidable lending quantum to governments to avoid a suboptimal risk-return outcome. A sizeable transition linker market would both allow these investors to smooth returns across higher and lower warming scenarios, as well as decrease the

probability of the financially less attractive outcomes, and this with no cost from an expectations/risk-neutral perspective. The inflation linked bond market has been central to our developing understanding of price volatility, even if its only a few percentage points of the total government bond market. The transition linker should be able to play a similar role.

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9 Appendix: Pricing with Black-Scholes model and drift parameters.

From Mielnik and Erlandsson (2022)

Pricing the transition linker in continuous time is fairly straightforward using a Black-Scholes type of model. The model is explicit in terms of the 'law of motion' - defining the probability distribution – for the progress toward the performance target, which in the context of a transition linker is the probabilistic inference on reaching NDCs/the transition target.

Consider a performance-linked bond (PLB) that promises to pay coupons C_t at future times $t = [0, \ldots, \tau, \ldots T]$ and a principal N at maturity T. However, if a predefined Performance Target (PT) is not met at a specified date $t = \tau < T$, the bond will pay additional coupons CSU_t (Coupon Step-Ups) between time τ and T.

The PT is set up as a condition on one KPI set against a defined baseline, D. For the purpose of the below model, we will consider that the PT is linked to only one metric called KPI_t and that the PT is met if $KPI_\tau < D \cdot KPI_0$ 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 PT in the negative, i.e. the option is only called when the PT 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, it does not reset, even if the company performs in line or better with the PT after τ. As the PT is based on an improvement of the KPI between $t = 0$ and τ, the option is in-the-money at the time the performance-linked bond is issued.

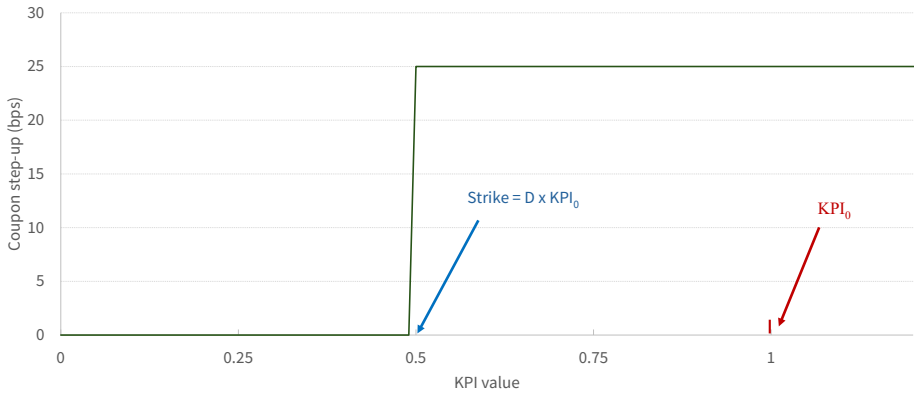
An investor buying the bond is thus long an ITM European binary call option with strike KPI_τ paying a stream of coupons between τ and T, as illustrated in Figure 21.

$$PLB_0 = PLB_0^1 + PLB_0^2 \tag{6}$$

where

$$PLB_0^1 = PV\left(\sum_{t=1}^{n} C_t + N\right) \tag{7}$$

Figure 21: Pay-out of a PLB 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%).



$$PLB_0^2 = \mathbb{E}\left[\sum_{t=\tau}^{n} 1_{(KPI_\tau \geq D \cdot KPI_0)} \cdot CSU_t\right] \tag{8}$$

We assume that, under the no-arbitrage hypothesis, the value of a PLB_0^1 is equal to the discounted value of the future cash flows it is expected to generate:

$$PLB_0^1 = \left(\sum_{t=1}^{n} \frac{C_t}{B(0,t)} + \frac{N}{B(0,n)}\right) \tag{9}$$

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 $B(0,t) = e^{-r_t t}$, 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 below).

Assuming CSU_t and KPI_t are independent, we can write PLB_0^2 in the following form:

$$PLB_0^2 = \mathbb{E}\left[1_{\{KPI_\tau \geq D \cdot KPI_0\}}\right] \cdot \mathbb{E}\left[\sum_{t=\tau}^{n} CSU_t\right] \tag{10}$$

The equation simply specifies that the value of the binary option is the expectation that the PT will be met multiplied by the discounted value of

the coupon step-up cash flow if the option triggers. Equation (6) can be reduced to a simpler expression:

$$PLB_0^2 = \mathbb{E}\left[1_{\{KPI_\tau \geq D \cdot KPI_0\}}\right] \cdot \sum_{t=\tau}^{n} \frac{CSU_t}{B\left(0,t\right)} \tag{11}$$

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

Equation (1) confirms what we have seen in the discrete pricing: in the PLB 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.

We can use this framework to also apply more dynamics to define the forward probability distribution of the target. Let the KPI be defined as the issuer's carbon emissions CE_t at time t, and CE_0 is the emission at the time zero, i.e. at issuance of the bond. Thus,

$$PLB_0^2 = \mathbb{E}\left[1_{\{CE_\tau \geq D \cdot CE_0\}}\right] \cdot \sum_{t=\tau}^{n} \frac{CSU_t}{B(0,t)} \tag{12}$$

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:

$$\frac{dCE_t}{CE_t} = \delta dt + \sigma dW_t \tag{13}$$

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 meet the PT. This is an important point worth repeating: high confidence

that the company could reach the target (= a high volatility factor) implies, ceteris paribus, lower probability for the investor that the coupon step-up will be paid out.

Using the closed form of the Black-Scholes formula for binary options pricing, see Hull(2014), and the law of motion in (7), the price of the SC coupon stream PLB_0^2 can then be expressed as:

$$PLB_0^2 \ = \phi\left(d_2\right) \cdot \sum_{t=\tau}^{n} \frac{CSU_t}{B\left(0,t\right)} \tag{14}$$

with:
- ϕ the cumulative distribution function,
- $d_2 = d_1 - \sigma\sqrt{t_\tau}, \quad d_1 = \frac{ln\left(\frac{CE_0}{D}\right)+\left(\delta+\frac{\sigma^2}{2}\right)\bullet t_\tau}{\sigma\sqrt{t_\tau}}$,
- 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 PLB'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 effects on the price of the option/PLB.