The new bonds on the block – Incentives via Alternative Green Bonds Design

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Source: Dahlen, Fehrenkötter, Schreiter (2023): The new bonds on the block - Analyzing alternative green bond designs using a simulation-based approach

In our research project we attempt to find green bond structures that set incentives to reduce CO2 emissions instead of regulatory frameworks

IDEA

- Green bonds are intended to help bridging the financing gap for achieving the 2°-goal
- However: There is no clear definition of what a green bond is nor is there a universal way to check the quality of the investments made with it

=> Instead of defining a regulatory framework wouldn't it be great to have an incentive structure signaling best intentions?!

METHODOLOGY

- Simulation-based approach to compare different types of green bonds including
  - Green fixed-rate
  - Green carbon-linked
  - Green inflation-linked
  - Green convertible
- Bonds are used to finance an emission-reducing project where the NPV depends upon carbon prices and financing costs, s.t. default risk
- Carbon prices and inflation are modeled stochastically

FINDINGS

- Carbon-linked bonds with a reversed coupon structure yield higher NPV and earlier project start
- Carbon-linked bonds might be an instrument to set incentives to invest in emission-reducing projects
- More complex bonds (e.g. inflation-linked) do not set superior incentives to traditional fixed-rate bonds

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Transition to “green(er)” economy requires large financial resources – Solutions required to narrow financing gap

- **Green transition –** Countries and organizations have defined climate targets e.g. net zero ambition 2050 which require decline of emissions over a certain period of time
- **Financing gap –** Scholars believe that there is a high financing gap to reach the objective - for example, McCollum et al. 2018 estimate a financing gap of USD 320 billion p.a. to achieve the Paris 2°-goal
- **Debt instruments –** Bond market is one of the most important sources for sovereign and corporate (debt financing) and is established across the world
- **Green bonds –** “Green bonds” have experienced a surge but come with various shortcomings e.g. inconsistent global definition and risk of greenwashing

Are there bond designs that do overcome some of the shortcoming of green bonds and set an incentive to invest in “green” projects?

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Before we define the research approach, some key elements need to be further outlined

Green bonds

- Green bonds have similar characteristics than "traditional" bonds but come with a "use of proceed" clause
- The "use of proceed" clause defines that the proceeds are earmarked for climate-friendly projects
- First issuance in 2007 started a surged of demand for green bonds

Fixed-rate (green) bonds

- Fixed-rate bonds are the most basic and traditional bond in the market
- It offers a coupon with a fixed interest rate until maturity (e.g. 2% on the Face Value of the bond)
- The cashflows of the bonds do not change until maturity

Carbon-linked (green) bonds

- Carbon-linked bonds were first issued shortly after the first green bond issuance in 2008
- The coupon is linked to the development of a carbon price[1]
- After initial issuance by the World Bank it did not experience much demand

Inflation-linked green bond

- (Partly) offers protection against inflation development
- Inflation development is reflected in bond either by a) changing the coupon or b) changing the principal
- Initial green inflation-linked bonds issued by governments, e.g., France

Convertible (green) bonds

- Convertible bonds can be converted from debt to equity (shares) during the lifetime of the bond
- Conversion ratio (shares vs. bond) is pre-defined
- Initial green convertible bonds issued in 2019

Carbon prices & trading schemes

- Carbon prices are either in the form of taxes or "cap-and-trade" systems
- The European Trading Scheme (ETS) is the largest market for CO2 certificates
- Corporates need to cover their emissions with certificates
- Market price increased rapidly in the last years – after very low prices in the early 2000s

1. The first two carbon-linked bonds had a coupon structured that was also linked to the realized vs. expected carbon savings from a project that is financed by it
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At the core of our paper is an investment project which yields returns in the form of CO2 certificates and which is financed by green bonds

Investment project

- Financing: Company is partially debt financed and uses bond proceeds for project financing
- Return: Due to the emission reduction, CO2 certificates are saved and thus the project yields a return - No other financial returns are generated
- Operating cost: Project comes with constant operating cost to account for realistic set-up
- Project start: Project is only started if it is profitable for company (when carbon price exceeds a certain level)

Project financing

Bond type #1: Green fixed-rate
Fixed coupon structure e.g. 2% interest per year
→ *Constant CF per period*

Bond type #2: Green carbon-linked
Coupon is linked to the development of the carbon price
→ *CF depend. on carbon price*

Bond type #3: Green inflation-linked
Coupon is linked to development of inflation
→ *CF depend. on inflation*

Bond type #4: Green convertible
Coupon is constant until maturity but final CF depends on share price
→ *CF constant until maturity*

Underlying processes

Carbon price: We assume a cap-and-trade carbon market similar to the European ETS market – we assume that the price development follows a Geometric Browning Motion

Inflation: We assume that the inflation follows a mean-reverting process given the central bank policy

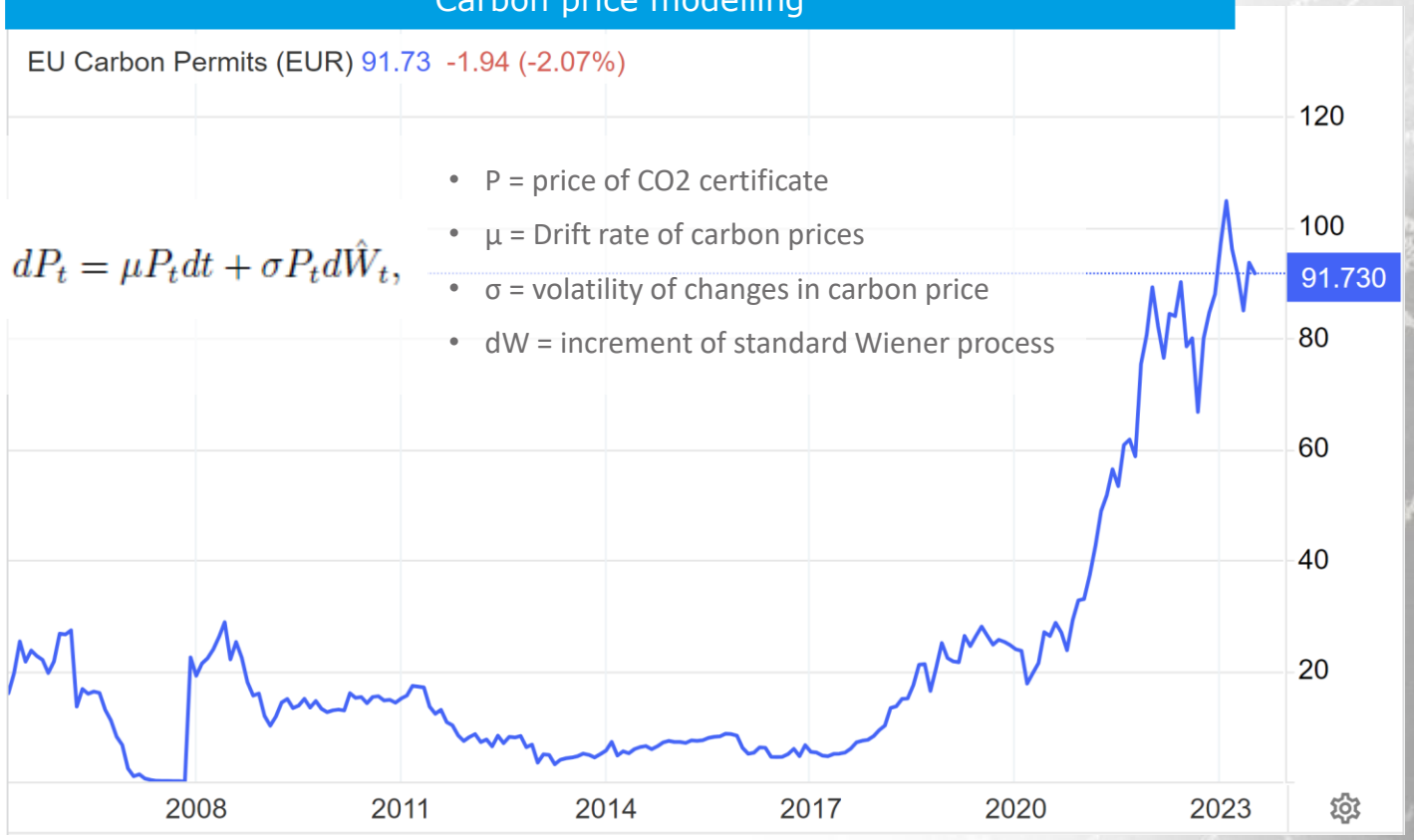
Share price: We assume that the share follows a Geometric Browning Motion

Correlation: We assume that the processes are not independent but interact with each other – for that we use a Cholesky Decomposition

Source: Dahlen, Fehrenkötter, Schreiter (2023): The new bonds on the block - Analyzing alternative green bond designs using a simulation-based approach

We apply a simulation-based approach to model the development of the underlying processes including carbon, inflation and share price

Carbon price modelling



Description

- Key for the model is the development of the carbon price which we describe in the first equation
- It follows previous work of Bloch (2011) and has the form of a geometric Browning Motion
- Inflation is expected to follow a mean reverting process
- We assume that share price follows a GBM, too

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We apply a simulation-based approach to model the development of the carbon price and thus the project return and CP-bond coupon

Coupon and bond pricing

Fixed-rate

c_{fix} – Constant coupon payment in each period until maturity

Carbon-linked

$$c_{up,i}=\begin{cases} c^1_{up,i}, P < y_1 \\ c^2_{up,i}, y_1 \le P < y_2 \\ c^3_{up,i}, y_2 \le P < y_3 \\ \vdots \end{cases} \qquad c_{down,i}=\begin{cases} c^1_{down,i}, P < y_1 \\ c^2_{down,i}, y_1 \le P < y_2 \\ c^3_{down,i}, y_2 \le P < y_3 \\ \vdots \end{cases}$$

Inflation-link

$$cir_{IL} = \frac{(inf_{cur} - inf_{iss}) + inf_{iss}}{inf_{iss}} \cdot 100 \qquad c_{IL} = FV \cdot cit_{IL} \cdot cir_{IL}$$

convertible

$$CV = \frac{FV_c}{CP} \qquad CV(V,r,t) \ge \gamma(V - nN(V,r,t)).$$

Description

- The coupon of the carbon linked bond either increases (cp-up bond) or decreases (cp-down bond) with increasing carbon prices
- The exact interest rates for the carbon-linked bond are derived to make it comparable with the fixed rate bond (discounting expected CFs)
- For the inflation-linked bond we follow the structure of the latest issuance of the French Treasury – it combines a fixed coupon and a coupon that is linked to the development of the inflation rate
- For the convertible bond we use the structure of a green convertible bond issued by NEOEN – it has a fixed coupon structure until maturity. At maturity the cashflow depends whether the bond is converted or not

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After we have defined the properties for the carbon price and used bonds, we need to define the investment project

Simulation of coupon levels

$$D_0 = \sum_{i=1}^{N=\frac{T_B}{\Delta t}} \frac{c_{(.),i} \cdot \Delta t \cdot FV}{(1+r_f)^{i \cdot \Delta t}} + \frac{FV}{(1+r_f)^{T_B}},$$

- Face values of bonds need to be comparable
- Thus, we calculate the required coupon payment in each step for the CP-linked bond

Cashflows of investment project

$$CF_{(.),j} = \begin{cases} \mathrm{X}(P_j - C_{pro}) - c_{(.),j} FV, t_{pro} \leq j < T_B \\ \mathrm{X}(P_j - C_{pro}) - (1 + c_{(.),j}) FV, t_{pro} \leq j = T_B \\ \mathrm{X}(P_j - C_{pro}), t_{pro} \leq T_B < j \leq t_{pro} + T_{pro} \end{cases}$$

- X = Saved Co2 certificates
- P = Price of CO2 certificate
- C_{pro} = Operating cost of project
- σ = Volatility of changes in carbon price
- T_B = Time to maturity of bond
- T_{pro} = Lifetime of the project
- J = specific point in time

NPV of investment project

$$\max_{b^*_{(.)}} NPV_{pro,(.)} = \max_{b^*_{(.)}} \sum_{j=t_{pro}}^{M=t_{pro}+T_{pro}} \frac{CF_{(.),j}}{(1+r_f)^j} .$$

- b* = Optimal boundary to start project that maximizes NPV

Description

- Depending on the point in time of the project, different cashflows are realized
- CF 1 = Cashflow after project was started but before bond is redeemed
- CF 2 = Cashflow in the period in which bond is redeemed
- CF 3 = Cashflow after bond was redeemed
- Based on those cashflows a value-maximizing starting point is derived based on the project NPV
- This depends on the development of the carbon-price and coupons of the bonds

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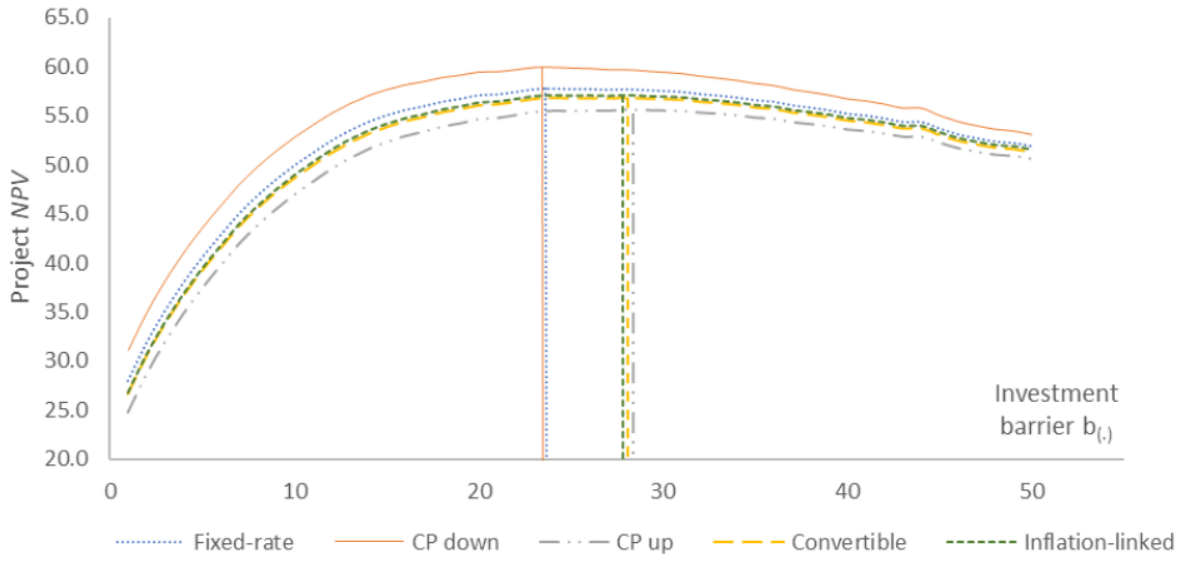
CP-linked bond with a reversed coupon structure yields higher NPV and earlier project execution



Green fixed bond		Green CP-linked up bond		Green CP-linked down bond		Green inflation-linked Bond		Green convertible bond	
NPV	**Barrier**	**NPV**	**Barrier**	**NPV**	**Barrier**	**NPV**	**Barrier**	**NPV**	**Barrier**
57.75	24	55.66	28	59.96	24	57.11	28	56.82	28

Key results

- We compare the different bonds based on the NPV and project execution
- Our results indicate that a CP-linked down bond has a higher NPV than both fixed-rate and CP-linked bond down
- Thus, the carbon-linked down bond design sets incentives to invest earlier and it generates higher returns
- Still, the results are relatively close together – especially comparing the fixed bond with the cp-linked down bond

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Our results are robust to changes in the underlying parameters – sensitivities for key parameters do not change result

	Volatility			Correlation			Fixed rate		CP-linked up		CP-linked down		Inflation - linked		Convertible	
Model version	σ_{cp}	σ_{i}	σ_{SP}	$\rho_{CP,HCPI}$	$\rho_{HCPI,SP}$	$\rho_{CP,SP}$	NPV	BR	NPV	BR	NPV	BR	NPV	BR	NPV	BR
Original	0.35	0.1	0.25	0.23	0.1	0.2	57.75	24	55.66	28	59.96	24	57.11	28	56.82	28
Sensi 1	0.35	0.1	0.25	0.1	0.05	0.05	59.90	24	57.71	25	62.10	24	59.55	24	59.02	24
Sensi 2	0.35	0.1	0.25	0.3	-0.05	0.15	58.30	24	56.16	27	60.50	24	57.44	27	57.11	27
Sensi 3	0.35	0.1	0.25	0.4	-0.1	0.1	59.35	28	57.32	28	61.38	28	58.35	28	58.48	28
Sensi 4	0.15	0.05	0.15	0.23	0.1	0.2	16.59	9	15.78	9	17.42	8	15.64	10	16.33	9
Sensi 5	0.25	0.25	0.25	0.23	0.1	0.2	38.87	18	37.31	18	40.49	16	37.63	18	37.88	18

Table 7: Sensitivities - Table shows the results of the simulation using different specifications. Volatility of changes in carbon price (σ_{cp}), inflation (σ_i) and share price (σ_{SP}) are modified. Furthermore, correlation of inflation and carbon price ($\rho_{CP,HCPI}$), inflation and share price ($\rho_{HCPI,SP}$) and share price and carbon price ($\rho_{CP,SP}$) are adjusted. Original version corresponds to specification and results as in table 6. *BR* stands for the barrier (carbon price level).

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Our model should be the first stepping stone and thus offers many areas for future research

Limitations

- The carbon price might be modelled with additional processes. We apply a geometric Brownian Motion but other models might be appropriate as well
- Additional specifications for investment project possible – we tried to find a simple yet realistic investment project
- The reason why carbon-linked bonds did not succeed in the market yet are unknown to us – additional qualitative interviews/surveys might shed light on that

Future research

- Inclusion of other parameters that might affect calculation
- Changes in the assumption of the investment project – further relating it to existing project finance
- Applying more sophisticated models for simulating the carbon price development
- Inclusion of default probabilities in the model

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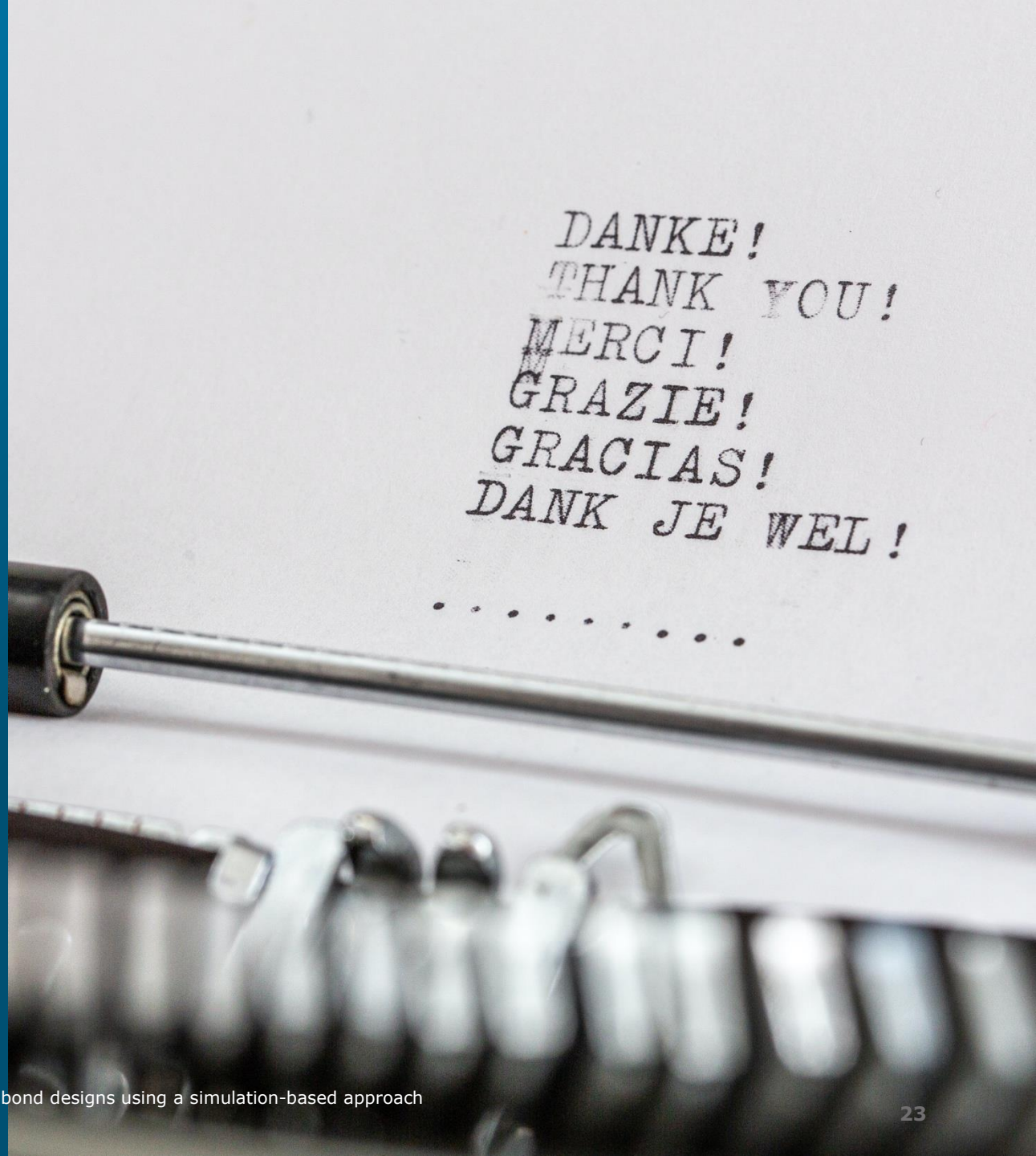
Thanks a lot!

I am looking forward to your feedback!



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