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Design and Incentives of Sustainability-Linked Bonds

6th Fudan-Ulm Symposium on Finance and Insurance | An Chen, Maria Hinken & Gunter Löffler | 5th - 6th September 2024

Motivation

- United Nations (UN) Climate Change Conference
- 17 Sustainable Development Goals of UN

→ Sustainability and, especially, environmental actions are becoming increasingly important in the current time

- A lot of financial instruments have emerged to promote environmentally friendly and sustainable incentives
  - First green bond was issued by European Investment Bank in 2007
  - Recent addition: Sustainability-linked bonds (SLBs)
    - Payments of SLB depend on achievement of sustainability performance targets (SPTs) and key performance indicators (KPIs)
    - Most commonly: Coupon step-up if SPTs are not achieved by KPI

Motivation: Example SLB

Deutsche Post AG (ISIN XS2644423035)

- Issue date: 2023
- Maturity: 2033
- Regular coupon: 3.375% (paid annually)
- Key Performance Indicators (KPIs)
  - KPI 1: GHG Emissions (Scope 1 + Scope 2)
  - KPI 2: GHG Emissions (Scope 3)
- Examination date: 2030
- Sustainability Performance Targets (SPTs)
  - SPT 1: 42% reduction of KPI 1 compared to 2021
  - SPT 2: 25% reduction of KPI 2 compared to 2021
- Penalty payment: Coupon step-up +0.25% from 2031 to 2033 if one or two targets are missed or KPI is not reported

Motivation: Common views

- Ambition of SPTs and the size of coupon step-ups are viewed by market participants as indicator of SLB's contribution to sustainability
  - Sustainability targets should "represent a material improvement in the respective KPIs" (ICMA (2023), p.3)
  - Rating agencies (e.g., Sustainalytics or Moody's) evaluating ambition of sustainability targets when providing second party opinions on SLBs
  - "In the case of a coupon step-up, its level should be high enough that the achievement of an SPT has a meaningful influence on the issuer's sustainability journey and credit profile." (AXA (2022), p.6)
- Research Questions:
  - Do more ambitious targets or higher penalties indicate a higher commitment of the issuer?
  - Will an SLB create incentives to do more for the environment?
  - Alternatively, can the company pursue this with the sole intention of lowering its financing costs?

Motivation

- Research approach: We use risk-neutral pricing and consumption-based capital asset pricing model (CCAPM) for pricing SLBs to answer the research questions
  - Valuation of SLBs through risk-neutral pricing and CCAPM to determine financing costs
  - Systematic assessment of how financing costs vary with features of the SLB
- Literature overview:
  - Richardson (2022), Kölbel & Lambillon (2022), Ul Haq & Doumbia (2022): Empirical studies related to SLBs
  - Berrada *et al.* (2023): One-period model in which firms decide whether to exert effort towards greater sustainability
  - Erlandsson & Mielnik (2022), Erlandsson *et al.* (2022): Employ risk-neutral pricing of SLB's

Overview

Payoff structure and valuation

Numerical analysis

Robustness check

Outlook

Conclusion

Model

- Finite time horizon $T > 0$
- Face value $F > 0$
- Payment dates $\underline{\underline{T}} := \{0 < t_1 < \cdots < t_n := T\}$

Coupon payments consist of two components

1. Constant payments: $c_0 \geq 0$
2. Payment linked to achievement of sustainability targets
   - Reward payment (e.g., coupon step-down) if sustainability targets are **achieved** by key performance indicator
   - Penalty payment (e.g., coupon step-up) if sustainability targets are **not achieved** by key performance indicator

Model

- Key Performance Indicator (KPI):

$$I_t = I_0(1 + \alpha t) + \sigma W_t$$

  with $\alpha \in \mathbb{R}$ constant, volatility $\sigma > 0$ and risk driver W standard Brownian motion under real-world measure $\mathbb{P}$

- Sustainability Performance Targets (SPTs):

$$B_t = B_0(1 + gt)$$

  with $B_0, g \in \mathbb{R}$

- Most commonly used KPI: GHG emissions
  - Aim: reduce GHG emissions over time

  $\rightarrow$ $B_0 > 0$ and $g < 0$ (or $B_0 < 0$ and $g > 0$)

Model

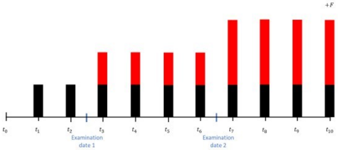
- Second component of coupon payment: coupon step-up as penalty payment
  - Examination dates $0 < \tau_1 < \ldots < \tau_m \leq T$
  - Situation: aim to reduce KPI over time period
    - $I_{\tau_i} \leq B_{\tau_i} \Rightarrow$ SPTs by KPI achieved $\Rightarrow$ Coupon payment c_0 at the following payment dates (no penalty payment)
    - $I_{\tau_i} > B_{\tau_i} \Rightarrow$ SPTs by KPI not achieved $\Rightarrow$ Coupon payment c_0 and additional penalty payment $\Delta c_i > 0$ at the following payment dates
- Cash flow at payment time $t \in \underline{\underline{T}}$ of SLB:

$$C_t := \begin{cases} c_0 & \text{if } t < \tau_1, \\ c_0 + \Delta c_i \mathbb{1}_{\{I_{\tau_i} > B_{\tau_i}\}} & \text{if } \tau_i \leq t < \tau_{i+1},\ i \in \{1, \ldots, m\} \\ F \mathbb{1}_{t=T} + c_0 + \Delta c_m \mathbb{1}_{\{I_{\tau_m} > B_{\tau_m}\}} & \text{if } \tau_m \leq t \end{cases}$$

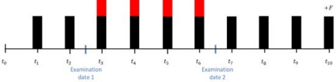
Model

Exemplary payoff structure of an SLB:

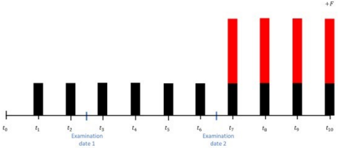
Case 1: Targets are missed at both examination dates



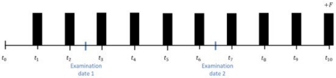
Case 2: Targets are missed at the first examination date but not at the second



Case 3: Targets are achieved at the first examination date but not at the second



Case 4: Targets are achieved at both examination dates



Legend: ■ Regular coupon payments ■ Penalty coupon step-up payments

Risk-neutral price of SLB

- Price: r risk-free interest rate

$$P = \sum_{t \in \underline{\underline{T}}} e^{-rt} \mathbb{E}_{\mathbb{Q}}[C_t]$$

$$= e^{-rT} F + \sum_{t \in \underline{\underline{T}}} c_0 e^{-rt} + \sum_{i=1}^{m-1} \sum_{\substack{t \in \underline{\underline{T}} \\ \tau_i \leq t < \tau_{i+1}}} \Delta c_i e^{-rt} \Phi(-d(\tau_i))$$

$$+ \sum_{\substack{t \in \underline{\underline{T}} \\ \tau_m \leq t}} \Delta c_m e^{-rt} \Phi(-d(\tau_m))$$

with $d(t) := \frac{B_t - I_0(1+\alpha t)}{\sigma \sqrt{t}} + \lambda \sqrt{t}$, where λ is market price of risk of W and $\mathbb{Q}$ the risk-neutral measure given λ

- Interpretation:
  - Price of corresponding regular coupon-bearing bond
  - Additional price due to penalty payments

Yield of SLB

- Yield y of the SLB (i.e., the financing costs) is defined through

$$\sum_{t \in \underline{\underline{T}}} e^{-rt} \mathbb{E}_{\mathbb{Q}}[C_t] = \sum_{t \in \underline{\underline{T}}} e^{-yt} \mathbb{E}_{\mathbb{P}}[C_t]$$

  with $\mathbb{P}(I_t > B_t) = \Phi(-\tilde{d}(t))$, where $d(t) = \tilde{d}(t) + \lambda\sqrt{t}$

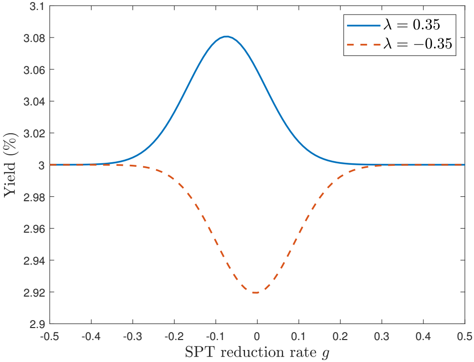
- $\lambda > 0 \Rightarrow y > r$
  - Higher return compared to risk-free investment
  - Explanation: Penalty payment are subject to systematic risk

- $\lambda < 0 \Rightarrow y < r$
  - Lower return compared to risk-free investment
  - Explanation: Hedge of relevant risk or preference for sustainability

Base case parameter values

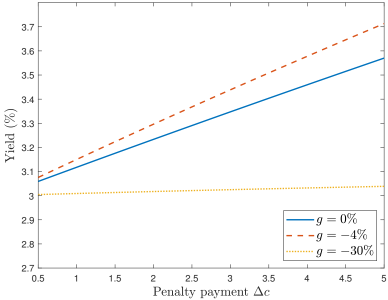
Parameter	Symbol	Values
Face value	F	100
Maturity	T	10
Payment date	$(t_1, \ldots, t_{10})$	(1,...,10)
Coupon payment	c_0	$3\% \cdot F = 3$
Risk-free rate	r	3%
KPI initial value	I_0	1000
KPI reduction rate	α	-4%
KPI volatility	σ	200
SPT initial value	B_0	1000
SPT rate	g	-4%
Market price of risk	λ	{-0.35,0.35}
Examination date	τ	4.75
Penalty payment	Δc	0.5

Yield y (financing costs) w.r.t. SPT reduction rate g

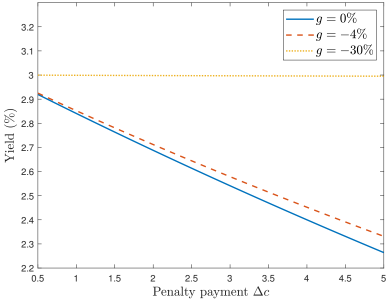


- Lower $g \Rightarrow$ Higher ambition of sustainability targets
- $\lambda > 0$: More ambitious targets may be set by firm only to lower financing costs.

Yield y (financing costs) w.r.t. penalty payment Δc



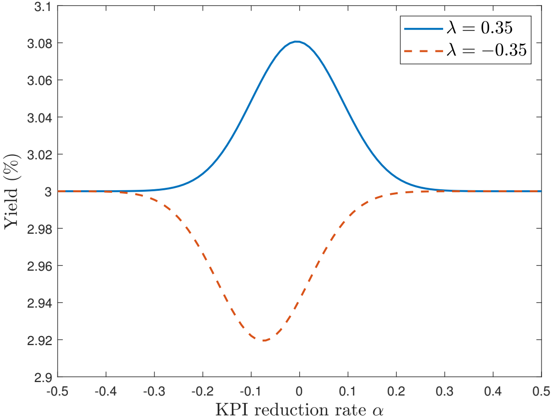
(a) $\lambda = 0.35$.



(b) $\lambda = -0.35$.

- Sustainability targets ambitious enough $\Rightarrow$ Increase in penalty payment without material increase in financing costs
- $\lambda < 0$: Higher penalty payments lead to lower financing costs

Yield y (financing costs) w.r.t. KPI reduction rate α



- Higher $\alpha \Rightarrow$ Lower expected sustainability performance
- Situations: Reduction of financing costs by reduction of sustainable effort

Robustness check: CCAPM approach

Consider a representative agent with

- Subjective discount factor β,
- Utility u given by a power utility function

$$u(x) := \frac{x^{1-\gamma}}{1-\gamma}$$

  with risk aversion coefficient $\gamma \in \mathbb{R}_+ \setminus \{1\}$, and
- Consumption level x_t at time t given by

$$\ln(x_t) = \ln(x_0) + \mu_x t + \sigma_x W_t^x$$

  with initial consumption level x_0, expected log consumption growth $\mu_x \in \mathbb{R}$, volatility of log consumption growth $\sigma_x > 0$ and risk driver W^x given by a Brownian motion under $\mathbb{P}$ correlated with factor $\rho \in [-1, 1]$ to KPI's risk driver W.

Robustness check: CCAPM approach

- Price of SLB:

$$P^{\text{CCAPM}} = \sum_{t \in \underline{\underline{T}}} \beta^t \mathbb{E}_{\mathbb{P}} \left[\frac{u'(x_t)}{u'(x_0)} C_t \right]$$

$$= F \tilde{\beta}^T + c_0 \sum_{t \in \underline{\underline{T}}} \tilde{\beta}^t + \sum_{i=1}^{m-1} \Delta c_i \Phi(-\hat{d}(\tau_i)) \sum_{\substack{t \in \underline{\underline{T}} \\ \tau_i \le t < \tau_{i+1}}} \tilde{\beta}^t$$

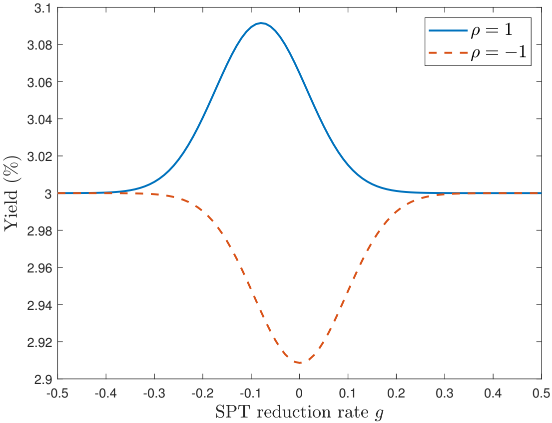
$$+ \Delta c_m \Phi(-\hat{d}(\tau_m)) \sum_{\substack{t \in \underline{\underline{T}} \\ \tau_m \le t}} \tilde{\beta}^t,$$

with $\tilde{\beta} := \beta e^{-\gamma \mu_x + \frac{1}{2}\gamma^2 \sigma_x^2}$ and $\hat{d}(t) := \tilde{d}(t) + \gamma \sigma_x \rho \sqrt{t}$

→ Similar structure as under the risk-neutral pricing approach

- Yield of SLB: $P^{\text{CCAPM}} = \sum_{t \in \underline{\underline{T}}} e^{-yt} \mathbb{E}_{\mathbb{P}} [C_t]$

Yield y w.r.t. SPT reduction rate g



- Parameter: $\sigma_x = 4\%$, $\mu_x = 1\%$, $\beta = 0.99005$ and $\gamma = 10$
- The results remain stable regarding the pricing method (also for α and Δc).

Robustness check: Default

- We model default risk to analyze its impact on the financing costs
- Simplifying assumption: Occurrence of default event is triggered by an external event beyond firm's control.
- The results are similar to the non-defaultable case.

Outlook

- We incorporate effort exerted by the firm to improve their sustainability performance into the model and analyze a decision problem of the firm issuing an SLB
- The more effort is exerted by the firm, ...
  - ... the better the firm's sustainability performance.
  - ... the higher the costs for the firm and, thus, the lower the firm's assets.
  - ... it is more likely that the SPTs are achieved by the KPI and, thus, the lower the firm's liabilities regarding the SLB holders.
- Decision problem: Maximize firm's expected utility of its financial and sustainable performance regarding the exerted effort
- Questions to answer:
  - Does an SLB incentivize a firm to improve their sustainability performance?
  - Does the firm benefit from issuing an SLB?

Conclusion

- We value SLBs using risk-neutral and CCAPM pricing approach to determine SLB's financing costs
- More ambitious targets/higher penalties reliable indicator of greater commitment to sustainability?
  - More ambitious targets may lead to lower financing costs (non-monotonic behavior)
  - Higher penalty payments may lead to lower financing costs ($\lambda < 0$)
- Financial incentives for issuer to do more for the achievement of sustainability goals?
  - Reduction of planned effort before issue may lead to lower financing costs (non-monotonic behavior)

Thank you for your attention!

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Theoretical results on SLB's yield

Yield y of the SLB:

$$\sum_{t \in \underline{\underline{T}}} e^{-rt} \mathbb{E}_{\mathbb{Q}}[C_t] = \sum_{t \in \underline{\underline{T}}} e^{-yt} \mathbb{E}_{\mathbb{P}}[C_t]$$

Proposition (Yield relative to risk-free rate)

The yield of the SLB can be greater than, equal to or less than the risk-free interest rate, depending on the market price of risk:

- *If* $\lambda > 0$, *then* $y > r$.
- *If* $\lambda = 0$, *then* $y = r$.
- *If* $\lambda < 0$, *then* $y < r$.

Theoretical results on SLB's yield

Yield y of the SLB:

$$\sum_{t \in \underline{\underline{T}}} e^{-rt} \mathbb{E}_{\mathbb{Q}}[C_t] = \sum_{t \in \underline{\underline{T}}} e^{-yt} \mathbb{E}_{\mathbb{P}}[C_t]$$

Proposition (Convergence of yield)

Let all parameters be fixed. If the SPT reduction rate g with initial SPT value $B_0 \neq 0$ or the KPI reduction rate α converges to $\pm\infty$, the yield y converges to the risk-free rate r.

Theoretical results on SLB's yield

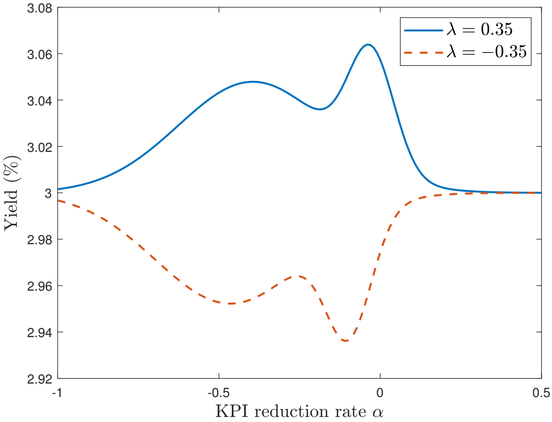
Yield y of the SLB:

$$\sum_{t \in \underline{\underline{T}}} e^{-rt} \mathbb{E}_{\mathbb{Q}}[C_t] = \sum_{t \in \underline{\underline{T}}} e^{-yt} \mathbb{E}_{\mathbb{P}}[C_t]$$

Proposition (Behavior of yield)

In the special case of one examination date, the yield y has a single peak (trough) with respect to the SPT level B or the KPI reduction rate α if the market price of risk λ is positive (negative) while keeping everything else fixed. Furthermore, for a given yield y, there exist at most two SPT levels or two KPI reduction rates if everything else is kept fixed.

Two examination dates



Parameter: $\tau_1 = 0.75$ with $\Delta c_1 = 0.5$ and $\tau_2 = 8.75$ with $\Delta c_2 = 0.75$; $B_0 = 700$ and $g = -4\%$

CCAPM Approach

Consider a representative agent with

- subjective discount factor β,
- utility u given by a power utility function

$$u(x) := \frac{x^{1-\gamma}}{1-\gamma}$$

  with risk aversion coefficient $\gamma \in \mathbb{R}_+ \setminus \{1\}$, and
- consumption level x_t at time t given by

$$\ln(x_t) = \ln(x_0) + \mu_x t + \sigma_x W_t^x$$

  with initial consumption level x_0, expected log consumption growth $\mu_x \in \mathbb{R}$, volatility of log consumption growth $\sigma_x > 0$ and risk driver W^x given by a Brownian motion under $\mathbb{P}$ correlated with factor $\rho \in [-1, 1]$ to KPI's risk driver W.

CCAPM Approach

- Price of SLB:

$$P^{\text{CCAPM}} = \sum_{t \in \underline{\underline{T}}} \beta^t \mathbb{E}_{\mathbb{P}} \left[\frac{u'(x_t)}{u'(x_0)} C_t \right]$$

$$= F \tilde{\beta}^T + c_0 \sum_{t \in \underline{\underline{T}}} \tilde{\beta}^t + \sum_{i=1}^{m-1} \Delta c_i \Phi(-\hat{d}(\tau_i)) \sum_{\substack{t \in \underline{\underline{T}} \\ \tau_i \leq t < \tau_{i+1}}} \tilde{\beta}^t$$

$$+ \Delta c_m \Phi(-\hat{d}(\tau_m)) \sum_{\substack{t \in \underline{\underline{T}} \\ \tau_m \leq t}} \tilde{\beta}^t,$$

with $\tilde{\beta} := \beta e^{-\gamma\mu_x + \frac{1}{2}\gamma^2\sigma_x^2}$ and $\hat{d}(t) := \tilde{d}(t) + \gamma\sigma_x\rho\sqrt{t}$

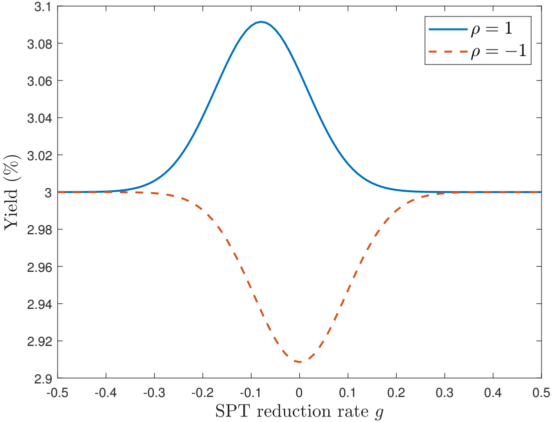
→ Similar structure as under the risk-neutral pricing approach

- Yield of SLB: $P^{\text{CCAPM}} = \sum_{t \in \underline{\underline{T}}} e^{-yt} \mathbb{E}_{\mathbb{P}} [C_t]$

Further parameter values for CCAPM

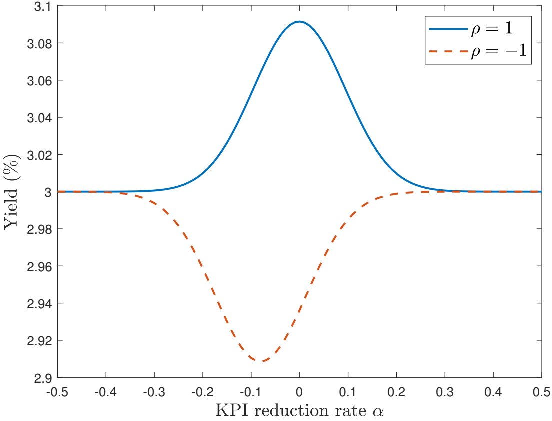
Parameter	**Symbol**	**Values**
Log consumption growth volatility	σ_x	4%
Expected log consumption growth	μ_x	1%
Subjective discount factor	β	0.99005
Risk aversion coefficient	γ	10
Correlation coefficient	ρ	{-1,1}

Yield y w.r.t. SPT reduction rate g



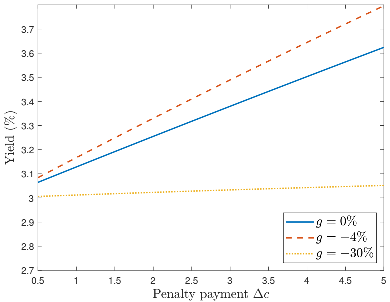
- Same behavior as under risk-neutral pricing approach

Yield y w.r.t. KPI reduction rate α

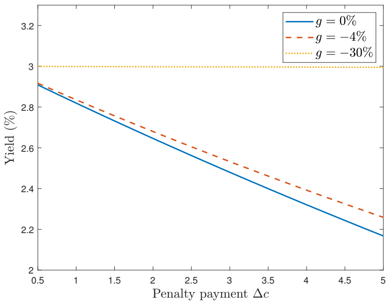


- Same behavior as under risk-neutral pricing approach

Yield y w.r.t. penalty payment Δc



(a) $\lambda = 0.35$.



(b) $\lambda = -0.35$.

- Same behavior as under risk-neutral pricing approach

Defaultable SLB

- Time at which the firm defaults δ (random variable)
  - Independent of the event that trigger SLB's penalty payments
  - Exponential distributed under risk-neutral default measure $\mathbb{Q}^d$ and under real-world measure $\mathbb{P}$
  - Risk-neutral probability that firm has not defaulted by time t

$$q(t) := \mathbb{Q}^d(\delta > t) = e^{-\mu^{\mathbb{Q}^d} t}$$

    where $\mu^{\mathbb{Q}^d}$ is constant (exogenous) intensity rate
  - Real-world probability that firm has not defaulted by time t

$$p(t) := \mathbb{P}(\delta > t) = e^{-\mu^{\mathbb{P}} t}$$

    where $\mu^{\mathbb{P}} \leq \mu^{\mathbb{Q}^d}$ is constant (exogenous) intensity rate
- Recovery payment $R \geq 0$ at time δ

Defaultable SLB

- Risk-neutral price of SLB

$$P^d = q(T) \sum_{t \in \underline{\underline{T}}} e^{-rt} \mathbb{E}_{\mathbb{Q}}[C_t] + \int_0^T \left(\sum_{t \in \underline{\underline{T}},\ t \leq s} e^{-rt} \mathbb{E}_{\mathbb{Q}}[C_t] + Re^{-rs} \right) q(s) \mu^{\mathbb{Q}^d} ds$$

where $\mathbb{Q}$ is standard risk-neutral measure

- Yield of SLB

$$P^d = p(T) \sum_{t \in \underline{\underline{T}}} e^{-rt} \mathbb{E}_{\mathbb{P}}[C_t] + \int_0^T \left(\sum_{t \in \underline{\underline{T}},\ t \leq s} e^{-rt} \mathbb{E}_{\mathbb{P}}[C_t] + Re^{-rs} \right) p(s) \mu^{\mathbb{P}} ds$$

Further parameter values for defaultable SLB

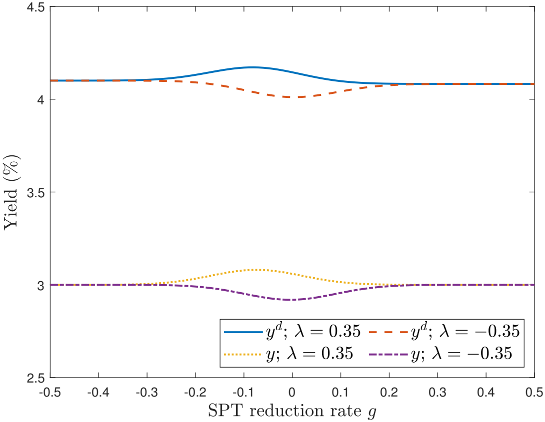
- Base case values as for risk-neutral pricing approach without default
- Intensity rates increases if the discounted penalty payments increases:

$$\mu^{\mathbb{P}} = 0.01 + \frac{\Delta}{F} \text{ and } \mu^{\mathbb{Q}^d} = 0.03 + \frac{\Delta}{F}$$

with $\Delta := \delta c \sum_{t \underline{\underline{T}},\, \tau \leq t} e^{-rt}$

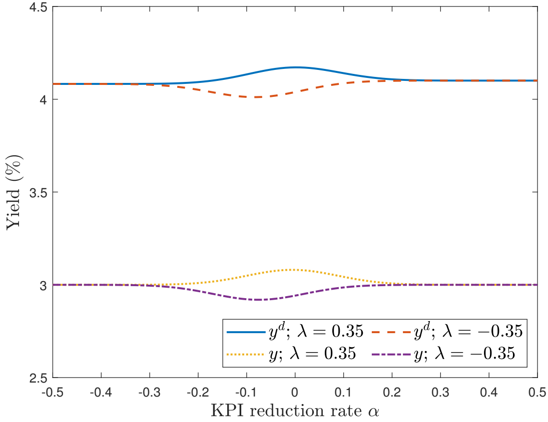
- Recovery payment 40% of face value, i.e., $R = 40$

Yield y w.r.t. SPT reduction rate g



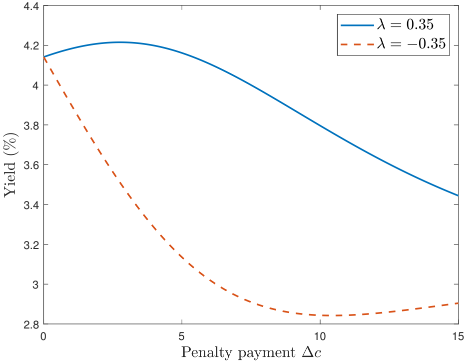
- Financing costs increase due to the firm's default risk
- Same behavior as without default

Yield y w.r.t. KPI reduction rate α



- Financing costs increase due to the firm's default risk
- Same behavior as without default

Yield y w.r.t. penalty payment Δc



- Assumption: Higher penalty payment $\Rightarrow$ Higher default probability
- Influence of default risk can exceed risk of not achieving SPTs by KPI if Δc is large enough

$\rightarrow$ Non-monotonic behavior w.r.t. Δc