Rationale and Design of a Scope 3 Capital Charge

Davide Trevisani, José Germán López, Chris Kenyon, Carlos Vázquez, and Mourad Berrahoui

Department of Mathematics and CITIC, University A Coruña, Spain
Department of Mathematics, University College London, UK
Lloyds Banking Group, UK
Correspondence: davide.trevisani@udc.es, jose.lsalas@udc.es, c.kenyon@ucl.ac.uk, carlos.vazquez.cendon@udc.es, mourad.berrahoui@lloydsbanking.com

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Abstract: Climate change is caused by greenhouse gas emissions, and governments have introduced over seventy carbon pricing instruments (CPIs). Banks finance a significant fraction of global emissions, and many have committed to reduce their facilitated, or Scope 3, emissions to (net) zero by 2050. However, it is possible that governments will introduce a CPI impacting banks on their Scope 3 emissions earlier. Here we design a Scope 3 capital charge to make banks resilient against the possibility, albeit not certainty, that governments could introduce such a Scope 3 CPI. Based on interest rate swaps, our numerical examples are financially significant for counterparties with significant emissions. The contribution of this work is to provide a technical basis for banks to be sufficiently resilient.

1 Introduction

Climate change is caused by greenhouse gas emissions (IPCC, 2021), and governments have introduced over seventy carbon pricing instruments (CPIs) (World Bank, 2023). Banks finance a significant fraction of global emissions and some of them publish their Scope 3 emissions. It is possible that governments will introduce a CPI impacting banks on this type of emissions before 2050. This introduction for banks would be a significant stress as it would have the characteristics of a correlated market event, thus creating an impact for every bank counterparty with significant facilitated emissions. In contrast to this possible scenario, in the financial industry, capital requirements already exist, and from a regulatory point of view, they are set to ensure that banks are "sufficiently resilient to withstand losses in times of stress" (BCBS, 2017). Regulators are highly aware of climate-related risks (BCBS, 2022; BoE, 2021a; European Central Bank, 2020; FSB, 2017) but have generally stated that the introduction of specific climate-related capital charges is not needed (BoE, 2021b, 2023). They expect climate effects to be already included through existing credit risk frameworks, although they remain open to proposals (Federal Reserve System, 2022). However, the aforementioned potential of governments acting directly to curb Scope 3 emissions via CPIs has not been considered (Holscher et al., 2022; Oehmke, 2022). In this work, we aim to consider this possibility (not certainty) and propose a design of a new Scope 3 capital charge. We also present some numerical examples that could be of interest from the regulators' perspective.

The plan of this work is as follows. In Section 2 we present the mathematical modeling, and the derivation of derivative pricing from regulators perspective by mean of semi-replication.

Section 3 is devoted to risk evaluation to define the CPI-capital measure (CPIC). Next, in Section 4 we present numerical examples based on vanilla IRSs. Finally, some conclusions are presented in Section 5.

2 Mathematical modelling

We denote by V_t the risk-free value of the derivative, and $\widehat{V}_t$ the value from the point of view of regulators. We start by considering a timeline $[T_0, T]$, and a filtered probability space $(\Omega, \mathcal{F}, (\mathcal{F}_t)_{t\in[T_0,T]}, Q)$. Such space is assumed to support three-dimensional correlated Brownian motions (W, W^F, W^S) and three Poisson processes J^B, J^C, and J^{co}, independent of each other. Given a larger maturity $\bar{T} \geqslant T$, the economy we consider is given by two blocks of Markovian dynamics. The first block is

$$dB_t/B_t = r_t\, dt \qquad \text{Riskless bank account,} \tag{38.1}$$

$$dP_{t,\bar{T}}/P_{t,\bar{T}} = r_t dt + \sigma_{t,\bar{T}} dW_t \qquad \text{Default-free bond,} \tag{38.2}$$

$$dP^B_{t,\bar{T}}/P^B_{t,\bar{T}} = r^B_t dt + \sigma^B_{t,\bar{T}} dW_t + (1 - R^B_t) dJ^B_t \qquad \text{Own bond,} \tag{38.3}$$

$$dP^C_{t,\bar{T}}/P^C_{t,\bar{T}} = r^C_t dt + \sigma^C_{t,\bar{T}} dW_t + (1 - R^C_t) dJ^C_t \qquad \text{Counterparty bond,} \tag{38.4}$$

while the second block is

$$dF_t/F_t = \mu^F_t dt + \sigma^F_t dW^F_t \qquad \text{Carbon Future contract,} \tag{38.5}$$

$$dS_t/S_t = \mu^S_t dt + \sigma^S_t dW^S_t \qquad \text{Counterparty share price.} \tag{38.6}$$

Furthermore, additional costs are due to CPI, that is the jump-diffusion process

$$\mathcal{T}_t := g(V_t, \text{BS}_t, F_t) J^{co}_t, \tag{38.7}$$

where the charge function g represents the mitigation cost of carbon emissions caused by V. In the absence of collateral, we have

$$g(V_t, \text{BS}_t, F_t) := \frac{\max(V_t, 0)}{\text{BS}_t} E_t F_t, \tag{38.8}$$

where E_t is the counterparty's emission in tonnes per year, and BS_t is the counterparty's balance sheet given by

$$\text{BS}_t := S_t \times (\#\text{ outstanding shares})_t\,. \tag{38.9}$$

2.1 Pricing by semi-replication

We derive a model to price derivatives from the regulators' perspective. The formulas here obtained extend the xVA approach of (Burgard and Kjaer, 2013), and they naturally extend to other types of derivatives. Namely, we consider a semi-replicating and self-financing portfolio Π of the form

$$\Pi = \widehat{V} + \delta P + \alpha^C P^C, \tag{38.10}$$

and financed by $\alpha^B P^B$ firm's bonds, and a mixed cash account β. Given our framework, the self-financing condition reads as

$$d\widehat{V} + \delta dP + \alpha^C dP^C = \alpha^B dP^B + d\beta + \mathcal{T} dt, \tag{38.11}$$

where

$$\mathcal{T} = g(V, \text{BS}, F) J^{co}.$$

represents instantaneous CPI costs. By a standard hedging argument (see Kenyon et al. (2023) for more details) we find that the cost of carbon taxes G is given by the solution of the PDE

$$\begin{cases} \frac{\partial G}{\partial t} + \mathcal{A}_t G = (r^B + \lambda^C) G + g(V, \text{BS}, F) J_t^{co}, \\ G_T(P) = 0, \end{cases} \tag{38.12}$$

with the differential operator $\mathcal{A}_t := rP\frac{\partial}{\partial P} + \frac{1}{2}\sigma^2 P^2 \frac{\partial^2}{\partial P^2}$. In particular, for the above-stated PDEs a dependence on the path-realization of $\mathcal{T}_t$ emerges. Accordingly, we introduce the notation $\mathcal{T}^t := \{\mathcal{T}_s | s \in [t, T]\}$ to denote the set of paths of $\mathcal{T}$ starting at time t. Under the assumption of existence and regularity, by Feynman-Kàc representation Theorem, the solution of (38.12) at time $t = T_0$ can be expressed as the random variable, defined for $\omega \in \Omega$ as

$$G(T_0, T, P, \mathcal{T}^{T_0}(\omega)) = \mathbb{E}\left[\int_{T_0}^{T} e^{-\int_{T_0}^{u} r_s^B + \lambda_s^C \, ds} \mathcal{T}_u(\omega) \, du \middle| P_{T_0} = P\right]. \tag{38.13}$$

3 Risk evaluation

From the previously outlined results, the random CPI introduction (38.13) determines an unexpected loss. We then start with a thorough examination of the expected-unexpected loss. By denoting with M_{T_0} the quadruple $(P_{T_0}, F_{T_0}, \text{BS}_{T_0}, J_{T_0}^{co})$ at present time T_0 we have

$$\begin{aligned} \text{EL}(T_0, T, M_{T_0}) &:= \mathbb{E}[G(T_0, T, P, \mathcal{T}^{T_0}(\omega)) | M_{T_0}] \\ &= \mathbb{E}\left[\int_{T_0}^{T} e^{-\int_{T_0}^{u} r_s^B + \lambda_s^C ds} g(V_u, \text{BS}_u, F_u) J_u^{co} \, du \middle| M_{T_0}\right], \end{aligned} \tag{38.14}$$

while, for an arbitrary $t \in [T_0, T]$, the expected loss accruing between t and T becomes

$$\text{EL}(t, T, M_t) = \mathbb{E}\left[\int_{t}^{T} e^{-\int_{T_0}^{u} r_s^B + \lambda_s^C ds} g(V_u, \text{BS}_u, F_u) J_u^{co} du \middle| M_t\right]. \tag{38.15}$$

Note that the expectations in (38.14) or (38.15) neglect the presence of potential fat tails of the CPI-profile. Hence, while this measure does offer insight into the scale of the issue, it is unsuitable for shielding the firm from extreme circumstances. The expected (unexpected) loss EL of (38.14) can be seen as an analogous counterpart to the expected exposure, as it is defined in (BCBS, 2023). Accordingly, we define the following CPI-capital measure (CPIC):

$$\boxed{\text{CPIC}(T_0, T, M_{T_0}) := \alpha \int_{T_0}^{(T_0+1y)\wedge T} \max_{t \in [T_0, s]} \mathbb{E}\left[\text{EL}(t, T, M_t) \middle| M_{T_0}\right] ds,} \tag{38.16}$$

where α denotes the capital scaling factor. For CCR capital, $\alpha = 1.4$ in the RWA formula, but note that this CPIC formula is a capital formula, not a RWA formula — in this, it is similar to the SA-CVA capital formula.

Indeed, an analogy of the measure (38.16) can be found for CCR-capital in CRE 53.13 (BCBS, 2023). To simplify the computation of CPIC, it follows by the Tower propriety of conditional expectation (see Mikosch (1999)) that

$$\mathbb{E}[\text{EL}(t, T, M_t) | M_{T_0}] = \mathbb{E}\left[\int_{t}^{T} e^{-\int_{t}^{u} r_s^B + \lambda_s^C \, ds} Q(J_u^{co} = 1) g(V_u, \text{BS}_u, F_u) \, du \middle| M_{T_0}\right]. \tag{38.17}$$

4 Numerical example

We focus on a vanilla interest rate swap (IRS). For this product, we compute the expected-expected losses, the CO_2eVA for different dates, and the resulting CPIC capital. The key quantity to consider is the participation charge g. As a function of the state variables we set

$$\tilde{g} = \tilde{g}(r_u, F_u, S_u) = x_t \beta_t \frac{\max(V(r_u), 0)}{\text{BS}(S_u)} E_u F_u = x_t \beta_t \frac{\max(\text{IRS}(r_u), 0)}{\text{BS}(S_u)} E_u F_u.$$

Factors x_t and β_t scale mitigation costs. The former, x_t, represents the gradual introduction of CPIs ; the latter, β_t denotes a reduction of the counterparty's emissions by its own efforts or technological improvements. We then consider a stylized regional low-cost airline and a stylized shipping company as possible counterpart of the IRS, which differ among themselves in terms of emissions and balance sheet (see Table 1).

Table 1: Characteristic of stylized airline and shipping companies. Note that the "shares" represent equity plus debt.

Example	CO2 million tonnes / year	Balance Sheet (milions USD)
Airline	2.7	2,600
Shipping	10.8	3,700

For both counterparties in our examples, β decreases linearly from $\beta_{T_0} = 100\%$ to $\beta_{2050} = 50\%$. In the respect of x_t, we consider $x_{T_0} = 0\%$, it increases linearly to 100% in 2040 and is constant thereafter. The other scenario uses 2040 as the reference point for x_t and β_t. We assume that the full annual mitigation cost is to be paid yearly after the reference point.

4.1 Stochastic dynamics

For simplicity, we consider a single-curve short-rate model. For the same reason, the counterparty stock price and the future carbon price are modelled through geometric Brownian motions (GBM).

1. For the short-rate we use a classical Hull-White dynamic

$$dr_u = [\vartheta(u) - a r_u]du + \sigma dW_u, \tag{38.18}$$

   with constant $a, \sigma \in \mathbb{R}^+$ and initial short-rate r_0. For simplicity and reproducibility of our results, we consider an hypothetical flat forward curve with a constant value of 3.2%. Likewise, the mean reversion parameter a and the volatility σ are equal to 5% and 2%, respectively.

2. Futures carbon prices are calibrated to inflation-adjusted NGFS scenarios, expressed in USD rebased from 2010. Future inflation is constant and equal to 3%.

3. Both the growth rate and volatility of counterparties' stock are constant and equal to $\mu^S = 10\%$ and $\sigma^S = 20\%$ respectively.

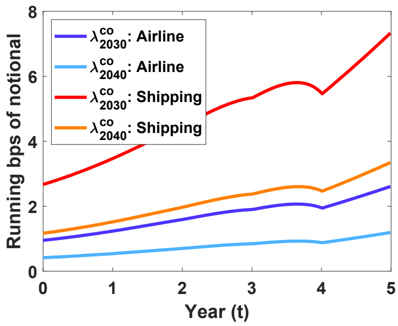
4. Counterparts' probability of default in 1-year is 1%, and no funding costs are considered.

5. Jumps intensity λ^{co} is chosen so that $Q(J^{co}_{2030} = 1) = 50\%$ or $Q(J^{co}_{2040} = 1) = 50\%$.

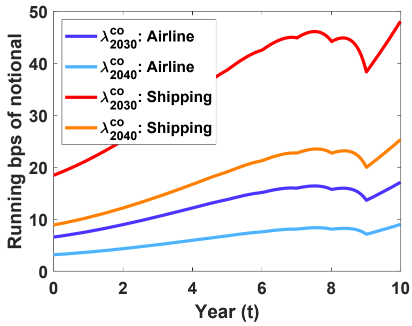
6. The correlation between the noises of the short rate and the carbon future is 50%. The other correlations are set equal to zero.

4.2 Results

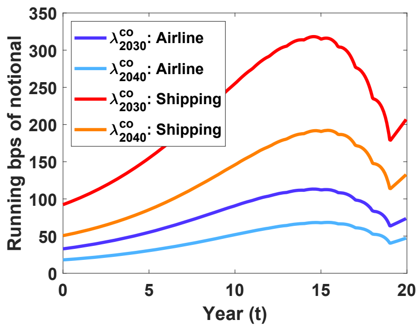
In this part, numerical results for ATM 5-10 and 20 years IRS are presented. We distinguish the cases given by the stylized airline and the shipping company, as well also different values of λ^{co}. For these results, the scaling factor x_t reaches 100% in 2040. During the life of the contract, the expected-expected CPIs costs evolve as in Figure 1.



(a) Maturity $T = 5$ years



(b) Maturity $T = 10$ years



(c) Maturity $T = 20$ years

Figure 1: Plots of expected-expected CPIs costs $t \mapsto \mathbb{E}[\mathrm{EL}(t, T, M_t)|M_{T_0}]$ (see (38.17)) for IRS with different maturities. The value of λ^{co} is the hazard rate for tax-introduction. In case CPIs costs arise with a cumulative probability of 50% before 2030, the hazard rate $\lambda^{co}_{2030} = 1042$ bps. Analogously, the hazard rate $\lambda^{co}_{2040} = 413$ bps. Because of higher chances of introduction, λ^{co}_{2030} gives higher CPIs costs.

Table 2 compares CPIC-capital levels to SA-CCR capital levels (i.e. SA-CVA RWA times 8% with 100% risk weight, so roughly BBB rating for AIRB). For short IRS, i.e. 5-year, the CPIC-capital is much smaller for the counterparties considered, at up to 24%. However, for longer IRS, 10-year and 20-year, the CPIC-capital levels are comparable to SA-CCR capital and become much larger. This non-linear effect is typical in climate pricing where there are increasing carbon costs over time, and increasing cumulative probability of Scope 3 CPI introduction.

Table 3 assesses the effectiveness of CPIC-capital. Particularly, in this table we report how often the CPIC-capital succeeds in covering the actual costs. Namely, for the random cost

$$X := \int_{T_0}^{T} e^{-\int_{T_0}^{u} r_s^B + \lambda_s^C \, ds} g(V_u, BS_u, F_u) J_u^{co} du, \tag{38.19}$$

we estimate the probability of $(X \leqslant \mathrm{CPIC})$.

Table 2: CPIC-capital compared with SA-CCR capital (i.e. SA-CCR RWA x 8% with 100% risk weight, so roughly BBB rating with AIRB). Hazard rate is $\lambda^{co}_{2040} = 413$ bps, and the capital scaling factor for CPI capital is set to $\alpha = 1$.

Example	Maturity (Years)	CPIC (bps of not.)	CPIC (run. bps of not.)	SA-CCR (bps of not.)	SA-CCR (run. bps of not.)	ratio CPIC / SA-CCR
A	5	2	0	25	5	0.08
A	10	33	3	44	4	0.75
A	20	379	19	71	4	5.35
S	5	6	1	25	5	0.24
S	10	92	9	44	4	2.09
S	20	1066	53	71	4	15.06

Table 3: Effectiveness of CPIC-capital. Given future histories we consider whether the capital is sufficient to absorb the CPI-introduction losses. Over 80% of the time, the CPI capital is effective. To increase CPIC effectiveness to 97.5% the capital required would need to be roughly 10x larger. Hazard rate is $\lambda^{co}_{2040} = 413$ bps, and the CPI capital scaling factor $\alpha = 1$.

Example	Maturity (Years)	CPIC (bps of not.)	(CPIs $\leqslant$ CPIC) (probability)	97.5-perc. (bps of not.)	ratio to get to 97.5-perc.
A	5	2	91%	25	13
A	10	33	86%	319	10
A	20	379	82%	2990	8
S	5	6	90%	70	12
S	10	92	86%	897	10
S	20	1066	82%	8404	8

5 Discussion and Conclusions

In this work we introudced a Scope 3 capital charge to make banks resilient against the possibility, though not certainty, that governments could introduce such a Scope 3 CPI. We focused our analysis on the Trading Book, i.e. derivatives, but the extension to the Banking Book, and thus loans, is a straightforward simplification. Our examples, based on interest rate swaps, show that as contracts increase from 5-years to 10-years or more the CPI-capital moves from a fraction of SA-CCR capital to multiples of SA-CCR capital. Thus, for the counterparties considered, the CPI-capital is highly necessary. Our Scope 3 CPI capital design is both effective, being sufficient in 80% of simulations, and parsimonious. To move the effectiveness to 97.5% would require an order of magnitude increase. This justifies our choice of a capital multiplier $\alpha = 1$. Of course, these numbers are indicative and any regulatory introduction would need more extensive justification.

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