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Relevance of Wrong-Way Risk in Funding Valuation Adjustments[☆]

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ABSTRACT

In March 2020, the world was thrown into financial distress. This manifested itself in increased uncertainty in the financial markets. Many interest rates collapsed, and funding spreads surged significantly, which increased due to the market turmoil. In light of these events, it is essential to understand and model Wrong-Way Risk (WWR) in a Funding Valuation Adjustment (FVA) context. WWR may currently be absent from FVA calculations in banks' Valuation Adjustment (xVA) engines. However, in this letter, we demonstrate that WWR effects are non-negligible in FVA modelling from a risk-management perspective. We look at the impact of various modelling choices, such as including the default times of the relevant parties, as well as stochastic and deterministic funding spreads. A case study is presented for interest rate derivatives.

1. Introduction

Suppose a corporate has a loan from a bank. Typically, the cheaper loans are based on a floating rate, paying a variable interest rate (IR), e.g., a Libor rate. When rates go up, the company has increased costs. To hedge against this, a company often purchases a payer IR swap (payer means that the company will pay the fixed rate and receive float) from a bank. From the perspective of the bank, this is a receiver swap. This way, the company has hedged the floating IR risk and only pays a fixed rate. Since the corporate does not post any security (collateral), this is an uncollateralized trade.

On the other hand, the bank now has a swap, which it hedges in the interbank/cleared market, where contracts are typically collateralized. Hence, the bank has to post collateral to the interbank counterparty, while not receiving any collateral from the corporate. The bank needs to fund the collateral amount, where it pays a funding spread over the risk-free rate. This is a funding cost for the bank, which should be included into the swap pricing. See Fig. 1 for a graphical overview of the situation.

Funding costs of unsecured transactions are incorporated in financial derivatives pricing through the so-called Funding Valuation Adjustment (FVA), a type of valuation adjustment (xVA). These adjustments to a derivative value reflect credit risk, funding, regulatory capital and margin, see for example, Brigo et al. (2019, 2016), Green (2015) and Gregory (2020). FVA represents the funding cost of eliminating market risk on non-perfectly collateralized deals. Credit Valuation Adjustment (CVA) is the adjustment for counterparty credit risk. CVA and FVA can together be interpreted as the cost of imperfect collateralization. For other intuition on CVA and the hedging thereof, see van der Zwaard et al. (2021).

During the period of financial distress following March 2020, significant market moves took place. Specifically, interest rates dropped, and funding spreads increased drastically. If a bank has many corporate clients entering this same type of swap, the bank's portfolio is unbalanced. When interest rates drop (e.g., due to the central bank's interventions), these swaps move deeply into the

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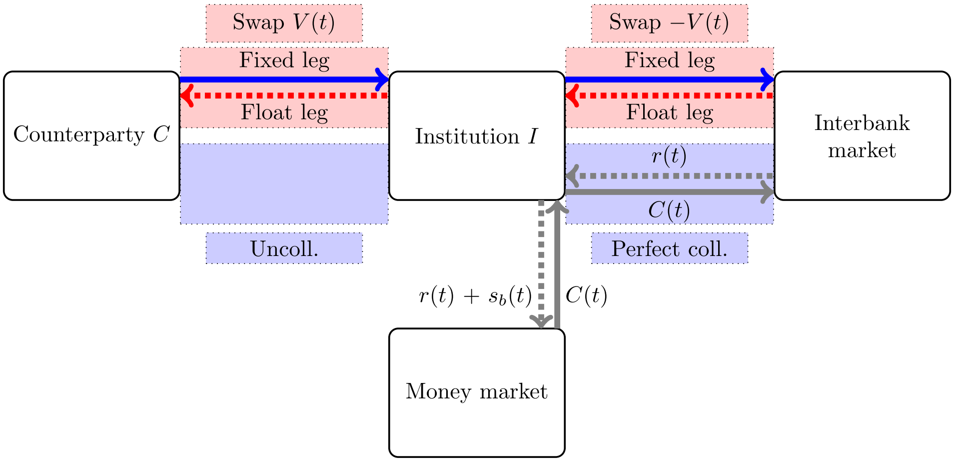


Fig. 1. An uncollateralized swap with value $V(t) > 0$, between counterparty C (a corporate) and institution I (a bank). The swap consists of a fixed and a floating leg with fixed and variable cash flows, respectively. The opposite hedge with value $-V(t) < 0$, in the interbank market, with perfect collateralization (coll.). All values are denoted from the institution's perspective. I needs to post collateral $C(t)$, for the hedge, to the interbank market counterparty. The collateral accrues at the risk-free rate $r(t)$. I needs to fund itself in the money market at the cost of a funding spread $s_b(t)$ over $r(t)$. Dotted lines refer to variable cash flows, while solid lines refer to fixed cash flows.

Fig. 2. Risk.net headlines (Becker, 2020a,b; Rega-Jones, 2020a,b; Tunstead, 2021; Woodall, 2021; Woodall and Bhollah, 2020).

money (ITM).[1] As a result, the bank needs to post more collateral on the hedge in the interbank market, while not receiving any collateral from the corporate. The funding requirement on this collateral, combined with exploding funding spreads, could explain the significant losses banks reported following the March 2020 events (Becker, 2020a). The loss sizes depend on the bank's portfolio composition, valuation methods, counterparty creditworthiness and the bank funding risk. The market turmoil and corresponding losses had a significant impact on the derivatives business, see Fig. 2.

The aforementioned simultaneous changes in the market are an example of Wrong-Way Risk (WWR), which occurs when "exposure to a counterparty is adversely correlated with the credit quality of that counterparty" (D'Hulster, 2001). This is generic WWR, as opposed to specific, which involves the specifics of a deal structure. Right-Way Risk (RWR) is the opposite of WWR and occurs when there is a favourable rather than adverse correlation.[2]

FVA WWR means increased funding risk due to increased market risk. For an unbalanced portfolio of receiver swaps, WWR occurs for a negative correlation between interest rates and funding spreads: if IR goes down, exposure goes up, implying that FVA

[1] ATM (at-the-money) means the current value of the swap is zero. ITM (in-the-money) and OTM (out-of-the-money) indicate that the swap value is respectively positive and negative.

[2] We will also use the term WWR to indicate RWR, as the difference is only in sign.

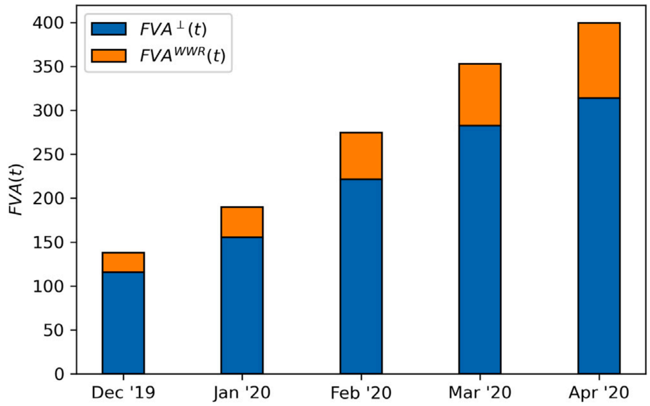


Fig. 3. FVA through time for a receiver swap which is ATM in December 2019, with partially synthetic market data. There is a split between the independent part, $\text{FVA}^{\perp}$, and the WWR part, FVA^{WWR}. Interest rates are negative, and decrease through time, such that the swap becomes ITM. The credit spreads are increasing through time. The other parameters are handpicked, such that the implied IR and credit volatilities are increasing through time. The correlation parameters are kept constant. The FVA results are for a stochastic funding spread, and both party's default times are excluded from the FVA definition. These concepts will be introduced in Section 2.

goes up, which increases the funding spread sensitivity and vice versa. In addition, the funding spread will go up due to the adverse relationship between IR and funding spread.

To demonstrate the relevance of incorporating WWR in FVA modelling, historical FVA is plotted through time in Fig. 3. These results indicate that FVA can increase significantly under unfavourable market moves. This is inline with the example from Turlakov (2013), who demonstrated that the FVA WWR effect can be substantial when considering tail risk. However, even without WWR, this FVA increase is significant.

Nevertheless, WWR is non-negligible in FVA modelling. FVA WWR models cross-gamma[3] risks between funding spreads and market exposure. These cross-gammas are challenging to hedge directly using standard financial derivatives. Alternatively, the hedging positions can be rebalanced more frequently. Yet, under stressed market conditions, these hedges become increasingly expensive due to low liquidity.[4] Hence, the WWR premium can be interpreted as a compensation for increased hedging costs. Furthermore, the cross-gammas help an xVA desk to assess their sensitivity to WWR market scenarios. This helps in risk management, where changing sensitivities can be anticipated when other market factors change. Rather than waiting for the overnight xVA calculation to finish and see how sensitivities are affected, the cross-gamma modelling allows the desk to start looking for a suitable hedge on the day the market moves. The next day, banks with similar books will look for similar hedges, and market liquidity might quickly disappear. Hence, accurate WWR modelling will help the desk stay within its risk limits. The effect of adding WWR to the modelling is two-fold: the WWR premium is a compensation for re-hedging at expensive moments, and also recognizing earlier when to re-hedge to limit the hedging costs. Furthermore, the cross-gammas will help the P&L explain process,[5] to lower the amount of unexplained P&L.

Our contribution in this letter is to understand how various modelling choices affect FVA WWR. We focus on including the default times of a trade's parties and the choice of funding spread. We will see that these choices significantly impact both the FVA levels and the dependency structure, which is relevant for hedging delta, vega and cross-gamma risks. Including the default times reduces FVA through a credit adjustment factor. This factor increases the complexity of the dependency structure. In our receiver swap examples, this factor even results in RWR, which may seem surprising. Furthermore, we consider a stochastic funding spread, and remark on the results for a deterministic spread. The former yields WWR through the stochastic funding spread, possibly dampened by the RWR effects from credit adjustment factors. The latter results solely in RWR.

2. FVA and Wrong-Way Risk

FVA can be split into a funding benefit (FBA) and cost (FCA). We assume that no profit can be made on potential funding benefits, i.e., an asymmetric funding assumption. In particular, a spread over the risk-free rate is paid when borrowing funds, but when lending out, the risk-free rate is earned. Consequently, $\text{FBA}(t) = 0$, such that $\text{FVA}(t) = \text{FCA}(t)$.

We examine FVA WWR for a single uncollateralized IR derivative V, between counterparty C and institution I, maturing at time T. All values are denoted from I's perspective. The FVA is based on borrowing spread $s_b > 0$ over risk-free rate r.

[3] Cross-gamma risks are second-order partial derivatives w.r.t. two different linear market data inputs.

[4] Low liquidity means it is difficult to quickly buy/sell an asset in the market at a price which reflects its current value.

[5] The goal of the P&L explain process is to explain how a portfolio is affected by market movements and other effects (e.g., the passing of time). For more information, see van der Zwaard et al. (2021).

First, we examine the default processes, affine short-rate dynamics used in this work, and discuss the correlation structure. Then, we derive the FVA equation and split this and the corresponding exposure into an independent part and a WWR part. Next, we choose a funding spread and apply it to the FVA equation to end up with an FVA exposure including WWR.

2.1. Default processes, model dynamics and correlations

We model default times τ_z, $z \in \{I, C\}$, as the first jumps of a Cox process[6] with hazard rate (intensity) λ_z. We impose affine short-rate models (Oosterlee and Grzelak, 2019) for interest rate r and hazard rates λ_I and λ_C. The integrated dynamics are written as:

$$\overline{z}(u) = x_z(u) + b_z(u),\ \ x_z(u) = \mu_z(t,u) + y_z(t,u),$$

where $\overline{z} \in \{r,\ \lambda_I,\ \lambda_C\}$ and subscript $z \in \{r,\ I,\ C\}$. Both $b_z(u)$ and $\mu_z(t,u)$ are deterministic quantities. Furthermore, $y_z(t,u)$ is a stochastic processes, with $\mathbb{E}_t\left[y_z(t,u)\right] = 0$.

Dependency between the processes can be introduced by correlating the Brownian motions in $y_z(t,u)$ (Munoz, 2013) or using a copula (Brigo et al., 2011a,b). We choose the former, with independent defaults of counterparties I and C, which is justifiable as this is not the main driver in WWR modelling. Since we look at the WWR impact for IR derivatives, the main driver will be the dependency between the funding spread and the IR exposure.[7] Further motivation for this choice of dependency structure is given in Appendix D.

In terms of the Brownian motions $W(t)$, the correlation assumptions read

$$W_r(t)W_I(t) = \rho_{r,I}\cdot t,\ \ W_r(t)W_C(t) = \rho_{r,C}\cdot t,\ \ W_I(t)W_C(t) = 0,$$

where the IR-credit correlations $\rho_{r,I}$ and $\rho_{r,C}$ can be estimated historically. If credit data is unavailable, e.g., for illiquid counterparties, techniques exist to map these counterparties to liquid counterparties and the corresponding credit contracts (Green, 2015).

2.2. FVA equation

Starting from the FVA definition (Albanese et al., 2015), we derive the following expression for the FVA of financial derivative V in Appendix A, under the assumption of independence of defaults. We assume that no defaults take place before today (t).

$$\mathrm{FVA}(t) = \mathbb{E}\left[\int_t^{T\wedge\tau_I\wedge\tau_C} \mathrm{e}^{-\int_t^u r(v)\mathrm{d}v} s_b(u)\,(V(u))^+\,\mathrm{d}u \,\middle|\, \mathcal{G}(t)\right] \tag{2.1}$$

$$= \int_t^T \mathbb{E}\left[\mathrm{e}^{-\int_t^u \lambda_I(v)+\lambda_C(v)\mathrm{d}v}\mathrm{e}^{-\int_t^u r(v)\mathrm{d}v} s_b(u)\,(V(u))^+ \,\middle|\, \mathcal{F}(t)\right]\mathrm{d}u$$

$$=: \int_t^T \mathrm{EPE}_{\mathrm{FVA}}(t;u)\mathrm{d}u. \tag{2.2}$$

Here, $(x)^+ = \max\{x,0\}$, $\mathcal{F}(t)$ is the 'standard' default-free filtration and $\mathcal{G}(t)$ is the enriched filtration with all available market information, including defaults. Going forward, we write $\mathbb{E}\left[\cdot\,|\,\mathcal{F}(t)\right] = \mathbb{E}_t\left[\cdot\right]$.

In Eq. (2.2), FVA represents the cost to fund positive exposure (EPE).[8] Hence, FVA is an integral over the expected valuation profile with the funding spread and accounts for the costs of funding at a different rate than the risk-free rate.

In the FVA definition (2.1), the integration range is $[t, T\wedge\tau_I\wedge\tau_C]$.[9] If a party defaults before maturity, I needs to fund for a shorter period than until maturity T. This results in a credit adjustment factors $\mathrm{e}^{-\int_t^u \lambda_I(v)\mathrm{d}v} < 1$ and $\mathrm{e}^{-\int_t^u \lambda_C(v)\mathrm{d}v} < 1$ for the potential default of I and C, which resembles the survival probability of the relevant parties. It can significantly decrease the overall FVA amount, depending on the credit quality of the parties. Hence, the assumption of including τ_I and/or τ_C in the FVA integral is a crucial modelling choice.

Depending on the correlations, the credit adjustment factors give rise to an extra dependency. This is particularly interesting if the funding spread is driven by the same underlying source of randomness as a credit adjustment factor, i.e., a party's credit process. In this situation, the WWR effects can become non-intuitive.

Furthermore, the assumption of including τ_I and/or τ_C in (2.1) is also relevant for hedging FVA. Hence, the modelling assumptions may depend on how an xVA desk hedges its FVA risks. The credit adjustment factor translates into adjusted FVA sensitivities and introduces new risk-factors to which the FVA is sensitive. This impacts first-order delta and vega risks and introduces cross-gamma risks with the existing risk-factors.

$\mathrm{EPE}_{\mathrm{FVA}}(t;u)$ from Eq. (2.2) can be written as the sum of the independent exposure $\mathrm{EPE}^{\perp}_{\mathrm{FVA}}(t;u)$ and a WWR exposure $\mathrm{EPE}^{\mathrm{WWR}}_{\mathrm{FVA}}(t;u)$, i.e.,

$$\mathrm{EPE}_{\mathrm{FVA}}(t;u) = \mathrm{EPE}^{\perp}_{\mathrm{FVA}}(t;u) + \mathrm{EPE}^{\mathrm{WWR}}_{\mathrm{FVA}}(t;u), \tag{2.3}$$

[6] A Cox process is Poisson process where both the magnitude and the probability of a jump are stochastic (Brigo and Mercurio, 2006).

[7] When dealing with credit derivatives, this dependency between defaults should definitely be present.

[8] Typically, the FVA formula is given in terms of a forward funding spread. However, that is only possible if the funding spread is independent of the exposure, which is currently not the case.

[9] This means that we integrate to maturity T, or to one of the default times τ_I or τ_C, whichever comes first.

where the precise form of these exposures for a specific funding spread will follow in Section 2.4. Now, FVA from Eq. (2.2) can be split into an independent part and a part that captures the cross-dependencies:

$$\mathrm{FVA}(t) = \int_t^T \mathrm{EPE}^{\perp}_{\mathrm{FVA}}(t;u)\mathrm{d}u + \int_t^T \mathrm{EPE}^{\mathrm{WWR}}_{\mathrm{FVA}}(t;u)\mathrm{d}u =: \mathrm{FVA}^{\perp}(t) + \mathrm{FVA}^{\mathrm{WWR}}(t). \tag{2.4}$$

2.3. Funding spread

The funding rate should reflect an institution's funding abilities in the market. We mainly focus on a stochastic funding spread containing institution's credit, $\lambda_I(t)$, and a possible liquidity adjustment term $\ell(t)$. For example, $\lambda_I(t)$ can be CDS-based, and $\ell(t)$ can be the bond-CDS basis.[10] Alternatively, $\lambda_I(t)$ can be bond-based or derived from asset swaps. We assume that it is CDS-based. Loss given default LGD_I is taken constant, based on market information. We define borrowing spread $s_b(t)$ as (Green, 2015):

$$s_b(t) = \mathrm{LGD}_I\ \lambda_I(t) + \ell(t).$$

WWR can be introduced through $s_b(t)$, if $\lambda_I(t)$ is stochastic and correlated with the other risk-factors. Using the model dynamics from Section 2.1, the borrowing spread is split into a deterministic component $\mu_S(t,u)$ and a stochastic component $y_I(t,u)$:

$$\begin{aligned} s_b(u) &= \mathrm{LGD}_I \left[x_I(u) + b_I(u)\right] + \ell(u) \\ &= \mathrm{LGD}_I \left[\mu_I(t,u) + b_I(u)\right] + \ell(u) + \mathrm{LGD}_I\ y_I(t,u) \\ &=: \mu_S(t,u) + \mathrm{LGD}_I\ y_I(t,u). \end{aligned} \tag{2.5}$$

Alternatively, the spread can be purely deterministic. Then, no WWR is introduced through the funding spread, but through the credit adjustment factors and exposure only.

2.4. FVA exposure under funding spread assumptions

The funding spread assumptions of Section 2.3 can now be applied to the independent and WWR exposures from Eq. (2.3). Derivations of the exposures presented here are available in Appendix B $\mathrm{EPE}^{\perp}_{\mathrm{FVA}}(t;u)$ is written as:

$$\begin{aligned} \mathrm{EPE}^{\perp}_{\mathrm{FVA}}(t;u) = {} & P_I(t,u)P_C(t,u)\mu_S(t,u)\mathbb{E}_t\left[\mathrm{e}^{-\int_t^u r(v)\mathrm{d}v}\,(V(u))^+\right] \\ & + \mathrm{LGD}_I\,\mathbb{E}_t\left[\mathrm{e}^{-\int_t^u \lambda_I(v)+\lambda_C(v)\mathrm{d}v} y_I(t,u)\right]\mathbb{E}_t\left[\mathrm{e}^{-\int_t^u r(v)\mathrm{d}v}\,(V(u))^+\right]. \end{aligned} \tag{2.6}$$

Here, survival probabilities $P_I(t,u)$ and $P_C(t,u)$ are independent, resulting from the correlation assumptions in Section 2.1. The μ_S-term in (2.6) matches the classical case of exposure without WWR. The y_I-term captures the dependency between the borrowing spread and the credit adjustment factors.

Using the correlation assumptions from Section 2.1, WWR will be present:

$$\mathrm{EPE}^{\mathrm{WWR}}_{\mathrm{FVA}}(t;u) = \mathbb{E}_t\left[\left(\mathrm{e}^{-\int_t^u r(v)\mathrm{d}v}\,(V(u))^+ - \mathbb{E}_t\left[\mathrm{e}^{-\int_t^u r(v)\mathrm{d}v}\,(V(u))^+\right]\right)\mathrm{e}^{-\int_t^u \lambda_I(v)+\lambda_C(v)\mathrm{d}v} s_b(u)\right], \tag{2.7}$$

and $\mathrm{EPE}^{\mathrm{WWR}}_{\mathrm{FVA}}(t;u) = 0$ if IR and credit are independent.

Eqs. (2.6)–(2.7) simplify when excluding τ_I and τ_C from the FVA definition, which is an assumption sometimes made in practice (Gregory, 2020).

The exposures $\mathrm{EPE}^{\perp}_{\mathrm{FVA}}(t;u)$ and $\mathrm{EPE}^{\mathrm{WWR}}_{\mathrm{FVA}}(t;u)$ can now be used to compute $\mathrm{FVA}^{\perp}(t)$ and $\mathrm{FVA}^{\mathrm{WWR}}(t)$ in Eq. (2.4). This is done in Section 3 to examine the WWR effects and the impact of various modelling choices.

3. FVA Wrong-Way Risk relevance

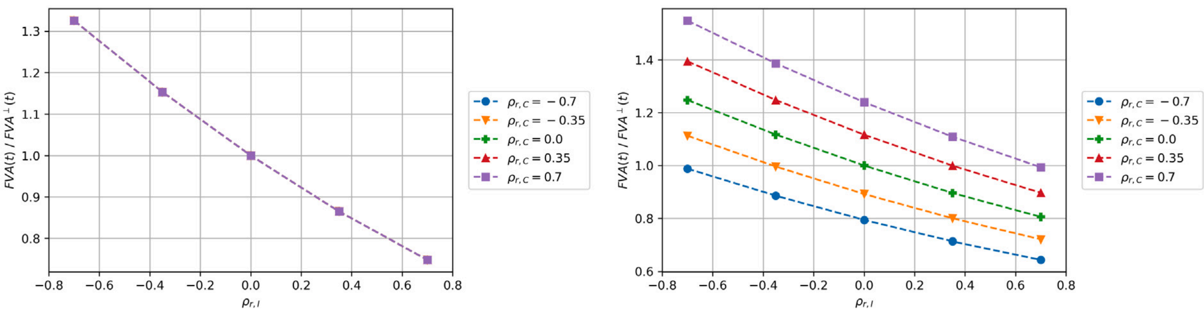
We illustrate the relevance of including WWR in FVA modelling using numerical examples. Furthermore, we give insights on the inclusion of τ_I and/or τ_C in the FVA definition. Finally, we consider the stochastic and deterministic funding spreads, and show the different WWR/RWR effects in both cases. We assess the correlation impact on FVA through the ratio $\frac{\mathrm{FVA}(t)}{\mathrm{FVA}^{\perp}(t)}$. A ratio larger than 1 corresponds to WWR, while a ratio smaller than 1 corresponds to RWR.

We consider a 30 year receiver swap with 10000 notional.[11] These results can easily be extended to other financial derivatives. FVA is computed using a Monte Carlo simulation. For the model dynamics, parameters and market data used in the experiments, see Appendix C.

We consider the stochastic funding spread first. The credit adjustment effect of including τ_I and/or τ_C in Eq. (2.1) is visible from the $\mathrm{FVA}^{\perp}(t)$ values in Table 1. This effect is the strongest for τ_C, as C has a lower credit quality than I. When including both τ_I and τ_C, the combined effects result in the lowest $\mathrm{FVA}^{\perp}(t)$. The $\mathrm{FVA}^{\perp}(t)$ reduction can be substantial, illustrated by a 74 basis point reduction in this example, which is approximately a 70% decrease.

Table 1
$\mathrm{FVA}^{\perp}(t)$ for the various choices of including/excluding τ_I and/or τ_C.

	τ_I excl.	τ_I incl.
τ_C excl.	107.64	95.31
τ_C incl.	36.10	33.63



(a) τ_I incl., τ_C excl., $\mathrm{FVA}^{\perp}(t) = 95.31$.

(b) τ_I incl., τ_C incl., $\mathrm{FVA}^{\perp}(t) = 33.63$.

Fig. 4. WWR effects for a stochastic spread and an ATM receiver swap.

In Fig. 4, the correlation effects are illustrated when including τ_I and changing τ_C. When excluding τ_I, similar results are obtained apart from a scaling factor. The WWR/RWR effects are non-negligible, as ratio $\frac{\mathrm{FVA}(t)}{\mathrm{FVA}^{\perp}(t)}$ is significantly different from 1 for non-zero correlations.

In Fig. 4(a), there is net WWR for $\rho_{r,I} < 0$, and the curves for different $\rho_{r,C}$ values overlap, as τ_C is excluded. WWR comes from the relationship between the funding spread and the discounted exposure. This matches the March 2020 market moves: for negative IR-credit correlation, we expect to see WWR for receiver swaps, i.e., the FVA goes up. Symmetrically, when the correlation sign flips, i.e., $\rho_{r,I} > 0$, WWR changes into RWR. Going forward, we focus on negative correlations, as the symmetry remains: a change in correlation sign changes the WWR/RWR effect. Furthermore, when including τ_I, the credit adjustment effect results in a slight RWR effect for $\rho_{r,I} < 0$: when excluding τ_I, $\frac{\mathrm{FVA}(t)}{\mathrm{FVA}^{\perp}(t)}$ is lower.

For $\rho_{r,C} < 0$, there is a RWR effect from C's credit adjustment factor: $\frac{\mathrm{FVA}(t)}{\mathrm{FVA}^{\perp}(t)}$ is lower for decreasing $\rho_{r,C}$, which is apparent when comparing Figs. 4(a) and 4(b). Fig. 4(b) illustrates the effects when including all model components. Whether there is net WWR or RWR depends on the magnitude of WWR from the funding spread and the degree of the RWR effects from the credit adjustment factors. In turn, this is driven by the correlation parameters, credit parameters, IR parameters and product type.

Furthermore, when setting one of the two correlations parameters to zero, the correlation magnitude effect is roughly linear in WWR/RWR. When both correlations are non-zero, the correlation effects can be non-trivial due to the mixing of effects.

Valsecchi comes to similar conclusions on the relevance and linear nature of WWR in the case of an uncollateralized IR swap (Valsecchi, 2021). Yet, in this case, the default times of both parties are excluded from the FVA definition.

Remark (*Right-Way Risk*)**.** Like WWR, RWR is also a cross-gamma risk, but with an opposite sign. This sign depends on the correlations, product type and modelling assumptions. In our examples, RWR comes from a different source in the modelling (the credit adjustment factors) than the WWR (the funding spread). The type of risk management for RWR is the same as for WWR, as there is only a difference in sign. In our case, RWR simplifies risk management due to the reduced overall cross-gamma risk. For an xVA desk, this could imply that hedging positions need to be rebalanced less frequently.

Remark (*Comparison with* CVA)**.** CVA WWR/RWR results from the correlation between counterparty default probabilities and exposure. Like for FVA, WWR increases CVA and RWR decreases CVA. However, FVA depends on I's credit, while CVA depends on C's credit. Whether the WWR/RWR effect is larger for FVA or CVA depends on the differences in the counterparties' credit quality and their correlations with the market risks. Special care is required when also including a Debit Valuation Adjustment, to avoid the double counting of a funding benefit (Gregory, 2020).

Remark (*Deterministic Funding Spread*)**.** For a deterministic spread, the credit adjustment effect on $\mathrm{FVA}^{\perp}(t)$ is similar as for the stochastic spread. These credit adjustment factors result in a RWR effect, which increases for lower credit quality. No WWR is present in this case, yet the RWR is non-negligible.

[10] The basis is negative when the CDSs spreads are lower than the bond spread for the same maturity. In March 2020 this spread was negative due to low liquidity.

[11] Such that all results can be interpreted as basis point effects.

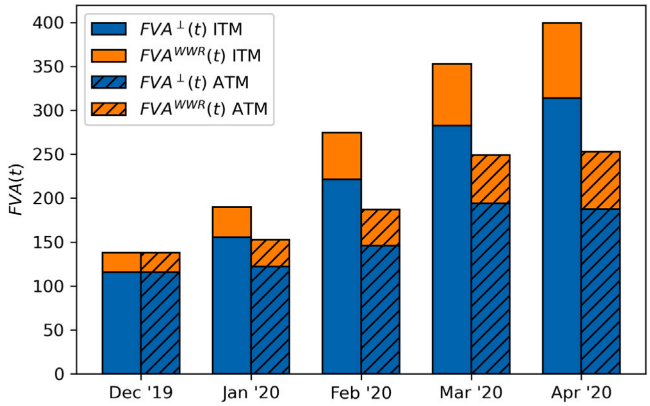


Fig. 5. The same situation as in Fig. 3, but compared with a similar ATM trade at all dates. If at each point in time a portfolio is rebalanced such that it is ATM rather than ITM, the increase through time of overall FVA is significantly less, but relatively the FVA^{WWR} becomes more important.

4. Conclusion

We wanted to understand FVA WWR and how it is affected by different modelling choices. The model reproduced the WWR effects observed in the March 2020 market moves. The modelling choices impact the FVA levels and the dependency structure significantly. There is a substantial credit adjustment effect from adding the possible default times in the FVA model, where we have seen examples of a 70% reduction in FVA. For lower credit quality, this effect increases.

The stochastic funding spread generates WWR, while the credit adjustment effects translate into RWR (for a receiver swap and $\rho_{r,I}, \rho_{r,C} < 0$). Depending on correlations, credit parameters, IR parameters and product type, the net result is WWR or RWR. For a deterministic funding spread, there is only RWR coming from the credit adjustment factors.

While much attention is given to including the default times in the FVA model, the correlation parameters remain the fundamental component of WWR modelling. Without correlation, there is no WWR. We focus on the inclusion of the default times as this is a new consideration.

In isolation, the correlation effects on WWR are linear. When mixing these effects, the overall impact becomes non-trivial.

The conclusions for the single IR derivative naturally extend to an ITM portfolio of FVA sensitive trades. WWR effects will always strongly depend on the portfolio composition, see Fig. 5. Actively adding products so that the portfolio is less ITM results in lower FVA variability, but this may be costly and not always feasible.

We have focused on FVA WWR in a qualitative sense. Yet, it is unclear how to compute this quantity efficiently, as a Monte Carlo approach is too expensive in practice. For each counterparty, an additional credit process needs to be simulated. As I likely has many counterparties, simulating even more risk-factors is undesired. Hence, the industry needs a new efficient method to compute FVA WWR. Our detailed quantitative approach is part of a forthcoming paper.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.frl.2022.103091.

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