Covered Interest Parity and XVAs

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Declaration

I declare that this dissertation is my own, unaided work. It is being submitted for the Degree of Master of Philosophy in the University of Cape Town. It has not been submitted before for any degree or examination in any other University.

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Abstract

Covered interest parity relies on a traditional no-arbitrage argument and states that the difference in interest rates between two currencies should be linked to the spot and forward exchange rates. One would expect an arbitrage opportunity to be traded away, however, the covered interest parity relationship has been shown to break down with the arbitrage opportunity persisting. This dissertation seeks to show that valuation adjustments can be considered one of the reasons why covered interest arbitrage persists. A classic covered interest parity trade is considered, where we borrow directly from the South African market and simultaneously synthetically lend rand, which involves entering a foreign exchange contract to fix the exchange rate. From this setup, we look to derive, from first principles, the net value of the strategy, highlighting the funding valuation adjustment. Further, the default of both parties within the strategy is considered, which allows us to consider the credit valuation adjustment and the debt valuation adjustment.

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Chapter 1

Introduction

The principle of covered interest parity (CIP) is not new, with the relationship having a standing in financial markets that goes back many decades. Keynes (1923) was however the first to formalise the relationship, which has now become an important gauge of how interconnected the modern global financial markets are. CIP relies on the no-arbitrage argument and states that the synthetic interest rates (constructed from foreign interest rates, spot, and forward foreign exchange contracts) should agree. Put more simply, the difference between the interest rate in the cash money markets and the implicit interest rate from the foreign exchange (FX) markets of two currencies is zero.

For example, an investor borrowing in South African Rand (ZAR), while simultaneously lending in a different currency, such as the United States Dollar (USD), and covering the foreign exchange risk using a forward-starting foreign exchange contract should be left with no profit. If this relationship breaks so does the no-arbitrage argument, thus leading to an arbitrage opportunity. This situation can then easily be exploited by borrowing at the lower interest rate and lending at the higher, while the foreign exchange risk remains hedged by the foreign exchange swap, leading to a seemingly riskless profit.

One would expect an arbitrage opportunity to be quickly traded away. However, the CIP violation has been shown to persist, especially since the 2008 Global Financial Crisis (GFC) (Du *et al.*, 2018). During the GFC, the violation was explained away by blaming high bank default rates and low access to funding. However, well after the GFC, a widened *basis* (the gap between observed rates and the one implied by CIP) remained despite recovered credit quality in banks and increased access to funding (Borio *et al.*, 2016). This poses the question of why the CIP relationship continues to break.

One explanation for the violation lies in wide bid-ask spreads, caused by poor market liquidity which ultimately leads to an inability to capitalise on an arbitrage opportunity when it presents itself (Cerutti *et al.*, 2021). Some, e.g. De J. Correia and Knight (1987), argue that transaction costs could be an explanation for the persistent violation, while others state that lower balance sheet capacity due to tighter regulations is a more viable explanation (Du *et al.*, 2018). Jauregui and Natraj (2017) found evidence that expansionary monetary policies used by some regions during the long period of negative interest rates post-GFC led to CIP violations widening and persisting. Borio *et al.* (2016) argue two forces are the cause, an increased demand for FX hedges, which leads to a positive basis, while constraints on arbitrage activity (like tighter regulations) keep the basis from dissipating.

Although the concept of CIP has deep roots, the concept of valuation adjustments only had its genesis post the Global Financial Crisis (GFC). The Credit Valuation Adjustment (CVA) was introduced before the crisis as an accounting fair value adjustment to derivative contracts. Post the financial crisis, there was a need for banks to more actively account for credit risk, funding costs, and other various charges on derivative contracts. This resulted in the creation of a plethora of valuation adjustments, colloquially known as X-valuation adjustments (XVAs). For a general account of XVAs, see Albanese *et al.* (2016) or Green (2015).

Andersen *et al.* (2019) look to marry these two concepts, and show that a specific valuation adjustment is a possible explanation as to why the CIP violation persists. Andersen *et al.* (2019) develop a model that shows the gains achieved by a firm's shareholders when implementing a chosen investment strategy, to deduce the impact that the Funding Valuation Adjustment (FVA) has on investment decisions. In the case of a CIP trade, the model identifies a funding cost that is required, which leads to an FVA. This funding cost is a potential reason why the arbitrage persists. Andersen *et al.* (2019) argue that once the FVA term is incorporated into the strategy, the gain is diminished, potentially to the extent that the arbitrage opportunity is eroded.

Fouché *et al.* (2022) investigate the framework of Andersen *et al.* (2019) as it applies to a CIP situation, which they briefly mention, but is not a focus in Andersen *et al.* (2019).

The purpose of this dissertation is to focus on a strategy that recreates a CIP scenario, extending the work done by Fouché *et al.* (2022). The default probabilities of the lender and the borrower are assumed equal in Fouché *et al.* (2022), however, this assumption is relaxed in this dissertation. We seek to derive from first principles, the net value of a CIP strategy under the Andersen *et al.* (2019) perspective, considering the potentially different default probabilities of the parties involved. This introduces not only an FVA but also other valuation adjustments.

The rest of this dissertation is laid out as follows. Chapter 2 starts by outlining the three main XVAs that are of relevance in this dissertation, showcasing what effect they have on the no-default value (NDV) of a transaction. The chapter then goes on to discuss the debate of double counting of the DVA and FVA. Lastly, Chapter 2 introduces the main proposition in Andersen *et al.* (2019) and outlines the CIP strategy used in this dissertation and the cashflows the strategy produces. Chapter 3 looks to differentiate the potential aspects of a CIP trade, specifically what XVAs apply, by outlining three different cases. The first case 3.1 looks at the scenario where the borrower is default-free, but the firm is defaultable. The second case, 3.2, looks at the converse, when the borrower is defaultable and the firm is default-free. The third and final case, 3.3, blends the two previous scenarios by looking at the scenario where both the borrower and the firm are defaultable. Chapter 4 discusses the data to be used and outlines the CIP trade for a specific day, illustrating the findings in Chapter 3 by identifying all the relevant quantities and explaining how the real-world quantities correspond to the theoretical ones. Chapter 4 then extends the basic result for the tenors of 1-, 3-, 6-, and 12-months over a specific period. Finally, Chapter 5 seeks to conclude the dissertation and summarize the key results.

Chapter 2

CIP and FVA

The 2008 GFC forced firms to face the new global environment where the effects of funding and credit costs, among other things, once minimal became material. Credit spreads widened rapidly and funding uncollateralised exposures became costly, as the risk-free funding assumption deteriorated. This created the need for firms to more actively manage their credit and funding exposures on derivative contracts. Since then, there has been an introduction of adjustments to the risk-neutral price of derivative contracts, known as XVAs. Within the context of this dissertation, the focus will be on three XVAs, namely CVA, DVA, and FVA.

2.1 CVA, DVA, and FVA

CVA is defined as the difference between the risk-free value of an instrument and the fair value of the instrument taking into account the possibility of counterparty default. In other words, CVA is the market value of counterparty risk or the adjustment made to the portfolio valuation to account for the creditworthiness of the counterparty. It is an expected value that incorporates both the possibility of default and the potential loss that the institution may incur as a result. It is typically applied to uncollateralised derivative assets. When collateral is introduced the credit risk decreases, which brings the CVA down. High-quality collateral could negate the CVA completely.

DVA, which is analogous to CVA, is defined as the difference between the risk-free value of an instrument and the fair value of the instrument taking into account the possibility of your default. In other words, DVA is the adjustment made to allow for your creditworthiness. It is typically applied to uncollateralised derivative liabilities. The CVA and DVA have opposite signs and thus opposite effects. The CVA has a deflationary effect on the value of the instrument, while the DVA has an inflationary effect on the value of that same instrument.

FVA is the adjustment made to the value of an instrument to reflect the funding cost of uncollateralised derivatives above the risk-free rate of return. It represents the costs and benefits of writing a hedge for a client who is not posting collateral, and then hedging that trade in the interbank market, where trades are fully collateralised. This cost includes any loss or benefit that may arise due to interest rate (on the collateral) and funding rate differentials, as well as financing the collateral. The FVA is meant to ensure that a dealer recovers its average funding cost when it trades and hedges derivatives. The everyday operations within derivatives contracts, namely lending and borrowing, render the FVA as either a funding benefit or cost.

Classic models like Black and Scholes (1973) and Merton (1973) assume that both sides of a transaction will fulfil their obligations. They produce the no-default value (NDV) of a transaction, which is dependent on the discount rate used. The result will produce a value that is consistent with the theory and with market prices found in the interbank market if a risk-free rate of interest is used. Hull and White (2012) state that after adjusting for credit risk, i.e. introducing a DVA and CVA, the portfolio value is:

$$\text{Portfolio value} = \text{NDV - CVA + DVA.} \tag{2.1}$$

For uncollateralised transactions, to include the dealer's average funding cost the FVA would need to be incorporated. This represents the difference in the NDV that arises when discounting is based on using the risk-free rate and the NDV that arises when discounting is based on the dealer's cost of funds. Extending Eq. (2.1) to include the FVA, we obtain:

$$\text{Portfolio value} = \text{NDV - CVA + DVA - FVA.} \tag{2.2}$$

It is important to note that the FVA has nothing to do with adjusting for credit risk. This can be seen in Eq. (2.2), where the credit risk is accounted for through the CVA and DVA.

This dissertation focuses on the position created by Strategy 2.1, which is introduced later. This position can be seen as a derivative, where the derivative we are entering is a synthetic loan, using the foreign lending market and a forward-exchange contract (FEC). This loan is funded by uncollateralised domestic borrowing.

2.2 Double counting

Although XVAs have gained attention since the GFC, many gaps remain, one being the controversial issue the derivatives market has had with the DVA, FVA, and double counting. Thus far we have deduced that the FVA and DVA take form from different perspectives of the derivative market. FVA is concerned with funding and the DVA concerns the firm's own credit risk. Hull and White (2014) have been at the forefront of this debate and much of this section is based on their framework.

The DVA definition can be split into two components. DVA_d refers to the value brought to a firm in the event of default on its derivative obligations. DVA_f refers to the value brought to a firm that arises in the event of default on the funding required on its derivative obligations. If we assume that the default risk is compensated by the entire credit spread, then the DVA_f of a derivative portfolio is equivalent to the FVA. Under the risk-free rate, the present value of the expected excess of the firm's funding for a derivative obligation should equate to the FVA. This would also equate to the compensation provided by the firm to its lender in the event the firm defaults, making it equivalent to the firm's benefit should the firm default on its funding. Further, the FVA and DVA_f have opposing signs. When funding is required in a derivative obligation, FVA is a cost while DVA_f is a benefit and vice versa. Consequently, FVA and DVA_f will cancel out each other. This leads to Eq. (2.2) becoming

$$\begin{aligned} \text{Portfolio value} &= \text{NDV - CVA + DVA}_d + \text{DVA}_f \text{ - FVA} &(2.3)\\ &= \text{NDV - CVA + DVA}_d. &(2.4) \end{aligned}$$

Under entirely uncollateralised transactions, the FVA and DVA_f are additive across the transactions. Hull and White (2014) state that for a derivative, this would result in the independence of the firm's FVA and DVA_f to other transactions entered into by the firm.

Eq. (2.4) shows that a firm with a derivatives portfolio against a counterparty would be correct to calculate the DVA_d. Hull and White (2014) take the simple situation where the counterparty and the firm enter into only one derivatives transaction. If the firm is long the funded position, we have that $\text{DVA}_d = 0$ since the position is always an asset to the firm. Hull and White (2014) show that in the case where the firm is short the funded position $\text{DVA}_d = -\text{FVA}$. This represents a benefit rather than a cost, since the firm benefits from the possibility of defaulting on a sold position. Thus, the firm reduces its liability in the case of a short position, as the FVA and DVA_d represent a benefit to the firm. The inclusion of both FVA and DVA_d in Eq. (2.3) would result in double counting. Hull and White (2014) claim that the choice between whether to include FVA and DVA_d in Eq. (2.3) is a false one. Recall that it was mentioned above that the FVA and DVA_f cancel each other out, which would mean that when pricing, only the DVA_d should be included. This is seen in Eq. (2.4). It is only appropriate to exclude DVA_d and rather include FVA when the firm only has negative value positions. Hull and White (2014) further look at the effect of incrementally adding a new position, and find that $\text{DVA}_d > -\text{FVA}$ for an entire portfolio.

Ultimately, Hull and White (2014) state that, for over-the-counter (OTC) transactions, FVA inclusion creates arbitrage opportunities because it is impossible to price in such a way that the firm's derivative funding costs are reflected and achieve consistency with market prices. An end user with a low default probability can enter into a transaction with a firm facing high funding costs and simultaneously enter into an opposite transaction with a firm facing low funding costs to benefit when buying or selling derivative contracts.

In the CIP context, introduced formally below, DVA_f is positive from the firm's perspective since the firm defaulting on their funding would mean they avoid a payment, which is a benefit. However, in the Andersen *et al.* (2019) CIP context we are taking, the focus is on the shareholder perspective. In the event of the firm defaulting, the shareholders avoid the funding payment, however, they also do not receive the synthetic loan repayment. In other words, the shareholders walk away with nothing, while the firm's creditors recoup the repayment from the synthetic loan. In short, $\text{DVA}_f = 0$ from the shareholder perspective. Shifting to the DVA_d, the position created by Strategy 2.1 only involves positive cashflows to the firm and the shareholders, thus $\text{DVA}_d = 0$. If the firm had cashflows that they had to pay, then defaulting would result in a benefit as no repayment would be made. The payment in the context of this dissertation is negative, meaning we, as the firm, are due the payment. This results because Hull and White (2014) define the payments as representing the value of the strategy to the end user, i.e. the counterparty. This solidifies that $\text{DVA}_d = 0$. Lastly, the FVA in our context is positive and not a benefit.

So, usually, the DVA_f is offset by the FVA. Due to funding the position net costs arise from the credit spread applied, but this is proportional to the benefit arising from defaulting on the funding. This is how the credit spread is determined - whoever is exposed to the default potential of another will charge a credit spread they believe offsets the potential implications of the counterparty defaulting. This dissertation does not consider the DVA_f that applies to the firm as a whole but rather considers the perspective of the shareholder, which is not traditional. The same approach is taken by Andersen *et al.* (2019), where it is proposed that the CIP may persist because after accounting for any XVA components the shareholders no longer have the incentive to pursue the CIP strategy depicted below in Strategy 2.1.

2.3 Andersen *et al.*

Andersen *et al.* (2019) take the view of the firm's shareholders and look at the impact that a new financial position will have on the firm's shareholders. They let Y indicate the payoff of the position at maturity, while S depicts the firm's credit spread, which is relevant, as it is assumed that the new position is funded with debt. Lastly, G represents the value to the firm's shareholders of implementing the position. The main result in Andersen *et al.* (2019, p.155) is given as follows. The proof is given in Andersen *et al.* (2019), but a derivation in the special case of a CIP trade can be found below in Section 2.4.

Proposition: The marginal shareholder gain G in equity value is given by,

$$G = p^*\pi - \delta\text{Cov}(\mathbb{I}_D^f, Y) - \Phi, \tag{2.5}$$

where

- p^* is the risk-neutral survival probability of the firm,
- δ is the discount factor corresponding to the maturity of the new position,
- $\mathbb{I}_D^f$ is an indicator for the firm's default,
- $\pi = \delta\mathbb{E}(Y) - u$ is the marginal profit on the trade made by a hypothetical risk-free arbitrageur. Here, u is the marginal purchase price of the asset (and is therefore the amount of funding that is required) and Y is the payoff of the asset.
- $\Phi = p^*\delta uS$ is the FVA.

It should be noted that all probabilities and expectations are risk-neutral. Here the FVA represents the present value of the shareholders' portion of the net financing cost uS. An intuitive explanation is given of the terms that make up the FVA,

$p^* \delta u S$. The additional funding cost resulting from the firm's credit risk is represented by uS. The present value is then given by $\delta u S$. This cost will only be paid if the firm survives, which introduces the risk-neutral survival probability of the firm p^* to give the expected present value. The covariance term in Eq. (2.5) can be seen as an additional adjustment. This covariance adjustment applies if the firm's possible default is correlated with the financial instrument with a resulting payoff of Y.

2.4 CIP arbitrage strategy

We seek to focus on a specific trading strategy, namely the CIP strategy, which is detailed below. Within this example, South Africa serves as the domestic entity and the US as the foreign entity. This results in ZAR as the domestic currency and USD as the foreign currency. The CIP argument states that the return on the synthetic and direct leg of the strategy should be the same. This principle is one of the oldest in finance, going back to Keynes (1923), with significant scholarship since, examples being Du *et al.* (2018), Andersen *et al.* (2019) and others. The spread, or the CIP basis, is the breakdown of the CIP argument. The key link between Proposition 2.3 and a specific trading strategy is the cashflow Y. Thus, Y is set to correspond to the CIP trade strategy.

The settlement time is at $t = 0 + 2bd$, where bd is a business day. An initial and maturity time of $t = 0$ and $t = \tau + 2bd$ are considered. The allowance of two business days captures the settlement delay, which is a convention of FX trades. By going long the strategy, the following would result:

Strategy 2.1.

1. *Borrow ZAR, directly from the South African market, at the domestic interest rate r_d.*

2. *Sell ZAR against USD FX Spot, which is denoted by X, to obtain an amount of u/X USD.*

3. *Invest the USD in the USD money market, at the currently available USD interest rate r_f. Simultaneously entering into an FEC contract that has a forward spot exchange rate of X^f. This allows the currency exchange to be reversed at a predetermined price in the future.*

4. *At maturity, repay the ZAR debt and collect the ZAR from the FEC contract.*

Figure 2.1 is a visual demonstration of the Strategy 2.1. Strategy 2.1 creates a negative cashflow at maturity, corresponding to a debt repayment H, and a positive cashflow which can be seen as an investment return $\overline{G}$. These cashflows can be expanded using the CIP basis b, which captures the degree to which CIP is violated, the risk-free rate r, and the credit spread S. When $b = 0$, there is no arbitrage, and so this corresponds to classical CIP. However, as mentioned in Chapter 1, and as will be seen in Chapter 4, b is typically not zero nor close to zero. Here we assume that the credit riskiness of the firm, represented by S, is the same as that of the

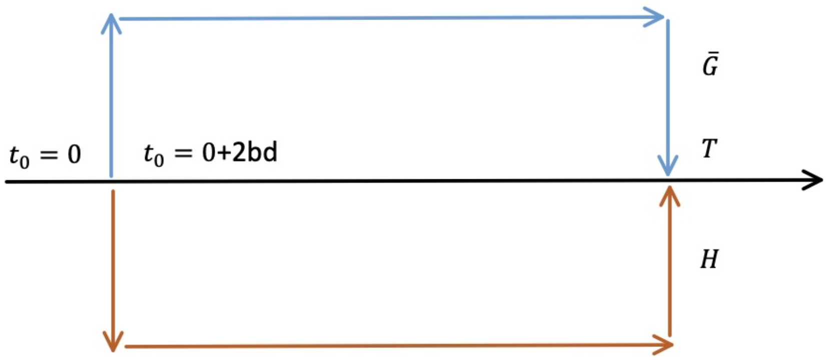

Fig. 2.1: Simple CIP trade strategy.

counterparty. Thus, when the firm and its counterparty are considered default-free, this leads to a debt repayment of

$$H = (1 + r_d\tau) = u(1 + (r + S)\tau) \tag{2.6}$$

and an investment return of

$$\overline{G} = (1 + r_f\tau)X^f/X = u(1 + (r + S + b)\tau). \tag{2.7}$$

The basis is defined by taking the difference between Eq. (2.7) and Eq. (2.6). This dissertation uses an annualised basis as well as annualised rates and spreads, whereas this is not the case in Andersen *et al.* (2019). Related to this, another issue is that Andersen *et al.* (2019) do not introduce a time to maturity so τ does not appear in their results. This dissertation does introduce the idea of a maturity time τ which features in the results.

If we include the possibility of default for both the firm and its counterparty, a random element to the cashflows would be introduced.

Letting ψ denote the rate recovered by the firm in the event of the counterparty defaulting, the arbitrageur's gain from implementing Strategy 2.1 is denoted and given as follows:

$$I = \begin{cases} \overline{G} - H, & \text{if neither the firm or counterparty default,} \\ \psi\overline{G} - H, & \text{if the counterparty defaults,} \\ 0, & \text{if the firm defaults.} \end{cases} \tag{2.8}$$

The marginal shareholder gain G is simply the value of the discounted gains expected when the firm does not default, G can be defined as

$$G = \mathbb{E}\big[\delta I\big] = \mathbb{E}\big[\delta \mathbb{I}_s^f (Y - u(1 + \tau r + \tau S))\big], \tag{2.9}$$

where the discount factor and the survival indicator of the firm are defined, respectively, by $\delta = 1/(1 + \tau r)$ and $\mathbb{I}_s^f$, and Y is defined as

$$Y = u\psi(1 + \tau r + \tau S + \tau b) + u(1 - \psi)(1 + \tau r + \tau S + \tau b)\mathbb{I}_s^{CP}, \tag{2.10}$$

where $\mathbb{I}_s^{CP}$ represents the survival indicator of the counterparty. So in Eq. (2.9) if we survive, we receive the cashflow Y, however, we would have to repay the loan amount $u(1 + \tau r + \tau S)$. If the firm defaults, the full cashflow is zero, since we are taking the perspective of the shareholders, seen in Andersen *et al.* (2019), who give up all payoffs in the event of the firm defaulting. Thus, G from Eq. (2.9) is the discounted expectation of the shareholders' position.

Fouché *et al.* (2022) show that G, as in Eq. (2.9), can be evaluated to give

$$G = p^*\pi - \delta \text{Cov}(\mathbb{I}_D^f, Y) - p^*\delta u\tau S, \tag{2.11}$$

within the CIP setup seen in Strategy 2.1. This is a special case of Proposition 2.3 seen in Andersen *et al.* (2019), with the difference coming in due to the annualisation of the spread. Andersen *et al.* (2019) do not assume the payoff function Y, which consequently has them relying on a much more involved proof of Proposition 2.3. Fouché *et al.* (2022) contrarily assume the relatively simple, linear payoff Y that is created by Strategy 2.1. Further, the derivation in Fouché *et al.* (2022) relies on the definition of covariance and the fact that,

$$1 = \mathbb{E}\big[\delta(\psi(1 + \tau r + \tau S) + (1 - \psi)(1 + \tau r + \tau S)\mathbb{I}_s^{CP}\big], \tag{2.12}$$

Further, Fouché *et al.* (2022) assume that $p^* = \hat{p}$, where $\hat{p}$ is the survival probability of the counterparty, which is the quantitative link between the default indicator and the credit spread. This assumption ensures that the credit spread is fairly priced, given the default and recovery characteristics of the counterparty. This links to the assumption that the credit spread S applies to both the firm and the counterparty. In other words, equal credit risk is assumed.

Within the Fouché *et al.* (2022) context, the $p^*\delta u\tau S$ term in Proposition 2.3 is the FVA. Fouché *et al.* (2022) note that the FVA term is not impacted by the default risk of the counterparty and that the term cannot be mistaken for the CVA or DVA. In their derivation Fouché *et al.* (2022), they assume that the shareholders would surrender all assets in the event of the firm defaulting. So, the case of the firm defaulting is not considered, leading p^* to be 1. It can be concluded that there is neither a DVA nor CVA term. Thus, it is reasonable to assume that $p^*\delta u\tau S$ represents the FVA, which is the cost the shareholders bear to execute Strategy 2.1.

Fouché *et al.* (2022) provide another point of view. In order to be able to fund Strategy 2.1, the firm will likely need to borrow funds, and so the possibility of default arises. Thus, $p^* \neq 1$ and a credit spread is introduced, $S \neq 0$, which is a cost to the firm. So as the default risk of the firm increases, the cost of borrowing to fund Strategy 2.1 also increases. This breakdown shows that the default of the firm and counterparty is not relevant, and so the CVA and DVA also have no relevance in this context. The firm needing to borrow in order to fund Strategy 2.1 results in a funding cost arising, and so the same conclusion is reached, that it is reasonable to assume that the FVA represents this cost.

Chapter 3

Extended derivation

This dissertation seeks to extend the work of Fouché *et al.* (2022). As mentioned above, the Fouché *et al.* (2022) context assumes that the counterparty and firm have the same survival probability, $p^* = \hat{p}$. Strategy 2.1 results in a linear payoff, which allows the use of Eq. (2.12) for the straightforward simplification of the cashflows' expected value. This all leads to the derivation of Eq. (2.5), from Andersen *et al.* (2019), where the conclusion is that $p^* \delta u \tau S$ represents the FVA which is the cost the shareholders bear to execute Strategy 2.1.

We seek to explore the scenario where the firm and the counterparty have different survival probabilities. In other words, we assume that it is possible to have $\hat{p} \neq p^*$, where once again $\hat{p}$ is the survival probability of the counterparty and p^* is the survival probability of the firm. In the context of XVAs, one would expect that the probability of default of the firm would lead to DVA while the probability of default of the counterparty would lead to CVA.

In Strategy 2.1 there are two loans, one normal and one synthetic, and thus two borrowers. When the counterparty is mentioned below we are referring to the foreign borrower. To differentiate varying potential aspects of a CIP trade, three cases will be considered. The first case assumes that the counterparty is default-free but we, as the firm, are defaultable. The second case assumes the opposite. We, as the firm, are default-free but the counterparty is defaultable. The third case assumes both we, as the firm, and the counterparty are defaultable. In all cases, a recovery rate of zero is assumed ($\psi = 0$), while we lend $u = 1$ unit, for a term τ, with no collateral. Fouché *et al.* (2022) assumed that the firm and the counterparty had the same credit spread, S. We are assuming that the two entities do not have the same credit spread, since they do not present the same default probability. Thus, we will use S to represent the firm's credit spread, and $\bar{S}$ for the counterparty's credit spread.

3.1 First case

The first case assumes that the counterparty is default-free, but the firm is defaultable. In the Andersen *et al.* (2019) perspective the focus is on their default, in other words, the firm's default risk and in particular the shareholders' default risk. This is uncommon since usually, the natural interest is on the counterparty default risk rather than our own.

Here it is obvious that the CVA $= 0$, since there is no scenario of the counterparty defaulting to price in. If only the lending cashflow is considered, the DVA would also traditionally be given as zero, while Andersen *et al.* (2019) takes a non-traditional view as the focus is on the shareholders' perspective. We can be more precise here. It was mentioned in Section 2.2 above that DVA_d is zero from both perspectives, while DVA_f is zero from the non-traditional shareholders' perspective. If we consider just the lending cashflow, the firm as the lender does not have to make any future cashflows, as there are no defaultable cashflows. Thus, whether the firm defaults or not is irrelevant to the contract price. However, this takes the perspective of the entire firm, not just the shareholder perspective. The shareholders would not receive the loan repayment if the firm defaults before maturity, τ, although they will also avoid repaying the funding cashflow. Under this perspective, it could be argued that there is a non-zero DVA for the shareholders. The DVA would not be considered a benefit to the shareholders but be considered a benefit to the firm because default would mean avoiding repayments. However, the firm also borrows to finance the loan. Thus, there will be a repayment cashflow at maturity if the firm does not default. So, taking the perspective of the firm, we have the following cashflows;

- $(1 + r\tau) - (1 + (r + S)\tau) = -S\tau$, if the firm does not default, and
- $(1 + r\tau) - 0 = (1 + r\tau)$, if the firm defaults.

If the firm does not default, the firm's creditors receive the loan repayment but also need to make the funding repayment. Conversely, if the firm does default the firm receives loan repayment but defaults on the funding payment. Thus, from the firm's perspective,

- the CVA $= 0$, since there is no counterparty default, and
- the DVA $= \frac{1+(r+S)\tau}{(1+r\tau)} - 1$, since the firm needs to repay $1 + (r + S)\tau$ which results in a non-zero DVA.

The DVA here is the actual price, that takes into account the fact that the firm will sometimes default and not have to repay the $1+(r+S)\tau$, minus the price assuming the firm cannot default and thus always repays the $1+(r+S)\tau$ amount. The current value is 1, so we can find the firm's spread S such that Eq. (3.1) is satisfied, which just involves the payoff of the funding leg;

$$1 = \mathbb{E}\left[\frac{1}{1 + r\tau}\big(1 + (r + S)\tau\big)\mathbb{I}_s^f\right], \tag{3.1}$$

where

$$\mathbb{I}_s^f = \begin{cases} 1, & \text{if the firm does not default, and} \\ 0, & \text{if the firm defaults and the recovery rate } \psi \text{ is } 0. \end{cases} \tag{3.2}$$

Thus, the difference between the funding value, ignoring default which sets the indicator $\mathbb{I}_s^f = 1$, and the fair value of the funding leg which is 1, is

$$\text{DVA} = \frac{1 + (r + S)\tau}{1 + r\tau} - 1. \tag{3.3}$$

This dissertation seeks to focus on the shareholder perspective rather than the perspective of the firm as a whole, which is referred to as the Andersen *et al.* (2019) view. Thus, taking the perspective of the shareholders, the following cashflows emerge;

- $(1 + r\tau) - (1 + (r + S)\tau) = -S\tau$, if the firm does not default, and
- 0, if the firm defaults.

When the firm does not default, there is no difference between the cashflow from a shareholder or firm perspective. The difference comes in the case where the firm defaults, the shareholders default on the funding repayment but do not receive the loan repayment as that goes to the firm's creditors. The default can be seen to bring in a minute benefit for the shareholders since paying 0 is better than having to pay $S\tau$. The value of the small benefit that default brings to shareholders is $\delta(1-p^*)S\tau$. The value would change when we consider the CIP Strategy 2.1 because then the shareholders would also have to forgo the basis from the CIP Strategy 2.1. Thus, for shareholders, there is no DVA. This is corroborated by the fact that DVA_f and DVA_d are both zero from the shareholder perspective, which was mentioned in Section 2.2.

The FVA would depend on how the firm finances its position, in other words how the firm gets the u units to lend. If we assume that the firm is risk-free, and thus can fund the position with no spread, then the total value of the deal including the funding is zero. If the firm can borrow the u units at the risk-free rate and lend at the risk-free rate this means that the debt payments made and received by the firm cancel out to give zero (receive $1 + r$ and repay $1 + r$).

In reality, the firm cannot borrow and lend at the risk-free rate. Thus, we account for the firm's credit spread, S, which is non-zero since the firm in this case is defaultable. So, the assumption is made that the firm can borrow 1 unit at $r + S$, and so:

- if the firm survives, the firm will receive $(1 + r\tau)$ but the firm would need to repay an amount of $[1 + (r + S)\tau]$, and
- if the firm defaults, there is a zero cashflow since the firm will not need to repay the financing loan, however, it will not receive the synthetic loan repayment.

Taking the difference in the cashflows above gives the actual value of the deal from the perspective of the shareholders. Thus, the difference between the discounted value of the deal when default is ignored, which is zero, and the actual discounted value of the deal when default is considered is

$$\text{FVA} = 0 - \frac{1}{1 + r\tau}\left[(1 + r\tau)p^* - [1 + (r + S)\tau]p^*\right] = p^*\delta u\tau S. \tag{3.4}$$

For consistency, we set $u = 1$ in Eq. (2.5) from the Proposition 2.3 in Andersen *et al.* (2019). Recall that the maturity symbol τ does not appear in Andersen *et al.* (2019) as they do not annualise their rates.

For completion and a sense check let us consider the counterparty perspective in this scenario. It should be noted that we will only consider the counterparty perspective on a firm level and not a shareholder level. Therefore, using bars to denote the counterparty's XVAs, we have

- the $\overline{\text{DVA}} = 0$, since the counterparty is default-free,
- the $\overline{\text{FVA}} = 0$, since the counterparty is not generating funding, and
- the $\overline{\text{CVA}} = 0$, and is the answer to what happens if the firm defaults. In this scenario, the counterparty would have to pay regardless of whether the firm defaulted or not.

3.2 Second case

The second case assumes that the firm is default-free, but the counterparty is defaultable. It follows that the DVA $= 0$ since the firm is default-free, thus no self-default scenario needs to be priced in. This case leads to the DVA being a benefit from the counterparty's perspective. If the firm is default-free, the firm can borrow at the risk-free rate. FVA is defined as the adjustment from a simplified world with no funding spreads and the real world where funding spreads are accounted for. If the firm can borrow at the risk-free rate no funding adjustment would need to be made. So, FVA $= 0$ because the perfect world scenario would be equivalent to the real world scenario as the firm's credit spread is zero. Thus, we have that

- the DVA $= 0$, and
- the FVA $= 0$.

Shifting to the CVA, it is necessary to calculate the fair spread to charge depending on the default risk. The current value is 1, so we can find the counterparty's spread $\bar{S}$ such that Eq. (3.5) is satisfied, which just involves the payoff of the lending leg;

$$1 = \mathbb{E}\left[\frac{1}{1+r\tau}\big(1 + (r+\bar{S})\tau\big)\mathbb{I}_s^{CP}\right] \tag{3.5}$$

where

$$\mathbb{I}_s^{CP} = \begin{cases} 1, & \text{if the borrower does not default, and} \\ 0, & \text{if the counterparty defaults and the recovery rate } \psi \text{ is 0.} \end{cases} \tag{3.6}$$

So there are two entities, the firm borrowing funding and the counterparty to whom the firm is lending the funding. The survival probabilities of these two entities are not the same. So the difference between the loan value, ignoring default which sets the indicator $\mathbb{I}_s^{CP} = 1$, and the fair value of the lending leg which is 1, is

$$\text{CVA} = \frac{1 + (r+\bar{S})\tau}{1+r\tau} - 1. \tag{3.7}$$

Once again we consider the counterparty's perspective, on a firm level, in this scenario. Here,

- the $\overline{\text{CVA}} = 0$, since the firm is default-free,
- the $\overline{\text{FVA}} = 0$, since the borrower is not generating funding, and
- the $\overline{\text{DVA}} = \text{CVA} = \frac{1+(r+\bar{S})\tau}{1+r\tau} - 1$, since the borrower needs to repay $1+(r+\bar{S})\tau$.

The $\overline{\text{DVA}}$ can be found using the same logic as seen in Eq. (3.7). Intuitively, the fact that $\overline{\text{DVA}} = \text{CVA}$ makes sense given the analogous nature of the two adjustments.

3.3 Third case

The final case looks to bring the two previous cases together with the assumption that both the firm and the counterparty are defaultable. The credit spread in this case would be a combination of the probability of default and recovery. If it is assumed there is a non-zero recovery, it would mean that the possibilities extend from only no cashflow or the full cashflow to an additional 'part' cashflow. This would ultimately lower the credit spread. Here, for simplicity, it is assumed that the recovery rate ψ is zero.

Assuming maturity τ, the firm will lend at $r + \bar{S}$ and borrow at $r + S$ in order to finance Strategy 2.1, where $\bar{S}$ is the counterparty's spread and S is the firm's spread. Here $\bar{S}$ and S would be determined by solving Eq. (3.5) and Eq. (3.1). Two clear legs emerge;

$$\begin{cases} -1 \longrightarrow +(1+(r+\bar{S})\tau)\mathbb{I}_s^{CP} \\ +1 \longrightarrow -(1+(r+S)\tau)\mathbb{I}_s^{f}. \end{cases}$$

The first leg represents the lending leg while the second leg represents the funding leg, in other words, how the firm finances Strategy 2.1. The CVA would form part of the lending leg, while the DVA would form part of the funding leg. Focusing on the CVA, the adjustment would only be required when the counterparty is defaultable which is the case here. Assuming that S and $\bar{S}$ are correct, the fair value of the contract is equal to 1. In a world where default is not considered, the firm would be getting an inflated value and an adjustment would be needed. This adjustment between the ideal and real world is the CVA, as seen in Eq. (3.7) in Section 3.2. Now shifting focus to the DVA, the funding leg results in a non-zero DVA as seen in Eq. (3.3) in Section 3.1. However, this is the DVA that rises when the perspective of the firm as a whole is taken. What we are interested in is the shareholder perspective taken by Andersen *et al.* (2019). In Case 3.1 above, we determined that $\text{DVA} = 0$ from the shareholder perspective. To emphasise, the following adjustments apply thus far,

$$\text{DVA} = 0$$
$$\text{CVA} = \frac{1+(r+\bar{S})\tau}{1+r\tau} - 1.$$

Strategy 2.1 is funded with uncollateralised debt, represented by the funding leg, which introduces the FVA. In an ideal world, it would be possible to fund

Strategy 2.1 at the risk-free rate, however in the real world, this is not possible. So much like the CVA above, the adjustment is the difference between the two perspectives,

$$\text{FVA} = 0 - \mathbb{E}\left[\mathbb{I}_s^f[(1+(r+\bar{S})\tau)\mathbb{I}_s^{CP} - (1+(r+S)\tau)]\frac{1}{1+r\tau}\right] \tag{3.8}$$

$$= -up^*[(1+r\tau) - (1+(r+S)\tau)]\delta \tag{3.9}$$

$$= u\tau p^* S\delta. \tag{3.10}$$

The two indicators in Eq. (3.8) can be split because of the assumption that the two entities defaulting are independent, and are thus not related. It could be argued that this assumption is both reasonable and unreasonable. One could argue that it is reasonable because we are looking at two different countries, one much more developed than the other. Conversely, it could be argued that assuming independence is not reasonable given the increasingly connected global economy. This leads to the possibility that the two entities have dependent defaults. In this case an additional covariance adjustment is made, which can be seen in the Andersen *et al.* (2019) proposition in Section 2.3. Andersen *et al.* (2019) define the covariance term as the adjustment made if the firm's possible default is correlated with the financial instrument that has a payoff of Y, which indirectly refers to the default dependence of the two entities. The simplification in Eq. (3.9) is possible as a result of Eq. (3.5) and the fact that

$$\frac{1}{1+r\tau} = \delta.$$

3.4 Connection to CIP strategy

A CIP trade, when broken down, is just the granting of a (synthetic) loan funded by debt. In other words, it is funded by another loan where the arbitrageur (the firm in this dissertation) borrows in order to grant the original loan. One loan is synthetic involving a spot FX trade, a foreign loan, and a FEC. This CIP scenario is precisely what is depicted in the two legs considered in the cases above - a lending leg and a financing leg, which is financed by borrowing in an unsecured way.

Andersen *et al.* (2019) talk about a position that is financed by issuing uncollateralised debt. This is what a CIP trade involves because it is a position that finances itself since it contains a lending and borrowing leg. So Andersen *et al.* (2019) applies to positions that are financed by issuing uncollateralised debt. The CIP Strategy 2.1 is a position that finances itself because it contains a lending and a borrowing leg.

What Andersen *et al.* (2019) propose is that the firm's shareholders decide whether to go through with the trade and so Andersen *et al.* (2019) look at the FVA from the shareholders' perspective. The shareholders will only view the CIP Strategy 2.1 as favourable if the CIP basis is greater than the FVA. The CIP Strategy 2.1 can be viewed as a long/short arbitrage trade and simultaneously as some position that requires financing. The possibility of default inherent on both sides introduces the FVA. Our assumptions about the default probabilities then weave CVA and DVA into the picture.

Chapter 4

Analysis

4.1 Data

To empirically investigate a CIP strategy as seen in Strategy 2.1, market data is required. The following data was collected from Bloomberg with a start date of 21 June 2016 and an end date of 18 November 2022:

- the USDZAR spot exchange rate,
- the 1-, 3-, 6-, and 12-month USDZAR forward exchange contract (FEC) rates,
- the 1-, 3-, 6-, and 12-month Johannesburg Interbank Average Rate (JIBAR),
- the 1-, 3-, 6-, and 12-month US London Interbank Offered Rate (LIBOR),
- the South African Repo Rate (REPO), and
- the US Secured Overnight Funding Rate (SOFR).

The JIBAR rate is the main South African money market rate and is used as a barometer for short-term interest rates. The US LIBOR rate has an equivalent meaning just in US terms. For both JIBAR and US LIBOR, the 3-month rate is the most widely used and accepted.

A repurchase repurchase agreement (often shorted to repo) is a contract in which the seller of a security agrees to repurchase it from the buyer at an agreed price. A repo typically uses low-credit-risk securities as collateral, primarily government securities or securities issued by government agencies and guaranteed by the central bank, thus possessing the same credit risk as government bonds. The interest rate implicit in these repos are a proxy for the risk-free rate. One reason for this is the minimal credit risk attached to repos due to the collateral posted. The collateral can still be affected by market movements, allowing a small credit risk exposure to remain. One way this is addressed is through overcollateralisation, which is the provision of collateral that is worth more than enough to cover potential losses in cases of default. Lastly, the overnight collateral repos are highly liquid with the short term being of relevance for this dissertation. Thus, the South African Repo Rate (REPO) can be used as a proxy for the risk-free rate. In Figure 4.1 the 1-, 3-, 6-, and 12-month JIBAR rates as well as the REPO rate are graphed from 18 July 2016 to 18 November 2022. JIBAR, for all tenors, was highest in 2016, fluctuating until

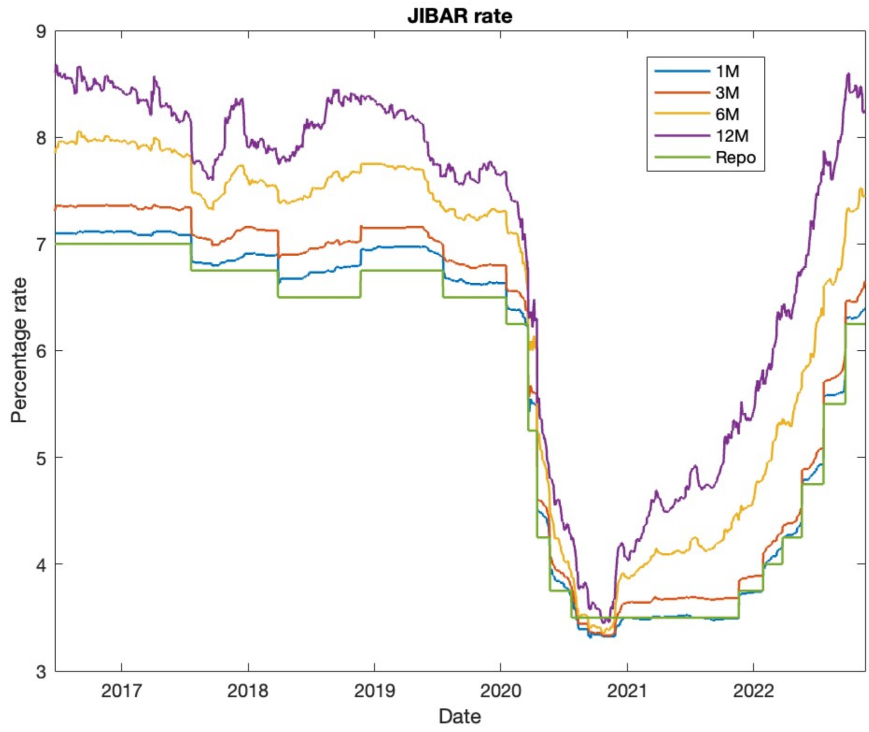

Fig. 4.1: JIBAR rates and REPO rate from 18 July 2016 to 18 November 2022.

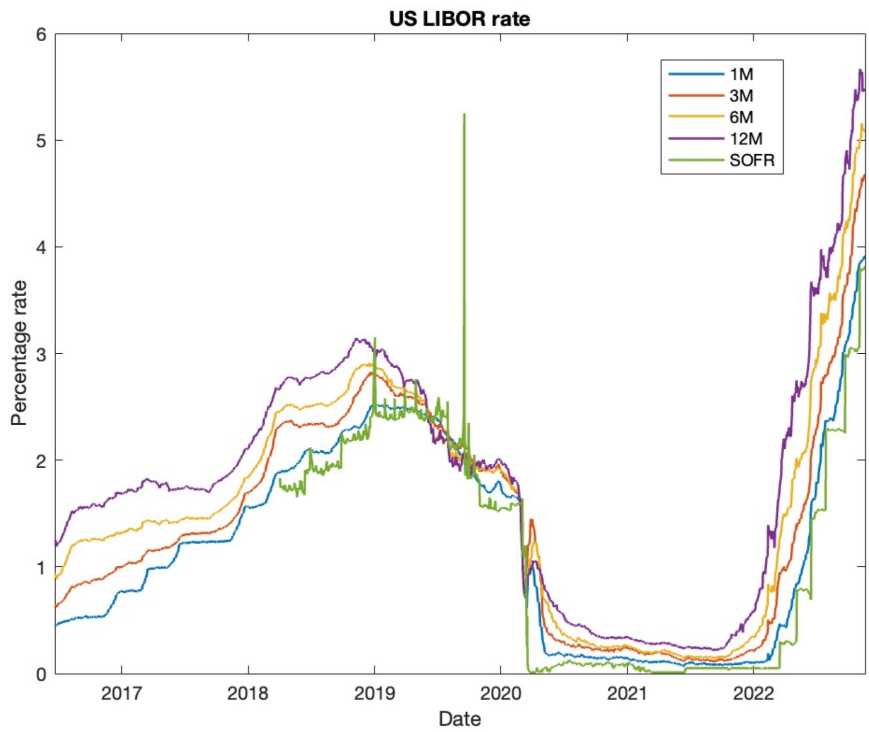

Fig. 4.2: US LIBOR rates and SOFR rate from 18 July 2016 to 18 November 2022.

2019 but overall remaining high. In early 2020 there was a sharp decline in rates, with the the turning point coming just before 2021, after which rates began to climb again. Figure 4.2 shows the 1-, 3-, 6-, and 12-month US LIBOR rates as well as the SOFR rate from 18 July 2016 to 18 November 2022. This set of rates follows a similar theme as seen in Figure 4.1. The US LIBOR rates were following an upward trend from 2016 until 2019, at which point they peaked and slowly declined. From early 2020, a sharp decline was once again observed, with rates dropping close to zero. Post 2022 rates started to increase. The decline seen in both Figure 4.1 and Figure 4.2, corresponds to the COVID-19 pandemic during which interest rates decreased rapidly as central banks injected cash into the economy, in an effort to support the economy. Post-pandemic the world economy saw a high inflation environment. The increase in rates post the pandemic corresponds to central banks raising rates in order to control the high inflation environment. The SOFR rate is only available from 2018 onward, as it replaced the discontinued overnight LIBOR.

The 1-, 3-, 6-, and 12-month USDZAR FEC rates mentioned above are provided by Bloomberg in the form of forward points, which is the conventional way in which FECs are quoted. A transformation of forward points, x_p, to rates, X^f is required and implemented using the following formula:

$$X^f = x_p/10000 + X. \tag{4.1}$$

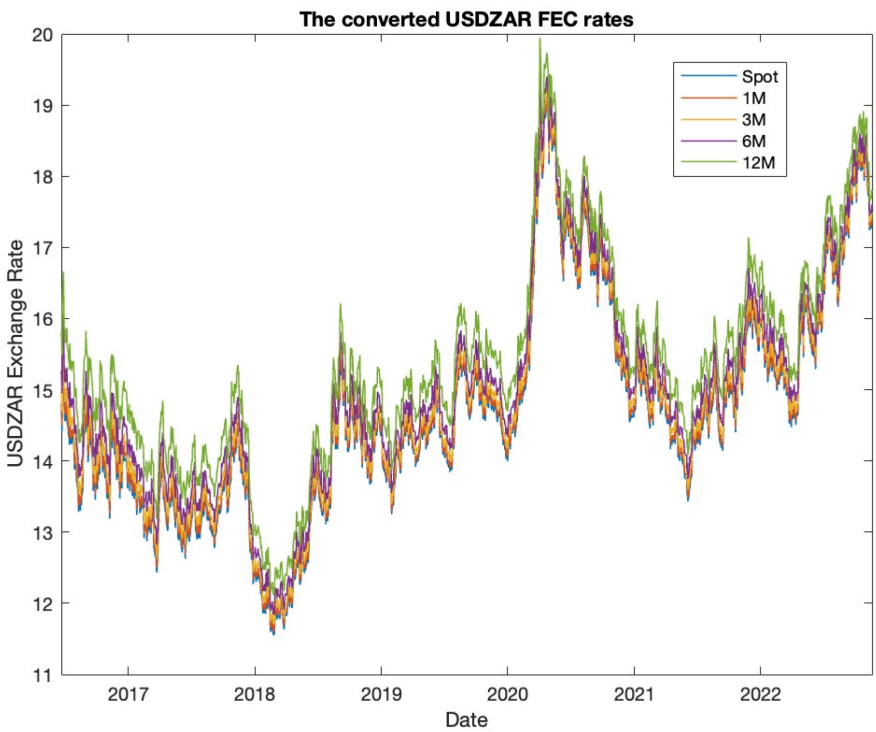

Fig. 4.3: The USDZAR spot rate and FEC rates from 18 July 2016 to 18 November 2022.

The USDZAR spot exchange rate and the US and South African FEC rates are depicted in Figure 4.3. It would be expected that the FEC rates are comparable to the USDZAR spot rate. The shortest tenors would be most similar, which can be seen as the 1-month USDZAR spot rate is closest to the 1-month FEC rate. There is an upward-sloping term structure to the FEC rates, so the spot is the lowest over the 1-month maturity and it increased from there with maturity. Over the COVID-19 pandemic period, between 2020 and 2021, it can be seen that the ZAR depreciated against the USD.

4.2 Evaluation of Strategy 2.1

The CIP strategy depicted by Strategy 2.1 is implemented by using JIBAR and LIBOR rates, for the 1-, 3-, 6-, and 12-month tenors. This dissertation estimates the credit spread of an average bank in each economy. This is what defines the JIBAR and LIBOR rates. The difference between the one-month ZAR/USD interbank rates (JIBAR and LIBOR) and the REPO and SOFR rates is interpreted as the credit spread. Specifically, 1-month JIBAR-REPO is used as a proxy for S, the firm's credit spread. Conversely, 1-month LIBOR-SOFR is used as a proxy for $\bar{S}$, the counterparty's credit spread. Using this as a proxy for the credit spreads over all the time horizons, not just the 1-month data is reasonable. The 1-month interbank rate is greater than the respective SOFR and REPO rates, for two reasons. The inherent credit risk is the first reason, while the term or liquidity risk is the second. A 1-month time horizon is fairly short which means the liquidity risk has less of an effect, allowing the credit spread to be reasonably interpreted as the difference between the 1-month rate and the risk-free overnight rate. As the time horizon increases, the liquidity risk factor has more significance. Thus, using, for example, the difference between the 6-month rate and the risk-free overnight rate as a proxy for the credit spread is less reasonable and likely overestimates the spread, as the portion attributable from liquidity increases. Ultimately using the difference between the 1-month rate and the risk-free overnight rate for all time horizons is reasonable proxy for the credit spreads.

Going long Strategy 2.1 entails borrowing in ZAR to fund the USD synthetic loan which is built using the USDZAR spot rate and the relevant FEC rate. Going short the strategy would involve the converse, borrowing in USD and lending in ZAR. For a long strategy, the profit would be given as,

$$u\left(\frac{1}{X}\left[1+\underbrace{(r_f+\bar{S})}_{\text{LIBOR}}\tau\right]X^f-\left[1+\underbrace{(r_d+S)}_{\text{JIBAR}}\tau\right]\right), \tag{4.2}$$

where the nominal is represented by u. Referring back to Eq. (2.6) and Eq. (2.7), we have a domestic loan and a synthetic loan via the foreign market, from which the basis is determined. Similar logic follows in Eq. (4.2) above, where the basis is implicit in the difference between the two loans. Eq. (4.2) also represents the NDV since it ignores the possibility of counterparty default. Conversely, for a short strategy, the profit would be given as

$$u\Bigg(\big[1\underbrace{(r_d+S)}_{\text{JIBAR}}\tau\big]-\frac{1}{X}\big[1+\underbrace{(r_f+\bar{S})}_{\text{LIBOR}}\tau\big]X^f\Bigg). \tag{4.3}$$

This dissertation has until now been focusing on loans, however, we know that the CIP strategy seen in Strategy 2.1 has a CIP basis b. The CIP basis can be defined as the additional interest received, relative to domestic interest rates if a loan is synthesized using a FEC and the foreign market. Eq. (4.2) and Eq. (4.3) involve the same cashflows that are seen in the three cases observed in Chapter 3, where the basis was left out for the sake of simplicity. The profit from going long/short the strategy depicted by Eq. (4.2) and Eq. (4.3) represents the CIP basis. Focusing on the long position in Strategy 2.1, the first part represents the ZAR-denominated synthetic loan which involves converting to USD, lending the USD at LIBOR and converting back to ZAR using a FEC. The ZAR-denominated synthetic loan is where the CIP basis would materialise, rather than the JIBAR borrowing inherent in the second leg of the strategy. In the above equations, Eq. (4.2) and Eq. (4.3), the basis is implicit in the difference between the two loans.

One way this could be extended would be to model the longer-term borrowing and lending rates that are available to banks. This would be done by the use of bootstrapped rates out to the five-year mark, which is the longest FEC obtainable. Furthermore, bid and ask rates on both the spot and forward exchange rates could be incorporated to account for market frictions that are present in real-world scenarios. It should be noted that when implementing Strategy 2.1, the interest rates used did not account for the two-day settlement delay seen in foreign-exchange instruments, both FEC and spot.

One can work backwards from the profit produced by the strategy to derive the basis b, however, we have not yet introduced the observed XVA terms which could outweigh the CIP basis. In Chapter 3, Case 3.3 discusses the scenario where both the firm and the borrower are defaultable. This is the scenario we want to consider in our evaluation of the CIP trade, and ultimately recover the marginal shareholder gain, G, as described by Andersen *et al.* (2019) in Proposition 2.3, for Strategy 2.1. The value π in Proposition 2.3 is defined by Andersen *et al.* (2019) as the profit to a hypothetical default-free agent, which means a CVA term is included as the counterparty can default. Crucially, the π value as defined by Andersen *et al.* (2019) would not include FVA and DVA terms. So, π is an extension of Eq. (4.2) and Eq. (4.3) defined above. Looking at the long strategy, π is given by

$$\pi=\mathbb{E}\Bigg(u\frac{1}{\delta}\Bigg(\frac{1}{X}\big[1+\underbrace{(r_f+\bar{S})}_{\text{LIBOR}}\tau\big]X^f\mathbb{I}_s^{CP}-\big[1+\underbrace{(r_d+S)}_{\text{JIBAR}}\tau\big]\Bigg)\Bigg), \tag{4.4}$$

where $\mathbb{I}_s^{CP}=1$ if the counterparty survives. Thus, to get π from Eq. (4.2) the counterparty default is accounted for by the survival indicator $\mathbb{I}_s^{CP}$ and the discounted expected value is then taken. These two additions effectively subtract the CVA term from the NDV given in 4.2. Lastly, by accounting for the FVA term we retrieve the marginal shareholder gain, G, in Proposition 2.3 for Strategy 2.1,

$$G = p^*\pi - \text{FVA}, \tag{4.5}$$

where p^* is the survival probability of the firm and the FVA is given by FVA $=$ $u\tau p^* S\delta$. It is assumed that the firm's possible default is not correlated with the financial instrument that has a resulting payoff of Y. Thus, the covariance term in Eq. (2.5) is zero. Since we are looking at the third case, Case 3.3 in Chapter 3, only the CVA and FVA terms are relevant.

This empirical study requires us to empirically estimate the credit quality of the two institutions apparent in the Andersen *et al.* (2019) way, represented by p^* and $\hat{p}$. The survival probability of the firm, p^* can be estimated from Eq. (3.1);

$$1 = \mathbb{E}\left[\frac{1}{1+\underbrace{r_d}_{\text{REPO}}\tau}\left(1+\underbrace{(r_d+S)}_{\text{JIBAR}}\tau\right)\mathbb{I}_s^f)\right],$$

where r_d represents the domestic risk-free rate. Solving for p^* we get,

$$1 = \frac{1}{1+r_d\tau}\left(1+(r_d+S)\tau\right)\mathbb{E}\left[\mathbb{I}_s^f\right], \tag{4.6}$$

simplifying,

$$p^* = \mathbb{E}\left[\mathbb{I}_s^f\right] = \frac{1+r_d\tau}{1+(r_d+S)\tau}. \tag{4.7}$$

Similarly, the survival probability of the firm, $\hat{p}$ can be estimated from Eq. (3.5),

$$1 = \mathbb{E}\left[\frac{1}{1+\underbrace{r_f}_{\text{SOFR}}\tau}\left(1+\underbrace{(r_f+\bar{S})}_{\text{LIBOR}}\tau\right)\mathbb{I}_s^{CP})\right],$$

where r_f represents the foreign risk-free rate and $\hat{p}$ is given as,

$$\hat{p} = \frac{1+r_f\tau}{1+(r_f+\bar{S})\tau}. \tag{4.8}$$

This dissertation assumes a zero recovery rate ψ, which is modelled by the survival indicators. Although it is more realistic to assume that on default a portion of the obligation is recovered, our assumption allows for a clear link between the credit spread and the default probabilities. This relationship can be seen clearly in Eq. (3.1) and Eq. (3.5) and the variations above. If the credit spread is zero there is no default, while a high credit spread results in a high chance of default.

4.3 Empirical results

We start by implementing the CIP strategy depicted by Strategy 2.1 for a single day using the relevant 1-month rates. We only consider the case where a long position in Strategy 2.1 is taken. On the 25 May 2021, the

- USDZAR spot exchange rate, X, is 13.8689,
- 1-month USDZAR FEC, x_p (forward point), is 619,
- 1-month JIBAR rate is 3.517%,
- 1-month LIBOR rate is 0.09%,
- South African Repo rate is 3.5%, and
- US SOFR rate is 0.01%.

The forward point, x_p, is converted to a forward rate X^f using Eq. (4.1), $X^f = 619/10000 + 13.8689 = 13.9308$. Lastly, we determine the credit spread, S and $\bar{S}$, which is given as,

- $S = \text{1m JIBAR} - \text{Repo} = 3.517\% - 3.5\% = 0.017\%$, and
- $\bar{S} = \text{1m LIBOR} - \text{SOFR} = 0.09\% - 0.01\% = 0.08\%$.

We evaluate the CIP trade using Eq. (4.5) where each quantity is given as,

- $p^* = \frac{1+r_d\tau}{1+(r_d+S)\tau} = \frac{1+0.035\times\frac{1}{12}}{1+0.03517\times\frac{1}{12}} = 0.99999$,
- $\hat{p} = \frac{1+r_f\tau}{1+(r_f+\bar{S})\tau} = \frac{1+0.0001\times\frac{1}{12}}{1+0.0009\times\frac{1}{12}} = 0.99993$,
- $\text{FVA} = u\tau p^* S\delta = 1 \times \frac{1}{12} \times 0.99999 \times 0.00017 \times \frac{1}{1+0.03517\times\frac{1}{12}} = 1.41251e^{-4}$,
- $\text{NDV} = u\left(\frac{1}{X}\left[1 + (r_f + \bar{S})\tau\right]X^f - \left[1 + (r_d + S)\tau\right]\right)$

  $= \frac{1}{13.8689}\left[1 + 0.0009 \times \frac{1}{12}\right] \times 13.9308 - \left[1 + 0.03517 \times \frac{1}{12}\right]$

  $= 0.00161$, and
- $\pi = u\frac{1}{\delta}\left(\frac{1}{X}\left[1 + (r_f + \bar{S})\tau\right]X^f\hat{p} - \left[1 + (r_d + S)\tau\right]\right)$

  $= \frac{1}{1+0.035\times\frac{1}{12}}\left(\frac{1}{13.8689}\left[1+0.0009\times\frac{1}{12}\right]\times 13.9308\times 0.99993 - \left[1+0.03517\times\frac{1}{12}\right]\right)$

  $= 0.00153$.

Thus, the marginal shareholder gain is,

$$\begin{aligned} G &= 0.99999\pi - \text{FVA} \\ &= 0.99999 \times (0.00153) - 1.41251e^{-4} \\ &= 0.00139. \end{aligned}$$

The profit from going long the strategy (0.00161) is diminished after the CVA term is accounted for in the value of π (0.00153) and further diminished when the FVA term is accounted for in the marginal shareholder gain calculation (0.00139). It is clear that on the chosen date, the FVA and CVA terms reduce the CIP basis resulting from implementing Strategy 2.1 under the methodology of Andersen *et al.* (2019).

The empirical exercise is extended across all the tenors of 1-, 3-, 6-, and 12-months for the period 21 June 2016 to 18 November 2022, once again assuming a nominal of R1. We start by looking at the calculation of the CIP basis, which is represented by Eq. (4.2), the NDV of Strategy 2.1. Only the long position in Strategy 2.1 is considered, in some cases this results in a negative basis. In those scenarios, shorting the strategy would result in a profit. Figure 4.4 shows the result of implementing Eq. (4.2), and thus the size of the CIP basis created by Strategy 2.1 at maturity, for the period of 18 July 2016 to 18 November 2022. One of the most

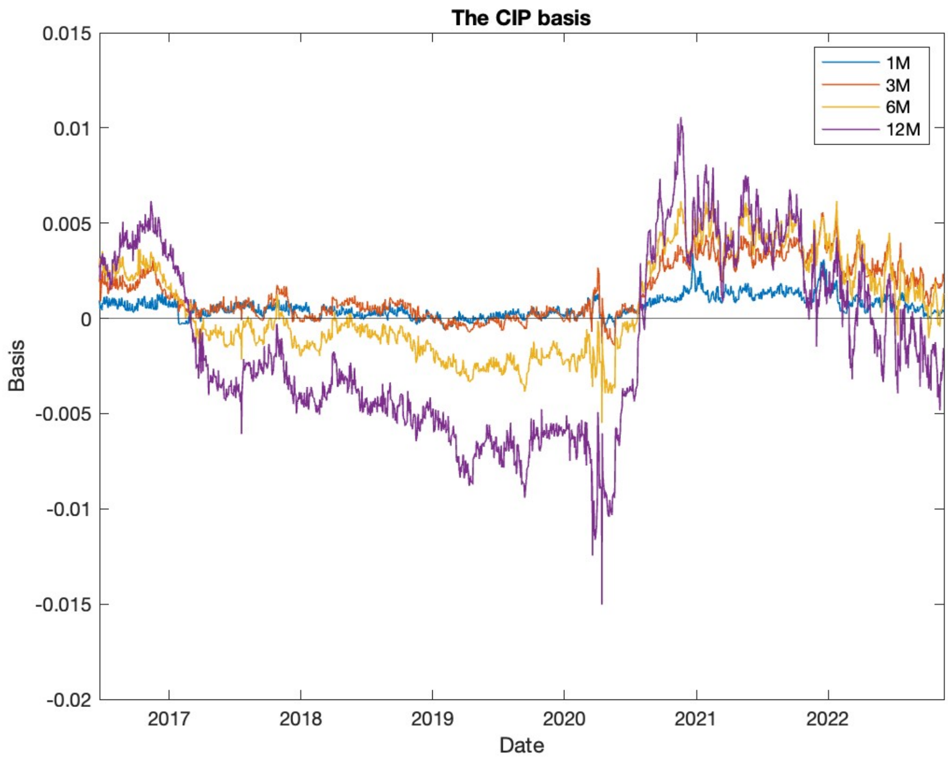

Fig. 4.4: The CIP basis, b, resulting from implementing Strategy 2.1 using JIBAR and LIBOR from 18 July 2016 to 18 November 2022.

notable differences between the basis created by each tenor is the size. Compared to the longer tenors the shorter tenors, particularly the 1-month tenor, lead to a smaller CIP basis. Longer tenors allow for the synthetic loan in Strategy 2.1 to build up a greater profit by maturity, while the shorter 1-month tenor does not benefit from the longer accumulation period. Another key observation is that some tenors remain near or above the zero mark while others convincingly cross it. Over the 1-month tenor, the CIP basis remains positive throughout the period considered, resulting in the arbitrageur always favouring going long Strategy 2.1. This is plausible as the interest and FEC rates exhibit more stability over 1-month. The CIP basis for the

3-month tenor depicts slightly more volatility but also remains generally positive. The volatility in the CIP basis significantly increases over the longer tenors, with the 6- and 12-month tenors fluctuating greatly over the period. From early March 2017 to late July 2020 the CIP basis for the 6- and 12-month tenors remain negative. One explanation for this phenomenon is the greater instability in the FEC rates for the longer tenors. Another conclusion for the volatility in the basis could be that interest rates between the two economies varied with more significance over the longer 6- and 12-month tenors. After July 2020 all tenors produce a positive CIP basis until December 2021, when the 12-month tenor basis becomes negative. Over this period, the 12-month CIP basis seems to be smaller when compared to the previous period, while the CIP basis produced by the 1-, 3-, and 6-month CIP is larger than before. The period under consideration, July 2020 and December 2021, corresponds with the period of the COVID-19 pandemic. The financial markets likely felt the impact of the pandemic through a larger than-normal CIP basis which can be seen in Figure 4.4. Over longer tenors, the arbitrageur would be able to short Strategy 2.1 for periods of negative CIP basis and conversely over periods of positive CIP basis to long the Strategy 2.1.

We now seek to represent the impact of XVAs, through the Andersen *et al.* (2019)

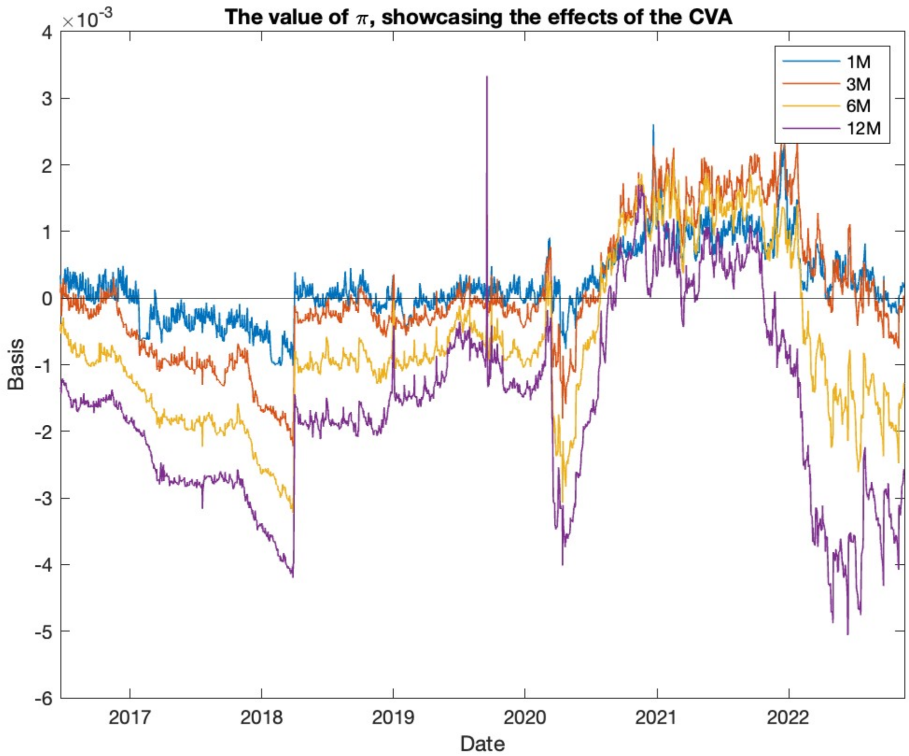

Fig. 4.5: The value of π, in Proposition 2.3, which showcases the effects of the CVA on Strategy 2.1 using JIBAR and LIBOR from 18 July 2016 to 18 November 2022.

lens, on the CIP basis over the period considered. Figure 4.5 graphs Eq. (4.4), the value π seen in Proposition 2.3, showcasing the effects of CVA on Strategy 2.1. It is instantly clear from Figure 4.5 that the basis produced in Figure 4.4 is decreased for all the tenors over the period when the CVA is accounted for. The 1-month tenor now has periods where a negative CIP basis was recorded. However, the size of the basis remains small compared to the longer tenors, highlighting the greater stability in interest and FEC rates over 1-month. The CIP basis for the 3-month tenor showed greater volatility, remaining largely negative until early 2020. Once again the longer tenors showed bigger negative swings in the CIP basis, with the 12-month basis being the most volatile. Both the 6- and 12-month tenors showed large fluctuations over the period, remaining firmly negative until July 2020. Once again all tenors produced a positive, albeit smaller, CIP basis during the period of the COVID-19 pandemic, from July 2020 until December 2021.

Figure 4.6 seeks to graphically represent the impact of XVA (FVA and CVA) on the

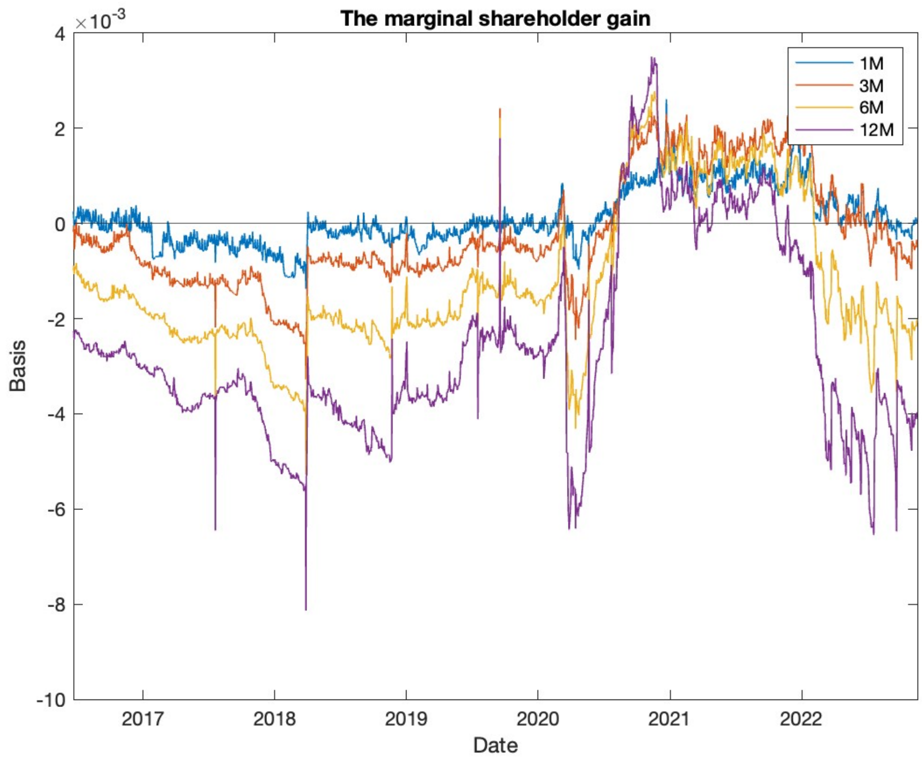

Fig. 4.6: The marginal shareholder gain, G, in Proposition 2.3, resulting from implementing Strategy 2.1 using JIBAR and LIBOR from 18 July 2016 to 18 November 2022.

CIP basis through the marginal shareholder gain, G, in Eq. (4.5). The same themes play out in Figure 4.6 as seen in Figure 4.5, with the account of the FVA further decreasing the CIP basis produced by all the tenors of the period.

Chapter 5

Conclusion

Covered interest parity postulates that the difference in interest rates between two currencies should correlate with the spot and forward exchange rates, eliminating arbitrage opportunities. However, this relationship has been shown to fail, particularly in the aftermath of the 2008 GFC, allowing arbitrage opportunities to persist. This dissertation explores whether valuation adjustments serve as an explanation. A classic CIP trade is examined in Chapter 2, involving borrowing in the South African market and synthetically lending rand through a foreign exchange contract to fix the exchange rate. The FVA is highlighted during the derivation of the strategy's net value. The CVA and DVA are then incorporated as the default of both parties in the strategy is considered.

In Chapter 2 the CVA, DVA, and FVA are formally defined, which allows the NDV to be defined. The main proposition in Andersen *et al.* (2019), defining the marginal shareholder gain, G, is introduced and applied to a CIP situation. The cashflows produced by the CIP transaction are defined in Section 2.4 which are carried through to Chapter 3. The third case, Case 3.3, in Chapter 3 is used to recover the marginal shareholder gain, G, which ultimately showcases the impact the FVA and CVA have on the gain achieved by the firm's shareholders when implementing Strategy 2.1. The CIP basis is calculated and graphed for the 1-, 3-, 6- and 12-month tenors using market data that spans from 21 June 2016 to 18 November 2022. When comparing the basis with and without the impact of the FVA and CVA, it is concluded that the FVA and CVA costs provide a plausible reason for why the CIP basis persists.

Bootstrapping and modelling the longer-term borrowing and lending rates that are available to banks serves as a possible extension to this dissertation. Furthermore, bid and ask rates on both the spot and forward exchange rates could be incorporated to account for market friction in real-world scenarios. Additionally, the interbank rates used could be swapped out for data specific to select institutions, while other currency pairs could be considered.

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