DERIVATIVE PRICING

A TECHNICAL GUIDE, PART II

Table of Contents

List of Abbreviations

The following abbreviations and symbols are used in this guide:

AAF	Annuity adjustment factor
ac.APM	The option pricing tool described in these notes
ac.SRM	The interest rate derivative pricing tool
APM	Asset price model
ATM	At-the-money, the situation when the price of the underlying security equals the strike price
ATMF	At-the-money forward option, the situation when the price of the underlying security equals the option strike price on the forward market
bps	Basis point (same as pip, equal 1/100th of 1%)
BS	Black-Scholes
BSM	Black-Scholes-Merton
BV	Book Value
CCY	Currency
CDS	Credit default swap
DC	Deal contingent
DTCC	Depository Trust And Clearing Corporation
ES	Expected shortfall
FMV	Fair market value
FV	Forward value
FXIP	FX Information Portal Bloomberg function
G/L	Gain and loss
M&A	Merger and acquisition
MTM	Marked-to-market
OCI	Other comprehensive income
OECD Guidelines	"BEPS Actions 8 – 10, Financial Transactions", a draft published in July – September 2018 for the purposes of public discussion
OV	Bloomberg option valuation tool
P&L	Profit and loss
Pip	Percentage in point (same as bps, equal 1/100th of 1%)
PP	Purchase Price
PPE	Purchase price equation
SRM	Short rate model of interest rates
VaR	Value-at-risk

Section 1 Introduction

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Section 2 Hedging

The derivative prices are derived assuming market completeness by replicating the derivative instrument payoff structure. A derivative instrument is often used to hedge the risks of the underlying securities. Alternatively, underlying securities can be added to a derivative instrument to offset movements in the derivative price movement.

2.1 Hedging objectives

The first step in the design and implementation of a hedging strategy is to determine the objective of hedging. The objective is typically set as risk minimization. Therefore, the first step is to define and measure risk exposure.

One standard measure of risk that is traditionally applied in financial industry is value-at-risk (**VaR**) measure. VaR can be selected at different levels (e.g. at one or two standard deviations or at 'worst loss' level, where the VaR levels are estimated based on historical data). Formally, VaR metrics does not satisfy the definition of risk measure (see [8]). A general risk measure is modelled using **spectral risk** measure, which is defined as

(2.1)
$$M(X) = -\int_0^1 \theta(p) F_X^{-1}(p)\,dp$$

where $F_X^{-1}(p)$ is the inverse of cumulative distribution function of factor X and $\theta(p)$ is the spectral function which assigns weights to different outcomes of X. The metrics satisfies the definition of risk if function $\theta(p)$ satisfies the following properties:[1]

1. Function $\theta(p)$ is non-negative: $\theta(p) \geq 0$;
2. Function $\theta(p)$ is normalized to one: $\int_0^1 \theta(p)dp = 1$
3. Function $\theta(p)$ is non-increasing: $\theta(p) \downarrow_p$

Note that VaR metrics does not satisfy property 3 from the above list. The modification of VaR metrics which satisfies the above properties is the expected shortfall (**ES**) metrics. The spectral function $\theta(p)$ for VaR and ES is described below:

(2.2)
$$\begin{cases} VaR: & \theta(p = \alpha) = 1 \\ ES: & \theta(p \leq \alpha) = \dfrac{1}{\alpha} \end{cases}$$

where α is the threshold probability value. The weights assigned to all other scenarios are equal to zero. Effectively, VaR metrics assigns full weight to the scenario which corresponds to the threshold value α, while the ES metrics assigns equal weights to all m scenarios which correspond to the threshold value α or below.

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[1] https://en.wikipedia.org/wiki/Spectral_risk_measure.

2.2 Option Greeks

Greeks measure option sensitivity to different parameters. Greeks are typically applied for the following purposes:

1. Assess exposure to model parameters (such as underlying asset price, price volatility, time, risk-free rate, etc.);
2. Greeks are used as a convenient metrics to standardize market terminology such as bid/ask spread (measured in terms of volatility spreads) or difference between spot and strike price (measured in terms of option delta).

Exhibit below summarizes option Greeks.

Exhibit 2.1 Summary of option Greeks

Greek name	Option parameter	Hedging strategy
Delta (δ), Gamma (Γ)	Spot price	Option exposure to asset price can be covered by the purchase of the underlying asset
Vega (ν)	Volatility	
Rho	Discount (risk-free) rate	Exposure to interest rate can be hedged by purchase of interest rate futures
Theta	Remaining maturity term	

The Greeks are illustrated selectively in the exhibits below.

Exhibit 2.2 Delta and Vega Greeks illustrated for a FX call option (GBP/CAD)

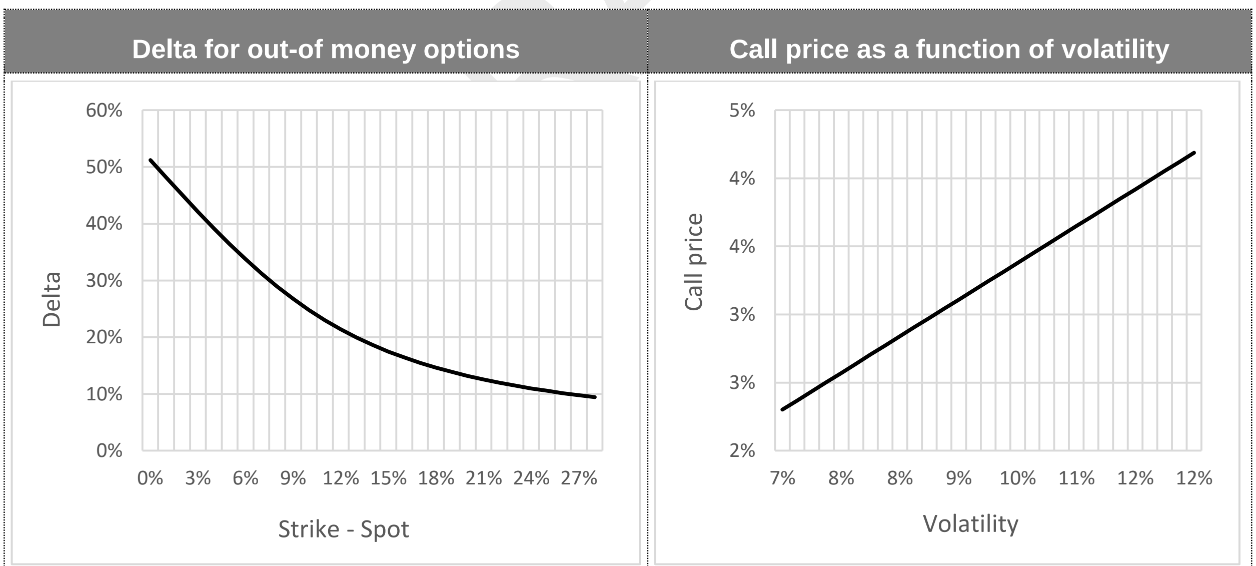


Exhibit above show that delta for the ATM option equals 0.5. The bid/ask spreads for out-of-money options are typically quoted in terms of delta: e.g. 25D refers to the option with difference between strike and spot corresponding to $\delta = 0.25$ (the lower is delta, the deeper is the option out-of-money). A standard practice in financial industry is to describe out-of-money options in terms of delta (see examples in Appendix A.5).

The right panel of the exhibit above illustrates that ν is approximately constant for the option (in the example, $\nu = 33.69\%$). A standard practice in financial industry is to quote premium spreads on options in terms of volatility spreads (see examples in Appendix A.5). For example, a 1% vol premium on a call option is estimated as follows: (i) get the mid-market option price; (i) apply BSM equation to estimate the implied volatility that corresponds to the mid-market price; (iii) add a 1% premium to the implied volatility and recalculate the option price using BSM equations. In the example above, the call price equals 2.6% of the notional amount. A 1% vol premium corresponds to 0.34% premium on call option price.

2.3 Delta hedging

2.4 Hedging FX risk

Net exposure.

2.5 Hedging bond default risk

2.6 Accounting considerations

Fair value hedge.

Cash flow hedge.

Hedging a portion of risk component.

2.7 Examples of hedging strategies

A list of some frequently used hedging strategies is presented below.[2]

2.7.1 Covered call

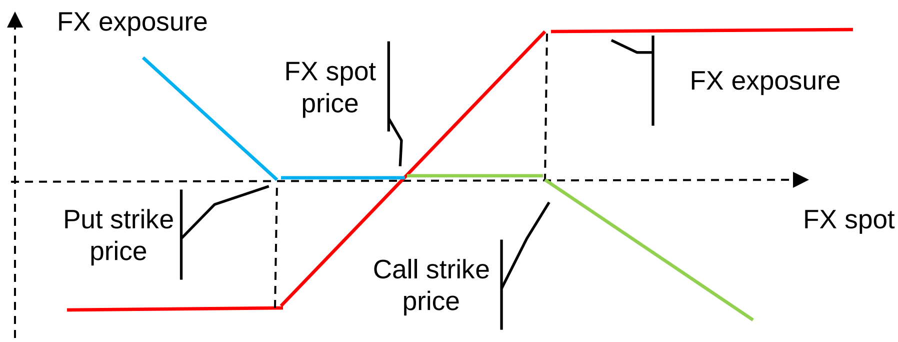
2.7.2 Married put

2.7.3 Protective collar

A collar strategy that is constructed by (i) holding shares of the underlying stock, (ii) buying a put option to protect against the downside risk; and (iii) sell call option to reduce the hedging price by limiting the upside gain. The exposure in the collar strategy is illustrated in the diagram below.

[2] https://www.investopedia.com/trading/options-strategies/

Exhibit 2.3 'Collar' hedging strategy

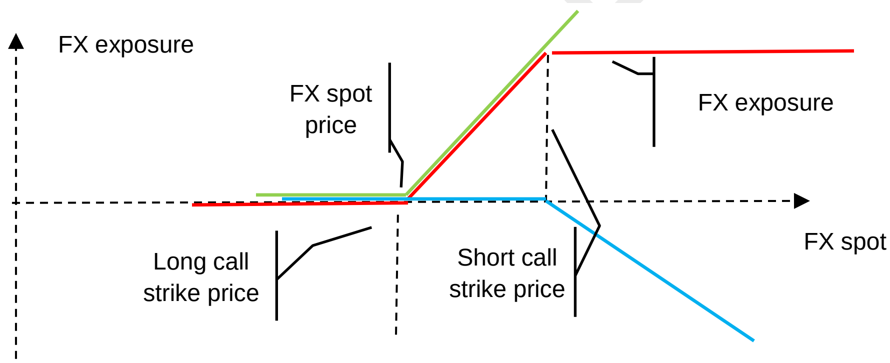


The payout in the call and put option contracts are shown by the blue line.

2.7.4 Bull call spread

The 'bull call spread' strategy provides limited protection of the asset price by hedging the price movement above the 'short call strike price'. The buyer has price exposure within the [long call strike, short call strike] range. Limited protection is compensated by lower cost of the hedging strategy.

Exhibit 2.4 'Bull call spread' hedging strategy

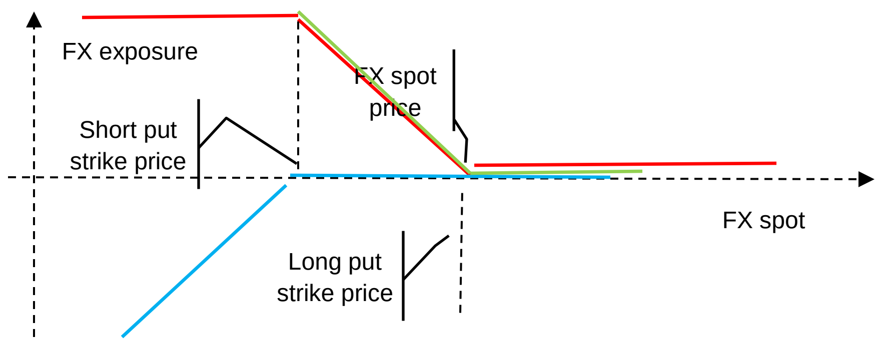


If compared to an insurance policy, 'bull call spread' strategy can be viewed as an insurance against upward price movement with the cap on the total payout under the insurance policy.

2.7.5 Bear put spread

The 'bear put spread' strategy provides limited protection of the asset price by hedging the price movement within the [long put strike, short put strike] range of price movement. Limited protection is compensated by lower cost of the hedging strategy.

Exhibit 2.5 'Bear put spread' hedging strategy



If compared to an insurance policy, 'bull call spread' strategy can be viewed as an insurance against downward price movement with the cap on the total payout under the insurance policy.

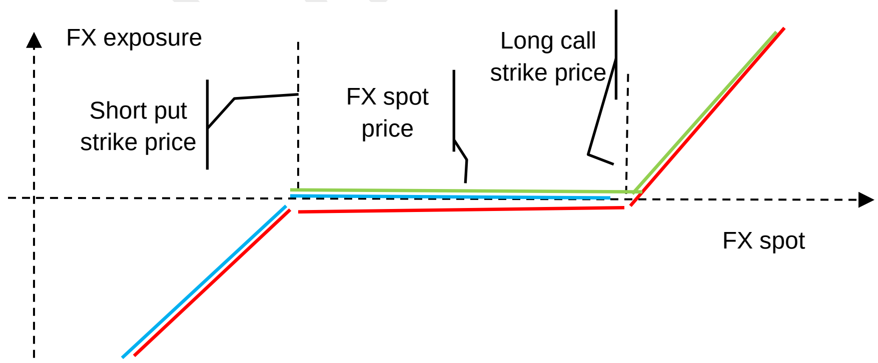
2.7.6 Long straddle

2.7.7 Long strangle

2.7.8 Risk reversal (RR) strategy

Risk reversal is a bullish strategy which involves (i) buying an out-of-money call option and (ii) selling an out-of-money put option. The buyer of the strategy bets on a large increase in the asset price and loses money if there is a large drop in the asset price.

Exhibit 2.6 'Risk reversal' hedging strategy



Bid/ask spreads on risk reversal option strategy are quoted in Bloomberg FXIP tool.

2.7.9 Butterfly (BF) spread strategy

Under the butterfly spread strategy the option buyer gains profit if the deviation from the spot price is small (effectively the option buyer bets on the price stability). The buyer of the BF strategy is protected from large deviations in the underlying asset price.

Exhibit 2.7 'Butterfly spread' hedging strategy

Bid/ask spreads on butterfly spread option strategy are quoted in Bloomberg FXIP tool.

2.8 Comparing derivatives and insurance contracts

Premium

Payout

Deductible – strike price

Cap on payout

Section 3 Summary

This section presents the summary of the key results and equations which are spread out across this guide. The section also provides a link to the sections were the equations are derived and discussed in more detail.

Appendix A Bloomberg Tools

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A.1 OVML tool

OVML tool is applied for FX and commodity price option valuation.

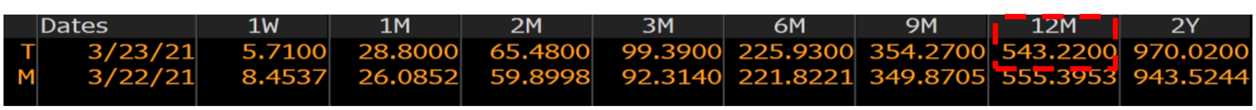
A.1.1 Commodity price options

This section describes Bloomberg's OV valuation tool applied to commodity price options and forwards. The tool is illustrated for the gold commodity. Bloomberg print screen with the OV tool output is illustrated below.

Exhibit A.1 Bloomberg OV tool output for the commodity price option

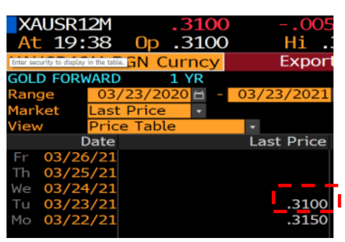
The tool uses the following default options:

1. The strike price is set equal to the gold futures price (ATMF – at the money forward price).

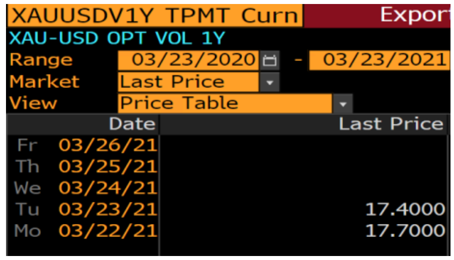


	Dates	1W	1M	2M	3M	6M	9M	12M	2Y
T	3/23/21	5.7100	28.8000	65.4800	99.3900	225.9300	354.2700	543.2200	970.0200
M	3/22/21	8.4537	26.0852	59.8998	92.3140	221.8221	349.8705	555.3953	943.5244

The gold forward points are available through the 'FXXUUS01 Index' series or, alternatively through the 'XAUSR12M Index' series which presents forward points in bps of the gold spot price.



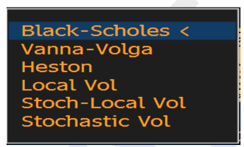
2. Volatility is linked to Bloomberg volatility series, such as 'XAUUSDV1Y TPMT Curncy'[3] shown below (the series represents XAUUSD 1 year ATM implied volatility).



3. Discount rate is set at USD deposit rate. The rates are defined as 'USD SOFR overnight index swap rates'[4] which are the swap rates constructed for the SOFRRATE Index[5] curve.

	Dates	9M	10M	11M	12M
T	3/23/21	0.0350	0.0378	0.0400	0.0404
M	3/22/21	0.0300	0.0337	0.0362	0.0390

4. Model. The list of models that can be selected for the option estimation is shown below. The default model is Black-Scholes.



The results of the Bloomberg commodity option price test are shown in the exhibit below.

Exhibit A.2 Test results for the Bloomberg commodity price option tool

A.1.2 FX options

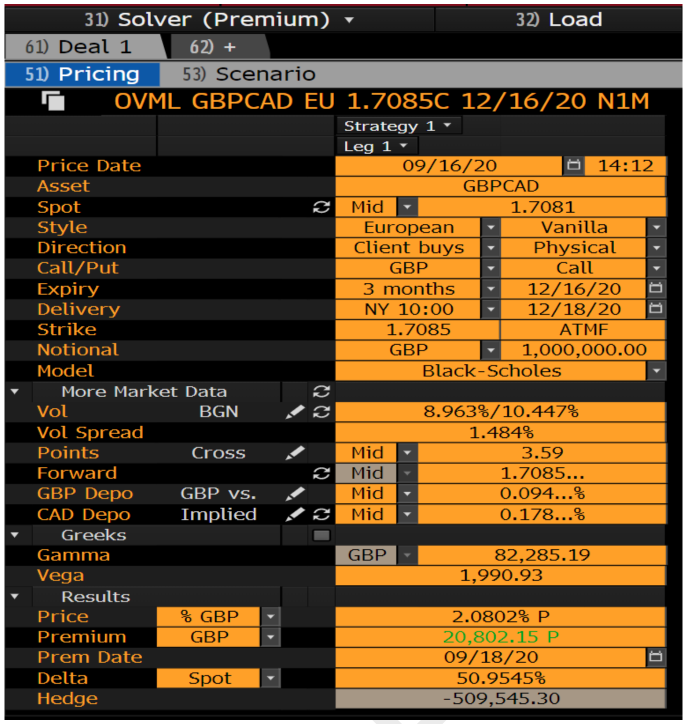
This section describes Bloomberg's OV valuation tool applied to FX options and forwards. The tool is illustrated for the GBP/CAD currency pair. Bloomberg print screen with the OV tool output is illustrated below. (Bloomberg screen for the OV tool can be alternatively presented using Bloomberg's **OVML** tool).

[3] For consistency, we select the same source TPMT as in the option valuation tool.

[4] The swap rates are reported through the YCSW0490 USD SOFR (vs. Fixed Rate) Bloomberg curve.

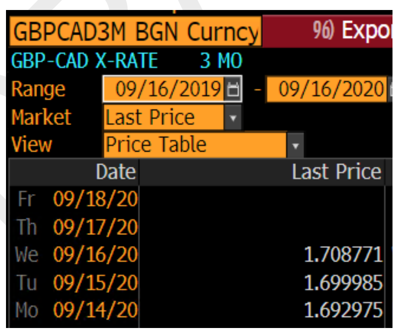
[5] SOFRRATE (Secured Overnight Financing Rate) is the index for the broad measure for the cost of borrowing cash overnight collateralized by Treasury securities.

Exhibit A.3 Bloomberg OV tool output for the FX option



The tool uses the following default options:

1. The strike price is set equal to the futures price



2. GBP risk-free rate. Bloomberg constructs a custom curve for the GBP risk-free rate. Other options include (i) GBP overnight rate (BP00O/N ticker); (ii) Overnight Index Swap (OIS) rate (which swaps floating overnight rate into equivalent fixed rate with given maturity), e.g. BPSWSC for a 3-month swap rate
3. CAD risk-free rate. Bloomberg constructs a custom curve for the CAD risk-free rate. Other options include (i) Canadian overnight Repo rate (CAONREPO ticker); (ii) Overnight Index Swap (OIS) rate, e.g. CDSOC for a 3-month swap rate.
4. The price is quoted as a percentage of spot price.

The Bloomberg print screen with the OV calculation results was replicated using equation **Error! Reference source not found.**. The results are shown in the exhibit below.

Exhibit A.4 Test results for the Bloomberg FX option tool

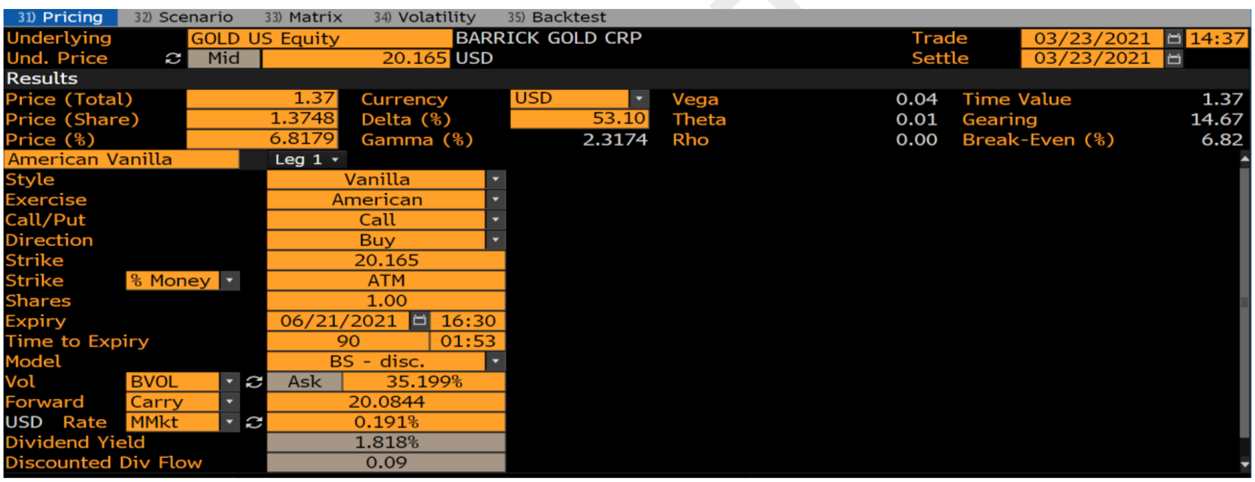
Parameters							Option calculation		
#	T	S	K	sigma	r	d	call	call (% of spot)	implied volatility
Bloomberg OV tool test									
1	0.25	1.7081	1.7085	8.963%	0.178%	0.094%	0.031	1.79%	8.96%
2	0.25	1.7081	1.7085	10.447%	0.178%	0.094%	0.036	2.08%	10.45%

The 2.08% option price is replicated using 10.447% volatility (upper bound of the volatility range) and by dividing the calculated call option price by FX spot price.

A.2 OVME tool for stock price options

This section describes Bloomberg's OV valuation tool applied to stock price options and forwards. The tool is illustrated for the 'GOLD US Equity' stock ticker (Barrick Gold Corporation). Bloomberg print screen with the OV tool output is illustrated below.

Exhibit A.5 Bloomberg OV tool output for the stock price option

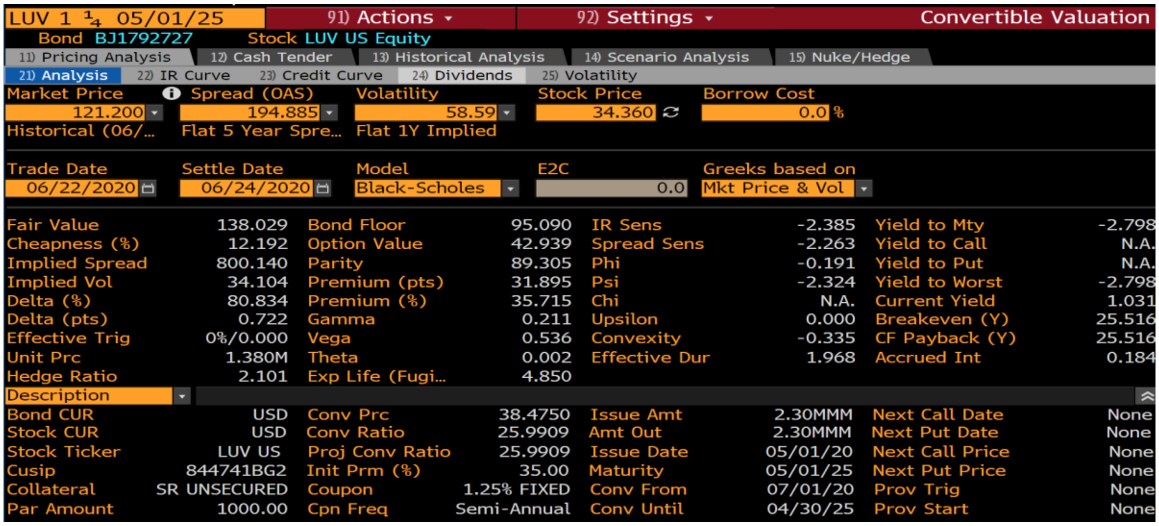


The strike price is set equal to the stock spot price (20.165). The yield rate proxy for the stock can be obtained through the DVD Bloomberg function.

A.3 OVCV tool

In this section we present the results of convertible bond valuation performed for the bond illustrated in Sections **Error! Reference source not found.** and **Error! Reference source not found.**. Bloomberg print screen with the convertible bond valuation output is shown below.

Exhibit A.6 Bloomberg OVCV tool output



LUV 1 ¼ 05/01/25 | 91) Actions | 92) Settings | Convertible Valuation

Bond BJ1792727 Stock LUV US Equity

11) Pricing Analysis | 12) Cash Tender | 13) Historical Analysis | 14) Scenario Analysis | 15) Nuke/Hedge

21) Analysis | 22) IR Curve | 23) Credit Curve | 24) Dividends | 25) Volatility

Market Price	Spread (OAS)	Volatility	Stock Price	Borrow Cost
121.200	194.885	58.59	34.360	0.0 %
Historical (06/...	Flat 5 Year Spre...	Flat 1Y Implied		

Trade Date	Settle Date	Model	E2C	Greeks based on
06/22/2020	06/24/2020	Black-Scholes	0.0	Mkt Price & Vol

Fair Value	138.029	Bond Floor	95.090	IR Sens	-2.385	Yield to Mty	-2.798
Cheapness (%)	12.192	Option Value	42.939	Spread Sens	-2.263	Yield to Call	N.A.
Implied Spread	800.140	Parity	89.305	Phi	-0.191	Yield to Put	N.A.
Implied Vol	34.104	Premium (pts)	31.895	Psi	-2.324	Yield to Worst	-2.798
Delta (%)	80.834	Premium (%)	35.715	Chi	N.A.	Current Yield	1.031
Delta (pts)	0.722	Gamma	0.211	Upsilon	0.000	Breakeven (Y)	25.516
Effective Trig	0%/0.000	Vega	0.536	Convexity	-0.335	CF Payback (Y)	25.516
Unit Prc	1.380M	Theta	0.002	Effective Dur	1.968	Accrued Int	0.184
Hedge Ratio	2.101	Exp Life (Fugi...	4.850				

Description

Bond CUR	USD	Conv Prc	38.4750	Issue Amt	2.30MMM	Next Call Date	None
Stock CUR	USD	Conv Ratio	25.9909	Amt Out	2.30MMM	Next Put Date	None
Stock Ticker	LUV US	Proj Conv Ratio	25.9909	Issue Date	05/01/20	Next Call Price	None
Cusip	844741BG2	Init Prm (%)	35.00	Maturity	05/01/25	Next Put Price	None
Collateral	SR UNSECURED	Coupon	1.25% FIXED	Conv From	07/01/20	Prov Trig	None
Par Amount	1000.00	Cpn Freq	Semi-Annual	Conv Until	04/30/25	Prov Start	None

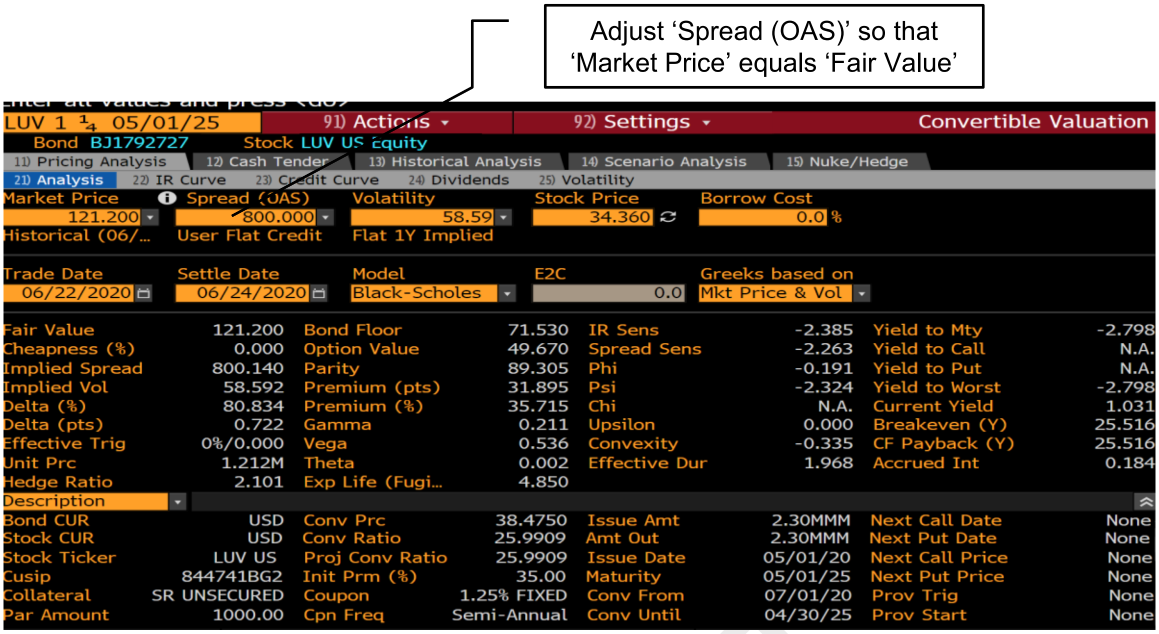
The parameters of the OVCV tool are interpreted as follows:

1. **Market Price**: price of the convertible bond (as shown by Bloomberg HP function).
2. **Spread (Credit)**: bond risk premium. The spread is added to risk-free rate to discount projected cash flows in Black-Scholes model.
3. **Volatility**: stock price volatility. Parameter can be set either based on historical or implied volatility.
4. **Implied volatility**: the value of volatility which produced the bond fair value equal to the quoted market value.
5. **Cheapness**: difference between the model and the market price expresses as a percentage of model price.
6. **Bond floor**: NPV of fixed income components
7. **Option value**: difference between the bond fair value and bond floor
8. **Yield to Maturity (YTM)**: the YTM value is estimated based on the bond market price.

The valuation convertibility option value is estimated based on the estimated historical volatility and estimated risk spread. As a result, the bond FMV value 134.550 does not match the market bond price 121.728. The convertibility option is valued based on the estimated FMV value (39.274 = 134.550 – 95.276).[6]

Alternatively, spread estimate can be replaced with the implied spread or volatility to ensure consistency between the bond market price and the FMV.

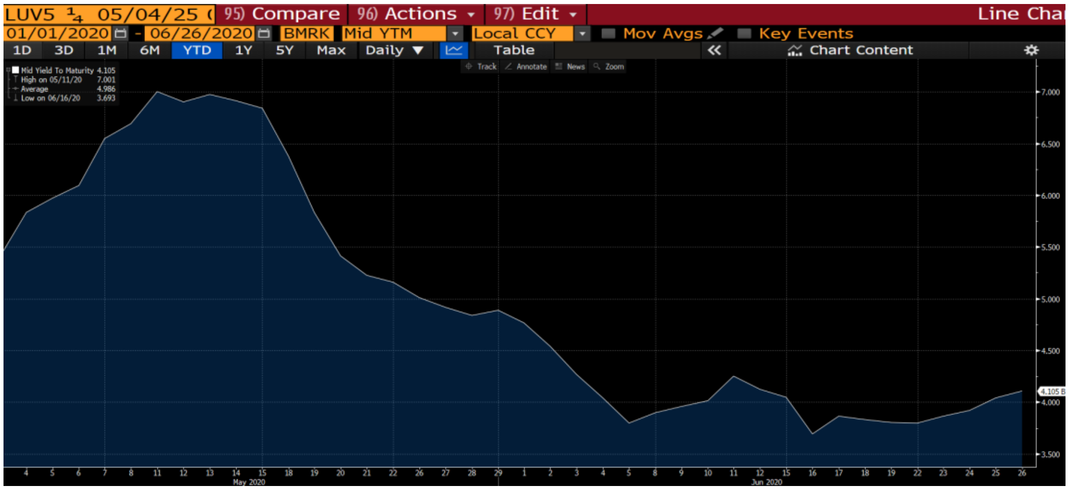
[6] The yield rates (e.g. yield to maturity = -2.888) are reported based on the market price of 121.728.



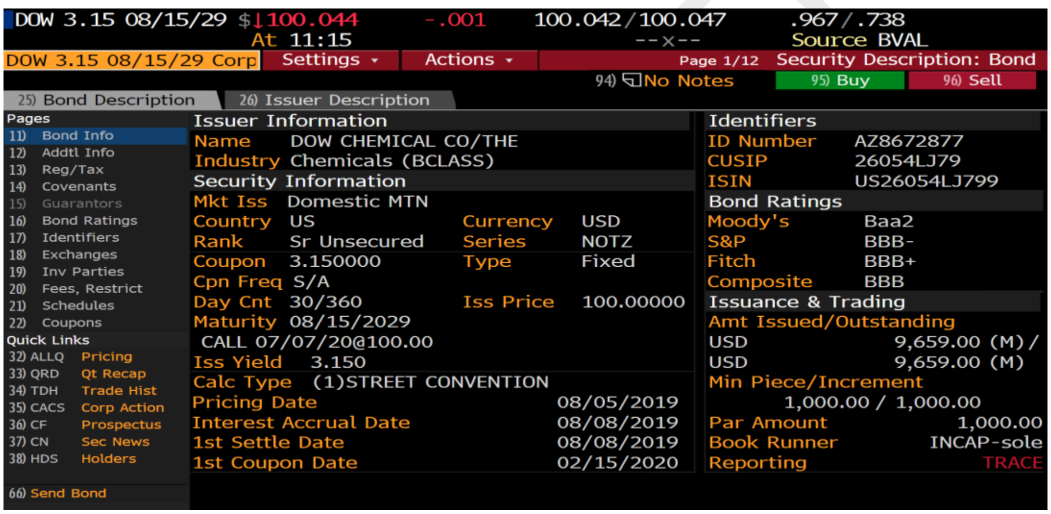
The example shows that implied spread generates in this case a significantly higher adjustment for bond convertibility option.

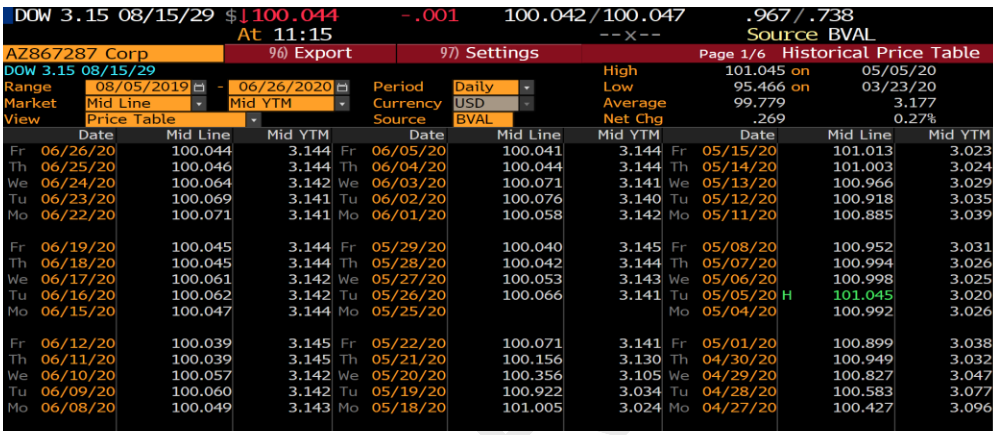
The yields on a comparable non-convertible bond issued by the same company are shown in the exhibits below.

The yield rates on the non-convertible bond are shown in the exhibit below.


LUV5 1⁄4 05/04/25
95) Compare
96) Actions
97) Edit
Line Cha
01/01/2020 - 06/26/2020
BMRK
Mid YTM
Local CCY
Mov Avgs
Key Events
1D 3D 1M 6M YTD 1Y 5Y Max Daily
Table
Chart Content
7.000
6.500
6.000
5.500
5.000
4.500
4.000
3.500
May 2020
Jun 2020

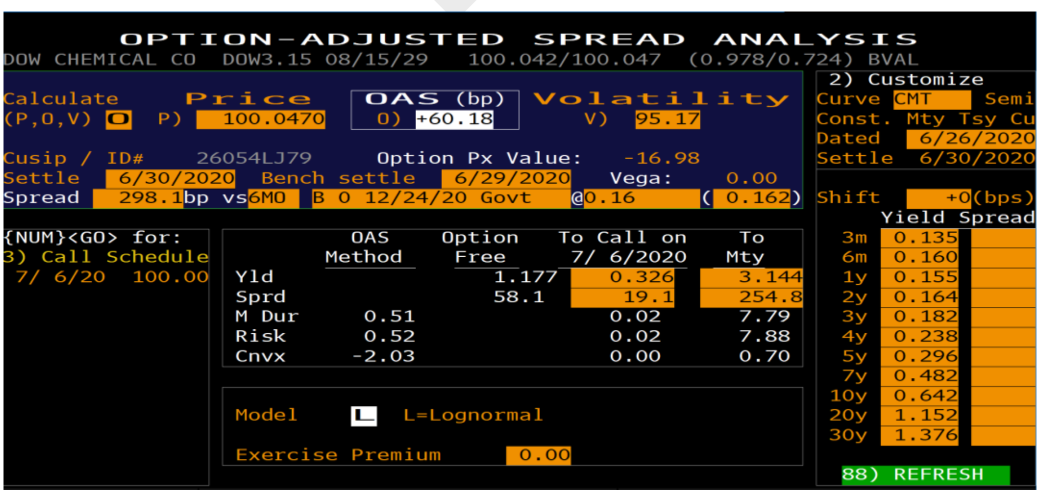
A.4 OAS1 tool


DOW 3.15 08/15/29 $↓100.044 -.001 100.042/100.047 .967/.738
At 11:15 --x-- Source BVAL
DOW 3.15 08/15/29 Corp
Settings
Actions
Page 1/12 Security Description: Bond
94) No Notes
95) Buy
96) Sell
25) Bond Description
26) Issuer Description
Pages
11) Bond Info
12) Addtl Info
13) Reg/Tax
14) Covenants
15) Guarantors
16) Bond Ratings
17) Identifiers
18) Exchanges
19) Inv Parties
20) Fees, Restrict
21) Schedules
22) Coupons
Quick Links
32) ALLQ Pricing
33) QRD Qt Recap
34) TDH Trade Hist
35) CACS Corp Action
36) CF Prospectus
37) CN Sec News
38) HDS Holders
66) Send Bond
Issuer Information
Name DOW CHEMICAL CO/THE
Industry Chemicals (BCLASS)
Security Information
Mkt Iss Domestic MTN
Country US
Currency USD
Rank Sr Unsecured
Series NOTZ
Coupon 3.150000
Type Fixed
Cpn Freq S/A
Day Cnt 30/360
Iss Price 100.00000
Maturity 08/15/2029
CALL 07/07/20@100.00
Iss Yield 3.150
Calc Type (1)STREET CONVENTION
Pricing Date 08/05/2019
Interest Accrual Date 08/08/2019
1st Settle Date 08/08/2019
1st Coupon Date 02/15/2020
Identifiers
ID Number AZ8672877
CUSIP 26054LJ79
ISIN US26054LJ799
Bond Ratings
Moody's Baa2
S&P BBB-
Fitch BBB+
Composite BBB
Issuance & Trading
Amt Issued/Outstanding
USD 9,659.00 (M) /
USD 9,659.00 (M)
Min Piece/Increment
1,000.00 / 1,000.00
Par Amount 1,000.00
Book Runner INCAP-sole
Reporting TRACE



Date	Mid Line	Mid YTM	Date	Mid Line	Mid YTM	Date	Mid Line	Mid YTM
Fr 06/26/20	100.044	3.144	Fr 06/05/20	100.041	3.144	Fr 05/15/20	101.013	3.023
Th 06/25/20	100.046	3.144	Th 06/04/20	100.044	3.144	Th 05/14/20	101.003	3.024
We 06/24/20	100.064	3.142	We 06/03/20	100.071	3.141	We 05/13/20	100.966	3.029
Tu 06/23/20	100.069	3.141	Tu 06/02/20	100.076	3.140	Tu 05/12/20	100.918	3.035
Mo 06/22/20	100.071	3.141	Mo 06/01/20	100.058	3.142	Mo 05/11/20	100.885	3.039
Fr 06/19/20	100.045	3.144	Fr 05/29/20	100.040	3.145	Fr 05/08/20	100.952	3.031
Th 06/18/20	100.045	3.144	Th 05/28/20	100.042	3.144	Th 05/07/20	100.994	3.026
We 06/17/20	100.061	3.142	We 05/27/20	100.053	3.143	We 05/06/20	100.998	3.025
Tu 06/16/20	100.062	3.142	Tu 05/26/20	100.066	3.141	Tu 05/05/20 H	101.045	3.020
Mo 06/15/20	100.047	3.144	Mo 05/25/20			Mo 05/04/20	100.992	3.026
Fr 06/12/20	100.039	3.145	Fr 05/22/20	100.071	3.141	Fr 05/01/20	100.899	3.038
Th 06/11/20	100.039	3.145	Th 05/21/20	100.156	3.130	Th 04/30/20	100.949	3.032
We 06/10/20	100.057	3.142	We 05/20/20	100.356	3.105	We 04/29/20	100.827	3.047
Tu 06/09/20	100.060	3.142	Tu 05/19/20	100.922	3.034	Tu 04/28/20	100.583	3.077
Mo 06/08/20	100.049	3.143	Mo 05/18/20	101.005	3.024	Mo 04/27/20	100.427	3.096

OAS1 function



B 0 12/24/20 ↑0.1600 -- 0.1650 / 0.1600 0.167 / 0.162
At 13:42 -- x -- Source BGN

B 0 12/24/20 Govt | Settings | Actions | Page 1/11 Security Description: Bond
95) Buy | 96) Sell

25) Bond Description | 26) Issuer Description

Pages
11) Bond Info
12) Addtl Info
13) Covenants
14) Guarantors
15) Bond Ratings
16) Identifiers
17) Exchanges
18) Inv Parties
19) Fees, Restrict
20) Schedules
21) Coupons

Quick Links
32) ALLQ Pricing
33) QRD Quote Recap
34) CACS Corp Action
35) CN Sec News
36) HDS Holders

66) Send Bond

Issuer Information
Name TREASURY BILL
Industry Treasury (BCLASS)

Security Information
Issue Date 06/25/2020
Interest Accrues
1st Coupon Date
Maturity Date 12/24/2020
Floater Formula N.A.
Workout Date
Security Type USD
Cpn Frequency Type ZERO
Mty/Refund Type NORMAL Series
Calc Type DISCOUNT
Day Count ACT/360
Market Sector US GOVT
Country US Currency USD
TENDERS ACCEPTED: $54000MM.

Identifiers
ID Number 9127963L1
CUSIP 9127963L1
ISIN US9127963L18
SEDOL 1 BL5BS66
FIGI BBG00VLFHK10

Issuance & Trading
Disc @ Issue .175000
Risk Factor .487
Amount Issued 56068 (MM)
Amount Outstanding 56068 (MM)
Minimum Piece 100
Minimum Increment 100
SOMA Holdings N.A.

B 0 12/24/20 ↑0.1600 -- 0.1650 / 0.1600 0.167 / 0.162
At 13:42 -- x -- Source BGN

9127963L Govt | 96) Export | 97) Settings | Page 1/1 Historical Price Table

B 0 12/24/20
Range 06/22/2020 - 06/26/2020 Period Daily
Market Mid Line Mid YTM Currency USD
View Price Table Source BGN

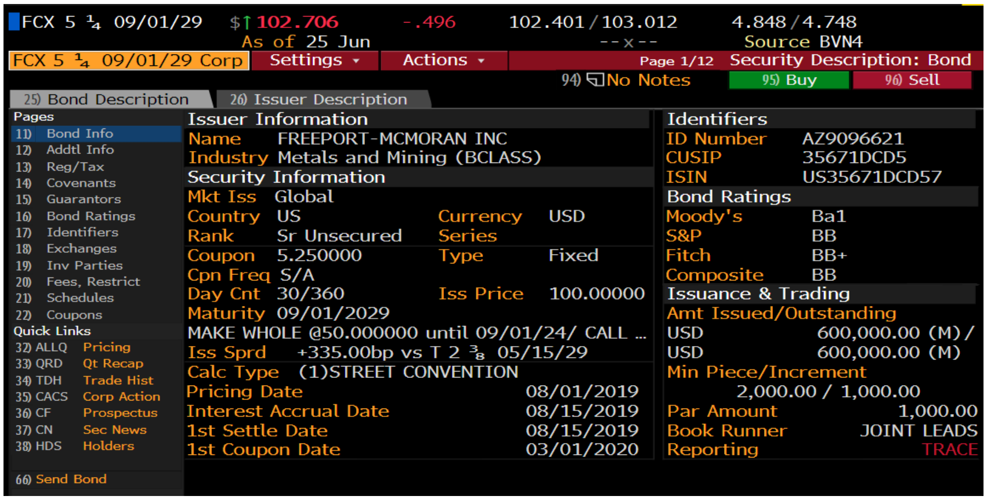
		High	.1675 on	06/23/20
		Low	.1625 on	06/24/20
		Average	.1643	.167
		Net Chg	-.0016	-0.95%

	Date	Mid Line	Mid YTM	Date	Mid Line	Mid YTM	Date	Mid Line	Mid YT
Fr	06/26/20	.1625	.165						
Th	06/25/20	.1650	.167						
We	06/24/20 L	.1625	.165						
Tu	06/23/20 H	.1675	.170						
Mo	06/22/20	.1641	.166						

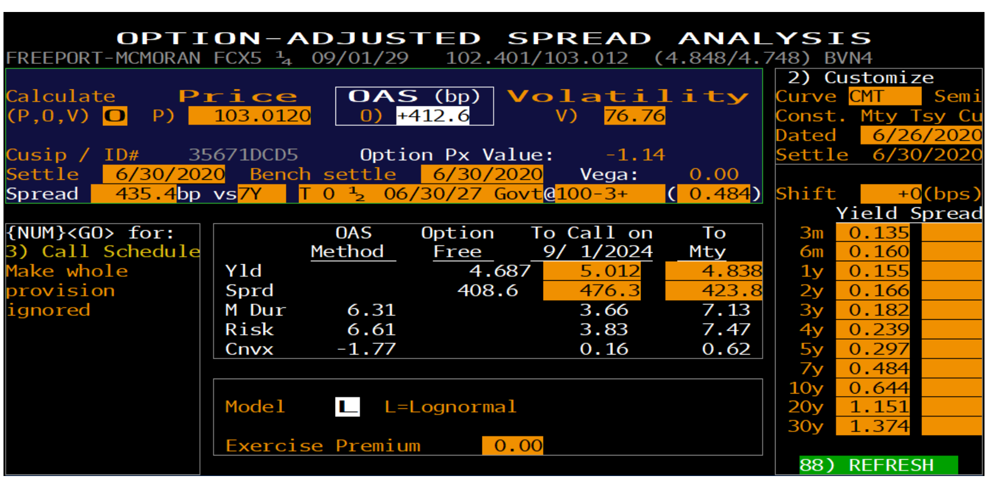
HOAS function

HISTORICAL OAS
DOW 3.15 08/15/29 Page 1/ 1

	Date	Price	OAS	Volatility	Duration	Convexity
hursday	6/25/20	100.04	80.31	95.	.59	-2.34
ednesday	6/24/20	100.06	-12.70	101.	.03	-.10
uesday	6/23/20	100.07	88.29	93.	.75	-2.98
onday	6/22/20	100.07	85.13	95.	.73	-2.89
riday	6/19/20	100.04	83.67	97.	.71	-2.83
hursday	6/18/20	100.04	83.49	97.	.72	-2.88
ednesday	6/17/20	100.06	4.75	101.	.12	-.47
uesday	6/16/20	100.06	106.62	100.	1.22	-4.85
onday	6/15/20	100.05	118.42	101.	1.49	-5.86
riday	6/12/20	100.04	113.87	106.	1.36	-5.45
hursday	6/11/20	100.04	109.85	106.	1.26	-5.02
ednesday	6/10/20	100.05	107.59	98.	1.12	-4.45
uesday	6/ 9/20	100.06	95.35	98.	1.31	-5.22
onday	6/ 8/20	100.05	105.86	89.	1.37	-5.46
riday	6/ 5/20	100.04	102.02	90.	1.47	-5.88
hursday	6/ 4/20	100.04	89.49	90.	.98	-3.91
ednesday	6/ 3/20	100.07	-47.60	99.	.01	-.03
uesday	6/ 2/20	100.07	40.04	98.	.30	-1.17
onday	6/ 1/20	100.06	81.46	100.	.63	-2.50
riday	5/29/20	100.04	117.82	88.	.92	-3.66


FCX 5 ¼ 09/01/29 $↑102.706 -.496 102.401 / 103.012 4.848 / 4.748
As of 25 Jun --x-- Source BVN4
FCX 5 ¼ 09/01/29 Corp Settings Actions Page 1/12 Security Description: Bond
94) No Notes 95) Buy 96) Sell
25) Bond Description 26) Issuer Description
Pages
11) Bond Info
12) Addtl Info
13) Reg/Tax
14) Covenants
15) Guarantors
16) Bond Ratings
17) Identifiers
18) Exchanges
19) Inv Parties
20) Fees, Restrict
21) Schedules
22) Coupons
Quick Links
32) ALLQ Pricing
33) QRD Qt Recap
34) TDH Trade Hist
35) CACS Corp Action
36) CF Prospectus
37) CN Sec News
38) HDS Holders
66) Send Bond
Issuer Information
Name FREEPORT-MCMORAN INC
Industry Metals and Mining (BCLASS)
Security Information
Mkt Iss Global
Country US Currency USD
Rank Sr Unsecured Series
Coupon 5.250000 Type Fixed
Cpn Freq S/A
Day Cnt 30/360 Iss Price 100.00000
Maturity 09/01/2029
MAKE WHOLE @50.000000 until 09/01/24/ CALL ...
Iss Sprd +335.00bp vs T 2 ⅜ 05/15/29
Calc Type (1)STREET CONVENTION
Pricing Date 08/01/2019
Interest Accrual Date 08/15/2019
1st Settle Date 08/15/2019
1st Coupon Date 03/01/2020
Identifiers
ID Number AZ9096621
CUSIP 35671DCD5
ISIN US35671DCD57
Bond Ratings
Moody's Ba1
S&P BB
Fitch BB+
Composite BB
Issuance & Trading
Amt Issued/Outstanding
USD 600,000.00 (M) /
USD 600,000.00 (M)
Min Piece/Increment
2,000.00 / 1,000.00
Par Amount 1,000.00
Book Runner JOINT LEADS
Reporting TRACE


FCX 5 ¼ 09/01/29 $↑102.706 -.496 102.401 / 103.012 4.848 / 4.748
As of 25 Jun --x-- Source BVN4
FCX 5 ¼ 09/01/29 Corp Settings Actions Page 11/12 Security Description: Bond
94) No Notes 95) Buy 96) Sell
25) Bond Description 26) Issuer Description
Pages
11) Bond Info
12) Addtl Info
13) Reg/Tax
14) Covenants
15) Guarantors
16) Bond Ratings
17) Identifiers
18) Exchanges
19) Inv Parties
20) Fees, Restrict
21) Schedules
22) Coupons
Quick Links
32) ALLQ Pricing
33) QRD Qt Recap
34) TDH Trade Hist
35) CACS Corp Action
36) CF Prospectus
37) CN Sec News
38) HDS Holders
66) Send Bond
Schedules
Call Schedule
Call with minimum 30 days notice
Callable on and anytime after date(s) shown
Date Price
09/01/2024 102.625
09/01/2025 101.750
09/01/2026 100.875
09/01/2027 100.000


OPTION-ADJUSTED SPREAD ANALYSIS
FREEPORT-MCMORAN FCX5 ¼ 09/01/29 102.401/103.012 (4.848/4.748) BVN4
Calculate (P,O,V) O
Price P) 103.0120
OAS (bp) O) +412.6
Volatility V) 76.76
2) Customize
Curve CMT Semi
Const. Mty Tsy Cu
Dated 6/26/2020
Settle 6/30/2020
Cusip / ID# 35671DCD5 Option Px Value: -1.14
Settle 6/30/2020 Bench settle 6/30/2020 Vega: 0.00
Spread 435.4bp vs 7Y T 0 ½ 06/30/27 Govt @100-3+ (0.484)
Shift +0(bps)
Yield Spread
{NUM}<GO> for:
3) Call Schedule
Make whole provision ignored
OAS Method | Option Free | To Call on 9/ 1/2024 | To Mty
Yld 4.687 5.012 4.838
Sprd 408.6 476.3 423.8
M Dur 6.31 3.66 7.13
Risk 6.61 3.83 7.47
Cnvx -1.77 0.16 0.62
Model L L=Lognormal
Exercise Premium 0.00
3m 0.135
6m 0.160
1y 0.155
2y 0.166
3y 0.182
4y 0.239
5y 0.297
7y 0.484
10y 0.644
20y 1.151
30y 1.374
88) REFRESH

HISTORICAL OAS

FCX 5 1/4 09/01/29 Page 1/ 11

	Date	Price	OAS	Volatility	Duration	Convexity
Thursday	6/25/20	102.40	420.89	73.	6.50	-1.11
Wednesday	6/24/20	103.00	411.38	73.	6.33	-1.59
Tuesday	6/23/20	103.36	401.37	68.	6.29	-1.64
Monday	6/22/20	104.01	389.62	70.	6.13	-1.98
Friday	6/19/20	104.08	389.55	70.	6.09	-2.12
Thursday	6/18/20	104.21	386.52	70.	6.07	-2.14
Wednesday	6/17/20	104.48	381.10	69.	6.01	-2.28
Tuesday	6/16/20	104.89	372.53	65.	5.93	-2.44
Monday	6/15/20	103.92	389.09	64.	6.19	-1.84
Friday	6/12/20	103.92	391.94	69.	6.17	-1.96
Thursday	6/11/20	103.13	407.36	71.	6.37	-1.51
Wednesday	6/10/20	105.64	360.53	65.	5.70	-3.02
Tuesday	6/ 9/20	105.61	350.64	58.	5.92	-2.06
Monday	6/ 8/20	106.73	327.63	56.	5.71	-2.28
Friday	6/ 5/20	106.21	332.90	55.	5.91	-1.76
Thursday	6/ 4/20	105.79	348.32	58.	5.88	-2.19
Wednesday	6/ 3/20	105.82	353.26	65.	5.77	-2.61
Tuesday	6/ 2/20	105.80	357.46	69.	5.71	-2.99
Monday	6/ 1/20	104.30	390.30	73.	6.01	-2.62
Friday	5/29/20	102.83	416.77	72.	6.43	-1.58

As of 25 Jun --x-- Source BVN4

AZ909662 Corp | 96) Export | 97) Settings | Page 1/6 Historical Price Table

FCX 5 1/4 09/01/29

Range 08/02/2019 - 06/25/2020 | Period Daily | High 108.642 on 01/16/20

Market Mid Line | Mid YTM | Currency USD | Low 79.914 on 03/24/20

View Price Table | Source BVN4 | Average 101.171 | 5.120

Net Chg 4.300 | 4.37%

Date	Mid Line	Mid YTM	Date	Mid Line	Mid YTM	Date	Mid Line	Mid YTM
Fr 06/26/20			Fr 06/05/20	106.406	4.397	Fr 05/15/20	97.175	5.644
Th 06/25/20	102.706	4.879	Th 06/04/20	106.001	4.449	Th 05/14/20	97.432	5.607
We 06/24/20	103.202	4.813	We 06/03/20	105.973	4.453	We 05/13/20	98.214	5.497
Tu 06/23/20	103.564	4.765	Tu 06/02/20	106.000	4.450	Tu 05/12/20	99.545	5.312
Mo 06/22/20	104.227	4.678	Mo 06/01/20	104.500	4.645	Mo 05/11/20	99.045	5.381
Fr 06/19/20	104.396	4.656	Fr 05/29/20	103.031	4.838	Fr 05/08/20	98.897	5.401
Th 06/18/20	104.447	4.649	Th 05/28/20	103.598	4.764	Th 05/07/20	98.801	5.415
We 06/17/20	104.834	4.599	We 05/27/20	102.106	4.962	We 05/06/20	98.798	5.415
Tu 06/16/20	105.122	4.561	Tu 05/26/20	103.491	4.778	Tu 05/05/20	98.704	5.428
Mo 06/15/20	104.124	4.692	Mo 05/25/20			Mo 05/04/20	97.540	5.591
Fr 06/12/20	104.124	4.692	Fr 05/22/20	102.255	4.943	Fr 05/01/20	97.491	5.598
Th 06/11/20	103.665	4.753	Th 05/21/20	101.508	5.043	Th 04/30/20	99.022	5.384
We 06/10/20	105.895	4.462	We 05/20/20	101.500	5.044	We 04/29/20	98.460	5.462
Tu 06/09/20	105.960	4.454	Tu 05/19/20	98.562	5.448	Tu 04/28/20	96.602	5.724
Mo 06/08/20	106.952	4.327	Mo 05/18/20	98.477	5.460	Mo 04/27/20	95.279	5.914

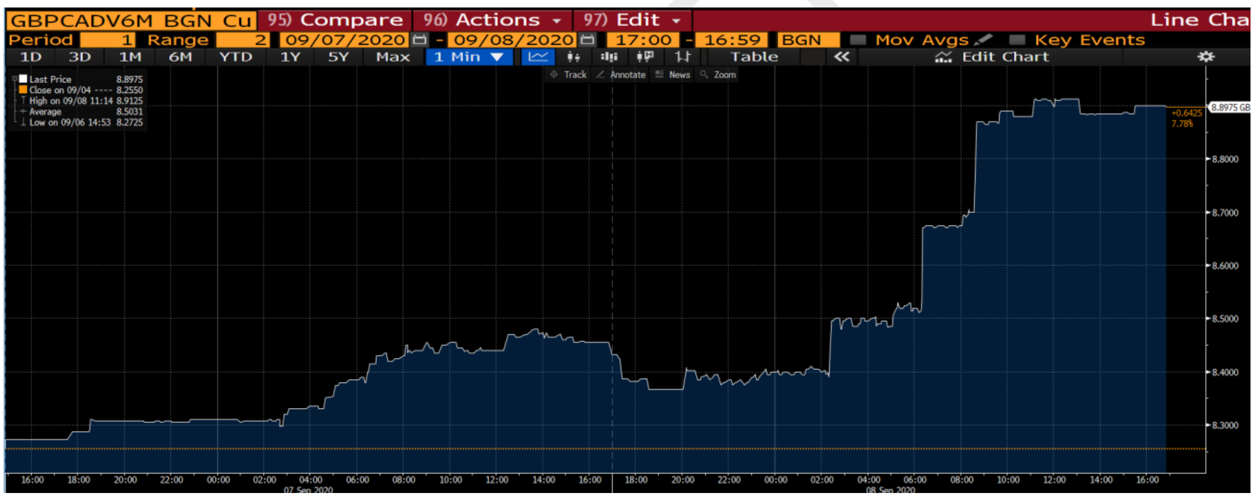
A.5 Implied volatility

Bloomberg calculates implied volatility for FX options and reports them as curves. For example, the implied volatility for the 6-month GBP/CAD currency pair is reported in the GBPCADV6M BGN Curncy Bloomberg curve. The Bloomberg print screen for the curve is illustrated below.

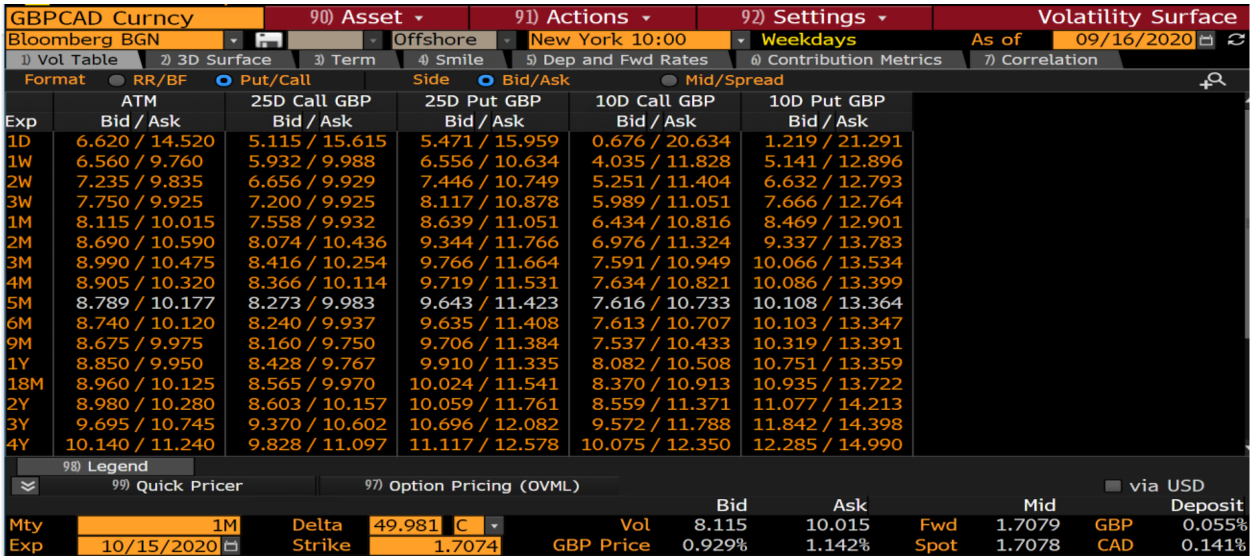
Exhibit A.7 Bloomberg screen for the 6-month GBP/CAD implied volatility

Bloomberg allows to set a custom range of dates and custom period tick starting from 1 minute tick. An illustrative print screen of implied volatility graph for the GBP/CAD pair is illustrated below.

Exhibit A.8 Change in implied volatility over 1-day period using 1 minute tick



Alternatively, FX option implied volatility can be estimated using the following function: **FXIP**> FX options and Volatility> (30) Volatility continuum – Real Vol ® to Future Implied Vol (I) | OVDV. The function output is illustrated below.



GBPCAD Curncy | 90) Asset | 91) Actions | 92) Settings | Volatility Surface

Bloomberg BGN | Offshore | New York 10:00 | Weekdays | As of 09/16/2020

1) Vol Table | 2) 3D Surface | 3) Term | 4) Smile | 5) Dep and Fwd Rates | 6) Contribution Metrics | 7) Correlation

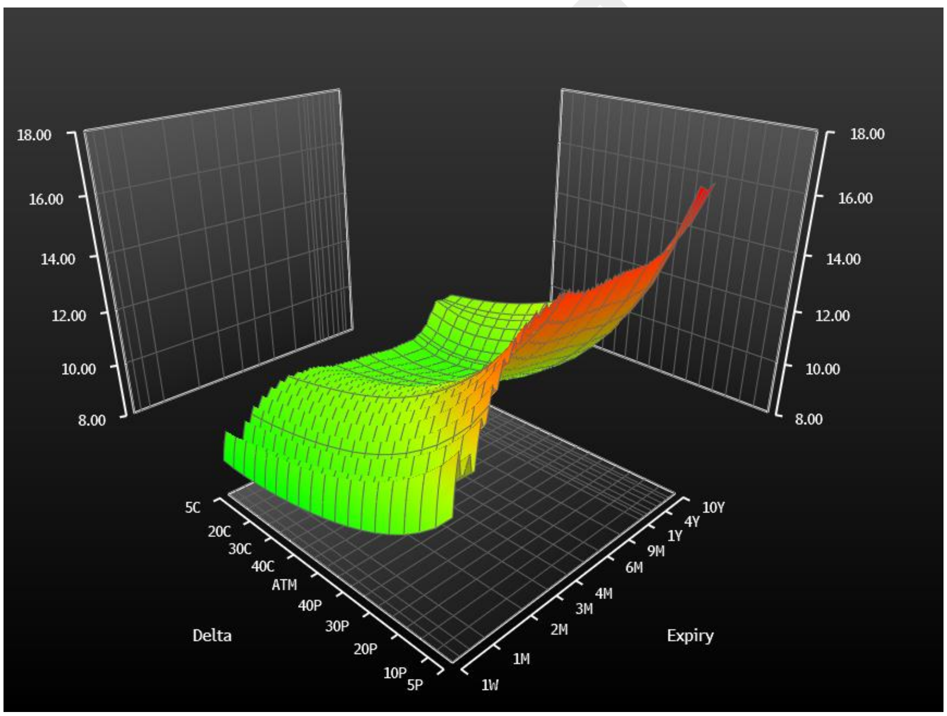
Format RR/BF Put/Call | Side Bid/Ask Mid/Spread

Exp	ATM Bid / Ask	25D Call GBP Bid / Ask	25D Put GBP Bid / Ask	10D Call GBP Bid / Ask	10D Put GBP Bid / Ask
1D	6.620 / 14.520	5.115 / 15.615	5.471 / 15.959	0.676 / 20.634	1.219 / 21.291
1W	6.560 / 9.760	5.932 / 9.988	6.556 / 10.634	4.035 / 11.828	5.141 / 12.896
2W	7.235 / 9.835	6.656 / 9.929	7.446 / 10.749	5.251 / 11.404	6.632 / 12.793
3W	7.750 / 9.925	7.200 / 9.925	8.117 / 10.878	5.989 / 11.051	7.666 / 12.764
1M	8.115 / 10.015	7.558 / 9.932	8.639 / 11.051	6.434 / 10.816	8.469 / 12.901
2M	8.690 / 10.590	8.074 / 10.436	9.344 / 11.766	6.976 / 11.324	9.337 / 13.783
3M	8.990 / 10.475	8.416 / 10.254	9.766 / 11.664	7.591 / 10.949	10.066 / 13.534
4M	8.905 / 10.320	8.366 / 10.114	9.719 / 11.531	7.634 / 10.821	10.086 / 13.399
5M	8.789 / 10.177	8.273 / 9.983	9.643 / 11.423	7.616 / 10.733	10.108 / 13.364
6M	8.740 / 10.120	8.240 / 9.937	9.635 / 11.408	7.613 / 10.707	10.103 / 13.347
9M	8.675 / 9.975	8.160 / 9.750	9.706 / 11.384	7.537 / 10.433	10.319 / 13.391
1Y	8.850 / 9.950	8.428 / 9.767	9.910 / 11.335	8.082 / 10.508	10.751 / 13.359
18M	8.960 / 10.125	8.565 / 9.970	10.024 / 11.541	8.370 / 10.913	10.935 / 13.722
2Y	8.980 / 10.280	8.603 / 10.157	10.059 / 11.761	8.559 / 11.371	11.077 / 14.213
3Y	9.695 / 10.745	9.370 / 10.602	10.696 / 12.082	9.572 / 11.788	11.842 / 14.398
4Y	10.140 / 11.240	9.828 / 11.097	11.117 / 12.578	10.075 / 12.350	12.285 / 14.990

98) Legend

99) Quick Pricer | 97) Option Pricing (OVML) | via USD

					Bid	Ask		Mid		Deposit
Mty	1M	Delta	49.981 C	Vol	8.115	10.015	Fwd	1.7079	GBP	0.055%
Exp	10/15/2020	Strike	1.7074	GBP Price	0.929%	1.142%	Spot	1.7078	CAD	0.141%



A.6 SDRV tool

The SDR Derivative volumes (SDRV) tool shows the individual FX options, swaps, CDS and other derivative contracts traded in the OTC markets. The print screen for the GBP / CAD vanilla options is illustrated in the print screen below.

Exhibit A.9 A sample of individual FX option contracts

Source DTCC | Period Custom 09/10/20 – 09/16/20

1) Credit | 2) Rates | 3) FX | 4) Comdty | 5) Equity

11) Options | 12) NDF

	Underlying	Type	Strike	Expiry	Notional	Curr	Premium	Curr	Style	Code	Clr	Trd Time
	GBP CAD											
1.	GBP CAD Vanilla Option	C	1.78	12/18/20	5	GBP	22,550.56	GBP	EU	TR	U	09/16 12:1
2.	GBP CAD Vanilla Option	P	1.63	12/18/20	5	GBP	29,475.00	GBP	EU	TR	U	09/16 12:1
3.	GBP CAD Vanilla Option	C	1.78	12/18/20	5	GBP	28,951.69	GBP	EU	TR	U	09/16 12:0
4.	GBP CAD Vanilla Option	P	1.63	12/18/20	5	GBP	32,265.00	GBP	EU	TR	U	09/16 12:0
5.	GBP CAD Vanilla Option	C	1.7455	02/10/21	30	GBP	384,004.59	GBP	EU	TR	U	09/15 12:3
6.	GBP CAD Vanilla Option	C	1.817	02/10/21	61	GBP	240,946.61	GBP	EU	TR	U	09/15 12:3
7.	GBP CAD Vanilla Option	P	1.68	10/23/20	20	GBP	184,800.00	GBP	EU	TR	U	09/15 11:5
8.	GBP CAD Vanilla Option	C	1.81	03/15/21	2	GBP	15,679.56	GBP	EU	TR	U	09/15 04:5
9.	GBP CAD Vanilla Option	P	1.55	03/15/21	2	GBP	12,950.00	GBP	EU	TR	U	09/15 04:5
10.	GBP CAD Vanilla Option	C	1.81	03/15/21	7	GBP	39,359.12	GBP	EU	TR	U	09/15 04:3
11.	GBP CAD Vanilla Option	P	1.55	03/15/21	7	GBP	35,210.00	GBP	EU	TR	U	09/15 04:3
12.	GBP CAD Vanilla Option	P	1.653	03/08/21	20	GBP	374,000.00	GBP	EU	TR	U	09/11 09:0
13.	GBP CAD Vanilla Option	C	1.74	12/11/20	2	GBP	13,965.52	GBP	EU	TR	U	09/11 06:2
14.	GBP CAD Vanilla Option	P	1.61	12/11/20	2	GBP	15,110.00	GBP	EU	TR	U	09/11 06:2
15.	GBP CAD Vanilla Option	C	1.74	12/11/20	7	GBP	50,758.62	GBP	EU	TR	U	09/11 05:3
16.	GBP CAD Vanilla Option	P	1.61	12/11/20	7	GBP	48,860.00	GBP	EU	TR	U	09/11 05:3
17.	GBP CAD Vanilla Option	C	1.79	03/11/21	5	GBP	44,798.88	GBP	EU	TR	U	09/10 05:5
18.	GBP CAD Vanilla Option	P	1.63	03/11/21	5	GBP	48,400.00	GBP	EU	TR	U	09/10 05:5

The tool reports the following information: type of the option (put / call); underlying FX notional amount, option strike price, option expiry date, option premium, option style (European / American), option exercise time. The tool shows instruments for one-month period only. The transactions data can be exported into an Excel file.

Appendix B Implementation of Lease Residual Value Risk Model

The lease model was presented in Section 2 and the risk-neutral probabilities and lease derivative prices were derived in Appendices B and C. In this section, the implementation of the lease valuation model is discussed in more detail. The discussion covers all steps starting from the data required for the model estimation (and respective data request to the client) and ending with the results presentation that are provided to the client.

B.1 Modelling background

The buyer of the residual value risk reimbursement contract owns a portfolio of assets which are leased to third-party lessees. The buyer projects a residual value of the asset at the end of each lease contract. The residual value determines the monthly fee charged in the lease contract. The buyer is exposed to the residual value risk in the event if the actual residual value is below the projected expected value.

The risk exposure is hedged by entering into the residual value risk reimbursement contract with the contract seller. The hedging contract specifies the strike price (e.g. 90% of the expected residual value) such that any decrease of the residual value below the strike price is compensated by the contract seller. The premiums are paid by the contract buyer on an annual basis. The contract may be rolled over (including the update of the contract premiums) on an annual basis.

B.2 Data

Requesting data is the first step required before the analysis can be started. The objective of the step is to ensure that the required data is available and is reviewed for missing or incorrect information.

B.2.1 Data request

The following lease data is requested for the valuation analysis:

1. Lease insurance **contract agreement**. The terms of the agreement include
   - Definitions of the projected and actual residual value of the cars
   - Schedule with the projected residual values
   - Reference to the methodology for the actual residual value estimation[7]
   - Strike price for the lease insurance claims
2. Individual **contract data**. The data includes for each specific car lease contract the following information
   - Car type, build year, purchase year, and purchase price
   - Lease issue date, termination date, monthly rate, and lease factor
   - Car estimated depreciation schedule and residual value
3. Historical data on lease insurance contract **claims**

[7] The methodology should be requested from the client.

- ► For destroyed cars: the percentage of the destroyed cars in the overall portfolio and salvage values of the destroyed cars
- ► For terminated leases, the residual car value as of the lease termination date

4. **Market data**. The following additional data is necessary or recommended for the valuation model
   - ► Market risk-free rates
   - ► Market price data for the leased cars. Market data for individual car types are generally not publicly available but may be requested from the client who may maintain a database with the price information obtained through catalogues or other sources.

B.2.2 Lease insurance contract

The contracts are referred to as “Residual Value Risk Reimbursement” contracts.

Background

The contract background summarizes the following key facts: (i) the lease payments depend on the projected residual value of the underlying car assets; (ii) the lessor is exposed to the residual value risk: in the event that the actual market value of the car at the lease termination date is below the projected residual value, the lease payments do not fully compensate for the loss in the car value. As a result, the lessor incurs losses in the lease contract.[8] The purpose of the lease insurance contract is to protect the lessor against the residual value risk exposure.

The contracts typically include the following definitions and terms.

Definitions

- ► Seller and Buyer full legal name
- ► Trade / effective date: the lease insurance issue / amendment date
- ► Projected Residual Value (V^R) is specified in the agreement schedule
- ► Strike Price (K) is calculated as a given percentage (s) of Projected Residual Value: $K = s \times V^R$
- ► Actual Residual Value (V^A) is assigned to the car at the end of the lease and is calculated as follows:[9]
  - ► The NPV of the lease cash flows over the car remaining useful life is estimated by the lease insurance Buyer
  - ► If the Seller and the Buyer disagree on the estimated actual residual value, the parties get the appraisal from a third-party to which they both mutually agree
  - ► If the parties disagree on the appraisal, they follow the dispute resolution process.

---

[8] Note that the risk exposure is two-sided: the market value of the car on the lease termination date may be above the projected residual value. In this case, the lessor obtains an additional gain from the car residual value.

[9] Note that the definition of the Actual Residual Value assumes that the car is not traded in the market and the direct market value of the car is not available.

Terms

- ► Reimbursement Payout value is calculated as the difference between strike price (e.g. 90% of V^R) times the Projected Residual Value and Actual Residual value or zero (whichever is greater):

$$P = \max[0, s \times V^R - V^A]$$

- ► Request for Risk Reimbursement Payout is provided within a specific period and shall be supported by the documentation with the Actual Residual Value appraisal
- ► Premiums and Payment Terms. The Premiums (F) paid by Buyer to Seller are specified in the agreement schedule. Premiums are calculated as a percentage (f) of the Projected Residual Value and are allocated annually (on XXX date of each year) on a straight-line basis (consistently with the Projected Residual Value depreciation schedule)

$$F = f \times V^R$$

- ► Car Additions. New cars are added automatically to the portfolio covered automatically by the insurance contract. The applicable premiums are calculated as per the agreement premium schedule. Upon the addition of new cars, the Seller has a specific period to object to the new cars addition to the portfolio covered by the insurance contract.
- ► Lease Termination Terms. The lease insurance agreement is terminated in the even if (i) one of the parties becomes insolvent; (ii) one of the parties undergoes xx% change in ownership; or (iii) the Buyer disposes from xx% of the portfolio assets within a calendar year.[10]

B.2.3 Data review and transformation

The provided data on individual lease contracts typically needs to be reviewed and transformed to be applied in the valuation model. The following steps are typically performed to present the data in the appropriate format.

1. Data reduction. Typically, the data set includes a significant amount of redundant information which is not relevant for the valuation purposes. The data set is reviewed to ensure that all necessary fields are present and then the data set is reduced to include only necessary fields. The fields are listed in Appendix E.1.1.
2. Data aggregation. The data set often includes multiple records of effectively identical leases. An identification label is created for each specific contract type and the leases are grouped based on the identification label. The id can be built, for example, as a combination of the following fields:
3. lease id = (car type, lessee id, car build date, car purchase date, lease termination date, lease monthly fee)
4. Data screening. Some lease contracts may have missing fields (which are required for lease valuation) or the field values result in inconsistent pricing.[11] The contracts should be screened to remove the outliers from the valuation model. The contracts should be reviewed and discussed with the client separately to identify the source of values inconsistency.

[10] Formally, the agreement should specify the payouts in the event of assets disposal and termination of the respective insurance contracts. In the absence of such terms, it is either assumed that the payouts are zero or the payouts are estimated based on the residual value of the insurance contracts.

[11] The data should be screened for (i) missing fields values; (ii) zero (or small) car purchase price values; (iii) zero (or small) lease monthly fee values.

After performing the steps above, a data set is created which is used to estimate the parameters of the residual risk valuation model.

B.3 Modelling approaches

Based on the analysis of the insurance claims, the selected modelling approach can be broadly classified either as a (i) CDS approach or (ii) as a Black-Scholes approach.

1. **CDS approach** should be selected whenever the insurance claims are consistent with the evidence that the primary risk which triggers the insurance claims is the destruction of the lease assets. Under the approach, the value of the asset is modelled as a binary process with the states corresponding to destroyed / non-destroyed asset.
2. **Black-Scholes approach** should be applied whenever the insurance claims are consistent with the evidence that the risk which triggers the insurance claims is related to the continuous depreciation of the lease asset value. The claim is submitted in the event when the actual depreciation is accelerated relative to the expected depreciation resulting in the lease value being below the contract strike price at the lease contract maturity. The continuous stochastic depreciation of the lease asset can be attributable to various factors such as technological risk, market risk, regulatory risk, and other.

Under both the CDS and Black-Scholes approaches, the residual risk reimbursement contract can be priced either as an insurance contract or a derivative contract. The distinction between the two approaches can be summarized as follows.

1. Under the **insurance approach**, the price is derived based on the estimation of the costs and profit margins of the risk reimbursement contract. The costs can be broken down into (i) the costs related to the insurance claims payments (when the insurance event is triggered); and (ii) administrative costs related to issuing, valuation, execution, and monitoring the contracts. The costs and profit margins are estimated based on the analysis of historical financial statements and insurance claims of the tested entities or comparable entities with publicly available market data.
2. Under the **derivative approach**, the price of the residual value risk reimbursement contract is estimated as a derivative of market prices including (i) lease fees and (ii) applicable market risk-free rate. The derivative approach assumes that implied costs and profit margins are incorporated into the lease fees and are respectively derived from the lease fees. More precisely, the residual value risk reimbursement contract is replicated using a portfolio of the lease contract and a risk-free bond and the price is derived based on the replication portfolio.

Implementation of the approach is discussed in detail in the sections below.

B.4 Estimation of model parameters

The objective of the parameter estimation step is to (i) estimate the expected depreciation term structure Λ_t; (ii) estimate the depreciation risk volatility parameter σ; and, if applicable, (iii) to estimate the asset destruction hazard rate $\gamma(s)$.

B.4.1 Approach

Suppose that the following lease portfolio data is available for analysis:

1. The build date and asset (product) type[12] for each lease underlying asset;
2. Each lease contract purchase date and purchase price. Lease purchase price represents the underlying asset residual value effective as of the lease purchase date;
3. Residual value estimation method applied by the lessor;
4. Each lease contract monthly payment and lease factor;
5. Tax rate applicable to the lease contracts.

The parameters can be used to specify the id of each lease contract in the following format:

id = product type – lessee id – build date – purchase date – lease termination date – monthly payment – lease factor.[13]

The **empirical** expected depreciation term structure Λ_t is estimated as follows.[14] The function Λ_t is estimated based on the lease contract purchase date and purchase price information. The purchase date is converted to the asset age value t. The purchase price corresponds to the residual value S_t. The data is constructed for each individual lease and is grouped by the underlying asset type i. The function Λ_t is estimated by performing a fixed-effect panel regression analysis for the $S_{i,t}$, where $S_{i,t}$ is the market residual value of the asset type i with age t. The model specification is based on the following two assumptions:[15]

1. The term structure does not change over time. The model specification uses only the asset age as parameter but not the date when asset was built.
2. The term structure does not change with the asset type. The parameters Λ_t are assumed to be independent of asset type indexed by i.

Based on the estimated lease asset depreciation term structure, implied lease factor is estimated as follows:

$$f = \frac{\frac{F \times (s-t)}{1+\tau} - (S_t - S_s)}{(S_t + S_s) \times (s-t)}$$

Implementation of the approach is illustrated in Appendix E.

B.4.2 Implementation

The valuation formulas presented in Appendices B.4.4 and C.2.4 require the following parameters to be estimated:

1. Risk-free rates

[12] In the case of equipment leasing, the asset type can correspond to different equipment products. For example, in the case of railcar leasing the product types can be different models of tank cars, covered hopper railcars, etc.

[13] The id assumes that all contracts in the portfolio are renewed on the same date (and therefore have the same lease issue date).

[14] An alternative approach is to estimate the **implied** depreciation term structure based on the implied residual value used by the lessor to calculate the lease monthly rate. The lease monthly rate, lease factor, and tax rate are used to estimate the implied residual value applied by the lessor in the monthly rate calculations. The implied depreciation term structure is calculated then based on the implied residual value sample using a fixed-effect panel regression analysis as discussed above. The monthly rate is calculated using the following equation: $F = \left[\frac{S_t - S_s}{s-t} + f \times (S_t + S_s)\right] \times (1+\tau)$. The implied residual value is estimated from the equation as follows: $V_s = \frac{S_t \times (f \times (s-t) + 1) - \frac{F \times (s-t)}{1+\tau}}{1 - f \times (s-t)}$.

[15] Validity of the assumptions is discussed in Katharina Nau, "An Empirical Analysis of Residual Value Risk in Automotive Lease Contracts".

2. Market-based car residual value schedule

Estimation of the risk-free rates is discussed in a separate guide ([reference]). This section presents details of the estimation procedure for the car residual value schedule.

The residual value schedule is estimated based on the following functional form assumption:

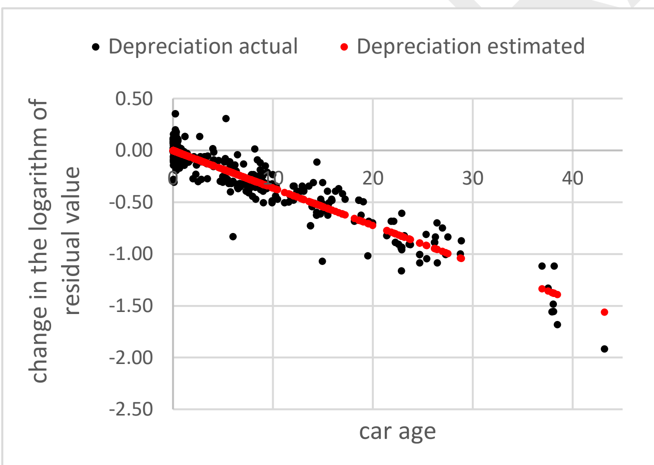
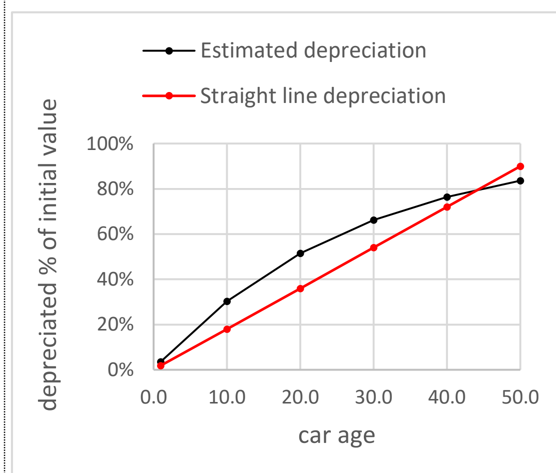
(B.1) $$s_{i,t} = s_{i,0} - \Lambda_t + \sigma W_t$$

where function Λ_t is assumed to have a linear form

(B.2) $$\Lambda_t = \lambda t$$

and $s_{i,t}$ is the natural logarithm of the type i car residual value at age t (and $s_{i,0}$ is the car value at the car build date). The unknown parameters $v_{i,0}$ and λ are unknown parameters estimated using a fixed-effect panel regression model.[16] Results of the regression model estimation are illustrated in the diagram below, where the red line represents the linear downward trend in the logarithm of the residual value ($-\lambda t$) and the black dots represent the sample of actual decreases in the logarithm of the residual value (($-\lambda t + \sigma W_t$). Exhibit below also compares the actual depreciation (estimated based on the data) against the straight-line depreciation (assuming 50-year term and 10% residual value after 50years).

Exhibit B.1 Residual value depreciation schedule

Expected and actual decreases in the logarithm of residual value	Actual depreciation compared to the straight-line depreciation
	

Under the Black-Scholes model specification, the residuals σW_t in the panel data model specification are serially correlated and heteroscedastic ($var\ \sigma W_t = \sigma^2 t$). The exhibit above does not show the increase in the residuals standard error with the increase in the car age. Therefore, the Black-Scholes model needs to be modified to be consistent with the empirical data.

[16] Depending on the data patterns, more complex functional form for the function Λ_t can be selected and tested.

B.5 Residual risk valuation for individual contracts

This section presents the model in which a residual value risk reimbursement contract is issued for each individual lease asset. The portfolio of the residual value risk reimbursement contracts is priced as a sum of individual contract prices.[17]

B.5.1 CDS approach

The CDS approach should be selected whenever the data indicates that majority of residual value risk claims are related to the destruction of underlying lease assets value.

The valuation can be performed using two alternative approaches: insurance approach and derivative approach.

CDS / Insurance approach

Under the insurance approach, the fee is estimated as the sum of the following components:

Fee = Expected Loss + Expense Load + Profit Provision

Each component of the fee is estimated as follows:

1. **Expected Loss**. Expected losses are calculated either (i) based on the client's historical losses and estimation of the respective empirical loss distribution; or, alternatively, (ii) based on the publicly available market historical loss data for comparable lease assets. The empirical loss distribution is estimated on an annual basis and losses are estimated as a percentage of the asset residual value.
2. **Expense Load**. The Expense Load encompasses the costs of doing business incurred by the insurer as a result offering such coverage. The cost includes the following components: production expenses (e.g., marketing expenses, broker/agent fees); general expenses (e.g., personnel, systems costs); other administrative expenses (i.e., miscellaneous expenses not covered elsewhere); and taxes, licenses and fees. The Expense Load can be estimated either based on the historical financial statements of the insurer / guarantor (if available) or based on the market financial data of the companies which perform similar functions.
3. **Profit Provision**. The profit margin is estimated either (i) based on the value-at-risk (VaR) analysis as a compensation for the insurer's capital balances required to guarantee that the insurance claims will be paid when due; or (ii) based on the transfer pricing analysis of profit margin estimated based on the market profit margin data estimated using a sample of comparable companies.

Structuring and valuation of the contract as an insurance contract should take into consideration that the seller of the contract may be required to meet the regulation requirements of an insurance company (for example, it may be required to have adequate capitalization).

CDS / Derivative approach

Under the CDS approach, the lease residual value risk reimbursement contracts are modelled similar to the amortized bond CDS contracts. Derivative approach is based on arbitrage-free prices which incorporates both the expected cost and profit components into the derivate price. Similar to the insurance approach, the derivative approach estimates the value of the reimbursement contract based on the hazard

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[17] In the following section, the pricing approach is presented for the case when a single residual value risk reimbursement contract is issued for the whole portfolio of lease assets.

rate of the asset destruction. Unlike the insurance approach, the implied hazard rate is derived from the lease market fees and not from historically observed asset destruction hazard rates.

The steps of the valuation approach are summarized as follows:

1. **Valuation date**. The market lease fee is observed only at the lease **issue date**. Therefore, the price information is available only as of the lease issue date.
2. **Lease fee adjustment**. The lease periodic monthly fee is adjusted for the operational cost to produce equivalent amortized bond periodic payments. The cost-adjusted lease fee in interpreted as the sum of (i) lease asset amortized value and (ii) interest payment on the leased asset;

   $$D_0 = F \times m^{op}$$

3. **Lease asset amortization (λ)**. Amortization schedule is estimated based on the historical panel regression data of the underlying asset residual values. Annual amortization is estimated as a percentage of the asset residual value:

   (B.3) $$v_t = v_0 - \lambda t + \sigma(t) \times W_t$$

   where $v_t = \ln V_t$ and V_t is the residual value of the asset with age t.

   Alternatively, amortization schedule is estimated assuming straight-line depreciation of the asset. The straight-line depreciation assumes a given (50-year) useful life of the asset (starting from the date when the asset was built) and a given residual value of the asset at the end of the useful life (e.g. 10% of the asset initial value). The asset initial value is estimated as the purchase price at the date when the asset was purchased.[18]

4. **Implied lease interest rate ($\boldsymbol{i}$)**. The cost-adjusted lease fee is converted into the implied interest rate by decomposing the fee into the amortized value and interest components:

   (B.4) $$S_0 = S_0 \times e^{-dT} + D_0 \times \frac{1 - e^{-i \times \frac{n+1}{12}}}{1 - e^{-i \frac{1}{12}}}$$

   where d is implied dividend rate; $i = d - \lambda$ is the implied lease interest rate; and n is the number of fixed monthly dividend payment over the term of the lease.

5. **Implied premium ($\boldsymbol{f}$)**. The implied premium is estimated as a difference between implied interest rate and risk-free rate (or group refinancing rate in the case of the intercompany lease derivatives. The group refinancing rate is used to adjust for the counter-party risk).

   (B.5) $$f = (i - r) \times \frac{k - \alpha}{1 - \alpha}$$

   where parameter r represents a one-year risk-free (or group refinancing) rate, k is the strike price parameter (represented as a percentage of the residual value); and α is the recovery rate parameter.

6. **Contract roll-over**. The derivative contracts are rolled-over and re-priced on an annual basis. The destroyed lease assets are removed from the portfolio and the insurance claims are settled. The

[18] Note that in many cases the asset purchase date is different from the asset's built date and the asset purchase price already includes asset depreciation that accumulated from the asset built date.

fee f is applied to all remaining contracts in the portfolio.[19] The effective maturity of each derivative contract is assumed to be **one year**. Therefore, a one-year risk-free (group refinancing) rate is applied in the premium estimation

The model parameters can be grouped as follows:

1. Parameters F (lease monthly fee), k (strike price), and T (lease term) are specified by each lease contract or residual risk reimbursement contract;
2. Parameter m^{op} is estimated from the lessor historical financial statements;
3. Parameter λ is estimated based on the panel regression model for the lease asset residual value data;
4. Parameter r is estimated as follows:
   - ► If r represents risk-free rate, then it is estimated based on the respective risk-free indices;
   - ► If r represents group refinancing rate, then it is estimated based on the interest benchmarking analysis performed for the group (or risk reimbursement contract seller).
5. Parameter α is estimated based on the observed historical recovery rates of the destroyed assets. By default, $\alpha = 0$;
6. Parameter i is estimated as implied parameter in equation (B.4);

Illustrative results of the approach implementation for an actual portfolio of railcar leases are provided below.

[results]

B.5.2 Black-Scholes approach

The Black-Scholes approach should be selected whenever the data indicates that majority of residual value risk claims are related to the decrease of continuously changing residual value below the contract strike price.

Similar to the CDS approach, the valuation can be performed using two alternative approaches: insurance approach and derivative approach.

Insurance approach

The insurance approach under the Black-Scholes valuation methodology is similar to the CDS / insurance approach. The total fee is presented as a sum of three components described above. The estimation methodology for the Expense Load and Profit Provision components is similar to the methodology described for the CDS / insurance approach.

The expected cost component tis estimated based on the residual value regression model described by the equation

$$s_{i,t} = s_{i,0} - \Lambda_t + \sigma W_t$$

[19] If the estimated fee depends statistically on the residual value (age) of the lease asset or lease maturity term, then the fee is adjusted accordingly for all contracts remaining in the portfolio.

The expected cost for the lease asset i is calculated formally as follows

$$l = E\left[\left(\ln K - v_{i,T}\right)^{+}\right]$$

where K is the contract strike price. The expected loss is normalized then as follows:

$$f^{L} = \frac{e^{l}}{S_0}$$

Derivative approach

Under the BS / derivative approach, steps one to three are the same as under the CDS / derivative approach. The difference starts from step four.

1. **Implied residual value drift parameter**. The implied drift parameter is estimated as follows

   (B.6) $$\mu \rightarrow = -\left(\lambda + (i - r) + \frac{\sigma^2(T)}{2T}\right)$$

   where $d = \lambda + i$ is implied dividend parameter, which is estimated from the following equation:

   (B.7) $$d = \frac{D_0}{T \times S_0} \times \frac{1 - e^{-r \times (n+1)/12}}{1 - e^{-r/12}}$$

   where T is the lease maturity term and $n \times D_0$ is the total lease fee paid during the term of the lease contract. Note that the drift parameter is lower than the parameter λ in the BS / insurance approach (assuming that $i - r \geq 0$) and, therefore, it can be interpreted as that the parameter includes both the cost and profit components;

2. **Volatility parameter**. The implied volatility function $\sigma^2(T)$ is estimated from the linear regression model (c.4.1);

3. **Put option price**. The value of the put option is estimated as

   (B.8) $$V^{put} = -N(-d_1) \times Se^{-dT} + N(-d_2) \times Ke^{-rT}$$

   Where parameters d_1 and d_2 are estimated as follows

   (B.9) $$\begin{cases} d_1 = \dfrac{1}{\sigma(T)} \times \left[\ln\dfrac{S}{K} + (r - d)T + \dfrac{\sigma^2(T)}{2}\right] \\ d_2 = d_1 - \sigma(T) \end{cases}$$

4. **Contract roll-over**. In the case of Black-Scholes model, the strike price is typically set as of the lease termination date and, therefore, rolling and re-pricing the reimbursement contracts on an annual basis is inconsistent with setting the strike price at the contract maturity. Re-pricing of the residual risk reimbursement contract requires also the annual re-evaluation of the underlying lease asset.

The model parameters can be grouped as follows. Parameters in groups (i) – (iv) are the same as in the CDS / derivative approach. Other parameters are grouped as follows:

1. Parameter d is estimated based on the equation (B.7);
2. Volatility function $\sigma^2(T)$ is estimated based on the panel regression model (together with parameter λ);
3. Parameter S_t is provided by the client. Alternatively, parameter S_t is calculated using (i) straight-line depreciation $S_t = S_0 - \delta t$ (where δ is depreciation parameter[20]); or (ii) expected market depreciation $S_t = S_0 e^{-\lambda t}$.

Illustrative results of the approach implementation for an actual portfolio of railcar leases are provided below.

[results]

B.5.3 Mixed CDS / Black-Scholes approach

B.5.4 Summary of the residual risk valuation modelling

A high-level summary of the valuation approach can be described as follows.

Selection of the approach

1. The are two alternative approaches to the residual risk hedging valuation: insurance approach and derivative approach;
2. The derivate approach estimates the price of the risk reimbursement contract as a derivative of the lease market fee (lease market price).
3. The derivative approach can be implemented either as a (i) CDS model or as a (ii) Black-Scholes model;

CDS approach

1. CDS approach assumes that the insurance event is triggered whenever the underlying asset is destroyed. The lease CDS model can be viewed as similar to the amortized bond CDS model. The equivalence of the two models can be presented as follows:
   - The destruction of the underlying asset is interpreted as a default on the bond. Therefore, the residual value risk is interpreted as the default risk when the underlying asset is destroyed;
   - The depreciation of the lease asset corresponds to the amortization of the bond;
   - Periodic lease fee includes two components: interest payment and the asset amortization payment.

[20] In general case, δ is calculated as $\delta = \frac{S_0 \times (1-\rho)}{T_{life}}$, where S_0 is the price of the asset at the date when it was acquired, T_{life} is expected remaining life of the asset (e.g. 50 years after the asset was built); and ρ is the residual value of the asset after the end of the expected life (e.g. 10%).

2. There are certain differences between the lease CDS and amortized bond CDS models, which result in models' implementation differences:

   - Lease management includes certain operational costs. Therefore, the lease fee includes not only the profit margin which compensates for the time value of money and lessee default / asset destruction risk but must also compensate for the operating costs (equivalent of admin fee in bonds);
   - The lease depreciation schedule is random unlike the bond amortization schedule. There are different approaches to model lease depreciation schedule (e.g. assume straight-line depreciation or estimate the depreciation based on market data);
   - The terms of an amortized bond transaction include both the bond amortization schedule and bond interest rate. The terms of the lease agreement include the periodic lease fee which must be decomposed into the lease depreciation and interest components. Decomposition of the lease fee into two components is part of the analysis and the results of the analysis depends on the lease depreciation modelling approach.

3. Under the CDS approach, the periodic premium is calculated using the following equation

$$f = k \times (i - r)$$

   where k is the strike price quoted as percentage of the asset residual value, i is the implied interest rate (estimated from the lease fee decomposition), and r is either the risk-free rate or the rate applicable to the 'insured' asset. In the latter case, the rate r models the counter-party default risk (which includes both the lessee default risk and the risk reimbursement contract seller default risk). In the case of the amortized bond transaction, i represents the bond yield rate.[21]

Black-Scholes approach

1. Black-Scholes approach assumes that the insurance event is triggered whenever the underlying asset is depreciated at accelerated rate than expected. The approach assumes continuous changes in the asset residual value (and, therefore, does not account for the asset destruction probability);
2. The Black-Scholes application to the lease asset residual value model can be implemented as a standard Black-Scholes model with implied dividend rate estimated based on the lease fee payments;
3. The asset depreciation empirical data is consistent with the geometric rate of reduction in the asset value and, therefore, consistent with the geometric Brownian motion.[22] The volatility of the residual value does not show the linear increase $\sigma(T) = \sigma^2 \times T$ over time. Therefore, the $\sigma^2 \times T$ term in the Black-Scholes equation should be replaced with a generic $\sigma(T)$ value estimated from the residual value regression model;
4. The risk-neutral expectation of the residual value percentage change in the Black-Scholes model can be presented as follows:

$$\mu \rightarrow= -\left(\lambda + (i - r) + \frac{\sigma^2(T)}{2T}\right)$$

[21] In a standard CDS model with no counter-party risk, r represents risk-free rate. In the model with the counter-party risk, r represents the interest rate applicable to the guarantor.

[22] The geometric Brownian process assumption for the asset value is one of the key assumptions in the Black-Scholes model.

where λ is expected asset depreciation rate and i is implied interest rate. The risk-neutral parameter μ depends only on the implied dividend rate $d = \lambda + i$ and does not depend on a specific decomposition of the dividend rate into the asset depreciation rate and interest rate.

5. The put option value under the Black-Scholes approach is described by equations (B.8) and (B.9).
6. To apply the Black-Scholes equations, the market residual value S_t must be estimated as of the residual risk reimbursement contract valuation date (by default, the S_t can be estimated using straight-line or depreciation schedule or the schedule estimated from the regression model). For consistency with the Black-Scholes modelling approach, the maturity term of the contract should be set equal to the lease termination date[23].

B.6 Residual risk valuation for a portfolio of contracts

[23] The contract not rolled over and re-priced on the annual basis.

Appendix C ac.finance.* option pricing tools

C.1 ac.finance.BSM

C.2 ac.finance.APM

The objective of the ac.APM tool is to implement the models presented in this guide. Numerical implementation of the models allows to select flexibly modelling parameters and produce model specifications which do not have simple analytical solutions.

C.3 Overview

The models simulated by the ac.APM tool are similar to the interest rate models (implemented by the ac.SRM tool). The tool models stochastic processes with a one-dimensional space of process states. The model is a specific case of the one-dimensional controlled Markov process.

There are two key differences of the ac.APM tool from the ac.SRM tool and general Markov processes.

1. The ac.APM models both (i) the value of the underlying asset and (ii) the value of the derivative instrument. The tool allows to assess the impact of the changes in the parameters of the underlying asset (e.g. change in the dividend payout ratio) on the value of the derivative contract;
2. The ac.APM tool estimates risk-neutral probabilities as part of the derivative contract modelling. Estimation of the risk-neutral probabilities requires that the market completeness requirement is satisfied (number of modelled assets equals to the number of states).

To summarize, the ac.APM tool is implemented using the following principles:

1. The tool assumes market completeness (by default, two assets and two states in each period of time);
2. The tool assumes existence of the risk-free asset with continuous rate of return $r \times dt$;
3. The tool derives both the underlying asset price and derivative prices;
   - ► The dividend process is specified by the user and the stock price is derived from the dividend process;
   - ► The stock price is modelled directly as a function of an abstract stochastic factor. The process for the abstract stochastic factor is specified by the user;
4. If the asset price is derived from the dividend process, the price is calculated using the contraction mapping principle summarized as follows:
   - ► fix terminal price V_T;
   - ► run backward recursion to estimate prices V_0 at $t = 0$;
   - ► At iteration n, set $V_T^{(n)} = V_0^{(n-1)}$ and re-run the backward recursion until $V_0^{(n)} = V_T^{(n)}$
5. For given estimated price process, estimate risk-neutral probabilities;
6. Estimate derivative prices

C.4 Model inputs

Model inputs include: (i) set of states for a one-dimensional stochastic factor; (ii) transition probabilities for the stochastic factor; (iii) collection of assets and mapping from the stochastic factor state into respective asset price; (iv) dividend function for each asset.

By default, one of the assets in the modelled collection of assets is a risk-free bond which maps each state of the stochastic factor into the bond price as follows: $B_{t+1} = (1 + r) \times B_t$, where r is the risk-free rate. The risk-free bond is modelled automatically by the tool and is not included in the collection of assets specified by the user.

Each process is modelled as a discrete tree (including continuous diffusion processes). In the tree model specification, the number of assets must be equal to the number of states to ensure that market completeness condition is satisfied, and risk-neutral probabilities can be derived from the model specification.[24] Note that risk-neutral probabilities are derived within the tool and not specified by the user.

[24] Note that this approach differs from the default approach in the ac.SRM tool process specification when the interest rate process is described directly by a diffusion process. Diffusion models in the ac.APM tool are explicitly approximated by discrete trees as described in this guide, for example, by the Black-Scholes equations for risk-neutral probabilities. For single-asset case, the tool provides an option to specify the asset price process explicitly as a diffusion process and the tool performs automatically the approximation of the diffusion with the binomial Markov tree.

Appendix D Derivative Markets Overview

This section provides a brief description of how the derivative markets operate by summarizing the content provided in [5] and [7] as well as other sources.

D.1 Risk transfer process

When a bank transacts with a counterparty (in option, forward or spot transaction), the bank will hedge itself in the interbank market with respective product. With the "risk transfer" approach, the transaction price offered to the counterparty is set equal to the mid market price plus pre-agreed risk transfer (execution) spread. The spread premium is added to compensate the bank for the risk taken by the bank to clear the transaction in the market. The mid market price is estimated as of the transaction execution time.

The "clearing" risk is present due to the following reasons:

1. **Execution time**. It may take significant amount of time to clear the transaction.[25] Spot markets can be very volatile. The mid market spot rate moves on a second-by-second basis.
2. **Market liquidity**. Liquidity of the FX markets differs by the currency pair. For example, execution of the GBP/CAD spot trade may require access to both GBP/USD and USD/CAD spot markets. Implied volatility (option) markets are typically not liquid. Transaction timing should be targeted to high market liquidity to reduce the transaction costs.[26] Banks use real-time data and analytics technology to screen for market liquidity conditions and market activity and to identify the time for transaction execution.
3. **Transaction size**. Large transactions have the ability to significantly move the market. **Confidentiality[27]** in large transaction execution is extremely important.[28] A large transaction can be executed either as a single trade or tranched in multiple trades. A spread premium in tranched transactions is smaller but there is a larger execution window and, therefore, a larger risk of spot rates movements.

Typical risk-transfer premium spreads are summarized below.

1. FX spot execution premium: 20-100bps.
2. FX forward execution premium: 1-5bps.
3. FX option execution premium: 1-3% of implied volatility.

Market clearing and settlement is processed by the Depository Trust & Clearing Corporation (**DTCC**), which performs the exchange of securities on behalf of buyers and sellers and functions as a central securities depository by providing central custody of securities. DTCC was established in 1999 as a holding company to combine The Depository Trust Company (DTC) and National Securities Clearing Corporation (NSCC).

[25] A two billion FX deal for major currencies can be executed within one day.

[26] For example, a GBP/CAD spot trade should be executed when both European and North American markets are open.

[27] Confidentiality is key to ensuring smooth execution and limiting information leakage.

[28] Options are executed in trades of less than C$50mln face value per trade in the interbank market with approximately a dozen of dealers. Therefore, large option trade transactions are very difficult to execute.

DTCC automates, centralizes, standardizes, and streamlines processes in the capital markets. Through its subsidiaries, DTCC provides clearance, settlement, and information services for equities, corporate and municipal bonds, unit investment trusts, government and mortgage-backed securities, money market instruments, and **over-the-counter derivatives**.[29] DTCC is the highest financial value processor in the world. DTCC operates facilities in the New York metropolitan area, and at multiple locations in and outside the United States.

D.2 Early termination of hedging contracts

EY also reviewed the ISDA Master Agreement. As stated above, the ISDA Master Agreement is a standardized agreement which governs over-the-counter derivative transactions. The rail residual reimbursement transaction could be effectively viewed as a derivative transaction and the terms outlined by the ISDA Master Agreement could be considered as being comparable to arm's-length terms. The ISDA Master Agreement states the following:

- An additional termination even is specified pursuant to the following: If any "Additional Termination Event" is specified in the Schedule or any Confirmation as applying the occurrence of such event (and, in such even the Affected party or Affected Parties shall be as specified for such Additional Termination Event in the Schedule or such Confirmation)."
- In the event of early termination: "…an amount will be payable equal to the Non-Terminating Party's Loss in respect of this Agreement. If that amount is a positive number, the Terminating Party will pay it to the Non-Terminating Party; if it is a negative number, the Non-Terminating Party will pay the absolute value of that amount to the Terminating Party."

EY identified a United States Tax Court Report (Report) titled "R.V.I. Guaranty Co., Ltd. and Subsidiaries, Petitioner v. Commissioner of Internal Revenue, Respondent" filed on 21 September 2015. A high-level summary of the report is outlined below:

1. RVI, is a residual value insurance provider for vehicles, commercial real-estate and commercial equipment. The Report outlines a court case involving RVI.
2. A portion of the Report outlines many of the terms that are typical to residual value insurance policies.
3. The Report states the following key items:
   - "[Residual value insurance] policies typically called for a single premium payable at inception of the contract. The premiums charged depended on how much risk [the insurer] assumed, i.e., on the magnitude of the gap between the expected residual value and the insured value."
   - "For [the insurer] to have a liability under a contract, the insured had to meet various conditions precedent, e.g., pay the premium, having an ownership interest in the covered property…"
   - If premiums are to be taxed upon receipt, they are to be treated as earned upon receipt.
   - "[Residual value insurance] policies call for nonrefundable premiums…" "An RVI policy will pay out, if at all, on upon lease termination. In certain circumstances – for example, if inflation develops during a long-term lease – the lessor may become confident that the residual value of his leased asset will exceed its insured value at lease termination. To prevent the insured from taking a self-serving "wait and see" attitude in this setting [the lessor] may rationally choose to disallow premium refunds upon mid-stream policy cancelations.

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[29] https://en.wikipedia.org/wiki/Depository_Trust_%26_Clearing_Corporation.

- “The IRS has recognized that there are other types of insurance, such as surety insurance, for which the policy may be made noncancellable and for which the premium therefore is non-refundable.”

Appendix E Examples

This section discusses some real-life hedging projects.

E.1 Deal contingent FX hedging

Suppose that a company (**Parent**) is acquiring a company (**Target**) in a foreign jurisdiction using foreign currency. Acquisition hedging is performed when there is the duration between the acquisition announcement (and price setting) date and the deal closure date is material (at least several months). The Parent is exposed in this case to FX risk when the fund for the acquisition are raised in one currency (e.g. $C) and acquisition price is set in a different currency (e.g. $GBP). The increased FX risk exposure may be due to material political changes that are expected to happen prior to the deal closure (e.g. Brexit).

The objective of the acquisition hedging strategy is to protect against the following risks:

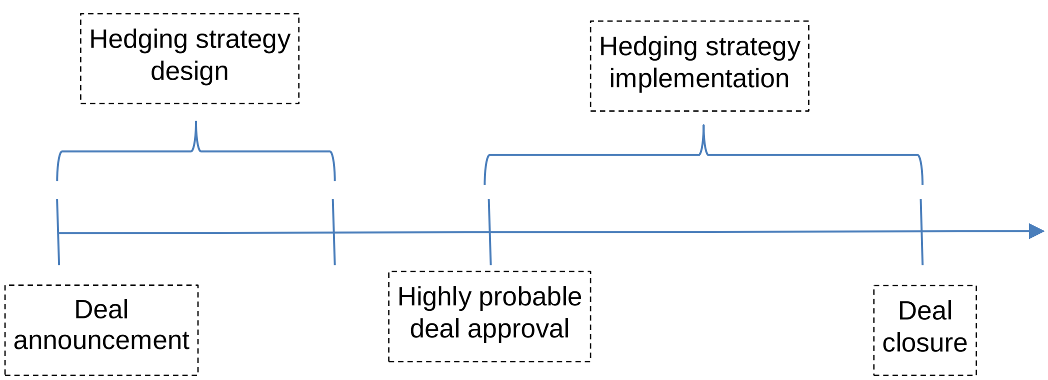
1. Hedging purchase price (**PP**)
2. Hedging book value (**BV**) accounts

This section presents a PP hedging example. The BV hedging example is presented in the next section.

E.1.1 FX hedging timing

The hedging timing is illustrated in the following diagram.

Exhibit E.1 FX hedging strategy timing



E.1.2 FX hedging strategy design

General hedging considerations are summarized in the exhibit below.

Exhibit E.2 General FX hedging strategy considerations

Strategy	Description
Acquisition financing	
Unwind existing hedges	

Strategy	Description
Deal contingent (DC) FX forwards	
FX call option	
FX forward	

A specific feature of acquisition hedging is that the following uncertainties need to be taken into account when designing a hedging strategy:

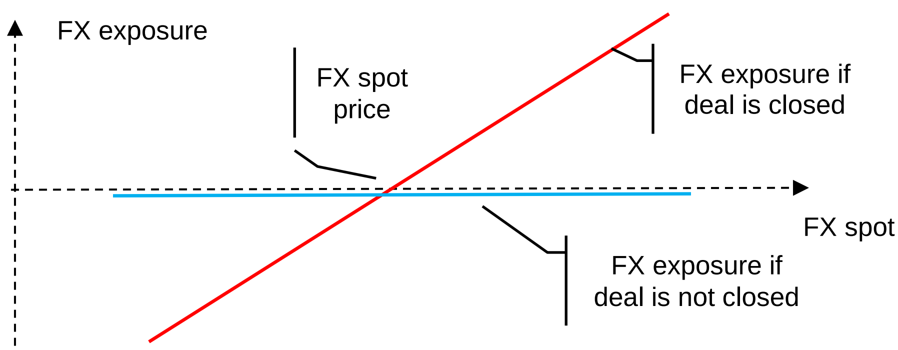
1. Uncertainty in the deal **closure**
2. Uncertainty in the deal **timing**

Then the deal timing uncertainty can be managed by **rolling over** the hedging contract if the deal is still not closed on the hedging contract termination date.

Deal uncertainty is more difficult to hedge and requires an OTC hedging contract with the bank. The problem raised by the deal uncertainty is that a forward contract provides a perfect hedge in the event if a deal closes but creates FX exposure to the Parent if the deal does not go through. Call option resolves partially the deal closure uncertainty since it hedges only the downside risk and regardless of whether the deal closes or not the Parent either receives the positive gain (in the upside scenario) or zero gain (in the upside scenario). However, because of the one-side exposure, the call options are typically expensive to use in hedging. Call option price however can be used as a reference price (upper bound price) for the DC forward since in the DC forward Parent does not have the positive gain in the upside scenario.

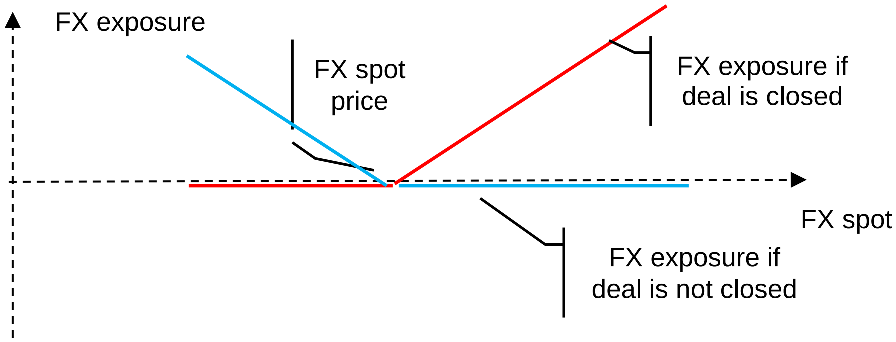
The exposure to the FX risk in the acquisition transaction is illustrated in the diagram below.

Exhibit E.3 FX exposure in the deal contingent transaction



From the Worst Loss risk measure perspective, the optimal hedging strategy which minimizes the risk and is not deal contingent is the FX put option with the ATM FX spot price (strike price is set to current FX spot price). Exposure in the deal contingent transaction hedged by the ATM put option is illustrated in the diagram below.

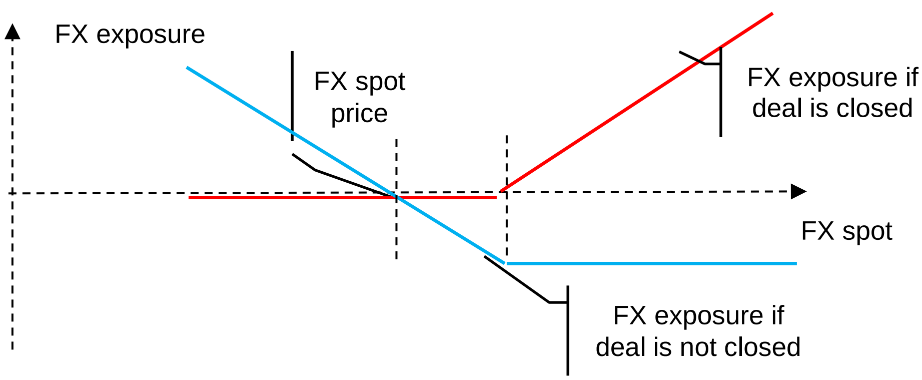
Exhibit E.4 FX exposure in the deal contingent transaction hedged by the ATM put option



The blue line, which shows the exposure in the case if the deal is not closed, also represents the payoff in the put option transaction. Under the hedging strategy, the minimum payoff with respect to deal closed or not closed contingencies is zero for any FX spot price. Therefore, any alternative hedging strategy will only increase the ES risk measure. (Suppose, for example, that the strike price of the put option is set above the spot price $K > S$ to reduce the price of the put option. Then the exposure equal to $S - K$ is created for downward movement in the spot price. The decrease in the put option price does not offset the created $S - K$ exposure.

If risk measure takes into account the probabilities of the deal closure and the probability that the deal will be closed is high, then the hedging costs can be reduced, for example, by selling the bull call spread. The exposure in this case is illustrated in the diagram below.

Exhibit E.5 FX exposure in the deal contingent transaction hedged by the ATM put option



The bull call spread creates exposure when the deal is not closed and reduces potential upside gain when the deal is not closed. On the other hand, it allows to reduce the cost of the hedging strategy. If the probability of the deal closure is assessed as high, then the exposure can be viewed as a reasonable price for the reduction in the hedging cots.

E.1.3 Valuation of a DC forward

As discussed above, a put option is the optimal strategy from the Worst Loss risk measure minimization. However, the put option is an expensive hedging strategy and the Bank can agree to sell a DC forward to hedge the FX price for a fraction of the put option price.

E.2 Book value hedging

Appendix F Technical Comments

In this section we provide some technical integration formulas used in the models described in this guide.

Appendix G References

List of literature references used in the notes is provided below

G.1 Lease valuation and hedging

[1] Literature references on lease valuation and hedging models.

[2] David C. Rode, Paul S. Fishbeck, Steve R. Dean, "Residual Risk and the Valuation of Leases under Uncertainty and Limited Information", Carnegie Mellon Electricity Industry Center, CEIC Working Paper 02-02, 2002[30]

[3] Katharina Nau, "An Empirical Analysis of Residual Value Risk in Automotive Lease Contracts", Dissertation, Hohenheim University, Institute of Financial Management, 2012[31]

[4] Sylvain Prado, "Hedging Residual Value Risk Using Derivatives", working paper, UPX, 2009-31, December 2008[32]

G.2 Derivative pricing

[5] CFA, Level I, Volume 6, "Derivative and Alternative Investments", 2013

[6] DerivativeEngines.com, Real Time Option Calculator, http://www.derivativeengines.somee.com/index-3.asp

[7] Financial Risk Manager (FRM), Part I, "Financial Markets and Products", 2016

[8] Financial Risk Manager (FRM), Part I, Book 4, "Valuation and Risk Models", 2014

[30] The paper is also published as Rode, D., P. Fischbeck, and S. Dean. "Residual Risk and the Valuation of Leases under Uncertainty and Limited Information". Journal of Structured and Project Finance 7:4 (2002): 37-49. Online link to the paper: https://pdfs.semanticscholar.org/c517/301420d394a05698a876adfd74e541504758.pdf

[31] https://core.ac.uk/download/pdf/56707500.pdf

[32] Online link: https://www.researchgate.net/publication/254406042_Hedging_residual_value_risk_using_derivatives