

# FX accumulator

## A technical note

*Handwritten technical notes on a green chalkboard background, covering various physics topics including wave mechanics, optics, thermodynamics, and electromagnetism.*

**Wave Mechanics:**

- $F = -kx$ ,  $k = m\omega^2$ ,  $\omega = \sqrt{\frac{F}{m}}$ ,  $T = 2\pi\sqrt{\frac{m}{k}}$
- $v(t) = \frac{1}{2}kx^2$ ,  $E_{\text{kin}} = v + k$
- $k(t) = \frac{1}{2}m\dot{v}^2$ ,  $v = \frac{dx}{dt}$
- $\phi = mgh$ ,  $b^2 < 4km$  (under damped),  $b^2 > 4km$  (over damped)

**Optics:**

- Polarization:**  $I = I_0 \cos^2 \theta$ ,  $n_1 \sin \theta_1 = n_2 \sin \theta_2$ ,  $\theta_c = \sin^{-1} \frac{n_2}{n_1}$
- Thin Film:**  $2L = (m + \frac{1}{2}) \frac{\lambda}{n}$  (minima),  $2L = m \frac{\lambda}{n}$  (maxima)
- Single Slit Diffraction:**  $a \sin \theta = m\lambda$  (minima),  $I \propto I_m \left(\frac{\sin \beta}{\beta}\right)^2$
- Diffraction Grating:**  $d \sin \theta = m\lambda$  (maxima),  $\Delta \theta_{\text{hw}} = \frac{\lambda}{2d \cos \theta}$  (half width)
- Circular Diffraction:**  $\theta = 1.22 \frac{\lambda}{d}$  (Rayleigh criterion)
- Plane Mirrors:**  $i = -p$ ,  $m = -\frac{i}{p}$

**Thermodynamics:**

- Multi Slab:**  $R_{\text{cond}} = \frac{A(T_1 - T_2)}{\sum \frac{L}{k}}$ ,  $R = 8.31 \frac{J}{mol \cdot K}$
- Heat Capacity:**  $Q = C \Delta T$ ,  $Q = Lm$  (heat of transformation)
- Adiabatic:**  $P_1 V_1^\gamma = P_2 V_2^\gamma$ ,  $T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$
- Equipartition:**  $E = \frac{1}{2} N k_B T$

**Electromagnetism:**

- Capacitors:**  $C = \frac{Q}{V}$ ,  $W = \frac{1}{2} C V^2$
- Resistors:**  $R = \frac{V}{I}$ ,  $P = I^2 R$
- Inductors:**  $L = \frac{\Phi}{I}$ ,  $W = \frac{1}{2} L I^2$

**Other:**

- Logarithms:**  $\log \frac{x}{y} = \log x - \log y$ ,  $\log x^y = y \log x$
- Binomial Expansion:**  $(1+x)^n = 1 + nx + \frac{n(n-1)}{2} x^2 + \dots$

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## Introduction

The higher trade tariffs imposed by the Trump Administration in the United States (US) and their legal fallout have altered the foreign exchange (FX) market fundamentals, leading to greater volatility and negative sentiment.

Given the rapidly changing landscape, investors have been seeking innovative strategies to mitigate the emerging risks and maximise returns.

We believe that the FX accumulator, a structured financial instrument in currency trading, can help counter tariff-related uncertainties.

We describe the product structure, payoff function, commercial backdrop, model test plan, the challenges that could emerge during the testing phase, and the ways to overcome those.

We have sourced and adapted a multitude of handbooks [e.g., (Wystup, 2006; Clark, 2011; Jewitt, 2015)] and open-source materials [e.g., (Wikibanking.Info, 2023; Numerix, 2024; Finpricing, 2025)], as well as leveraged our experience, to prepare this report.

## Objective

To describe the product payoff, risk characteristics and use cases of the FX<sup>1</sup> accumulator, and provide a handbook for traders<sup>2</sup>, model developers<sup>3</sup> and model risk management<sup>4</sup> professionals.

To appreciate the utility of accumulators in the FX markets, the rewards and drawbacks, and to understand how the distinctive features of an accumulator combine to generate a unique product structure.

## Summary

This paper is organised as follows:

- **Section 4** broadly defines the product with illustration and outlines the reasons for selecting the FX accumulator among structured products
- **Section 5** examines the business context for FX accumulators within the fixed-income pool, including their purpose, target clientele, and associated opportunities and limitations
- **Section 6** advances the understanding from Section 4 and presents an in-depth analysis of the key product features and accumulator types, providing a detailed view of their characteristics

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<sup>1</sup> Throughout this paper, the first and second currency of the default FX spot quotation is defined at the currency pair level (CUR1-CUR2), where 1 unit of CUR 1 is exchanged for either some S (FX spot rate) or K (contractual strike rate) units of CUR 2. According to (Clark, 2011), this is the standard FX market quote style. The accumulator contract has an FX fixing schedule: a pre-defined timetable of cash-flow sensitivity dates, on each of which the FX spot rates are published or 'fixed.'

<sup>2</sup> Support with market-making and the entire trade lifecycle of new bespoke and exotic products. These include 24/7 O/N support to traders, trade surveillance and front-office (FO) transformation.

<sup>3</sup> Model development, remediation and enhancement, rationalisation and optimisation, documentation, vendor model deployment, and ongoing monitoring (OM).

<sup>4</sup> Full scope/initial validation; regulation-compliant model validation plan; action plan validation/regulatory remediation; scope or change of validation; and (ongoing) model monitoring review.

- [Section 7](#) builds on Section 6 and explores the theoretical framework of product payoff. This includes a technical examination of the payoff mechanism and the no-arbitrage relationships that govern it, with a focus on the salient features of the product
- [Section 8](#) presents a sample test plan for FX accumulators and summarises the challenges faced by client financial institutions in pricing and risk modelling these exotic products, as well as the consulting we provide to help them navigate these complexities
- The [final section](#) explains our services for client financial institutions in the realm of structured products, highlighting our expertise and capabilities in this area

## Product definition and the reasons for selecting accumulators

An FX accumulator is a structured financial instrument comprising a sequenced bundle of FX forwards or FX options within a single, over-the-counter (OTC) derivative contract. The holder of an FX accumulator contract effectively buys (or sells in the case of a decumulator) a specific number of FX forwards or FX options at periodic intervals, like a strip. Accumulator contracts include a multiplier (gearing condition)—*leverage*—which is often different from one when the underlying FX rate lies within or beyond certain boundary levels. This leverage feature requires investors to accumulate in multiples (e.g., 1.5x or 0.8x) of the traded notional on each FX fixing date<sup>5</sup>. The payout feature of the FX accumulator is exercised periodically on the expiry dates of its constituent forwards or options, with each of these payouts modified by a leverage feature (Clark, 2011; Wystup, 2006; Jewitt, 2015).

Accumulator contracts are bespoke, and the product features are highly customisable to suit the business needs of an investor. With an aim to illustrate this aspect, this document analyses the example of a hypothetical spot starting FX accumulator forward knock-out (KO).

### Use case: FX accumulator forward up and knock-out

This subsection describes the product structure of a hypothetical FX accumulator forward up and knock-out (UKO) with key contract features, traces the generic payoff profile of the product for a spectrum of possible underlying FX rates for a buyer, and depicts the profit and loss (P&L) profile for three exercise dates across the life cycle of the trade. Table 1 summarises the term sheet of the spot starting FX accumulator UKO.

**Table 1: Term sheet summary for the FX accumulator UKO sample**

Contract feature	Specification
Pricing date	July 29, 2025
Trade start date	July 29, 2025
Underlying FX pair (CUR1-CUR2)	EUR-USD
FX spot rate	1.1581 <sup>6</sup>
FX strike rate	1.1400
Fixing frequency	Daily
Number of fixings	125
Maturity or (global) exercise date	January 28, 2026

<sup>5</sup> Cash-flow-sensitive date as per the FX rate publishing schedule in the trade.

<sup>6</sup> 1 EUR = 1.1581 USD. This quotation convention applies to the strike rate, the ranges and the barrier/KO levels presented in Table 1.

Contract feature	Specification
Total traded notional	1 million (M) EUR
Notional per fixing	1M EUR
Low range (low-mid boundary) for FX rate ( $L$ )	0.9000
High range (low-mid boundary) for FX rate ( $H$ )	1.2500
Low leverage factor ( $low$ )	1.0000
Mid leverage factor ( $mid$ )	2.0000
Up leverage factor ( $high$ )	1.5000
Up knock-out (i.e. deactivating upper barrier) level ( $B_L$ )	1.3500
Down knock-out level	Not applicable

The pricing date is July 29, 2025, and the EUR-USD FX spot rate as on the pricing date (the spot date: T+2 business days (BD) in practice) is 1.1581. We will let the contract take 125 daily European Central Bank (ECB) fixings and expire in six months on January 28, 2026. All fixing dates have equal weight in the accumulation of the trade notional. The contract holder gets to buy:

- 8,000 EUR at 1.1400 each day if the EUR-USD fixing is below 0.9000<sup>7</sup>
- 16,000 EUR at 1.1400 each day if the EUR-USD fixing is between 0.9000 and 1.2500
- 12,000 EUR at 1.1400 each day if the EUR-USD fixing is above 1.2500
- The 1.3500 level acts as the de-activating barrier condition, referred to as the knock-out (KO) feature in forward-type accumulators. In the future, if the FX spot rate ever reaches the KO level on the fixing dates, then the accumulation stops, but the client keeps 100% of the accumulated amount

The amount accumulated becomes the notional of the forward contract with the pre-determined delivery date. It is up to the product holder to either keep the product until maturity or unwind the trade and book profit/loss on the NPV.

Figure 1 is a screenshot from the Bloomberg database, which shows the key features of a spot starting EUR-USD FX accumulator forward with up and KO (UKO) barrier level in a template format. The price of this accumulator trade valued via the Black Scholes (BS) model as on July 29, 2025, is 59,653.14 USD.

<sup>7</sup> The contract can be customised with the total accumulated amount set to 1.25 million EUR, should the extreme scenario of all EUR-USD fixing rates falling below 0.9000 materialise. Regardless, in this use case, this clause is not incorporated and does not impact the pricing.

Figure 1: EUR-USD FX forward accumulator KO template in Bloomberg

OVML EURUSD 3L										
Strategy 1		Leg 1		Leg 2		Leg 3				
Price Date	07/29/25 16:01									
Asset	EURUSD		EURUSD		EURUSD		EURUSD		EURUSD	
Spot	Mid	1.1581	1.1581		1.1581		1.1581		1.1581	
Style			Accumulator KO		Accumulator KO		Accumulator KO		Accumulator KO	
Type			Range Inside		One Sided Below		One Sided Above			
Direction	Bank sells	Cash EUR	Bank sells	Cash EUR	Bank sells	Cash EUR	Bank sells	Cash EUR	Bank sells	Cash EUR
Expiry	6 months		6 months		6 months		6 months		6 months	
Delivery	NY 10:00		NY 10:00		NY 10:00		NY 10:00		NY 10:00	
Strike	Forward		1.1400	2.71% ITMF	1.1400	2.71% ITMF	1.1400	2.71% ITMF	1.1400	2.71% ITMF
Notional	EUR		EUR		EUR		EUR		EUR	
Accum. Barrier Dir.	Up & Out		Up & Out		Up & Out		Up & Out		Up & Out	
Accum. Barrier			1.3500		1.3500		1.3500		1.3500	
Upper Barrier			1.2500	7.94% OTMS			1.2500	7.94% OTMS		
Lower Barrier			0.9000	22.29% ITMS	0.9000	22.29% ITMS				
Frequency	Daily		Daily		Daily		Daily		Daily	
Amt. Accum.			0.00		0.00		0.00		0.00	
Start Date			07/30/25		07/30/25		07/30/25		07/30/25	
End Date			01/28/26		01/28/26		01/28/26		01/28/26	
Model			Black-Scholes		Black-Scholes		Black-Scholes		Black-Scholes	
Vol	BGN		7.260%		7.260%		7.260%		7.260%	
More Market Data										
Spread Data										
Vol Spread			0.000%		0.000%		0.000%		0.000%	
Greeks										
Results										
Price	USD pips	298.266 R	265.438 R		0.000		43.770 R			
Premium	USD	59,653.14 R	53,087.64 R		0.00		6,565.50 R			
Margin	USD Cash	0.00	0.00		0.00		0.00			
Prem Date		07/31/25	07/31/25		07/31/25		07/31/25			
T.V.		298.266 R	265.438 R		0.000		43.770 R			
Delta	Spot	-93.5538%	-80.0151%		0.0000%		-18.0516%			
Sticky Delta										
Hedge			1,871,075.38		1,600,302.06		0.00		270,773.31	

It is useful to characterise the FX accumulator trade in terms of its payoff to the purchaser. The payoff is calculated on the exercise date. The following equation shows the formula to calculate the payoff per unit notional ( $v_{ex}$ ).

$$v_{ex} = \text{accumulator function} \times \text{Leverage function} \times \text{Barrier condition indicator}$$

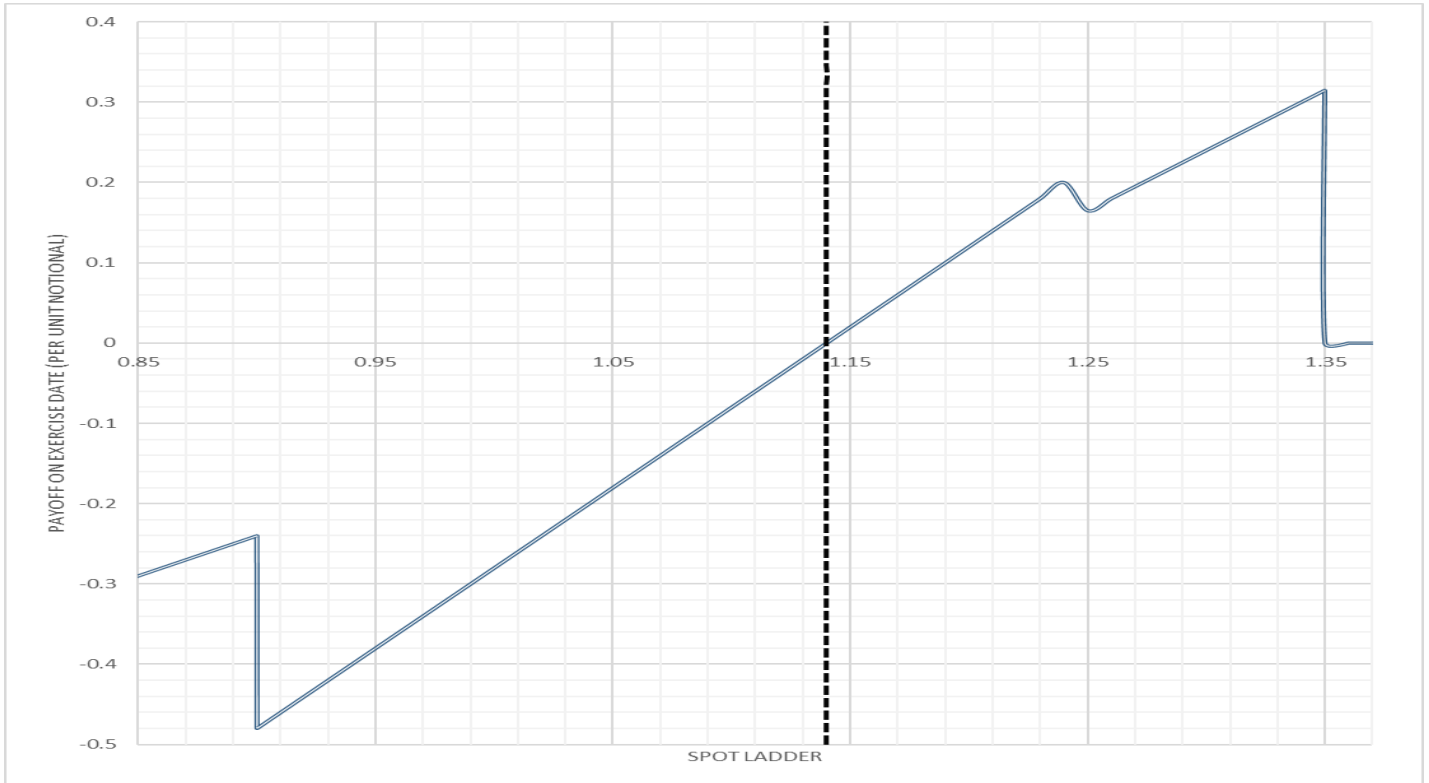
$$v_{ex} = (S_{ex} - K) \times (low \times \mathbb{1}_{S_{ex} < L} + mid \times \mathbb{1}_{L \geq S_{ex} < H} + high \times \mathbb{1}_{S_{ex} \geq H}) \times \mathbb{1}_{S_{ex} < B_L}$$

$\mathbb{1}$  denotes the indicator function, equal to 1 if the condition is satisfied and 0 otherwise. Figure 2 graphs the variations of the buyer's payoff ( $v_{ex}$ ) with the FX spot rate ( $S_{ex}$ ), while Table 2 presents select payoff scenarios.

**Table 2: Scenario analysis for the payoff (per unit notional) to the buyer on the exercise date**

Payoff scenario on exercise date: FX spot rate (EUR-USD)	Accumulation function (per unit notional)	Leverage (X or 100%)	Pre-barrier payoff	Contingent payoff ( $v_{ex}$ )
<b>Stress</b>				
0.88	-0.26	1	-0.26	-0.26
0.93	-0.21	2	-0.42	-0.42
<b>Unfavourable</b>				
1.02	-0.12	2	-0.24	-0.24
1.10	-0.04	2	-0.08	-0.08
<b>Favourable</b>				
1.18	0.04	2	0.08	0.08
1.25	0.11	1.5	0.17	0.17
<b>Windfall</b>				
1.28	0.14	1.5	0.21	0.21
1.32	0.18	1.5	0.27	0.27
<b>UKO (<math>\geq 1.35</math>)</b>				
1.35	0.21	1.5	0.32	0
1.37	0.23	1.5	0.35	0

**Figure 2: Payoff profile for a long position in the EUR-USD FX accumulator forward UKO use case (million USD)**



Often, financial institutions take a short position for market making or speculative reasons. It is worthwhile to look at the variations in P&L<sup>8</sup> for the other side of the contract, i.e., for the writer or seller. Figure 3 traces the P&L profile of this forward accumulator, from the perspective of the bank (seller) on three dates across the life cycle of the product – July 29, 2025 (start), August 28, 2025 (mid-life), and January 01, 2026 (expiry).

<sup>8</sup>  $P\&L = \begin{cases} \text{Payoff} - \text{Premium}; & \text{for buyer} \\ \text{Premium} - \text{Payoff}; & \text{for seller} \end{cases}$

Figure 3: P&L profile for a short position in the EUR-USD FX forward accumulator UKO – at the start, mid-life and expiry



It can be appreciated that the P&L profile is adjusted for the short position, the total trade notional and the initial premium. The shape of the seller's P&L profile on the expiry/exercise date is slightly modified from that of the buyer's payoff profile. The modification is notable for the KO regions.

In general, an accurate pricing engine should account for the fact that despite being in the KO zone on the expiry date, the trade has accumulated notional on previous fixings during its lifecycle as the FX rate has not hit the KO barrier level until the previous fixing.

Further, the trigger of the KO condition is irrelevant on the expiry date. The contract will terminate on the expiry date, regardless of whether the KO condition is triggered or not. In fact, even if the spot rate ( $S_{ex}$ ) exceeds ( $K$ ), the function ( $S_{ex} - K$ ) will still apply. There are no subsequent fixings anyway. Besides, there is a notion of spot rate and fixing rate cutoff times, which can give sufficient time to the FX rate trajectory to breach the KO level. The KO condition has more

impact on the earlier fixings. In the end, the model development or validation exercise must check the corner cases for any violation in the no-arbitrage (NA) bounds.

## Recapping product definition

Thus, an FX accumulator can bind on or allow its buyer to:

- a. Progressively earn a specific amount in CUR 1, representing a modified fraction of the trade notional, at predetermined intervals (e.g., daily, weekly or monthly) throughout the contract's lifetime
- b. Exchange the accumulated amount against CUR 2 at the contractual FX strike rate ( $K$ )<sup>9</sup> on specific dates at regular intervals

This periodic and incremental 'accumulation' of the trade notional, coupled with the staggered exercise of earnings, represents a significant enhancement over traditional FX forwards and FX options, which typically feature a single exercise date at maturity.

The total notional value of the accumulator contract is equal to the aggregate of the notional amounts of the constituent forwards/options, denominated in CUR 1. This total notional value is evenly distributed across each FX fixing date, with multiple FX fixing dates often intervening between the staggered exercise of two component forwards or options.

The notional amount applicable to each fixing date is then adjusted by applying a leverage function feature, whose value fluctuates in response to changes in the FX rate, contingent upon the satisfaction of pre-defined range conditions. Specifically, the leverage function is triggered when the FX spot rate exceeds or falls below a certain threshold or falls within a predetermined range, as agreed upon by the counterparties. The buyer periodically and incrementally accrues the modified (leveraged) per-fixing notional amount.

The running cumulative sum of the leveraged per-fixing notional amount is a critical component of the contract's performance. Each increment is subject to the leverage function, and the accrual behaviour is further characterised by the payoff function, which can be either the forward or option type, referred to as accumulation per unit of the notional. This payoff function facilitates the exchange of the accumulated leveraged notional from CUR 1 to CUR 2 as payout.

The table below illustrates the broader scenarios possible for the P&L for the buyer of an accumulator:

**Table 3: P&L outcomes for an FX accumulator buyer**

Sl. no.	Scenario	P&L for the buyer
1	FX fixing rate > FX strike rate on an exercise date	Cumulates profit.
2	FX fixing rate < FX strike rate on an exercise date	Cumulates loss if the payoff type is FX forward. Does not cumulate P&L on the exercise date if the payoff type is FX call option on CUR 1.
3	FX fixing rate < up and knock-in (UKI) or activating upper barrier	Accumulation conditions are not activated.
4	FX fixing rate > down and knock-in (DKI) or activating barrier	Accumulation conditions are not activated.
5	FX fixing rate > up and knock-out (UKO) or deactivating upper barrier	Product structure is terminated. All subsequent fixing dates are cancelled. No further cash flow is cumulated.
6	FX fixing rate > down and knock-out (DKO) or deactivating lower barrier	Accumulation conditions are not activated. All subsequent fixing dates are cancelled. No further cash flow is cumulated.

<sup>9</sup> Where one unit of CUR 1  $\equiv$   $K$  units of CUR 2

In contrast, a decumulator is the inverse of an accumulator, enabling investors to sell CUR 1 against CUR2 at the FX strike rate ( $K$ ). For the purposes of this document, all references to "buy," "earns" and "above the strike rate" in the context of FX accumulators shall be reversed and modified to 'sell', 'pays' or 'below the strike rate' when referring to a decumulator.

## Reasons for sampling FX accumulators

While we have worked extensively within the structured product (SP)<sup>10</sup> domain across asset classes, the rationale behind having FX accumulators as a sample product type is threefold:

- a. The distinction of FX as an asset class (refer to the hyperlink in the Appendix).
- b. The FX OTC market is huge and accurate risk management is crucial. According to Numerix (2024, b), the FX derivatives market is growing rapidly, with the outstanding notional amount increasing 12% on-year to 105 trillion USD in 2023. A 2024 study by the Bank of England (BoE) estimates that the net average size of the UK FX derivatives market is 3 trillion USD.

The SPs are largely issued as a cheap source of funding by investment banks, who engage in market making for the SPs or act as dealer banks. The valuation of these OTC products depends on the pricing model used. Risk management, especially that of model risk from the sophisticated SP<sup>11</sup> portfolios, is one of the biggest challenges these entities face.

- c. FX accumulators are a popular choice for SPs because of their market size, distinct business usage and sophisticated payoff structure. We discuss this specific motivation in detail in the following section.

## Importance of FX accumulators to financial institutions

The US government's sweeping tariff announcements in 2025 have triggered ripple effects in FX markets. In the short run, such events can create tradable price dislocation. In the long run, though, market volatility can lead to wide spreads and slippage. Market fluctuations can erode carry trade profits/interest rate alpha. In a rapidly changing FX landscape, investors are exploring new effective approaches to optimise risk-return profiles.

FX accumulators are an out-of-the-box class of products that can help investors navigate this volatile landscape.

### Business utility

FX accumulators serve as specifically tailored hedging (e.g. diversification), arbitrage or speculation/directional investing (e.g., yield enhancement) vehicles. The buyers of FX accumulators typically have a high degree of confidence in the specific direction of the FX spot rate trajectory.

The primary users of FX accumulators are portfolio management services, investment banks and corporations, particularly those in the UK and Europe with significant FX market exposure and experience with OTC products. These market participants have considerable FX market exposure and experience with OTC products, as well as the sophistication to appreciate the accumulator's payoff mechanism and potential returns.

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<sup>10</sup> Notable products are principal protected notes, capital guarantees, reverse convertible notes, auto-callable notes, Bermudan swaptions and constant maturity swap options, among others. We briefly discuss SPs and their generic strengths and weaknesses in the [Appendix](#).

<sup>11</sup> Hence, the pricing and risk management of SPs needs to be accurate. It can be simple, ranging from an internal valuation model to one as exotic as stochastic local volatility (SLV) models. Interest rate SPs such as Bermudan swaption and cap/floor are modelled using short-rate or Black 76 models, while FX derivative (FXD) SPs such as target redemption forwards (TARFs) and accumulators are often modelled with SLVs models and solved using Monte-Carlo numerical resolution schemes.

The stripped exercise/settlement approach of FX accumulators allows for ongoing exposure to a currency pair. As the different range conditions are met, corresponding leverage factors are applied and the traded notional is modified periodically. This makes the FX accumulator a zero-cost<sup>12</sup> forward or option enhancement<sup>13</sup> strategy. Nonetheless, we know from the [disadvantages](#) in Table 4 that if the FX spot rate moves in a direction contrary to the objectives of hedging or speculation, then the losses can be huge. In fact, according to [Point 4](#), FX accumulators do not have a guaranteed worst case. As a result, they are considered both a speculative product and a suitable add-on to a hedging portfolio of outright forwards and options or other enhanced forwards with guaranteed worst-case scenarios, such as TARFs.

Conversely, the trajectory of the FX spot rate may be favourable from a payoff perspective, but if the product has a deactivating barrier level, it may be terminated. Moreover, the product may have a partly favourable and partly unfavourable set of scenarios.

The accumulator holder, therefore, may need to unwind the trade and/or enter a new trade with features tailored to the current market environment, which can be challenging in illiquid markets. Therefore, the product holder requires active trade support from dealer banks and treasury services that consistently monitor the market.

## Commercial backdrop

The accumulator contract has a unique design that is customisable, and its payout is strongly path-dependent<sup>14</sup>. These factors lead to product usage, benefits and associated risks that are unique to FX accumulators<sup>15</sup>. These unique aspects foster the need for accurate and robust quantitative services support.

The total notional exposure in FX accumulators is estimated to be 800 billion USD as of 2023. The importance in terms of business need and product complexity is also underscored by the fact that third-party vendor platforms such as Bloomberg, Numerix and Murex have dedicated customisable templates for FX accumulators in their pricing engines.

## Risk and reward

FX accumulators often have multiple local expiries/settlements of accumulated earnings at regular intervals, unlike vanilla derivatives which have a single global expiry/settlement. This staggered schedule, combined with the leverage feature and the barrier condition (in some cases), leads to a set of advantages and drawbacks. Table 4 below highlights these pros and cons.

**Table 4: Opportunities and pitfalls with FX accumulators**

Sl. no.	Advantages	Disadvantages
1	<b>Lock-in of improved FX rate:</b> The buyer can lock in favourable contractual rate (strike rate) levels better than prevailing FX spot rates at the time of the purchase.	<b>Downside market risk:</b> This favourable strike rate is compensation for the uncertainty of the FX spot rate trajectory over time, which affects the leverage and, therefore, the total leveraged notional (leverage function multiplied on the trade notional) in addition to the accumulated payoff.
2	<b>Economical:</b> The favourable FX strike rate is a de facto discount, and the FX accumulators do not carry transaction costs or incidental costs, such as performance fees and interest.	<b>Realisation of risk:</b> In an adverse scenario, the FX accumulator buyer may be forced to buy or sell a dedicated amount of the base currency at an unfavourable FX rate, resulting in substantive losses.

<sup>12</sup> No subsequent costs are involved for payoff enhancement or when trade performance improves over the lifecycle.

<sup>13</sup> Refer to the advantages 2, 3 and 4 in Table 4.

<sup>14</sup> Where the payout is contingent on the specific evolution of the underlying FX spot rate over time.

<sup>15</sup> In fact, the drift process of the underlying asset in the FX accumulators is often modelled via SLV models, for which analytical solutions usually do not exist, and the stochastic differential equation must be solved using a numerical resolution scheme, e.g., partial differential equation (PDE).

Sl. no.	Advantages	Disadvantages
3	<b>Leverage feature and zero reinvestment risk:</b> The leverage feature and stripped settlement approach make accumulators a superior alternative to a stream of underlying forwards or options.	<b>Unknown trade amount:</b> The amount traded—total leveraged notional—is unknown at the time of trade entry, making it ineligible for hedge accounting under the IAS 39.
4	<b>Customisable settlement:</b> The stripped settlement can be customised to cater to the business transaction dates/corporate project timelines. Points 3 and 4 make FX accumulators effective hedging instruments.	<b>Unlimited loss potential:</b> Accumulator contracts do not define the worst-case loss or the cap on losses. The buyer may end up losing the entire trade notional amount. It is a principal-at-risk product.
5	<b>Customisable contract features:</b> The contract features of FX accumulators are highly customisable, rendering them suitable for investment capital optimisation. FX accumulators can lead to considerable gains in the specific FX market regimes.	<b>Liquidity risk:</b> Although the liquidity risk is high, similar to that for TARFs, early redemption of gains is not contractually enabled. In adverse market scenarios, if the buyer wishes to exit the accumulator trade, the asking prices can be lower than the previous bidding price. Points 1 through 5 imply that <b>capital preservation is not guaranteed.</b>
6	<b>Barrier feature:</b> The barrier feature can mitigate losses as well.	<b>Event risk:</b> The favourable FX strike rate is higher when the product carries deactivating barrier conditions, which can terminate the product and its future potential cash inflow streams owing to a single extreme FX spot rate, capping the upside potential.

## Product features and variants

While there are multiple ways to build these products, the trading parties agree on a payoff type, typically a forward or option. They specify a set of ranges for the leverage function, wherein the future published values of the FX spot rate will lie, on a schedule of fixing dates. On each fixing date, as each FX fixing rate lies within one of the ranges, a pre-determined notional amount of a specified currency accumulates for this payoff type.

### Fundamental features and payoff variants

The structure has two fundamental features:

- a. Leverage: This is a mathematical function that states the multiplicative factor on the notional amount per fixing date when the FX rate lies in the high, mid or low range in the future.
- b. Accumulation: This feature allows for the accumulation of the notional amount based on the FX spot rate. It has two connotations:
  - i. Per-unit notional forward/option type payoff ( $A_{ex}$ )
  - ii. Cumulative running sum of leveraged per fixing notional

A deactivating barrier feature can be applied on the accumulator product. If the FX rate (underlying variable) reaches the barrier level, then the structure is terminated. Table 5 below summarises the payoff types of accumulators.

**Table 5: Payoff structure of accumulators**

	Payoff type/structure	
<b>Payoff type</b>	FX accumulator forwards	FX faders
<b>Underlying</b>	FX forward	FX options (call and put)

	Payoff type/structure	
<b>Without barrier</b>	Accumulator forward $\equiv$ strip of forward	Fader $\equiv$ strip of vanillas
<b>With barrier</b>	Accumulator forward KO $\equiv$ strip forward KO	Fader barriers $\equiv$ strip of barriers

The accumulators have two variants:

- a. Fade-in (FI) accumulators, wherein the leveraged nominal is accumulated on the fixing dates.
- b. Fade-out (FO) accumulators (also known as decumulators), wherein the leveraged nominal is de-accumulated on the fixing dates. In accumulator forwards, if the FX rate is greater than the strike rate, the accrued nominal is deducted. In fader payoff, the nominal is deducted if the constituent FX option is in the money (ITM) on the fixing date.

## Key features

The additional features that determine the pricing of the FXD accumulators are:

- Whether the start date of the accumulator is before or after the pricing date
- The fixing schedule, i.e., number and the frequency of the FX rate fixings (daily, weekly, monthly)
- The exercise schedule tenor or residual time to expiry. The fixing and exercise schedules jointly determine the time to expiry
- Absence or presence of barriers

KO or deactivating barrier levels can be applied to the product, which will terminate the accumulation process once the barrier is reached. The barrier condition is accompanied by the accrual setting. Table 6 below summarises these nuances of the barrier feature.

**Table 6: Barrier and accrual features**

<b>Barrier</b>	<ul style="list-style-type: none"> <li>• None</li> <li>• Up and out (upon hitting high barrier level)</li> <li>• Down and out (upon hitting low barrier level)</li> <li>• Out (for double barrier level)</li> </ul>
<b>Barrier style</b>	<ul style="list-style-type: none"> <li>• American style <math>\equiv</math> barrier activation period is from pricing date to expiry</li> <li>• European style <math>\equiv</math> barrier activation is on discrete fixing dates only</li> </ul>
<b>Accrual setting</b>	If the barrier is reached, the buyer may receive the accrued amount until then (if the 'keep accrued' setting is on) or not (if the 'keep accrued' setting is off).

Three types of exercise schedules are possible as listed in Table 7.

**Table 7: Types of exercise schedules**

Single exercise date	The exercise date coincides with the single global expiry
<b>Multiple exercise dates: Number of exercise dates &lt; Number of fixing dates</b>	One exercise date will be common to a subset of fixing dates, and the subsequent exercise date will be common to the next subset of fixing dates. Thus, the product structure has more than one exercise date. Nonetheless, the number of exercise dates is lower than the number of fixing dates.
<b>Multiple exercise dates: Exercise schedule = fixing schedule</b>	Both schedules are identical, and the last exercise date is the global expiry.

## Payoff theory: Structure and relationships

### Payoff structure

On each fixing date, a portion of the nominal is multiplied by the leverage factor and the adjusted nominal is accrued over a series of fixing dates. The per unit nominal accumulator function is calculated based on the payoff differential between the FX rate on the exercise date and the strike rate (subject to any barrier condition). The total flow value is calculated by multiplying the accrued nominal by the payoff amount.

Table 8 lists the notations of the payoff features.

**Table 8: Payoff notations**

$n$	The total number of FX spot rate fixing dates as per the contractual fixing schedule
$t_i$	Time to the $i^{th}$ fixing date expressed in years, where $i = 1, 2, \dots, n$
$w_i$	Weight on the $i^{th}$ fixing date
$\psi (t_1, t_2)$	Discount factor between $t_1$ and $t_2$
$T$	Time to maturity expressed in years. Any fixing date or American style barrier condition date is $t \in [0, T]$
CUR 1 and CUR 2	The first and second currency of the default FX spot quotation defined at the currency pair level. One unit of CUR 1 is exchanged for some ( $S$ or $K$ ) units of CUR 2
$S_i$	(Underlying) FX rate spot value on the $i^{th}$ fixing date expressed in CUR 1-CUR 2
$K$	Contractually, pre-determined strike level of the underlying FX rate
$(\cdot)_{ex}$	Belongs to/or is an estimate on the exercise date. For instance, $t_{ex}$ and $A_{ex}$
$t_{ex}$	Time to exercise date expressed in years
$A_{ex}$	The accumulator (mathematical) function is estimated on an exercise date. It is the payoff of an FX forward or option. $A_{ex} = f(S_{ex}, K)$ . It is calculated per unit notional (N).
$[X]^+$	$= \max(X, 0)$ . It represents the payoff of a European vanilla option at expiry.
$H_i, L_i$	High- and low-level boundaries for the $i^{th}$ fixing date expressed in CUR 1-CUR 2
Up, mid and low	Multiplicative leverage factor if the FX spot rate (underlying) on the $i^{th}$ fixing date is a. Up: Lies above the $H_i$ boundary b. Mid: Lies within the $L_i$ and $H_i$ boundaries c. Low: Lies below the $L_i$ boundary
$\mathbb{1}_X$	It is an indicator random function that is equal to 1 when the condition $X$ is true and 0 otherwise
$\varepsilon$	Equal to 1 (v/s -1) if the call/put side is equal to call (v/s put) on CUR 1
$B_H, B_L$	Upper and lower deactivating barrier level in CUR 1-CUR 2 quotation
$N$	Total trade notional expressed in CUR 1: $N = n * N_i$
$N_i$	Nominal amount for the $i^{th}$ fixing date expressed in CUR 1
$N_{L_i}$	Leveraged nominal amount for the $i^{th}$ fixing date expressed in CUR 1

The traded nominal per fixing date and its leveraged counterpart are defined in the following two equations:

$$N_i = \frac{w_i}{\sum_{i=1}^n w_i} \times N_i$$

The multiplicative normalised weight factor is applied to the nominal on each fixing date to accommodate the possibility that each fixing date can have different weight.

$$N_{L_i} = N_i \times (low \times \mathbb{1}_{S_i < L_i} + mid \times \mathbb{1}_{S_i \leq L_i \leq H_i} + high \times \mathbb{1}_{S_i > H_i})$$

The accumulator function for the payout types is defined as follows:

Payoff type	Per unit notional accumulator function: $A_{ex} =$
Fader	$[\varepsilon \cdot (S_{ex} - K)]^+$
Fader barrier	$[\varepsilon \cdot (S_{ex} - K)]^+ \cdot \mathbb{1}_{B_L \leq S_t \leq B_H}$
Accumulator forward	$(S_{ex} - K)$
Accumulator forward KO	$(S_{ex} - K) \cdot \mathbb{1}_{B_L \leq S_t \leq B_H}$

The payoff at the expiry of a fade-in variant accumulator, with a single exercise date, can be expressed as:

$$V_{ex} = \left( \sum_{i=1}^n N_{L_i} \right) \times A_{ex}$$

The above payoff equations are generic and will acquire a specific form depending on the trade design linked to specific client needs—for instance, the presence of multiple exercise dates, the ‘cash’ or ‘delivery’ mode of settlement, and the position of the pricing date, with respect to the fixing date, which determines that the fixing dates are in the past or in the future.

The accumulators can be priced using a diffusion type Heston-based stochastic local volatility (SLV) model. The diffusion model can be implemented through a three-dimensional (spot, volatility, time steps) grid-based PDE numerical resolution (for instance, Crank Nicolson) scheme.

## Payoff relationships

a. The price of the corresponding fade-out accumulator can be verified by the fade-in-fade-out (FIFO) parity relation:

$$P_{AccIN} + P_{AccOUT} = P_{UNDER}$$

$P_{AccIN}$  and  $P_{AccOUT}$  represent the prices of the fade-in and fade-out accumulators, respectively.

$P_{UNDER}$  represents the price of the corresponding degenerate forward/forward KO/vanilla/barrier option.

b. Like the put call and forward (PCF) parity for vanilla options, the PCF parity holds for the accumulators, too.

$$P_{Acc}(CALL) - P_{Acc}(PUT) = P_{Acc}(FORWARD)$$

$P_{Acc}(CALL)$  [v/s  $P_{Acc}(PUT)$ ] represents the price of a fader with CALL on CUR 1 and PUT on CUR 2.

$P_{Acc}(FORWARD)$  represents the price of the corresponding accumulator forward.

## Product and model testing

### Product test plan

A select few tests of the entire suite that can be conducted to examine the pricing and the risk of the accumulators are as follows:

Calibration fit: To check if the calibrated diffusion mode parameters fit well.

Test of nominal leverage and accumulation feature: It verifies if the implementation of the leverage feature is applied correctly in the pricing engine.

Payoff consistency tests: The PCF and FIFO parity tests verify if the model independent parity conditions hold.

Payoff degeneracy tests: Strip of forwards (and with KO features), strip of vanilla (or barrier) options tests. If the leverage = 1 throughout, then does the pricing engine correctly degenerate the complex payoffs into simple ones?

(The above two tests are paramount as they check the validity of the no-arbitrage (NA) condition.)

Benchmarking tests: Does adding unrealistic barriers make the accumulator behave like a forward or vanilla that can be valued with another pricing model?

Ladder analysis: Traces and analyses the profiles of the NPV and Greek sensitivities across a range of FX spot and volatility values.

PDE discretisation test: How fast do the NPV and Greek sensitivities values stabilise upon varying the granularity level of the spot, volatility and time steps in the grid?

Lifecycle test: MV and sensitivities behaviour across multiple horizon dates.

Bucketed Greeks and DV01 (par) replication.

P&L attribution test: Explaining daily P&L via Taylor series decomposition with Greek sensitivities and DV01s.

### A few challenges in accumulators testing

- 1. Inconsistent vendor documentation:** Vendor documentation on structured products often lacks standardisation, leading to ambiguities and inconsistencies in product payoff explanations. For instance, the underlying forward or option-type payoff is applied only on exercise dates, and not on every fixing date as represented in documentation. A thorough review of the input file is necessary to appreciate this nuance, which leads to higher-order challenges.
- 2. Payoff function application:** The payoff function is applied in reverse, from the global maturity date to the final fixing date, and then to the earliest fixing date and pricing date. This approach can lead to incorrect NPV profiles.
- 3. Leverage and nominal accumulation:** It is crucial to ensure that the leverage feature and nominal accumulation feature are applied correctly. Users cannot rely solely on the input code and must consider the diffuse nature of future FX rates.
- 4. NPV calculation:** NPV variables are calculated outside of the SLV model in the 3D PDE or 2D MC grid. To fully understand the diffusion, accumulation and NPV estimation, it is essential to visualise the output files (e.g., in the hd5 format).

Mitigation strategies for challenge # 4:

- a. **NPV ladder/profile analysis:** Analyse the NPV ladder/profile by adjusting the high and low boundary and leverage ranges.
- b. **Dead trade replication:** Use published FX rates and replicate the NPVs of dead trades.
- c. **Life cycle testing:** Perform fixing and exercise events on a trade, with multiple exercise dates (in portfolio simulation module), and check for the cash amount and NPV across different horizons throughout the trade life cycle and replicate the NPV as strip of forwards/options.

## Additional challenges

1. **FX spot and FX fixing rate discrepancy:** The diffused FX spot (in cash settlement) is different from the FX fixing rate (in delivery settlement). The latter leads to a spot-forward deal. It may lead to mismatches in payoff degeneracy tests.
2. **Violation of no arbitrage (NA) bounds with 'Keep Accrued' feature = 'Yes':** If the 'Keep Accrued' feature is activated for trades with barriers, then it can result in incorrect NPV calculations in some cases.
3. **Replication of risk-free rate (RFR) DV01 sensitivities:** Numerical replication of the DV01 sensitivities can be incorrect due to incorrect settings with the collateralised spread curve (CSC).
4. **Development testing or validation of Greek risk sensitivities:** Models of third-party vendor platforms often use some form of automatic calibration systems with proprietary closed-form formulae applied on the NPV (and Greek values) over the same grid (spot, vol or time) to calculate Greeks (including second order ones), whereas the replication of the Greeks is a numerical/ finite-difference formula with bumps to the spot or vol grid. This can lead to numerical noise, particularly in the replication of second order Greeks (Gamma, Vanna, Volga). Furthermore, premium is pushed in the Delta (i.e.,  $\Delta_{\text{new}} = \Delta_{\text{old}} + \text{Premium}$ ) for certain currency pairs (for instance, AUD/JPY, USD/CAD) but Vega is not pushed in the Vanna calculation (i.e.,  $\text{Vanna}_{\text{new}} = \text{Vanna}_{\text{old}} + \text{Vega}$  does not happen), resulting in errors.

## How we support financial institutions

We are a strategic partner to financial institutions and support their quantitative market intelligence. We have rich consultative experience acquired from comprehensive delivery support to top-tier banks in the US, the UK, and the Asia-Pacific region. Our engagement team will go beyond effectively addressing the business and regulatory challenges encountered during investment banking activities and bring in global best practices to elevate our clients to a position of market advantage.

### Market making and establishing FO trading capabilities for new products

Our consulting and delivery support are driven to augment client capacity towards market making and trading structured products (SPs). We have offered long-term support to client banks not just on FX accumulators and TARFs but also on other derivatives, including single-name and multi-name derivatives, specifically credit default swaps (CDS and CDX) and credit default options (CDOs). Our services include independent pricing and valuation, model development testing or model validation of the pricing and risk outputs, and trade support on the vendor platforms (TR vertical).

1. Our pricing and model risk control support for structured products across asset classes include:
  - a. Derivatives pricing models for exotics (for instance, accumulators and TARFs) and securitised products models—CLO, CDO, ABS, MBS and non-agency RMBS

- b. Term structure-based models
- c. Volatility surface and calibration models
- d. Arbitrage modelling
- e. XVA (CVA, DVA and FVA) models
- f. Trade reserves and funding models
- g. Regulatory charge calculation models (for instance, SIMM)

In the recent past, our deliverables have led to the following value addition:

- Reduced development efforts for TARFs and accumulators. In fact, the average time taken to introduce new products was reduced by 35%
- Our project plans sequenced according to the vendor sprints, which provided huge cost and time savings for the client
- Another team assisted with model validation (we set up Chinese walls between these teams)
- In our experience, bank holding companies (BHCs) face challenges while mapping regulatory guidance or reconciling differences around the globe. We are fully adapted to regulatory expectations across the globe. Our deep understanding of regulatory requirements has been perfected into a target operating model. A few attributes are:
  - Segregation of technical writing and testing implementation
  - Documentation template design according to regulatory and internal policies
  - Two-level review of model documentation and test plan. Our high-quality developer documentation reports are in line with SR 11-7 or PRA SS 1/23 guidelines and industry best practices
- Our team provided 24/5 overnight (O/N) trading and analytics support to trading strategies:
  - The team made certain the traders' input sheets were running and consolidated in real time
  - It collaborated with the price quoter team and other dependent teams to pre-empt/resolve issues during trading hours

The support ensured that the quotes were published on the market on a real-time basis.

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## Appendix

### The distinction of FX as an asset class

Key considerations for the prominence of FX as an asset class include:

- FX markets are central to global trade and financial flows, with large financial institutions operating BHCs across multiple foreign jurisdictions, thereby necessitating FX transactions
- Market participants can take exposure and generate profits in two currencies rather than being limited to a single currency
- The flexibility inherent in FX, combined with the regulatory landscape, often results in industry practices such as reporting net present value (NPV) in the base currency and Greek risk sensitivities in the profit and loss (P&L) statement, denominated in the risky currency
- FX products are inherently more complex, with additional dimensions such as spot quotation conventions, pricing in 'big figures' and 'pips', and the need to consider multiple input volatility surfaces and zero-rate curves, which complicates the pricing and risk management process compared with single-currency products

## Structured product

A 'structured product' or a 'structured note' is a pre-packaged, market-linked investment strategy sold as an over-the-counter (OTC) product. The term 'structure' refers to the customised cash flow payout stream designed to achieve a specific risk-return profile. This security is a 'note' because it has the basic rigid cash flow pattern of a coupon paying bond-like debt security — just that the interim coupons and the final payout are random and not regular, let alone fixed. These scheduled payments are embedded derivatives (i.e., derivatives unto themselves) and defined on the performance of a single or multiple underlying assets that belong to equity, interest rates, credit, commodities, FX rate classes and even derivatives.

The design of these notes is often derived from a mathematically optimal solution to the client's financial objectives, incorporating features such as knock-in/knock-out (KI/KO) barrier levels, dual currency flexibility, and target levels for accumulated in-the-money (ITM) profits, which may lead to early redemption. Additional features, including buffers and maximum out-of-the-money (OTM) loss caps, help prevent investors' losses beyond a certain level. This tailored approach to risk-return profiles, aligned with market expectations, is a key advantage of these notes. Many other variations exist in which the maturity of the product is modified, increasing and decreasing the leverage and converting the income to capital gain. Once the note is designed, it is manufactured through a replication strategy using the underlying of the embedded derivatives.

However, structured notes also have potential drawbacks. These OTC products are thinly traded, posing considerable trading liquidity risk. The rigid 'lock in of final payout' cash flow stream, combined with limited trading liquidity, may result in investors missing cash flows if the underlying asset is volatile or trades sporadically. Further, early redemption of payouts may expose investors to higher market (timing) risk due to the need to reinvest cash flow proceeds, known as call risk. In addition, the higher fees associated with creation and maintenance are a trade-off for the time savings.

When designing a structured product, several factors must be considered, including:

- Is the note designed for income or capital gain?
- Does it include a capital guarantee?
- Is it easy to explain and understand?
- What is the required range of maturities?
- Is the note diversified, or should it be held as part of a broader portfolio of structured notes?
- What is the underlying asset class or sector to invest in?
- Does it incorporate the investor's (or analyst's) market view?
- Is the risk-reward profile appropriate?
- Are the fees reasonable, and does the provider offer fair and reliable after-sales service?
- What is the call risk, and what are the secondary liquidity options if the note is to be redeemed or repurchased early?

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## About Crisil

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Large and highly respected firms partner with us for the most reliable opinions on risk in India, and for uncovering powerful insights and turning risks into opportunities globally. We are integral to multiplying their opportunities and success.

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