FX Binary with Single Barrier Option
Product Specification

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Chapter 1

FX Binary with Single Barrier Option

1.1 Instrument Properties

An FX binary with single barrier option is a binary cash with single barrier option with the **cross currency** as the underlying and the payoff is the **cash payment** in **cash payment currency**. If we denote the **primary currency** per **cross currency** exchange rate on the **maturity date** by S_T, and the agreed **strike rate** by X, provided the appropriate barrier condition is met:

1) for a **knock-out type** option, the **barrier** is not **touched** during the life of the option, or

2) for a **knock-in type** option, the **barrier** is **touched** during the life of the option,

and the option expires in the money, in which a **call option** expires in the money if $S_T > X$ and a **put option** expires in the money if $S_T < X$, the holder of the option receives the **cash payment**, K amount in **cash payment currency**. In other words, it is an FX single barrier option where the payoff is like an FX binary option rather than an FX vanilla option payoff.

Provided either of the above barrier conditions holds, the payoff of an FX binary with single barrier option is illustrated in Table 1.1.

Option Type	Expiry Condition	Payoff (**cash payment currency**)
Call	$S_T \leq X$	0
	$S_T > X$	K
Put	$S_T \geq X$	0
	$S_T < X$	K

Table 1.1: Payoff at maturity for FX binary with single barrier option if the underlying option is active on the maturity date

1.2 Definitions

In this section, we define terms that are specific to FX binary with single barrier options.

barrier is the **primary currency** per **cross currency** exchange rate level such that, if it is **touched** before or on the **maturity date**, the **underlying option** becomes active (inactive) for **knock-in type** (**knock-out type**) options.

barrier direction is the direction that the **barrier** is considered to be **touched**.

call option gives the holder the right to receive the **cash payment** if the **primary currency** per **cross currency** exchange rate on the **maturity date** is greater than the **strike rate** and the option is **knocked-in** (not **knocked-out**) for a **knock-in type** (**knock-out type**) option.

cash payment is the amount in **cash payment currency** that the holder of the option receives if the option is exercised.

cash payment currency is the currency the **cash payment** is quoted in.

cross currency is the currency nominated as the underlying asset.

down is the **barrier direction** in cases where if the **primary currency** per **cross currency** exchange rate passes below the **barrier** before or on the **maturity date**, the **barrier** is considered to be **touched**.

knocked-in applies to **knock-in type** options and means the **barrier** was **touched** and the **underlying option** became active.

knocked-out applies to **knock-out type** options and means the **barrier** was **touched** and the **underlying option** became inactive.

knock-in type means the **underlying option** only becomes active if the **barrier** is **touched** before or on the **maturity date**.

knock-out type means the **underlying option** becomes inactive if the **barrier** is **touched** before or on the **maturity date**.

maturity date is the date the option expires.

primary currency is the currency that the deal is quoted in.

put option gives the holder the right to receive the **cash payment** if the **primary currency** per **cross currency** exchange rate on the **maturity date** is less than the **strike rate** and the option is **knocked-in** (not **knocked-out**) for a **knock-in type** (**knock-out type**) option.

strike rate is the agreed exchange rate between **primary currency** and **cross currency** if the option is exercised, quoted in **primary currency** per **cross currency**.

touched means for an option with **up** (**down**) barrier, the **primary currency** per **cross currency** exchange rate was above (below) the **barrier** before or on the **maturity date**.

underlying option is the underlying FX binary option that specifies the payoff of the option should the option be either **knocked-in** or not **knocked-out**.

up is the **barrier direction** in cases where if the **primary currency** per **cross currency** exchange rate passes above the **barrier** before or on the **maturity date**, the **barrier** is considered to be **touched**.

1.3 Representation

In the Risk Engine, products are specified by *representations*. In this section, we provide the representation of FX binary with single barrier options.

1.3.1 Default Representation

The *Default* representation consists of the mandatory trade fields in Table 1.2, with their restrictions in Table 1.3.

1.3.1.1 Required Curves

The following curves are required by an FX binary with single barrier option:

- *Currency FX spot curve*: FX Spot Curve — (FX.PRICE.Currency.BaseCurrency),
- *CrossCurrency FX spot curve*: FX Spot Curve — (FX.PRICE.CrossCurrency.BaseCurrency),
- *Currency discounting curve*: FX Zero Curve — (FX.ZERO.Currency.ReserveCurrency),
- *CrossCurrency discounting curve*: FX Zero Curve — (FX.ZERO.CrossCurrency.ReserveCurrency), and
- *Currency, CrossCurrency volatility grid*: FX Volatility Grid — (FX.GRID.CrossCurrency.Currency).

Field	*Description*	*Data Type*	*Symbol*
Currency	The **primary currency**	string	p
CrossCurrency	The **cross currency**	string	c
Strike	The **strike rate** as *Currency/CrossCurrency*	double	X
Barrier	The **barrier** level as *Currency/CrossCurrency*	double	H
CashPaymentCurrency	The **cash payment currency**	string	kc
CashPayment	The cash payoff in *CashPaymentCurrency*, *i.e.*, the **cash payment**	double	K
MaturityDate	The **maturity date**	date	MD
PutCall	Put option or call option on *CrossCurrency*	string	PC
UpDown	Direction of the barrier	string	UD
InOut	Knock-in option or knock-out option	string	IO
BoughtSold	Bought or sold the option	string	BS

Table 1.2: Mandatory trade fields for the Default representation of the FX Binary with Single Barrier Option

Field	*Restriction*
CrossCurrency	$\mathrm{c} \neq \mathrm{p}$
Strike	$X > 0$
Barrier	$H > 0$
CashPaymentCurrency	$\mathrm{kc} = \mathrm{p}$ or $\mathrm{kc} = \mathrm{c}$
CashPayment	$K > 0$
PutCall	Put, Call, P, C
UpDown	Up, Down, U, D
InOut	In, Out, I, O
BoughtSold	Bought, Sold, B, S

Table 1.3: Trade field restrictions for the Default representation of the FX Binary with Single Barrier Option

1.4 Formula

If the Valuation Date is less than or equal to the **maturity date**, the value of an FX binary with single barrier option in Base Currency is given by the *FX binary with single barrier option pricing function*[1],

$$\mathrm{FXBinaryWithSingleBarrier}\left(E_{\mathrm{p}}, E_{\mathrm{c}}, X, H, K, \mathbb{I}_{\mathrm{kc}}, r_{\mathrm{p}}, r_{\mathrm{c}}, \sigma, T, \mathrm{indicator}\right), \tag{1.1}$$

where

- E_{p} is the spot exchange rate in units of Base Currency per **primary currency**, from the Currency FX spot curve,
- E_{c} is the spot exchange rate in units of Base Currency per **cross currency**, from the CrossCurrency FX spot curve,
- X is the **strike rate** in units of **primary currency** per **cross currency**,
- H is the **barrier** level in units of **primary currency** per **cross currency**,
- K is the **cash payment** in **cash payment currency**,
- $\mathbb{I}_{\mathrm{kc}}$ indicates if the **cash payment currency** is the same as the **primary currency** or as the **cross currency**,
- r_{p} is the cross currency basis adjusted continuous zero rate of **primary currency** from Valuation Date to **maturity date** in Actual/365 (Fixed) day count convention, from the Currency discounting curve,
- r_{c} is the cross currency basis adjusted continuous zero rate of **cross currency** from Valuation Date to **maturity date** in Actual/365 (Fixed) day count convention, from the CrossCurrency discounting curve,

[1] See FX Binary with Single Barrier Option Pricing for details (p.8 of this document).

- σ is the volatility of the exchange rate between **primary currency** and **cross currency** from Valuation Date to **maturity date** in Actual/365 (Fixed) day count convention, from the Currency, CrossCurrency volatility grid,
- T is the time in years from Valuation Date to **maturity date** in Actual/365 (Fixed) day count convention, and
- indicator contains the put/call, up/down, in/out and bought/sold information.

If the Valuation Date is greater than the **maturity date**, then the FX binary with single barrier option has expired and thus has a value of zero.

1.5 Examples

This section provides some deal examples of FX binary with single barrier option.

Example 1.1. An FX binary with single barrier option in Default representation:
- Currency: AUD
- CrossCurrency: GBP
- Strike: 1.6685
- Barrier: 1.6725
- CashPaymentCurrency: AUD
- CashPayment: 10,000
- MaturityDate: 2013-11-15
- PutCall: Put
- UpDown: Up
- InOut: Out
- BoughtSold: Bought

a) If on 2013-11-15, the option expires in the money with the AUD/GBP exchange rate being 1.6515, with the AUD/GBP exchange rate never passing above the **barrier** (1.6725) before 2013-11-15, the holder of the option receives the **cash payment**, $10,000 AUD.

b) If on 2013-11-15, the option expires out of the money with the AUD/GBP exchange rate being 1.6715, with the AUD/GBP exchange rate never passing above the **barrier** (1.6725) before 2013-11-15, the payoff of the option is 0 as the **strike rate** (1.6685) is less than the AUD/GBP exchange rate (1.6715) on the **maturity date**.

c) If the AUD/GBP exchange rate passed above the **barrier** (1.6725) before 2013-11-15, the option was **knocked-out** because the **barrier** was **touched** before the **maturity date**, thus the payoff of the option is 0.

Example 1.2. An FX binary with single barrier option in Default representation:
- Currency: JPY
- CrossCurrency: USD
- Strike: 100.2
- Barrier: 97.5
- CashPaymentCurrency: USD
- CashPayment: 20,000
- MaturityDate: 2013-11-15
- PutCall: Call
- UpDown: Down
- InOut: In
- BoughtSold: Bought

a) If on 2013-11-15, the option expires in the money with the JPY/USD exchange rate being 102.5, with the JPY/USD exchange rate passing below the **barrier** (97.5) before 2013-11-15, the holder of the option receives the **cash payment**, $20,000 USD.

b) If on 2013-11-15, the option expires out of the money with the JPY/USD exchange rate being 98.4, with the JPY/USD exchange rate passing below the **barrier** (97.5) before 2013-11-15, the payoff of the option is 0 as the **strike rate** (100.2) is greater than the JPY/USD exchange rate (98.4) on the **maturity date**.

c) If the JPY/USD exchange rate never passed below the **barrier** (97.5) before 2013-11-15, the option was not **knocked-in** because the **barrier** was not **touched** before the **maturity date**, thus the payoff of the option is 0.

Chapter 2

FX Binary with Single Barrier Option Pricing

2.1 Inputs to Function

Description	*Symbol*	*min*	*max*	*Reasonable range*
Spot rate of primary currency	E_{p}	0^+	$+\infty$	
Spot rate of cross currency	E_{c}	0^+	$+\infty$	
Strike rate as primary currency/cross currency	X	0^+	$+\infty$	
Barrier as primary currency/cross currency	H	0^+	$+\infty$	
Cash amount of payoff in cash payment currency	K	0^+	$+\infty$	
Indicator for cash payment currency	$\mathbb{I}_{\mathrm{kc}}$			"Currency", "CrossCurrency"
Continuous zero rate of primary currency	r_{p}	0^+	$+\infty$	
Continuous zero rate of cross currency	r_{c}	0^+	$+\infty$	
Volatility of exchange rate between primary and cross currencies	σ	0^+	$+\infty$	
Time from value date to maturity in years	T	0^+	$+\infty$	
Put or Call on cross currency	indicator	–	–	"P", "C"
Up or Down		–	–	"U", "D"
In or Out		–	–	"I", "O"
Bought or Sold		–	–	"B", "S"

Table 2.1: Inputs for FX Binary with Single Barrier Option pricing function

2.2 Formula

The spot exchange rate of primary currency per cross currency is given by

$$S = \frac{E_{\mathrm{c}}}{E_{\mathrm{p}}}.$$

We can value an FX binary with single barrier option by calling the *binary cash with single barrier pricing function*[1] or the *binary asset with single barrier pricing function*[2] with appropriate inputs. The value of an FX binary with single barrier option in Base Currency is

$$\begin{cases} E_{\mathrm{p}} \times \mathbb{I}_{\mathrm{BS}} \times \mathrm{BinaryCashWithSingleBarrier}\left(S, X, H, K, r_{\mathrm{p}}, r_{\mathrm{c}}, \sigma, T, \mathrm{indicator}\right), & \text{if } \mathbb{I}_{\mathrm{kc}} = \mathrm{Currency}, \\ E_{\mathrm{p}} \times \mathbb{I}_{\mathrm{BS}} \times K \times \mathrm{BinaryAssetWithSingleBarrier}\left(S, X, H, r_{\mathrm{p}}, r_{\mathrm{c}}, \sigma, T, \mathrm{indicator}\right), & \text{if } \mathbb{I}_{\mathrm{kc}} = \mathrm{CrossCurrency}, \end{cases}$$

[1] See pricing specification *Binary Cash with Single Barrier Option* for details.
[2] See pricing specification *Binary Asset with Single Barrier Option* for details.

where

$$\mathbb{I}_{\text{BS}} = \begin{cases} 1, & \text{if indicator is 'B',} \\ -1, & \text{if indicator is 'S'.} \end{cases}$$

Glossary

Base Currency The currency that the risk engine is configured to return values in.

Reserve Currency The currency that all cross currency basis is benchmarked against.

Risk Engine The Vector Risk market risk and credit risk system.

Valuation Date The date that we value the trades as.