

Triangulation

This topic provides information on Triangulation.

Triangulation provides liquidity between premium-quoted options (PQO), [volatility-quoted options \(VQO\)](#), and the related underlying futures market. Liquidity across order books is supported by implied functionality and standard option pricing model calculations.

Contents

- [Testing and Certification](#)
- [Functionality Overview](#)
- [Product Availability](#)
- [Market Data](#)
 - [Security Definition](#)
 - [Delta Range](#)
 - [Beginning of the trading day](#)
 - [Example 1](#)
 - [Delta value changes during the trading day](#)
 - [Example 2](#)
 - [Example 3](#)
 - [Example 4](#)
 - [Market and Instrument States](#)
 - [Triangulation Book Dissemination](#)
 - [Trade Summary](#)
- [Mass Quote Protections](#)
 - [Mass Quote Protection Calculation](#)
 - [Example 1 – New Quote Fill \(X\) Protection](#)
 - [Example 2 – Execution \(Y\) Protection](#)
 - [Example 3 – Traded Quantity \(Z\) Protection](#)
 - [Example 4 – Buy/Sell Protection](#)
- [Self Match Prevention](#)
- [Triangulation Implied Functionality](#)
- [Option Pricing Inputs](#)
- [Aggregated Price-Time Priority](#)
 - [Order Priority](#)
 - [Matching Priority](#)
 - [Matching Algorithm](#)
- [CME Globex Processing Overview](#)
- [Triangulation Implied Matching Examples](#)
 - [Example 1 - Partial VQO Fill, Cancel Remaining VQO Quantity](#)
 - [Example 2 - Partial PQO Fill, Remaining PQO Quantity Rests on Book](#)
 - [Example 3 - Triangulation Implied Match Occurs in VQO Order Book](#)
 - [Example 4 - Triangulation Implied Match Occurs in PQO Order Book](#)
 - [Additional Implied Order Scenarios](#)
 - [Example A - VQO implied bid](#)
 - [Example B - VQO implied bid](#)
 - [Example C - Futures implied bid](#)
 - [Example D - Futures implied ask](#)
 - [Example E - VQO implied bid does not meet minimum quantity requirement](#)
 - [Example F - PQO implied ask](#)
 - [Example G - VQO implied bid, cancel aggressing order remainder](#)
- [Comparison of Triangulation and Options Implied Processing](#)

Testing and Certification

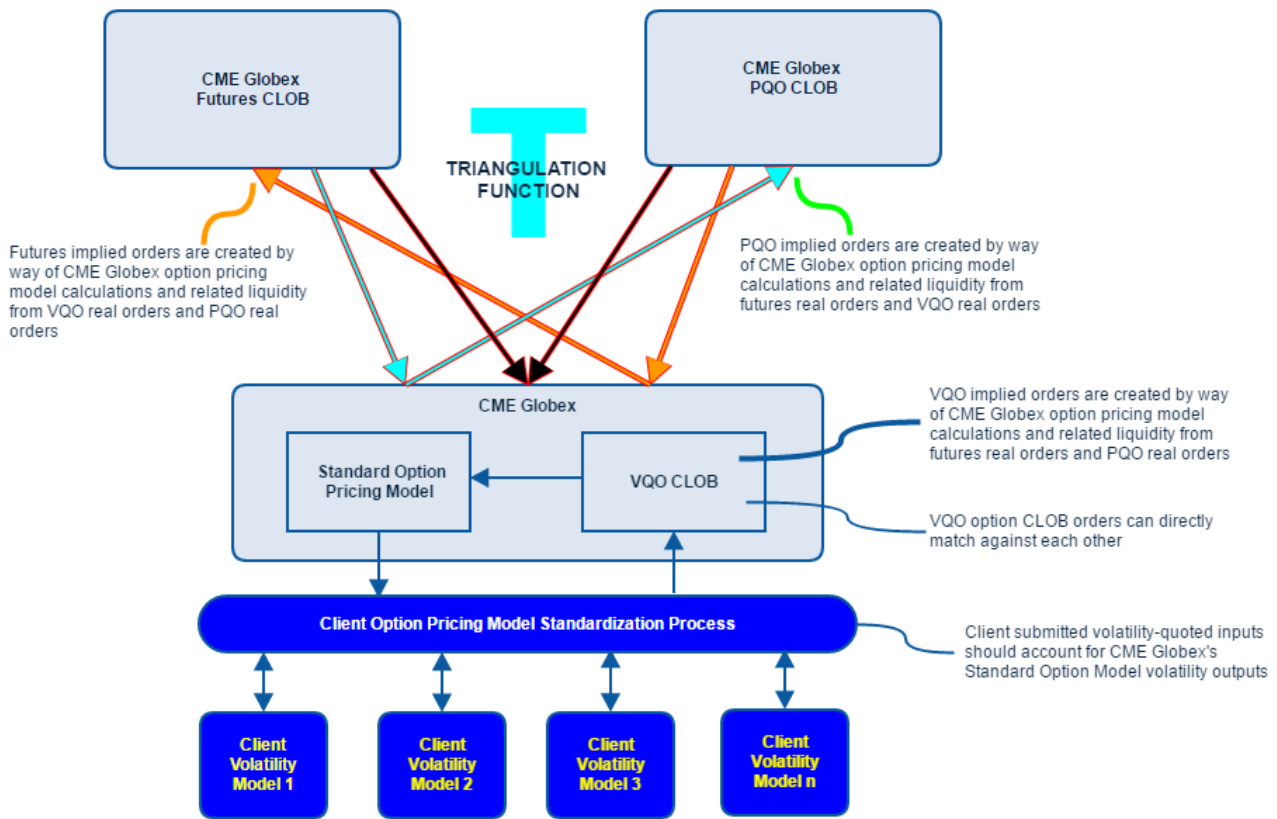
Certification via AutoCert+ is not required for Triangulation functionality.



CME Group strongly encourages all customers and system providers to test the functionality thoroughly in Certification before using the functionality in production.

Functionality Overview

This diagram provides an overview of Triangulation functionality.



Product Availability

Only European-style (2 PM Fix) CME FX options support Triangulation functionality.

The following CME FX futures, weekly options, serial options, and quarterly options combinations will support Triangulation functionality:

- Futures: the first two underlying quarterly futures of listed options
- Weekly Options: all four listed weekly options
- Serial/Quarterly Options: all three listed serial options (only two serials when the front month is a quarterly).

Product	iLink: tag 1151-Security Group MDP 3.0: tag 6937-Asset
Japanese Yen	Futures=6J Premium-Quoted Options=JPU, 1JY-5JY Volatility-Quoted Options: tag 6937=VXJ, VJA-VJE, VJ1-VJ5
British Pound	Futures=6B Premium-Quoted Options=GBU, 1BP-5BP Volatility-Quoted Options=VXB, VBA-VBE, VG1-VG5
Swiss Franc	Futures=6S Premium-Quoted Options=CHU, 1SF-5SF Volatility-Quoted Options=VXS, VSA-VSE, VE1-VE5
Canadian Dollar	Futures: tag 6937=6C Premium-Quoted Options=CAU, 1CD-5CD Volatility-Quoted Options=VXC, VCA-VCE, VC1-VC5

Euro FX	Futures: tag 6937=6E Premium-Quoted Options: tag 6937=E00, 1EU-5EU Volatility-Quoted Options: tag 6937=VXT, VTA-VTE, VE1-VE5
Australian Dollar	Futures=6A Premium-Quoted Options=ADU, 1AD-5AD Volatility-Quoted Options=VXA, VAA-VAE, VA1-VA5

VQO spreads are not supported. PQO spreads and futures spreads are not included in Triangulation functionality.

Market Data

Triangulation functionality has the following market data considerations.

Security Definition

The market data Security Definition message (tag 35-MsgType=d) will contain tag 872-InstAttribValue bit 19-Implied Matching Eligible=1 for VQO, PQO, and futures products with Triangulation, irrespective of whether a strike is inside or outside the configured Triangulation delta range configuration.



An *implied eligible* instrument is not necessarily Triangulated; Triangulation is only calculated for strikes within the defined delta range of 10 delta to 90 delta.

Delta Range

At the start of a trading session, the initial Triangulation delta range will be configured to only include strikes from 10 delta to 80 delta for Triangulation VQO books. No other strikes will be eligible for Triangulation throughout the trading day.

During the course of the trading day, Triangulation calculation and matching can range from 10 delta to 90 delta as CME Globex dynamically recalculates all option deltas.

Triangulation implied calculations and market data dissemination can activate/deactivate for a given strike during the course of the trading day as CME Globex dynamically recalculates all option deltas.

Beginning of the trading day

Example 1

Australian Dollar European Option (2 PM Fix)		
Strike	Delta	Triangulation Eligibility
7900	9	No
7750	20	Yes
7550	55	Yes
7500	71	Yes

Delta value changes during the trading day

Example 2

Australian Dollar European Option (2 PM Fix)		
Strike	Delta	Triangulation Matching Eligibility
7900	15	Yes
7750	24	Yes
7550	62	Yes
7500	80	Yes

Example 3

Australian Dollar European Option (2 PM Fix)		
Strike	Delta	Triangulation Eligibility
7900	4	No
7750	9	No
7550	30	Yes
7500	50	Yes

Example 4

Australian Dollar European Option (2 PM Fix)		
Strike	Delta	Triangulation Matching Eligibility
7900	15	Yes
7750	43	Yes
7550	91	No
7500	95	No

Market and Instrument States

Implied ON/OFF Security Status messages (tag 35=MsgType=f) **WILL NOT** be sent for Triangulation products.

Triangulation Book Dissemination

Only top-of-book, best bid, and best offer are disseminated for Triangulation VQO books via the Market Data Incremental (tag 35=X) message with tag 269=E (Implied Bid) or F (Implied Offer) for VQO outright. VQO Triangulation function implieds will only be published when the related PQO and futures books can both support the VQO 5-lot minimum quantity.



PQO and futures customer orders can be aggregated from multiple price levels to create the VQO Triangulation function best implied price.

There is no top-of-book Triangulation implied dissemination for the PQO and futures books because aggressing customer orders against PQO or futures Triangulation implied orders will not always fulfill a related VQO 5-lot customer order minimum match event size.

	Customer Order Book Publication	Triangulation Book Publication
VQO	3-deep	Top of book
PQO	3-deep	Not applicable but will calculate / match at top of book
Futures	10-deep	Not applicable but will calculate / match at top of book

Trade Summary

When a Triangulation implied order matches, Trade Summary messages will be published on each of the channels for the VQO, the PQO and the futures.

- The VQO and PQO market data messages will be published on PQO channel.
- The futures market data messages will be published on the futures channel.



Triangulation market data messages will always be on-tick.

A client representing a VQO customer order, PQO customer order or a futures customer order will not be able to determine from market data messages whether the orders are matched as part of a Triangulation implied match. There is no market data message value to indicate implied match.

Mass Quote Protections

To prevent over-filling across resting mass quotes in multiple Volatility-Quoted Options (VQO) and Premium-Quoted Options (PQO) strike prices, [Mass Quote Protections \(MQPs\)](#) are evaluated inter-event for a Triangulation implied trade originating from an aggressing futures order.



This feature applies only to Triangulation match events that result from an aggressing order on the futures instrument and protects Market Makers having mass quotes in multiple premium-quoted option (PQO) strikes and volatility-quoted option (VQO) strikes.

Mass Quote Protection Calculation

The following examples illustrate MQP calculations for Triangulation implied trades that occur in the futures order book.



For information on Triangulation implied trades that occur in the VQO and PQO order book, refer to [Mass Quote Protections](#).

The examples on this page show scenarios in which this feature will apply.

Example 1 – New Quote Fill (X) Protection

Given

- Assuming new quote fill protection = 2 for Market Maker 1 at the product Level
- Expiry for VQO + PQO strikes = 24 days
- Interest Rate = 1.345%

Market Maker 1 has mass quotes in multiple VQO strikes and Market Maker 2 has mass quotes in PQO strikes as shown below:

Strike Price	VQO Bid Book	VQO Ask Book	PQO Bid Book	PQO Ask Book
Call 9050	20@9.70	20@9.80	20@85	20@86
Call 9060	20@10.10	20@10.20	20@83	20@84
Call 9070	20@10.40	20@10.50	20@80	20@81

VQO Asks & PQO Bids generate the following implied futures bids:

	Strike Price	Implied bid in Future	Calculated Delta
Implied 1	9050	10@9038	0.4845488
Implied 2	9060	9@9036	0.4650445
Implied 3	9070	9@9033	0.445424

When

A futures Sell aggressing order arrives for Qty 100@9030, the order can trade with all resting implied orders.

Then

CME Globex creates 3 trades:

- The transaction is stopped after execution of trade 2, since it violated the MQP setting limit for Market Maker 1
- VQO 9070 MQ (Bid and Ask) is eliminated because of the MQP activation, which also cancels implied 3
- VQO 9050 and 9060 Bids are cancelled

Trades	Description	MQP count for Market Maker 1 after each trade
Trade 1	With Implied 1 for qty 10@9038	1
Trade 2	With Implied 2 for qty 9@9036	2
Trade 3	With Implied 3 for qty 9@9033	3

Example 2 – Execution (Y) Protection

Given

- Assuming execution protection = 3 for Market Maker 1 at the product Level
- Expiry for VQO + PQO strikes = 24 days

- Interest Rate = 1.345%

Market Maker 1 has mass quote in multiple VQO strikes & Market Maker 2 has mass quotes in PQO strikes as shown below:

Strike Price	VQO Bid Book	VQO Ask Book	PQO Bid Book	PQO Ask Book
Call 9050	20@9.70	40@9.80	40@85	20@86
Call 9060	20@10.10	40@10.20	20@83 and outright order for 20@83	20@84
Call 9070	20@10.40	20@10.50	20@80	20@81

VQO Asks & PQO Bids generate the following implied futures bids:

	Strike Price	Implied bid in Future	Calculated Delta
Implied 1	9050	19@9038	0.4845488
Implied 2	9060	19@9036	0.4650445
Implied 3	9070	9@9033	0.445424

When

- Futures Sell Aggressor 1 arrives for 10@9030 – can trade with implied 1.
- Futures Sell Aggressor 2 arrives for 50@9030 (within MQP interval).

Then

CME Globex creates 5 trades

- Implied 1 trades with multiple aggressors within MQP interval
- Each aggressor fill is counted in execution protection
- Implied 2 trades with the same aggressor for qty 20 and 20, but execution protection is counted as 1 and not 2
- Will stop the execution after Implied 2 trade, since it violated MQP
- MQP activates after implied 2 is completely traded
- VQO 9070 MQ is cancelled, so implied 3 is cancelled
- VQO 9050 bid and VQO 9060 bid are cancelled
- The changes related to per aggressor count are applicable only for the triangulation implied futures

Trades	Description	MQP count after each trade
Trade 1	With Implied1 for qty 10@9038	1
Trade 2	With Implied1 for qty 9@9038	2
Trade 3	With Implied2 for qty 10@9036	3
Trade 4	With Implied2 for qty 9@9036	3 (Count not incremented since same aggressor is trading with Implied2)
Trade 5	With Implied3 for qty 9@9033	4

Example 3 – Traded Quantity (Z) Protection

Given

- Assuming traded quantity protection = 40 for Market Maker 1 at product level
- Expiry for VQO + PQO strikes = 24 days
- Interest Rate = 1.345%

Market Maker 1 has mass quotes in multiple VQO and Market Maker 2 has mass quotes in PQO strikes as shown below:

Strike Price	VQO Bid Book	VQO Ask Book	PQO Bid Book	PQO Ask Book
Call 9050	20@9.70	20@9.80	20@85	20@86
Call 9060	40@10.10	40@10.20	20@83 (also a limit buy order for 20@83)	20@84
Call 9070	20@10.40	20@10.50	20@80	20@81

VQO Asks & PQO Bids generate the following implied futures bids:

	Strike Price	Implied bid in Future	Calculated Delta
--	--------------	-----------------------	------------------

Implied 1	9050	10@9038	0.4845488
Implied 2	9060 (VQO of 40, PQO MQ of 20 and PQO limit of 20)	19@9036	0.4650445
Implied 3	9070	9@9033	0.445424

When

Futures Sell aggressor arrives for qty 50@9030 and can trade with all resting implieds.

Then

CME Globex creates 4 trades:

- Implied 1 fully trades
- Implied 2 has multiple fills – trade 2 and trade 3
- Though MQP is violated after trade 2, trade 3 also goes through since the implied order from the same MQ is traded
- Will stop the execution after trade 3 since it violated MQP
- MQP activates after implied 2 is completely traded
- VQO 9070 MQ is eliminated, so implied 3 is cancelled
- VQO 9050 Bid and VQO 9060 Bid are cancelled

Trades	Description	MQP count after each trade	How is the count calculated?
Trade 1	With Implied 1 for qty 10@9038	20	VQO1 MQ qty 20
Trade 2	With Implied 2 for qty 10@9036	40	VQO2 MQ qty 20 + the previous counter value of 20
Trade 3	With Implied 2 for qty 9@9036	60	VQO2 MQ remaining qty of 20 + the previous counter value of 40
Trade 4	With Implied 3 for qty 9@9033	80	VQO3 MQ of 20 + the previous counter value of 60

Example 4 – Buy/Sell Protection

Given

- Assuming buy/sell protection = +/- 20 for Market Maker 1 at product level
- With interest rate = 1.345%
- Expiry = 24 days

Market Maker 1 has mass quotes in multiple VQO strikes & Market Maker 2 has mass quotes in PQO strikes as shown below:

Strike Price	VQO Bid Book	VQO Ask Book	PQO Bid Book	PQO Ask Book
Call 9050	20@9.70	20@9.80 (and VQO sell limit for 20@9.80)	40@85	40@86
Put 9060	40@8.60	40@8.70	20@91	20@92 (and PQO sell limit order for 20@92)
Call 9070	40@10.40	40@10.50	20@80 (and PQO bid limit order for 20@80)	20@81

VQO Asks & PQO Bids generate the following implied futures bids:

	Strike Price	Implied bid in Future	Calculated Delta
Implied 1	9050	19@9038	0.4845488
Implied 2	9060 Put (VQO bid of 8.6 and PQO ask of 92)	22@9036	0.5426779
Implied 3	9070	18@9033	0.445424

When

Futures Sell aggressor arrives for qty 100@9030 which can trade with all the resting implied orders.

Then

CME Globex creates 6 trades:

- Implied 1 fully trades – trade 1 and 2

- MQP protection value after implied 1 trade is -20
- MQP activates after trade 2 and stops the execution after trade 2
- VQO Put 9060 and VQO Call 9070 MQs are cancelled, so implied 2 and 3 are cancelled
- VQO Call 9050 Bid side MQ is also cancelled

Trades	Description	MQP count after each trade	How is the count calculated?
Trade 1	With Implied 1 for qty 10@9038	-20	VQO1 sell = -20,
Trade 2	With Implied 1 for qty 9@9038	-20	Same as previous value since there is no trade from VQO MQ
Trade 3	With Implied 2 for qty 10@9036	0	VQO2 Bid = +20, previous counter value = -20, net = 0
Trade 4	With Implied 2 for qty 9@9036	20	VQO2 Bid = 20, previous counter value = 0, net = +20
Trade 5	With Implied 3 for qty 9@9033	0	VQO3 sell = -20, previous counter value = +20, net = 0
Trade 6	With Implied 3 for qty 9@9033	-20	VQO3 sell = 20, previous counter value = 0, net = -20

Self Match Prevention

Self Match Prevention is **not** available for Triangulation.

Triangulation Implied Functionality

Triangulation only functions when the PQO quantity is at least a minimum quantity and sufficient futures hedge quantity is available.



- A minimum quantity of 5 lots is required for Triangulation execution.
- If the VQO customer order 5-lot minimum cannot be satisfied, then the related Triangulation implied match in the PQO or futures will not occur.
- The Triangulation implied for the PQO or futures order books will **not** be published, but will match, provided an aggressing customer order—into either order book—allows at least one related VQO customer order to match a 5-lot minimum.

All Volatility-Quoted Options have a 5-lot minimum order size. These minimums are designed to mitigate the risk of a VQO or Triangulated execution without an assigned future.

The maximum number of deltas that a VQO order can be out due to a Triangulation match is 99 deltas per volatility match level basis.

A Triangulated price is calculated and published as a single price value, but the customer order sources to create a triangulated price can be created from multiple orders and/or multiple prices levels.

Only the following combinations are supported:

1. VQO implied order = PQO customer order + futures customer order
2. PQO implied order = VQO customer order + futures customer order
3. Futures implied order = VQO customer order + PQO customer order

When futures customer order(s) are the limiting factor to create an implied VQO or implied PQO then the following formula will be used to create the implied quantity:

Implied VQO quantity = Minimum of (PQO Quantity, Calculated Options Quantity*)

Implied PQO quantity = Minimum of (VQO Quantity, Calculated Options Quantity*)

*Calculated Options Quantity = Round Down ((Future Quantity + 0.50) / Delta)

Note: If the calculated options quantity results in a positive integer, subtract 1 from calculated options quantity (see [Example A](#) below).

When a new customer order enters the futures, PQO, or VQO book, CME Globex first determines:

1. if there are opposite side resting customer order(s) to match against the incoming order, and
2. if Triangulation implied order(s) can match against the incoming customer order.

This table shows all Triangulation implied order matching combinations:

Customer Order	+	Customer Order	=	Triangulation Function Implied
PQO Call Bid	+	Futures Ask	=	Implied VQO Call Bid
PQO Call Ask	+	Futures Bid	=	Implied VQO Call Ask

PQO Put Bid	+	Futures Bid	=	Implied VQO Put Bid
PQO Put Ask	+	Futures Ask	=	Implied VQO Put Ask
VQO Call Bid	+	Futures Bid	=	Implied PQO Call Bid
VQO Call Ask	+	Futures Ask	=	Implied PQO Call Ask
VQO Put Bid	+	Futures Ask	=	Implied PQO Put Bid
VQO Put Ask	+	Futures Bid	=	Implied PQO Put Ask
VQO Call Ask	+	PQO Call Bid	=	Implied Futures Bid
VQO Call Bid	+	PQO Call Ask	=	Implied Futures Ask
VQO Put Bid	+	PQO Put Ask	=	Implied Futures Bid
VQO Put Ask	+	PQO Put Bid	=	Implied Futures Ask

Option Pricing Inputs

Triangulation is only available to European-style options and will use the Black 76 model. Please see [Volatility-Quoted Options](#) for more details about the CME Globex option pricing model.

The following option pricing model's inputs are consistent regardless of whether the Triangulation implied match occurred in the VQO, PQO or futures book.

Interest Rate	The daily interest rate will be based on the settlement price of the previous day's Eurodollar futures front month quarterly. If the front month Eurodollar futures is the quarterly month then the next quarterly futures settlement price will be used as the interest rate. Clients will be informed as to the exact interest rate value on www.cmegroup.com .
Time Decay	<ul style="list-style-type: none"> Time decay will be expressed in daily terms or "calendar days to expiration". Calendar days to expiration will be divided by 365 days to equate to a decimal equivalent value. Calendar days to expiration will be defined in CME Globex trade date terms; the CME Globex trade date changes with the 5 pm Central Time opening. The calendar days to expiration will be an integer value - there will be no fractional calendar days to expiration (e.g. decay not based on hours/minutes). Days to Expiry(DTE) = 1 on VQO Last Trading Day (LTD) - usually a Thursday, which is 1 day prior to the underlying option's expiration - usually a Friday.
Strike Price	Based on the VQO strike price.

Aggregated Price-Time Priority

Order Priority

Among Triangulation implied orders, the order priority is based on **Aggregated Price-Time**, i.e., the implied order priority will be determined using the last timestamp of the customer orders used to generate the implied.

For example, if a VQO customer order was entered at 12:00:00 p.m. CT and a PQO customer order entered at 12:00:01 p.m. CT, and those orders create an implied futures order, then the related timestamp for the implied futures order would be 12:00:01 p.m. CT, and that implied order would have priority over any implied order with a later timestamp.

Matching Priority

1. Within the VQO order book, at a given price level, if there are both customer orders and Triangulation implied orders, then an aggressing VQO order will match against those orders in the following sequence:

- VQO customer orders or VQO Triangulation implied orders based on the Aggregated Price-Time.

2. Within the PQO order book, at a given price level, if there are both customer orders and implied orders (i.e. RFQ-triggered implied orders *and* Triangulation implied orders), then an aggressing PQO order will match against those orders in the following sequence:

- PQO customer orders, PQO implied orders, or PQO Triangulation implied orders based on the Aggregated Price-Time.

A resting order can match without an incoming (aggressing) opposite side customer order entering its book or any of the related Triangulation books in the following scenario:

- at a new Trading Day's market opening, due to a new option pricing model calculation triggered by time decay and/or a new interest rate.

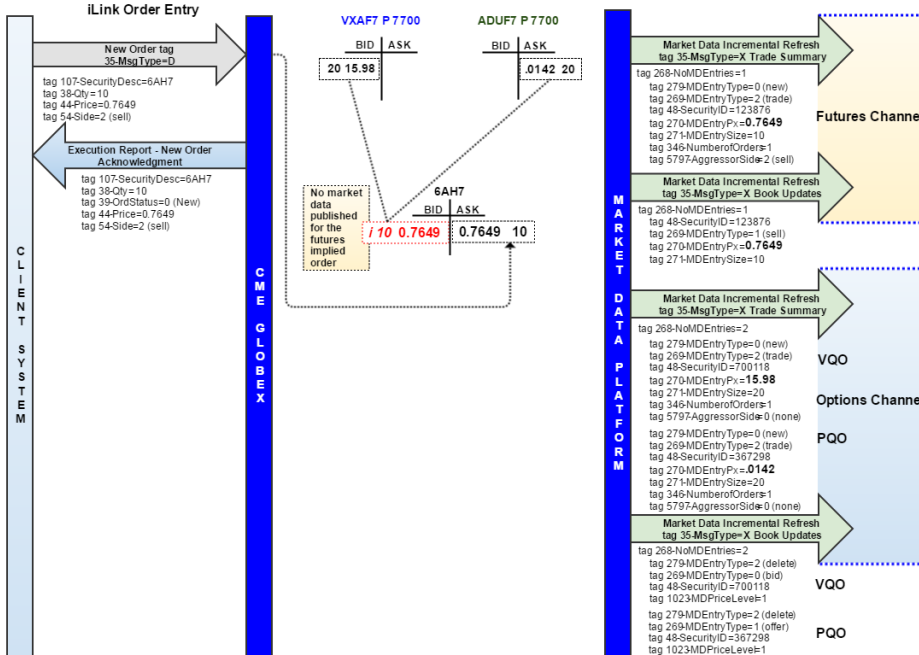
Matching Algorithm

Triangulation products will utilize the match algorithm that they currently employ.

CME Globex Processing Overview

Order entry and market data messaging for Triangulation products are standard CME Globex except where noted.

In this example, the bid in the volatility quoted book and ask in the premium quoted book create an *undisseminated* implied order in the underlying futures 6AH7 bid, which is matched when the client system submits a Sell 10 order in 6AH7.

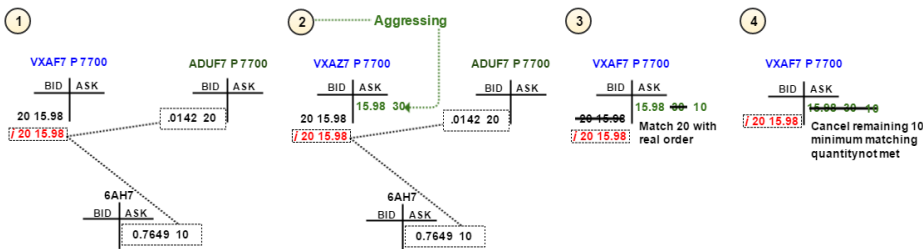


Triangulation Implied Matching Examples

The following examples show matching behavior for various Triangulation implied scenarios.

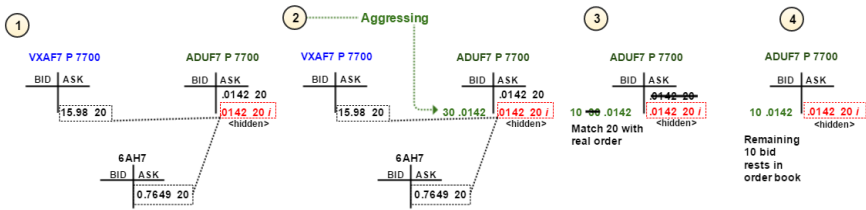
Example 1 - Partial VQO Fill, Cancel Remaining VQO Quantity

1. Starting VQO book with a customer bid of 20@15.98 and an implied bid of 20@15.98 (implied order has second priority).
2. Aggressing Ask for 24 at 15.98 hits VQO order book.
3. Aggressing Ask matches for 20 with customer order for 20 at 15.98.
4. Since the remaining Ask quantity of 4 does not meet the minimum VQO order quantity of 5, the remaining order quantity is cancelled.



Example 2 - Partial PQQ Fill, Remaining PQQ Quantity Rests on Book

1. Starting books with implied Ask order in the PQQ book.
2. Aggressing Bid for 24 at .0142 hits PQQ order book.
3. Aggressing Bid matches for 20 with customer Ask order. The minimum Triangulation function match quantity is **not** met.
4. Remaining Bid quantity of 4 rests at .0142 price level on the PQQ book.



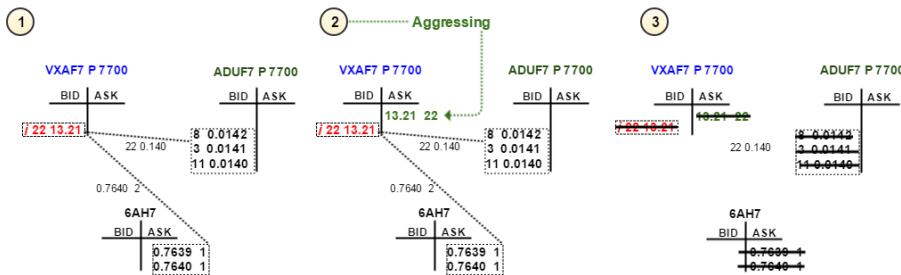
Example 3 - Triangulation Implied Match Occurs in VQO Order Book

In this example the available PQO orders and futures order generate an implied Bid order for 22 @ 13.21 in the VQO order book.

1. Starting books with implied Bid order in the VQO book.
2. Aggressing Ask for 22 @ 13.21 hits VQO order book
3. All VQO, PQO, and futures order fill completely in the following sequence:

iLink Messages for Triangulation Match

- VQO Fill: 8 @ 13.21% (ask)
- Premium Fill: 8 @ \$0.0142 (ask)
 - tag31-LastPX=\$0.0142 | tag 810-UnderlyingPx=\$0.7640 | tag811-OptionDelta=0.1132 | tag1188-Volatility=13.21% | tag1189-ExpiraitonTimeValue=x.x | tag1190-RiskFreeRate=x.x%
- Premium Fill: 8 @ \$0.0142 (bid)
- Future Fill: 1 @ \$0.7639 (bid)
- Future Fill: 1 @ \$0.7639 (ask)
- VQO Fill: 3 @ 13.21% (ask)
- Premium Fill: 3 @ \$0.0141 (ask)
 - tag31-LastPX=\$0.0141 | tag 810-UnderlyingPx=\$0.7640 | tag811-OptionDelta=0.1132 | tag1188-Volatility=13.21% | tag1189-ExpiraitonTimeValue=x.x | tag1190-RiskFreeRate=x.x%
- Premium Fill: 3 @ \$0.0141 (bid)
- VQO Fill: 11 @ 13.21% (ask)
- Premium Fill: 11 @ \$0.0140 (ask)
 - tag31-LastPX=\$0.0140 | tag 810-UnderlyingPx=\$0.7640 | tag811-OptionDelta=0.1132 | tag1188-Volatility=13.21% | tag1189-ExpiraitonTimeValue=x.x | tag1190-RiskFreeRate=x.x%
- Premium Fill: 11 @ \$0.0140 (bid)
- Future Fill: 1 @ \$0.7640 (bid)
- Future Fill: 1 @ \$0.7640 (ask)



Example 4 - Triangulation Implied Match Occurs in PQO Order Book

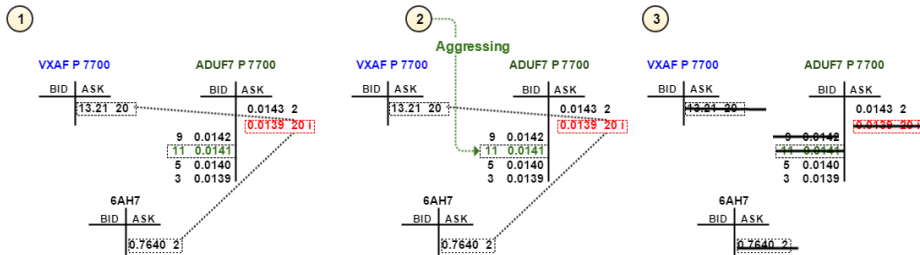
In this example the available VQO, PQO, and futures orders generate an implied Ask order for 20 @ 0.0139 in the PQO order book.

1. Starting books with implied Ask in PQO book.
2. Aggressing PQO bid for 11 @ 0.0141 hits the order book, satisfying the implied minimum quantity and matching at improved price of 0.0139.
3. Resting order fills:
 - PQO bid for 9 @ 0.0142 matches completely at 0.0142.
 - Resting VQO ask for 20@13.21 fills completely.
 - Resting Futures ask for 2 @ 0.7640 fills completely.

iLink Messages for Triangulation Match

- VQO Fill: 9 @ 13.21% (ask)
- Premium Fill: 9 @ \$0.0142 (ask)

- tag31-LastPX=\$0.0142| tag 810-UnderlyingPx=\$0.7640 | tag811-OptionDelta=0.1132 | tag1188-Volatility=13.21% | tag1189-ExpirationTimeValue=x.x | tag1190-RiskFreeRate=x.x%
- Premium Fill: 9 @ \$0.0142 (bid)
- Future Fill: 1 @ \$0.7640 (bid)
- Future Fill: 1 @ \$0.7640 (ask)
- VQO Fill: 11 @ 13.21% (ask)
- Premium Fill: 11 @\$0.0139 (ask)
 - tag31-LastPX=\$0.0139| tag 810-UnderlyingPx=\$0.7640 | tag811-OptionDelta=0.1132 | tag1188-Volatility=13.21% | tag1189-ExpirationTimeValue=x.x | tag1190-RiskFreeRate=x.x%



Additional Implied Order Scenarios

The following examples show scenarios in which Triangulation provides implied order quantity in the VQO, PQO, and Futures order book, depending upon book dynamics.

Example A - VQO implied bid

If the delta is 50 then the VQO Put implied bid will be published as a 24-lot: $(12\text{-lot futures} + 0.50) / 50 \text{ deltas} = 2500 \text{ deltas}$ (subtract 100 from 2500 deltas or VQO 24-lot implied order).

	Bid
VQO Put	24-lot Triangulation implied displayed
PQO Put (50 delta)	45-lot customer order
Futures	12-lot customer order

Example B - VQO implied bid

If the delta is 55, then the VQO Put implied bid will be published as a 22-lot: $(12\text{-lot futures} + 0.50) / 55 \text{ deltas} = 2272 \text{ deltas}$ (rounded down to 2200 deltas or VQO 22-lot implied order).

	Bid
VQO Put	22-lot Triangulation implied displayed
PQO Put (55 delta)	45-lot customer order
Futures	12-lot customer order

Example C - Futures implied bid

If the delta is 28 then an 8-lot futures will be implied: $VQO\ 30\text{-lot} * 28 \text{ delta} = 840 \text{ deltas}$ (rounded down to 800 deltas or 8 futures).

	Bid	Ask
VQO Put	30-lot customer order	
PQO Put (28 delta)		100-lot customer order
Futures	8-lot Triangulation implied displayed	

Examples D through F assume the following book dynamics:

	Bid	Ask
VQO Put	Implied 10.05% (20-lot) displayed	10.10% (20-lot)
PQO Put (50 delta)	38 bid (20-lot)	Implied 42 ask (20-lot) hidden
Futures	1 bid (10-lot)	Implied 2 offer (10-lot) hidden

Example D - Futures impiled ask

- VQO Put of 10.10% Ask (20-lot) and PQO Put of 38 Bid (20-lot) generates Futures Implied Ask of 2 Ask (10-lot)
- Futures goes 2 Bid (10-lot) – resulting matches and market data:
 - VQO 10.10% (20-lot)
 - PQO 38 (20-lot)
 - Futures 2 (10-lot)

Example E - VQO implied bid does not meet minimum quantity requirement

- PQO goes 42 Bid (4-lot); this calculates to a VQO implied Bid of 10.15% (4-lot)
- However, because the VQO implied does not meet the 5-lot minimum, no implied is created and no matching occurs.

Example F - PQO implied ask

- VQO Put of 10.10% Ask (20-lot) and Futures bid of 1 Bid (20-lot) generates PQO Implied Put of 42 Ask (20-lot)
- PQO goes 42 Bid (20-lot) – resulting matches and market data:
 - VQO 10.10% (20-lot)
 - PQO 42 (20-lot)
 - Futures 1 (10-lot)

Example G - VQO implied bid, cancel aggressing order remainder

	Bid
VQO Put	20-lot customer order @ 12.20% 22-lot Triangulation implied @ 12.20% displayed
PQO Put (55 delta)	45-lot customer order
Futures	12-lot customer order

If an incoming, aggressing VQO Put Ask 25-lot order enters the CLOB @ 12.20% then:

- the resting VQO Put 20-lot customer order @ 12.20% will fully match
- CME Globex will cancel the aggressing VQO Put Ask order remaining 5-lot.

Below are the rules for how an incoming order progresses through the Triangulation functionality:

1. An incoming customer order is evaluated to match against opposite side customer or triangulation implied order(s) in the same book based on the aggregated price-time.
2. If the incoming customer order has remaining quantity, then it, in turn, is evaluated to create Triangulation implied orders.
 - The incoming customer order's participation as part of the Triangulated implied order action occurs regardless of the customer order's qualifier instructions (e.g. FOK/FAK instructions).
3. If the incoming customer order has remaining quantity, then its order qualifier instructions are applied (e.g. FOK/FAK instructions).

Comparison of Triangulation and Options Implied Processing

The following table compares the behavior of implied processing of Triangulation and Options:

Feature	Triangulation	Options
Implied Book Levels Disseminated	1 (best implied price only) Only for the VQO book.	1 (best implied price only)
Frequency / Pace	Streaming	On-Demand driven by RFQs , Configured with Delay + Duration
Implication Direction	Complementary; INs + OUTs	Complementary; INs + OUTs
Spread Scope	Not supported	User Defined , limited to 8 spreads, 1:1 ratio
Order Priority	For the VQO and PQO order books, Aggregated Price-Time with no preferential treatment. For the futures order book, futures customer orders first, futures Triangulation implied orders next, and futures traditional implied orders last.	Aggregated Price-Time with no preferential treatment for customer orders.
Price Improvement	Aggressor order receives price improvement.	Aggressor order receives price improvement.
Implied Resolution	VQO order receives price improvement.	Spread receives price improvement.