



Synthetic Butterflies and Condors

Presentation of Synthetic Matching Concept

Agenda

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- 2 Concept of Synthetic Matching
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- 5 Synthetic Matching Conditions for Butterflies

Synthetic Butterflies and Condors

- Synthetic matching for simple instruments and calendar spread instruments available for various futures products at Eurex
- STIRs product suite offers additional complex instruments like futures condors and butterflies with four leg instruments
- Synthetic matching in condors and butterflies complements already existing calendar spread synthetic matching and enhances orderbook liquidity and transparency in these products



1 - Terminology

- Expiries A, B, C, D ordered by shorter expiry first, meaning $A < B < C < D$

Simple instrument with expiry A denoted by $SI(A)$:

buy (sell) $SI(A)$

Condor with expiry $A < B < C < D$ denoted by $Con(A, B, C, D)$:

buy (sell) $Con(A, B, C, D)$ → buy (sell) A ,
sell (buy) B ,
sell (buy) C ,
buy (sell) D

Calendar spread with expiry $A < B$ denoted by $Spd(A, B)$:

buy (sell) $Spd(A, B)$ → buy (sell) A ,
sell (buy) B

Butterfly with expiry $A < B < C$ denoted by $But(A, B, C)$:

buy (sell) $But(A, B, C)$ → buy (sell) A ,
sell (buy) twice B ,
buy (sell) C

2 – Concept of Synthetic Matching (1)

Notation *synbuy* $SI(A)$, *synsell* $But(A, B)$,
synbuy $But(A, B, C)$ or *snysell* $Con(A, B, C, D)$ is indicating
a synthetic combination resulting in the corresponding
orderbook side.

Closed Match Paths and Synthetic Path

- Considering **orderbook sides with best price level** and **accumulated quantity of best price level**; except on incoming side, individual orders are not considered
- Orderbook sides are combined in such way that the combination is completely balanced and results to a **closed match path**
 - **Example:** closed match path of length 2 $buy SI(A) \oplus sell Spd(A, B) \oplus sell SI(B)$
- Any orderbook side of a closed match path can **represent the incoming orderbook side** containing the incoming order with corresponding price and quantity; all remaining orderbook sides on the passive side are creating a **synthetic path resulting to an orderbook side opposite to the incoming orderbook side**
 - **Example:** incoming $sell SI(B)$ is opposite to $buy SI(A) \oplus sell Spd(A, B) =: synbuy SI(B)$
- **Any closed match path has a specific orientation**; change of orientation results to the opposite side of the incoming orderbook side
 - **Example:** opposite orientation of above $sell SI(A) \oplus buy Spd(A, B) \oplus buy SI(B)$

2 – Concept of Synthetic Matching (2)

Match Price and Quantity Condition

Match price condition:

- **Sum of sign-adapted price** of orderbook sides along a closed synthetic match path including incoming orderbook side must be **equal to or larger than zero** (all ask prices are multiplied by (-1) before summing up)
- Consequently, the price limit of an incoming buy (sell) order must be equal to or higher (lower) than the price limit of the synthetic path on passive orderbook side opposite to incoming aggressive one

Match quantity condition:

- **Minimum over quantity contributions of all orderbook sides** including incoming orderbook side along a closed path must be strictly larger than zero
- For any complex instruments with leg ratio 1 involved in closed synthetic match path, the match quantity condition is automatically satisfied


3 – Condor Synthetics: Closed Match Paths for Condor

Only the most essential synthetic condor combinations are considered.

- Condor synthetics is based on **4 different closed match paths** consisting of one **condor orderbook** side and additional orderbook sides of **simple instruments** or **calendar spreads**
 - Closed match path of length 4: $buy\ SI(A) \oplus sell\ SI(B) \oplus sell\ SI(C) \oplus buy\ SI(D) \oplus sell\ Con(A,B,C,D)$
 - Closed match path of length 3: $buy\ SI(A) \oplus sell\ SI(B) \oplus sell\ Spd(C,D) \oplus sell\ Con(A,B,C,D)$
 - Closed match path of length 3: $buy\ Spd(A,B) \oplus sell\ SI(C) \oplus buy\ SI(D) \oplus sell\ Con(A,B,C,D)$
 - Closed match path of length 2: $buy\ Spd(A,B) \oplus sell\ Spd(C,D) \oplus sell\ Con(A,B,C,D)$
- As mentioned before, closed match paths have two different orientations; only the sell side of the condor order book is given above
- Please note that the 4 different closed match paths contain the same condor with the same 4 expiries
- Other closed match paths containing **one or more condors are not considered**
 - Condor composed of diagonal calendar spread : $buy\ SI(A) \oplus sell\ Spd(B,D) \oplus sell\ SI(C) \oplus sell\ Con(A,B,C,D)$
 - Match path containing two condors: $buy\ Spd(A,B) \oplus sell\ Con(A,B,C,D) \oplus sell\ Con(C,D,E,F) \oplus sell\ Spd(E,F)$

3 – Condor Synthetics: Closed Match Paths for Butterfly

Butterflies can be treated as specific condors with second and third condor leg identical to each other.

- Consequently, the following 4 different closed match paths consists of one **butterfly orderbook** side and orderbook sides of **simple instruments** or **calendar spreads**:
 - Closed match path of length 4: $buy SI(A) \oplus sell SI(B) \oplus sell SI(B) \oplus buy SI(C) \oplus sell But(A, B, C)$ 
 - Closed match path of length 3: $buy SI(A) \oplus sell SI(B) \oplus sell Spd(B, C) \oplus sell But(A, B, C)$
 - Closed match path of length 3: $buy Spd(A, B) \oplus sell SI(B) \oplus buy SI(C) \oplus sell But(A, B, C)$
 - Closed match path of length 2: $buy Spd(A, B) \oplus sell Spd(B, C) \oplus sell But(A, B, C)$
- Again, closed match paths are **characterized by their orientation**, only sell side of butterfly orderbook mentioned above
- Please note that the 4 different closed match paths contain the same butterfly with the same 3 expiries
- Other closed match paths containing, e.g., **more than one butterfly are not considered**
 - Match path containing two butterflies: $buy Spd(A, B) \oplus sell But(A, B, C) \oplus sell But(B, C, D) \oplus sell Spd(C, D)$

3 – Condor Synthetics: Category 1 vs Category 2 Paths

- To avoid crossed orderbook situations, condor synthetics distinguishes between different categories of synthetic paths
- All paths resulting to a synthetic butterfly or synthetic condor are handled as synthetic paths of category 1 (implied-in), i.e., **any price or quantity update of a synthetic butterfly or condor path is immediately distributed via market data interfaces**
- All synthetic paths resulting to a simple instrument or calendar spreads and which contain a butterfly or condor orderbook side are treated as synthetic paths of category 2 (implied-out), i.e., **any update of price or quantity of synthetic simple instrument or calendar spread paths derived from condor synthetics is only triggered in case of an incoming simple instrument or calendar spread order** entering the opposite orderbook side
- Synthetic paths of category 1 are used to **create additional liquidity in butterflies and condors** and synthetic paths of category 2 are required to prevent crossed orderbook situations in butterflies and condors.



Example 1

Taking closed match path

$buy\ SI(A) \oplus sell\ SI(B) \oplus sell\ Spd(B,C) \oplus sell\ But(A,B,C)$,
the synthetic combination $buy\ SI(A) \oplus sell\ SI(B) \oplus sell\ Spd(B,C)$ is representing $synbuy\ But(A,B,C)$ orderbook side.

Any price or quantity update of $synbuy\ But(A,B,C)$ resulting from a price or quantity update in the orderbook sides $buy\ SI(A)$, $sell\ SI(B)$ or $sell\ Spd(B,C)$ will be published immediately.



Example 2

Taking closed match path

$buy\ SI(A) \oplus sell\ SI(B) \oplus sell\ Spd(B,C) \oplus sell\ But(A,B,C)$,
the synthetic combination $sell\ SI(B) \oplus sell\ Spd(B,C) \oplus sell\ But(A,B,C)$ is representing $synsell\ SI(A)$.

Matching of $synsell\ SI(A)$ against an incoming $buy\ SI(A)$ will prevent display of crossed orderbook $But(A,B,C)$ if incoming $buy\ SI(A)$ would be written to its orderbook instead of matching.

4 – Synthetic Matching Condition for Condors

General matching condition (reminder):

- Sum of sign-adapted price of orderbook sides along a closed synthetic match path (incl. incoming order) must be equal to or larger than zero
- Consequently, the price limit of an incoming buy (sell) order must be equal to or higher (lower) than the price limit of the synthetic path on passive orderbook side opposite to incoming aggressive one

Example 1: Incoming *sell Con* order of closed match path *buy SI(A)* \oplus *sell SI(B)* \oplus *sell Spd(C,D)* \oplus *sell Con(A,B,C,D)*

- **Match price condition:** $BP(SI(A)) - AP(SI(B)) - AP(Spd(C,D)) - AP^{inc}(Con(A,B,C,D)) \geq 0$ resulting to
 $AP^{inc}(Con(A,B,C,D)) \leq BP(SI(A)) - AP(SI(B)) - AP(Spd(C,D)) =: BP^{syn}(Con(A,B,C,D)) = TP(Con(A,B,C,D))$
- **Match quantity:** $TQ = MIN\{BQ(SI(A)); AQ(SI(B)); AQ(Spd(C,D)); AQ^{inc}(Con(A,B,C,D))\}$ (no specific match quantity condition)

Example 2: Incoming *buy Con* of closed match path *sell Spd(A,B)* \oplus *buy Spd(C,D)* \oplus *buy Con(A,B,C,D)*

- **Match price condition:** $-AP(Spd(A,B)) + BP(Spd(C,D)) + BP^{inc}(Con(A,B,C,D)) \geq 0$ resulting to
 $BP^{inc}(Con(A,B,C,D)) \geq AP(Spd(A,B)) - BP(Spd(C,D)) =: AP^{syn}(Con(A,B,C,D)) = TP(Con(A,B,C,D))$
- **Match quantity:** $TQ = MIN\{AQ(Spd(A,B)); BQ(Spd(C,D)); BQ^{inc}(Con(A,B,C,D))\}$ (no specific match quantity condition)

As usual, any price advantage available on closed synthetic match path is given to incoming order, and no specific match quantity condition to be considered.

5 – Synthetic Matching Condition for Butterflies

General matching condition (reminder):

- Sum of sign-adapted price of orderbook sides along a closed synthetic match path (incl. incoming order) must be equal to or larger than zero
- Consequently, the price limit of an incoming buy (sell) order must be equal to or higher (lower) than the price limit of the synthetic path on passive orderbook side opposite to incoming aggressive one
- **Separate handling required for closed butterfly match path of length 4 involving two times inner butterfly leg (see Appendix)**

Example 1: Incoming *buy SI(C)* order of closed match path *buy Spd(A, B) ⊕ sell SI(B) ⊕ buy SI(C) ⊕ sell But(A, B, C)*

- **Match price condition:** $BP(Spd(A, B)) - AP(SI(B)) + BP^{inc}(SI(C)) - AP(But(A, B, C)) \geq 0$ resulting to

$$BP^{inc}(SI(C)) \geq AP(SI(B)) - BP(Spd(A, B)) + AP(But(A, B, C)) =: AP^{syn}(SI(C)) = TP(SI(C))$$
- **Match quantity:** $TQ = MIN\{AQ(SI(B)); BQ(Spd(A, B)); AQ(But(A, B, C)); BQ^{inc}(SI(C))\}$ (no specific match quantity condition)

Example 2: Incoming *sell Spd(B, C)* of closed match path *buy SI(A) ⊕ sell SI(B) ⊕ sell Spd(B, C) ⊕ sell But(A, B, C)*

- **Match price condition:** $BP(SI(A)) - AP(SI(B)) - AP^{inc}(Spd(B, C)) - AP(But(A, B, C)) \geq 0$ resulting to

$$AP^{inc}(Spd(B, C)) \leq BP(SI(A)) - AP(SI(B)) - AP(But(A, B, C)) =: BP^{syn}(Spd(B, C)) = TP(Spd(B, C))$$
- **Match quantity:** $TQ = MIN\{BQ(SI(A)); AQ(SI(B)); AQ(But(A, B, C)); AQ^{inc}(Spd(B, C))\}$ (no restrictions)

Again, any price advantage available on closed synthetic match path is given to incoming order, no deviations to condors. Special handling is required for closed synthetic butterfly match path of length 4 exclusively containing simple instruments (see appendix).

Appendix

Appendix – Synthetic Matching Conditions for Butterflies (1)

Matching Condition of incoming **Outer Butterfly Leg** or of incoming **Butterfly** in case of closed match path only containing **SI**

- In line with general matching condition outlined before, **specific handling is required for closed butterfly match path** $buy SI(A) \oplus sell SI(B) \oplus sell SI(B) \oplus buy SI(C) \oplus sell But(A, B, C)$ (and its opposite closed synthetic match path)
 - **Match price condition:** $BP(SI(A)) - 2 \cdot AP_+(SI(B)) + BP(SI(C)) - AP(But(A, B, C)) \geq 0$
 - **Match quantity condition:** $TQ = MIN \{BQ(SI(A)); (AQ_+(SI(B))) DIV 2; BQ(SI(C)); AQ(But(A, B, C))\} > 0$
 - In case the best price level of $sell SI(B)$ only contains a 1 lot order, price $AP_+(SI(B))$ is considering the second-best price level and the quantity $AQ_+(SI(B))$ is the quantity accumulation of both price levels
 - Later, when orderbook allocation kicks in, the 1 lot price best order has higher priority than second best orders
- Thus, adapted match conditions do consider the **quantity contribution of inner butterfly leg which must be strictly larger than 1**, i.e., $BQ(SI(B)) > 1$ or $AQ(SI(B)) > 1$, to avoid that traded quantity would result to $TQ = 0$
- In case of incoming outer leg order or incoming butterfly order and by considering the adapted match conditions, calculation of synthetic price and matched quantity is straight forward by using AP_+ and AQ_+
- **Example:** Incoming $buy SI(C)$ order of closed path $buy SI(A) \oplus sell SI(B) \oplus sell SI(B) \oplus buy SI(C) \oplus sell But(A, B, C)$
 - Match price condition: $BP(SI(A)) - 2 \cdot AP_+(SI(B)) + BP^{inc}(SI(C)) - AP(But(A, B, C)) \geq 0$ is resulting to $BP^{inc}(SI(C)) \geq 2 \cdot AP_+(SI(B)) - BP(SI(A)) + AP(But(A, B, C)) =: AP^{syn}(SI(C)) = TP(SI(C))$
 - Match quantity condition: $TQ = MIN \{BQ(SI(A)); (AP_+(SI(B))) DIV 2; BQ^{inc}(SI(C)); AQ(But(A, B, C))\} > 0$

Appendix – Synthetic Matching Conditions for Butterflies (2)

Matching Condition of Inner Butterfly Leg in case of closed match path only containing SI

- Considering inner butterfly leg B of match path $buy SI(A) \oplus sell SI(B) \oplus sell SI(B) \oplus buy SI(C) \oplus sell But(A, B, C)$
- Matching condition is given by $BP(SI(A)) - 2 \cdot AP^{inc}(SI(B)) + BP(SI(C)) - AP(But(A, B, C)) \geq 0$ resulting to
 - **Match price condition:** $AP^{inc}(SI(B)) \leq \frac{1}{2} \cdot (BP(SI(A)) + BP(SI(C)) - AP(But(A, B, C))) =: BP^{syn}(SI(B)) = TP(SI(B))$
 - **Match quantity condition:** $TQ = 2 \cdot \min\{BQ(SI(A)); BQ(SI(C)); AQ(But(A, B, C)); (AQ_+^{inc}(SI(B))) DIV 2\} > 0$
 - $AQ_+^{inc}(SI(B))$ is considering an additional 1 lot order stored in the orderbook on the same side of the incoming order provided the price $AP^{book}(SI(B))$ of such a 1 lot order is equal to or better than $AP^{inc}(SI(B))$, i.e. $AP^{book} \leq AP^{inc}$.
 - Note that in case of price of passive 1 lot order $AP^{book}(SI(B))$ is better than price of incoming order $AP^{inc}(SI(B))$, the passive 1 lot order receives a match price advantage since matching takes place at price of $AP^{inc}(SI(B))$ or even better
 - In any case, passive 1 lot order has higher match priority than incoming order when orderbook allocation kicks in
- Same considerations apply to $sell SI(A) \oplus buy SI(B) \oplus buy SI(B) \oplus sell SI(C) \oplus buy But(A, B, C)$ for inner butterfly leg B
- In this case, matching condition is given by $-AP(SI(A)) + 2 \cdot BP^{inc}(SI(B)) - AP(SI(C)) + BP(But(A, B, C)) \geq 0$ resulting to
 - **Match price condition:** $BP^{inc}(SI(B)) \geq \frac{1}{2} \cdot (AP(SI(A)) + AP(SI(C)) - BP(But(A, B, C))) =: AP^{syn}(SI(B)) = TP(SI(B))$
 - **Match quantity condition:** $TQ = 2 \cdot \min\{AQ(SI(A)); AQ(SI(C)); BQ(But(A, B, C)); (BQ_+^{inc}(SI(B))) DIV 2\} > 0$ with quantity $BQ_+^{inc}(SI(B))$ enlarged by 1 lot book order if its price $BP^{book}(SI(B))$ satisfies the match price condition



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