Wrong-way risk in FX, cross-currency basis, and consistent multi-currency curve framework

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Top Quants

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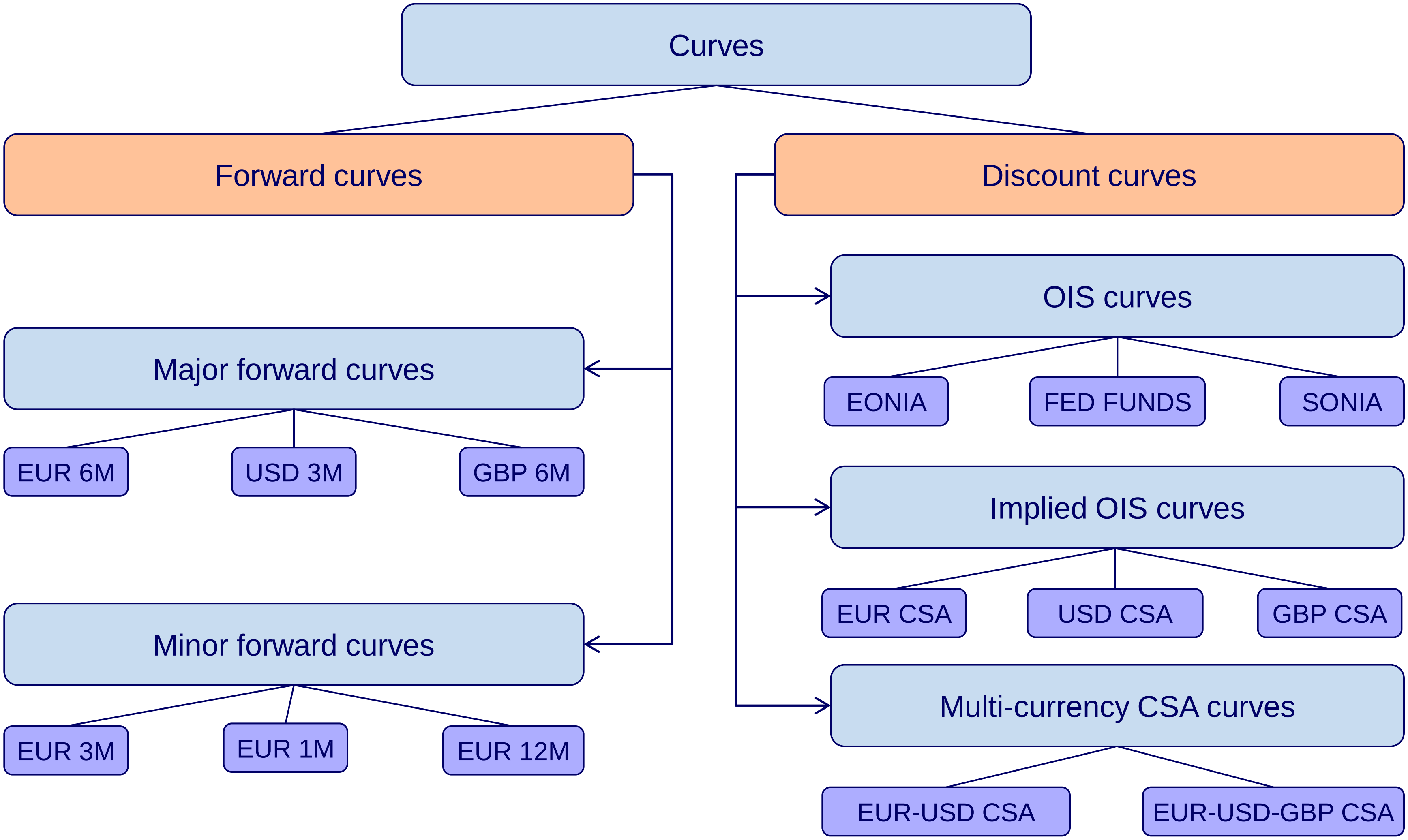
Outline

- Current market landscape for interest rates
- Cross-currency basis and related issues
- Modeling cross-currency risk
- Comparison to historical time series
- Consistency with the current OIS framework
  - Deal collateralized in foreign currency
- Effect on CVA / DVA calculations
  - CDS spread in different currencies
  - Uncollateralized deal in foreign / domestic currency
  - Uncollateralized XCCY swap
- Multi-currency curve consistent framework for OIS / CVA / DVA

Current market landscape



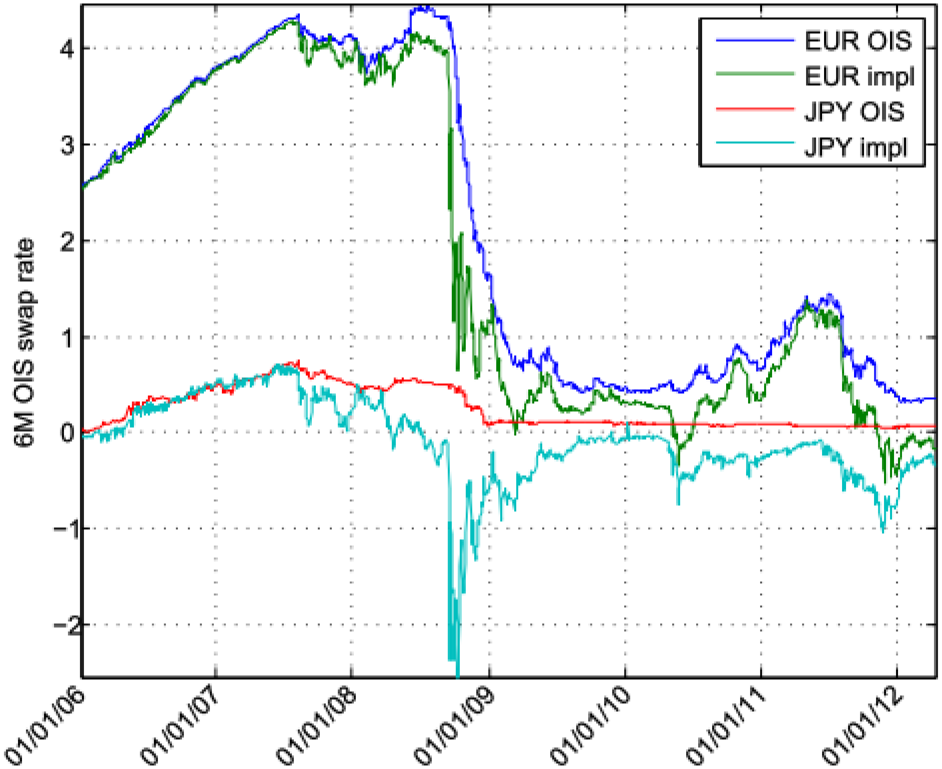
Cross-currency basis

6M OIS swap rate vs. implied OIS rate

Covered Interest rate Parity

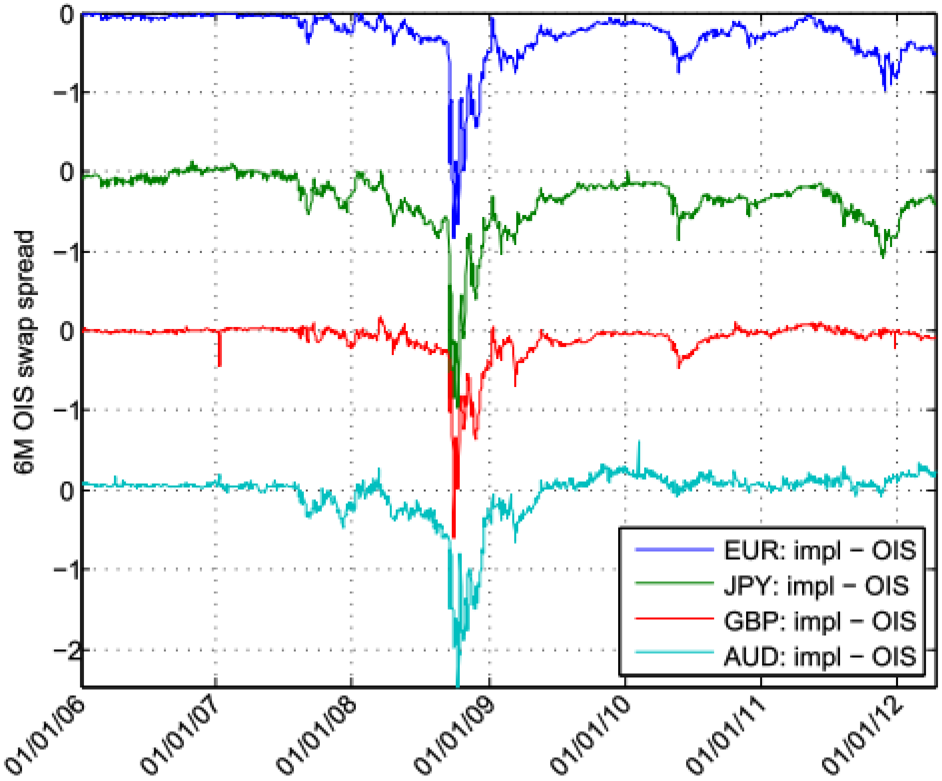
$$F(T) = S(0)\frac{D^f(T)}{D^d(T)}$$

$$r^d_{imp} = r^f_{ois} + \frac{1}{T}\ln\frac{F(T)}{S(0)}$$



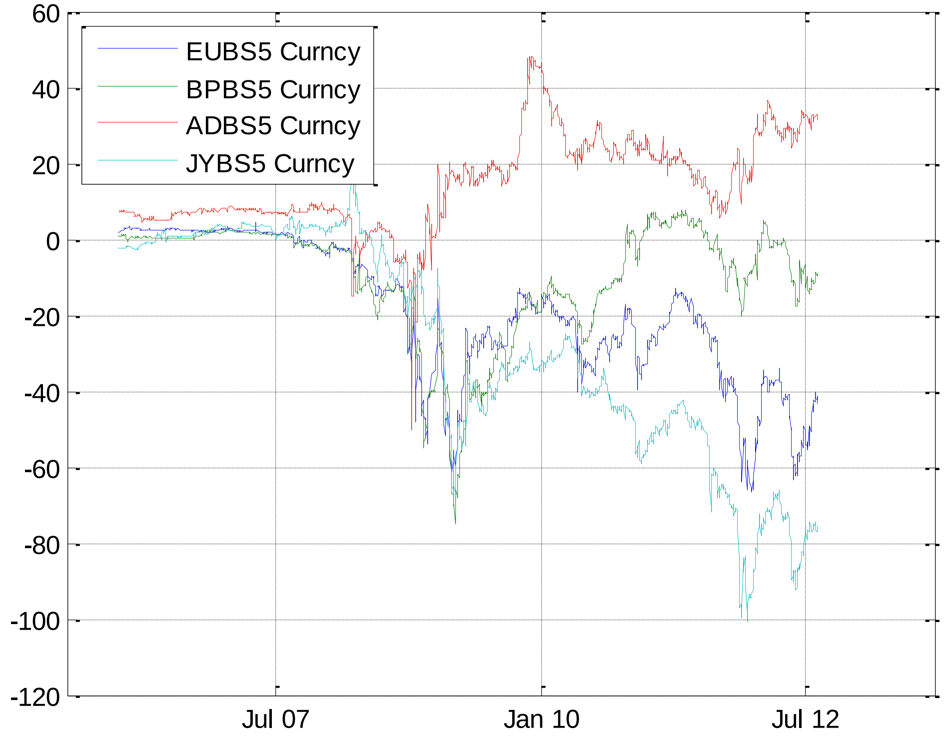
Cross-currency basis

Difference between 6M OIS swap rate vs. implied OIS rate



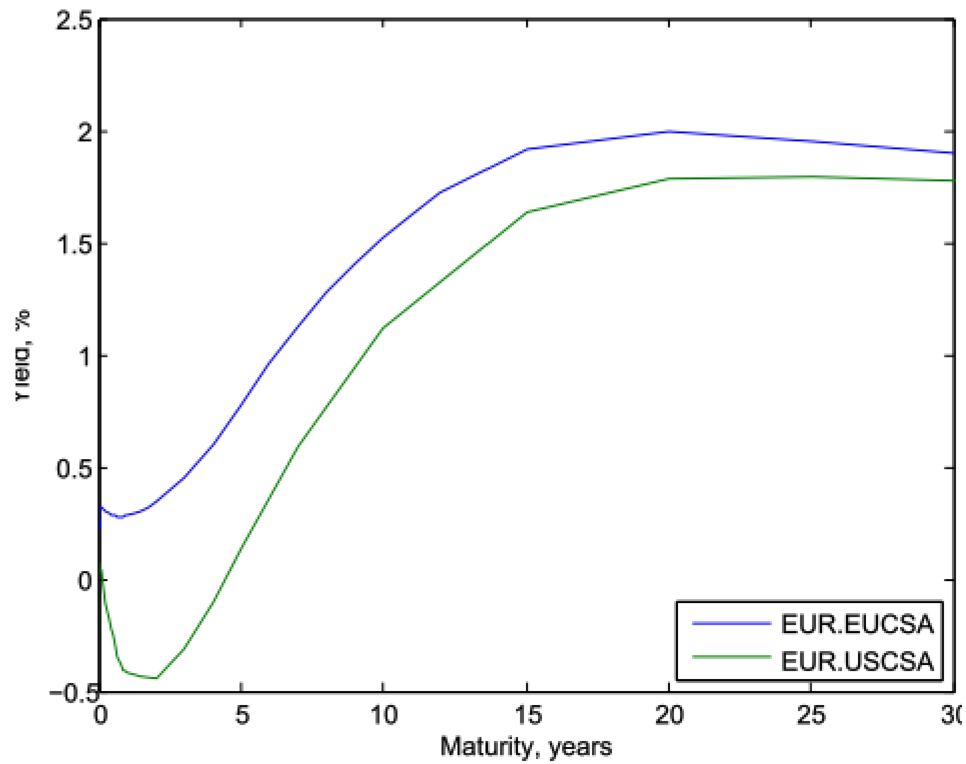
Cross-currency basis

XCCY basis



Cross-currency basis
CIP violation

EONIA curve and the implied EUR OIS discount curve



Cross-currency basis
Different collateral currencies

USD IR swap
$100M

Maturity	Par rate	MTM (par+1%)		abs diff	rel diff	swap spread	BVA
		USD CSA	EUR CSA				
2	0.41%	-2,028K	-2,016K	-12K	0.6%	0.6 bp	-65K
3	0.48%	-3,033K	-3,007K	-26K	0.8%	0.8 bp	-126K
5	0.81%	-5,017K	-4,963K	-54K	1.1%	1.1 bp	-279K
7	1.24%	-6,929K	-6,849K	-80K	1.1%	1.2 bp	-387K
10	1.74%	-9,615K	-9,498K	-117K	1.2%	1.2 bp	-548K
15	2.26%	-13,561K	-13,368K	-193K	1.4%	1.5 bp	-920K
20	2.47%	-16,930K	-16,609K	-321K	1.9%	2.0 bp	-1,589K
30	2.66%	-22,301K	-21,657K	-644K	2.9%	3.0 bp	-2,987K

Cross-currency basis

Default-free value for CVA / DVA

?

EUR or USD

$$\hat{V}(t) = V_{CSA} + CVA_{CSA} + DVA_{CSA}$$

$$\hat{V}(t,S) = E\left[e^{-\int_t^T r_{CSA}(u)du} V(T) \right]$$

$$- E\left[(1-R_C)\int_t^T \lambda_C e^{-\int_t^s r_{CSA}(u)du} SP_C(s)SP_B(s)V_{CSA}^{+}(s)ds \right]$$

$$- E\left[(1-R_B)\int_t^T \lambda_B e^{-\int_t^s r_{CSA}(u)du} SP_C(s)SP_B(s)V_{CSA}^{-}(s)ds \right]$$

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CIP violation

- CIP is obtained from no-arbitrage considerations (Hull, Shreve,…)

$$F(T) = S(0)\frac{D^f(T)}{D^d(T)}$$

- Yet little attention has been paid to the violation of CIP
  - Most of the work on the multi-currency curve construction has been expressed in terms of implied OIS curves.
  - Tuckman and Porfirio (2004) ascribed the XCCY basis to the riskiness of Libor rates compared to default-free overnight rates.
  - Fujii et al. (2010) introduced a spread between the collateral rate and an unobservable risk-free rate to cope the CIP violation.
  - Macey (2012) and Piterbarg (2012) recently showed that the results of Fujii et al. can be obtained without the assumption of risk-free rates. Possibility for FX market segmentation.

CIP violation

- CIP violation plays however an important role in asset pricing
  - It contradicts the theory of efficient markets as it implies arbitrage.
  - It is difficult to imagine that such an apparent arbitrage can exist already for a number of years.
  - Implied rates can be negative, in striking difference with large actual interest rates.
  - Swaps collateralized in different currencies have different NPV.
  - Multi-currency CSA have an imbedded option to choose collateral currency.
  - This became a blocking factor for the novation of swaps and for back-loading the existing deals to the clearing houses.
  - The implications of multi-currency CSA were a subject of broad debates, which lead ISDA to dramatically modify its Collateral Support Annex to a Standard CSA.
  - The problem of default-free reference value for uncollateralized trades.

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Explicit Wrong Way Risk
Taking currency risk into account

Two approaches:

- Diffusion correlation: Sokol (2010) and Hull and White (2011), for example, correlates exposure with the hazard rate.
- Defaults correlation: This model follows a different approach by taking explicitly into account simultaneous currency events and deal defaults.

Explicit Wrong Way Risk
Extreme event risk taken explicitly

Two approaches to WWR:

- Diffusion correlation: Sokol (2010) and Hull and White (2011), for example, correlates exposure with the hazard rate.
- Defaults correlation: This model follows a different approach by taking explicitly into account simultaneous currency events and deal defaults.
  - We consider extreme events explicitly
  - Directly specify market conditions at the event
  - Compute the loss at default
  - Estimate probability of default
  - Lots of assumptions
  - But it is still better than blind fitting of a model to scarce data
  - In essence, we combine CVA with Event Risk calculations
  - Tsvetkov (2012), Turlakov (2013), Pykhtin and Sokol (2013)
- XCCY wrong way risk

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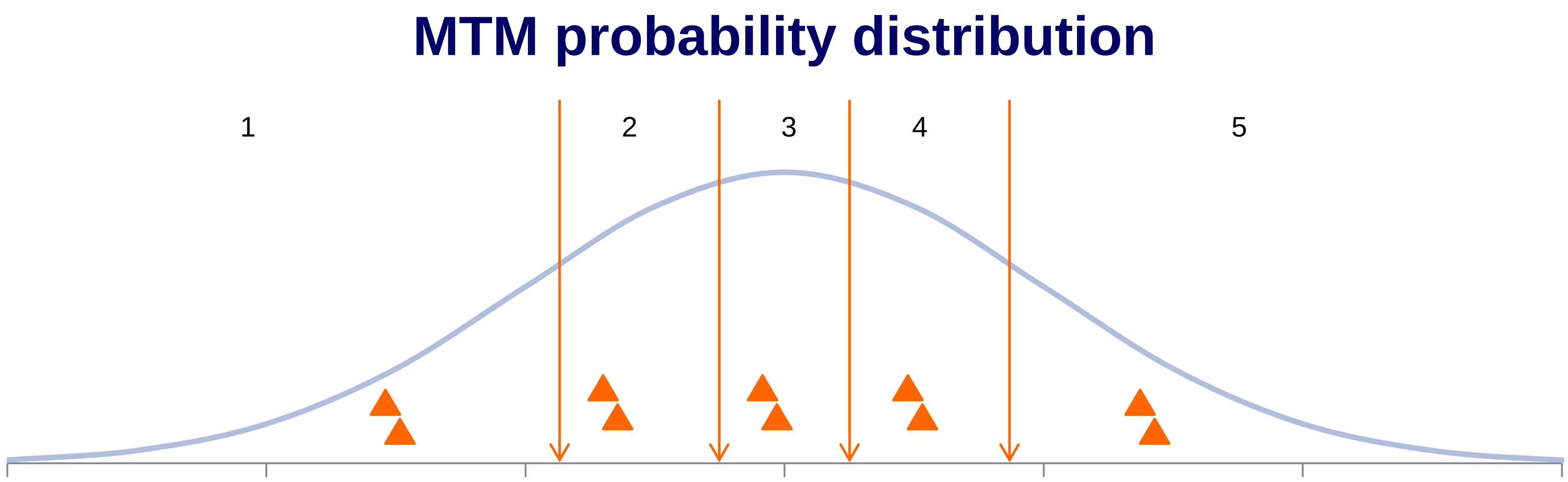
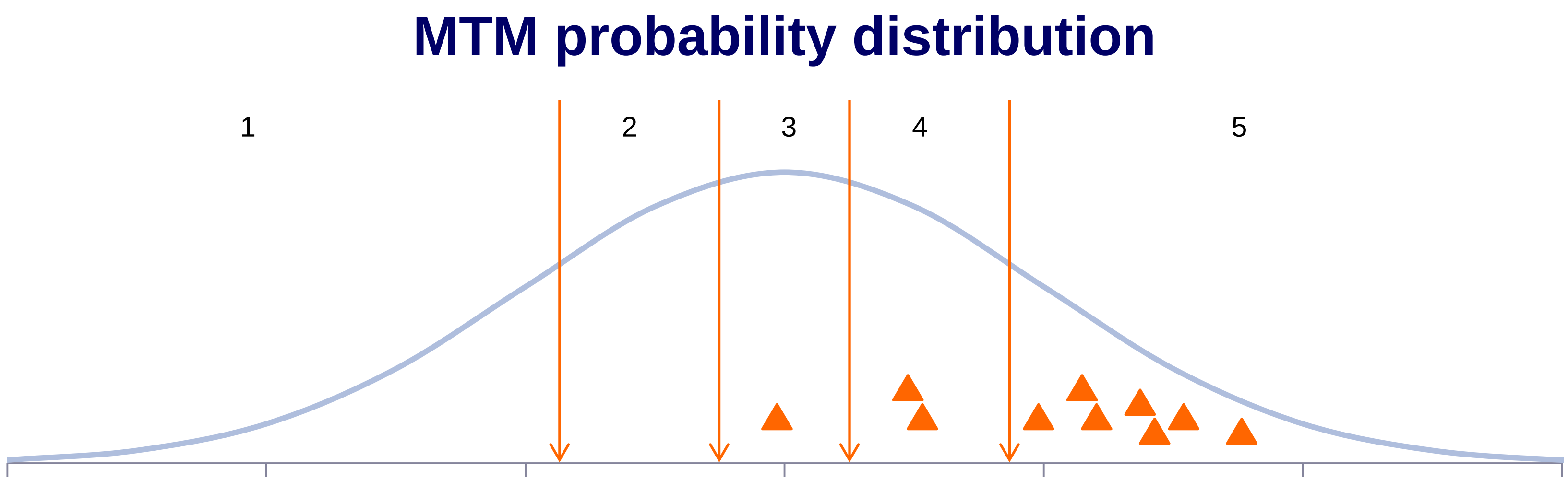
Wrong Way Risk



Credit Value Adjustment:

- CVA = EPE x PD x LGD
- Exposure and Probability of Default are independent

Wrong Way Risk



Wrong Way Risk:

- Probability of default depends on the exposure
- Example: Dutch real estate company Vestia speculating in IR swaps

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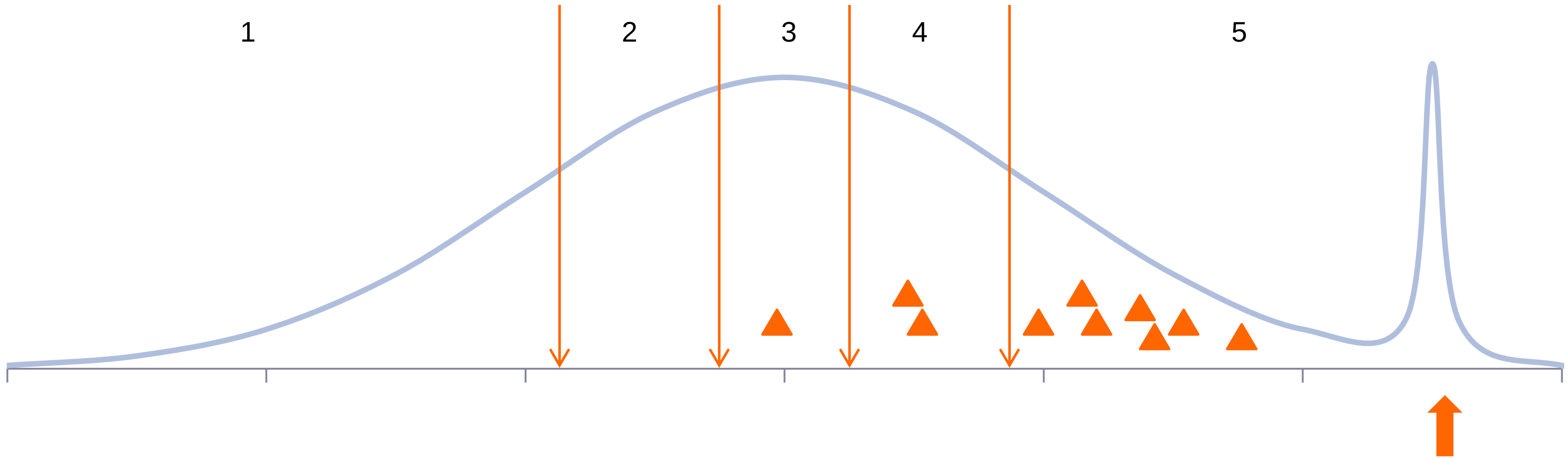
Wrong Way Risk

MTM probability distribution



Extreme Event Risk:

- Probability is very small
- Exposure can be quite dramatic
- Market changes qualitatively
- Very difficult to compute exposure
- Even more difficult to calibrate correlation of defaults

Extreme event risk taken explicitly

- We have one extreme event – S
- C \ S – counterparty has a credit event but event S does not happen
- C ∪ S – counterparty credit event coincides with event S
- B \ S – bank has a credit event but event S does not happen
- B ∪ S – bank credit event coincides with event S

$$
\begin{aligned}
\hat{V} \;=\; & V \\
& - \left(1 - R_{C \setminus S}\right) \int_0^T e^{-rt} V^{+}_{C \setminus S}(t) P_B \, dP_{C \setminus S}(t) \;-\; \left(1 - R_{C \cup S}\right) \int_0^T e^{-rt} V^{+}_{C \cup S}(t) P_B \, dP_{C \cup S}(t) \\
& - \left(1 - R_{B \setminus S}\right) \int_0^T e^{-rt} V^{+}_{B \setminus S}(t) P_C \, dP_{B \setminus S}(t) \;-\; \left(1 - R_{B \cup S}\right) \int_0^T e^{-rt} V^{+}_{B \cup S}(t) P_C \, dP_{B \cup S}(t)
\end{aligned}
$$

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Extreme event risk taken explicitly

Three things to determine

- $Q_{C \cup S}(t)$ – probability of default, $Q_{C \cup S} << Q_{C \setminus S}$
- $R_{C \cup S}(t)$ – recovery rate
- $V^{+}_{C \cup S}(t)$ – closeout and exposure at default

Explicit Wrong Way Risk
Taking currency risk into account

- FX swap or XCCY swap is a loan collateralized by a foreign currency asset.
- Distinguish
  - mark-to-market collateral
  - exchange-of-notionals collateral
- Currency event
  - Sovereign default
  - Capital or exchange control imposed by sovereign government
  - Sharp currency devaluation
- Counterparty defaults on margin calls
- Bank is left with illiquid and quickly depreciating currency
- PD of currency event is small, but LGD is enormous, much larger than MTM.

Explicit Wrong Way Risk
Taking currency risk into account

Assumption 1: Currencies can default

Sovereign	5Y CDS spread
Swiss	38
USA	43
UK	45
Germany	45
Australia	60
Japan	84
France	96

Assumption 2: Residual value is small

Estimating the residual currency value upon sovereign default

☐ **Empirical approach.** We studied depreciation over 92 sovereign defaults and 18 significant downgrades (see Manos, 1998). While we found substantial variation in the data, we still thought that valuable information could be extracted. Using a Markov chain approach, we produced the following estimates for the residual currency value, as a function of the current rating of a sovereign.

Sovereign residual values

Rating	Factor	Rating	Factor
AAA	17%	BB	41%
AA	17%	B	62%
A	22%	CCC	62%
BBB	27%		

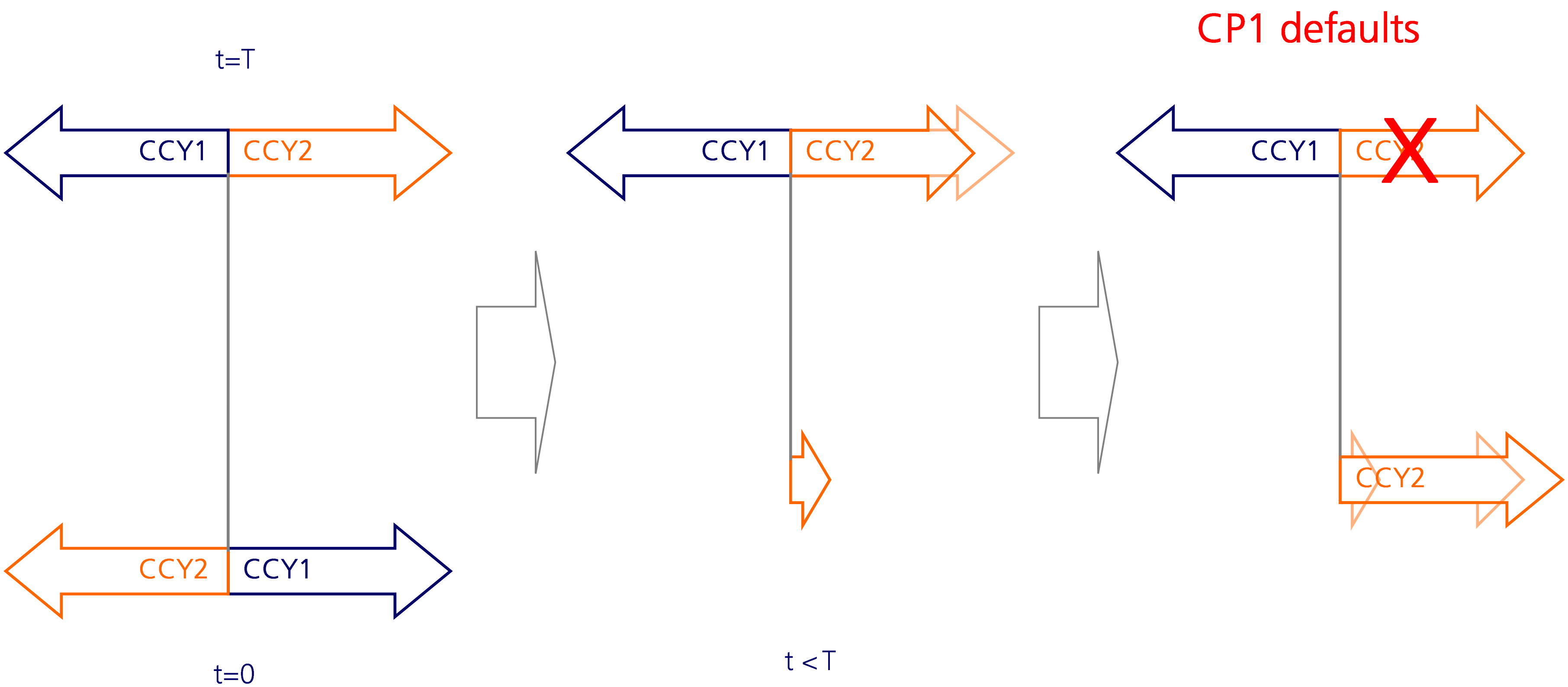
Levy and Levin (1999)

Assumption 3: Deal is canceled upon the currency event

- Quite plausible when the counterparty domiciled in the country of the currency
- Less trivial when the defaulted currency is not related to both counterparties. Still there will be some losses.

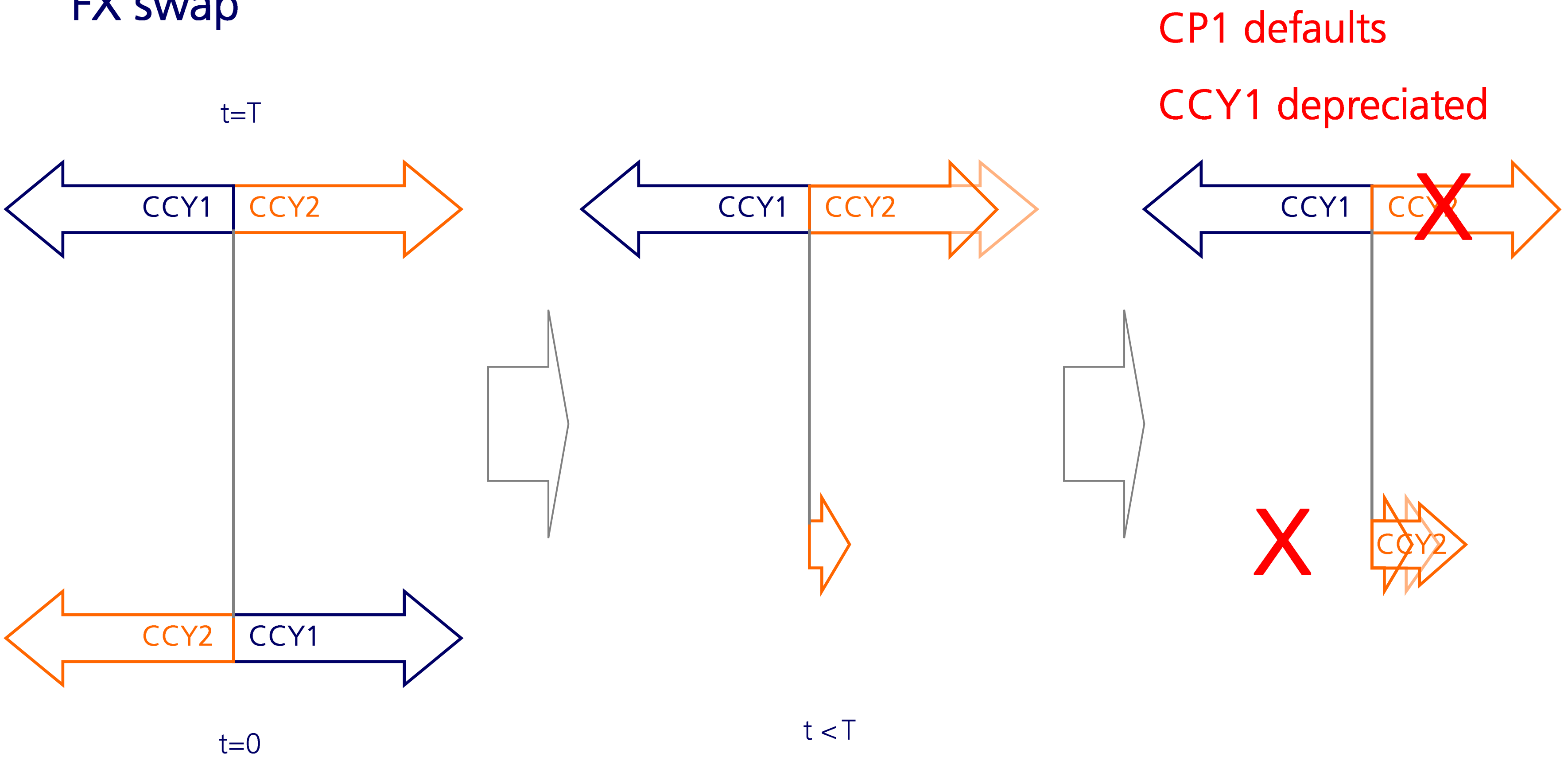
Taking currency risk into account

FX swap

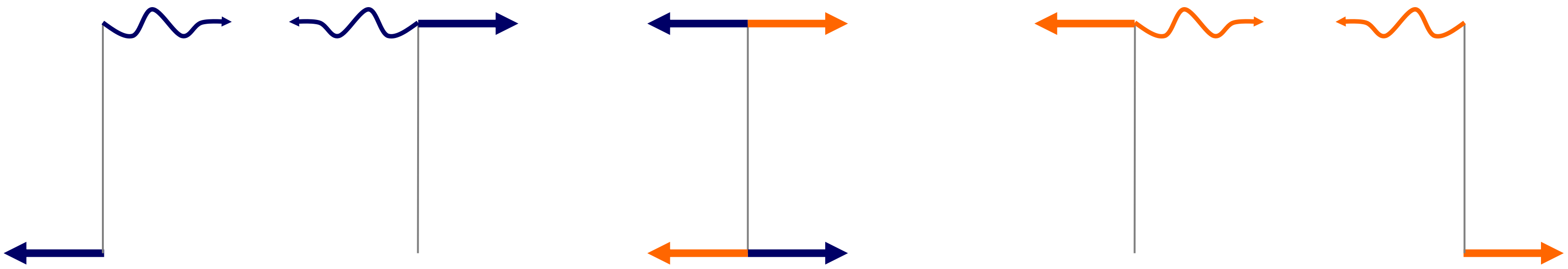


Taking currency risk into account

FX swap



Taking currency risk into account



1. No default $Q(\tau_1 > T, \tau_2 > T)$
2. CP1 defaults, CCY1 not $Q(\tau_1 < T, \tau_2 > \tau_1, \hat{\tau}_1 > \tau_1, \hat{\tau}_2 > \tau_1) = Q(CP1 \setminus CCY1)$
3. CP2 defaults, CCY2 not $Q(\tau_2 < T, \tau_1 > \tau_2, \hat{\tau}_1 > \tau_2, \hat{\tau}_2 > \tau_2) = Q(CP2 \setminus CCY2)$
4. CP1 and CCY1 default $Q(\hat{\tau}_1 < T, \hat{\tau}_1 = \tau_1, \tau_2 > \hat{\tau}_1, \hat{\tau}_2 > \hat{\tau}_1) = Q(CP1 \cup CCY1) = Q_1$
5. CP2 and CCY2 default $Q(\hat{\tau}_2 < T, \hat{\tau}_2 = \tau_2, \tau_1 > \hat{\tau}_2, \hat{\tau}_1 > \hat{\tau}_2) = Q(CP2 \cup CCY2) = Q_2$

Taking currency risk into account

$$V(0) = (1 - Q_1 - Q_2)\cdot\left(N_1 D_1^{OIS}(T) - n_1 - S_0\left(N_2 D_2^{OIS}(T) - n_2\right)\right)$$
$$+ Q_2 \cdot (-n_1 + S_0 r_{C2} R_{n2} n_2)$$
$$+ Q_1 \cdot (-r_{C1} R_{n1} n_1 + S_0 n_2)$$

n_1, n_2 – initial exchange of notionals

N_1, N_2 – final exchange of notionals

Q_1, Q_2 – default probabilities for CCY1 and CCY2

r_{C1}, r_{C2} – residual currency value

R_{n1}, R_{n2} – recovery rate on currency account

$$S_0 = n_1 / n_2$$

$$N_1 = n_1 \frac{1 - Q_1 - Q_2 r_{C2} R_{n2}}{(1 - Q_1 - Q_2) D_1^{OIS}(T)}$$

$$N_2 = n_2 \frac{1 - Q_2 - Q_1 r_{C1} R_{n1}}{(1 - Q_1 - Q_2) D_2^{OIS}(T)}$$

$$F(T) = \frac{N_1}{N_2} = S_0 \frac{D_2^{OIS}(T)}{D_1^{OIS}(T)} \frac{1 - Q_1 - Q_2 r_{C2} R_{n2}}{1 - Q_2 - Q_1 r_{C1} R_{n1}}$$

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Taking currency risk into account

$$F(T) = \frac{N_1}{N_2} = S_0 \frac{D_2^{OIS}(T)}{D_1^{OIS}(T)} \frac{1 - Q_1 - Q_2 r_{C2} R_{n2}}{1 - Q_2 - Q_1 r_{C1} R_{n1}}$$

Assuming $Q_2 << Q_1 r_{c1} R_{n1}$ and $R_{n1} = 1$ $\quad F(T) = S_0 \frac{D_2^{OIS}(T)}{D_1^{OIS}(T)} \frac{1 - Q_1}{1 - Q_1 r_{C1}}$ Levy and Levin (1999)

Assuming $Q_j r_{cj} R_{nj} << Q_i$ and $Q_i << 1$ $\quad F(T) = S_0 \frac{D_2^{OIS}(T)}{D_1^{OIS}(T)} \frac{SP_1(T)}{SP_2(T)}$

$$r_{imp}^d(T) = r_{OIS}^f(T) + \frac{1}{T} \ln \frac{F(T)}{S(0)}$$

$$r_{imp}^d(T) = r_{OIS}^d(T) - \lambda^d(T) + \lambda^f(T)$$

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Explicit Wrong Way Risk
Evidence from historical data

- Five currencies EUR,USD, GBP, AUD, and JPY have an extended history of OIS swaps, XCCY swaps, and CDS quotes.
- EUR rating is somewhere between AAA and D
- USD enjoys the status of the world reserve currency; effect of default is unpredictable
- Analysis is limited to GBP, AUD, and JPY
- GBP is chosen to become a reference currencies
- Most liquid CDS quotes are 5Y
- The comparison should be done with 5Y XCCY swaps and 5Y OIS swaps
- In this analysis, constant hazard rates are assumed

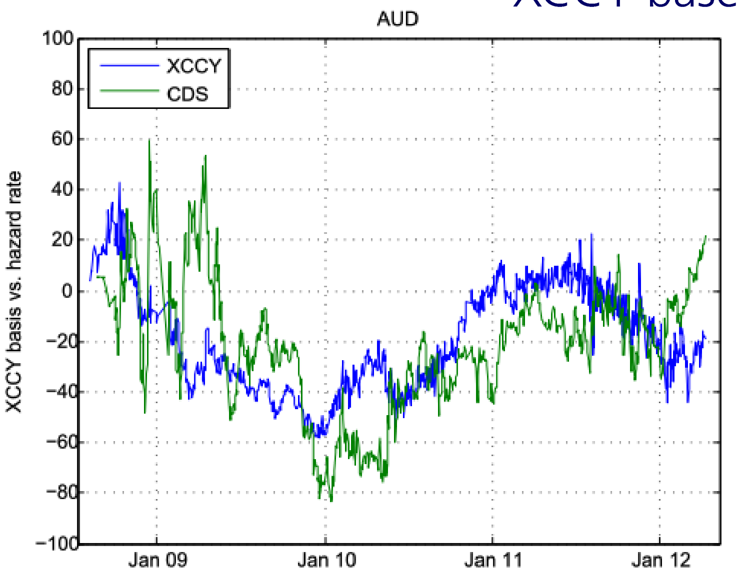
Explicit Wrong Way Risk
Evidence from historical data

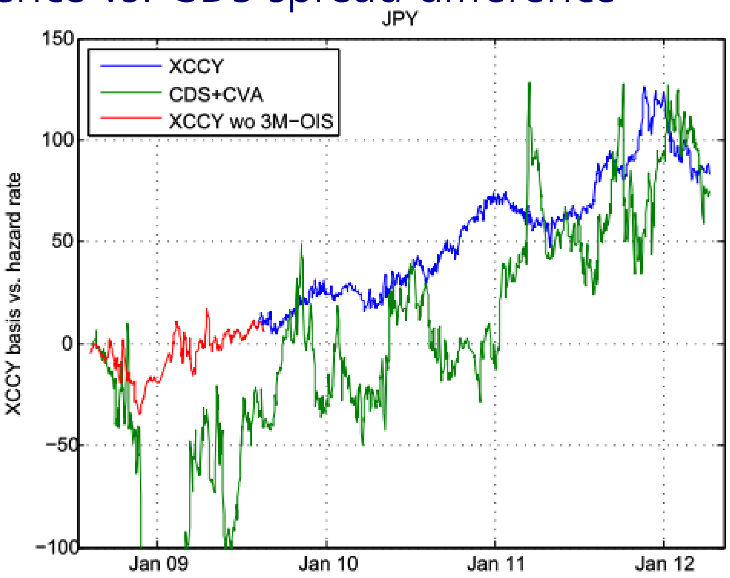
$$(b_1 + c_1)\frac{A_1}{T} - (b_2 + c_2)\frac{A_2}{T} =$$
$$\frac{CDS_2}{1-R} - \frac{CDS_1}{1-R} - EE\left(\frac{CDS_2}{1-R} - \frac{CDS_1}{1-R}\right)$$

Assuming $A_1 \approx A_2 \approx T$ and $EE = 0$

$$b_1 + c_1 - b_2 - c_2 = \frac{CDS_2}{1-R} - \frac{CDS_1}{1-R}$$

XCCY base difference vs. CDS spread difference





AUD vs. GBP

JPY vs. GBP

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Currency risk
Consequences for OIS discounting

- We just showed that even a collateralized XCCY swap has a substantial currency risk.
- Is the OIS curve framework still correct?
- OIS discounting theory is based on hedging arguments. See Piterbarg (2012).
- The proposed model is also based on hedging replication.
- They should give the same result.

OIS discounting
Collateral in foreign currency

	Loss given default	
MTM CP1	CP2ᴗCCY2	CP1ᴗCCY1
+	V	-V
-	V	-V

$$V(t,S) = E\left[e^{-\int_t^T r_1(u)du} V(T,S(T)) \right]$$

$$- E\left[\int_t^T \lambda_2 e^{-\int_t^s r_1(u)du} e^{-\int_t^s \lambda_1(u)du} e^{-\int_t^s \lambda_2(u)du} V(s)ds \right]$$

$$+ E\left[\int_t^T \lambda_1 e^{-\int_t^s r_1(u)du} e^{-\int_t^s \lambda_1(u)du} e^{-\int_t^s \lambda_2(u)du} V(s)ds \right]$$

$$\approx E\left[e^{-\int_t^T (r_1(u)-\lambda_1(u)+\lambda_2(u))du} V(T,S(T)) \right]$$

$$r_1^{imp}(T) = r_1^{OIS}(T) - \lambda_1(T) + \lambda_2(T)$$

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Issues at hand

Default-free value for CVA / DVA

?

EUR or USD

$$\hat{V}(t) = V_{CSA} + CVA_{CSA} + DVA_{CSA}$$

$$\hat{V}(t,S) = E\left[e^{-\int_t^T r_{CSA}(u)du} V(T) \right]$$

$$- E\left[(1-R_C)\int_t^T \lambda_C e^{-\int_t^s r_{CSA}(u)du} SP_C(s)SP_B(s)V_{CSA}^{+}(s)ds \right]$$

$$- E\left[(1-R_B)\int_t^T \lambda_B e^{-\int_t^s r_{CSA}(u)du} SP_C(s)SP_B(s)V_{CSA}^{-}(s)ds \right]$$

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Applications
CDS in different currencies

CDS spread in different currencies

Japan	Tier / Doc	CCY	1Y	3Y	5Y
Nomura	SNRFOR / CR SNRFOR / CR	JPY USD	171 186	268 293	318 339
Mizuho	SNRFOR / CR SNRFOR / CR	JPY USD	34 40	71 80	96 120
Sony	SNRFOR / CR SNRFOR / CR	JPY USD	121 126	286 302	386 411
Australia	**Tier / Doc**	**CCY**	**1Y**	**3Y**	**5Y**
Westpac Banking Corp	SNRFOR / MR SNRFOR / MR	AUD USD	37 42	82 93	124 142
Commonwealth bank of Australia	SNRFOR / MR SNRFOR / MR	AUD USD	37 42	81 92	123 141

- Recovery rate in different currencies is the same (Ehlers and Schonbucher 2006)
  - According to CDS contract specifications a party can deliver bonds in any eligible currency
- Expected currency depreciation **α**

$$(1-\alpha)\, dQ_C^d(t) = dQ_{C\setminus S}^d(t) + (1-\hat{\alpha})\, dQ_{C\cup S}^d(t)$$

$$dQ_{C\cup S}^d(t) = dQ_C^d(t) - dQ_{C\setminus S}^d(t)$$

$$\lambda_F = (1-\alpha)\,\lambda_D$$

Applications
Uncollateralized deal in foreign currency

Uncollateralized deal in CCY2: loss given default

	ΔS=0	
MTM CP1	CP1\CCY1	CP2\CCY2
+	0	$(1\text{-}R)V^{+}$
-	$(1\text{-}R)V^{-}$	0
	ΔS=ᾱS	
MTM CP1	CP1∪CCY1	CP2∪CCY2
+	0	$(1\text{-}\bar{\alpha})S(1\text{-}R)V^{+}$
-	$(1\text{-}R)V^{-}$	0

$$
\begin{aligned}
\hat{V} &= V \\
&\quad - \frac{(1-R)}{S_0}\int_0^T S_t V_t^{+} e^{-r_d t} dP_{C\setminus S}^{D}(t) - \frac{(1-R)(1-\hat{\alpha})}{S_0}\int_0^T S_t V_t^{+} e^{-r_d t} dP_{C\cup S}^{D}(t) \\
&\quad - (1-R)\int_0^T V_t^{-} e^{-r_f t} dP_{B\setminus S}^{F}(t) - (1-R)\int_0^T V_t^{-} e^{-r_f t} dP_{B\cup S}^{F}(t) \\
&= V - (1-R)\int_0^T V_t^{+} e^{-r_f t} dP_{C}^{F}(t) - (1-R)\int_0^T V_t^{-} e^{-r_f t} dP_{B}^{F}(t)
\end{aligned}
$$

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Applications
Uncollateralized deal in domestic currency

Uncollateralized deal in CCY1: loss given default

	ΔS=0	
MTM CP1	CP1\CCY1	CP2\CCY2
+	0	$(1\text{-}R)V^{+}$
-	$(1\text{-}R)V^{-}$	0
	Δ1/S=ᾱ/S	
MTM CP1	CP1∪CCY1	CP2∪CCY2
+	0	$S(1\text{-}R)V^{+}$
-	$(1\text{-}R)\,(1\text{-}\bar{\alpha}')\,V^{-}/S$	0

$$
\begin{aligned}
\hat{V} \;=\; & V \\
& - (1-R)\int_0^T V_t^{+} e^{-r_d t}\, dP^{D}_{C\setminus S}(t) \;-\; (1-R)\int_0^T V_t^{+} e^{-r_d t}\, dP^{D}_{C\cup S}(t) \\
& - (1-R)S_0\int_0^T \frac{V_t^{-}}{S_t} e^{-r_f t}\, dP^{F}_{B\setminus S}(t) \;-\; (1-R)(1-\hat{\alpha}')S_0\int_0^T \frac{V_t^{-}}{S_t} e^{-r_f t}\, dP^{F}_{B\cup S}(t) \\
=\; & V \;-\; (1-R)\int_0^T V_t^{+} e^{-r_d t}\, dP^{D}_{C}(t) \;-\; (1-R)\int_0^T V_t^{-} e^{-r_d t}\, dP^{D}_{B}(t)
\end{aligned}
$$

Applications
Uncollateralized XCCY swap

Uncollateralized cross-currency swap: loss given default

	ΔS=0	
MTM CP1	CP1\CCY1	CP2\CCY2
+	0	$(1-R)(V^D - SV^F)^+$
-	$(1-R)(V^D - SV^F)^-$	0
	ΔS=ᾱS or Δ1/S=ᾱ'/S	
MTM CP1	CP1∪CCY1	CP2∪CCY2
+	$(1-R)\,((1-\bar{\alpha}')V^D/S - V^F)$	$(1-R)\,(V^D - (1-\bar{\alpha})\,S\,V^F)$
-	$(1-R)\,((1-\bar{\alpha}')V^D/S - V^F)$	$(1-R)\,(V^D - (1-\bar{\alpha})\,S\,V^F)$

$$
\begin{aligned}
\hat{V} &= V_d^D - S_0 V_{f_{imp}}^F \\
&- \int_0^T \left(V_d^D - S_0 V_f^F\right)^+ e^{-r_d t} dP_C^D \\
&- \int_0^T \left(V_d^D - S_0 V_f^F\right)^- e^{-r_d t} dP_B^D \\
&- \int_0^T \left(V_d^D - S_0 V_f^F\right)^- e^{-r_d t} dP_{C\cup S}^D
\end{aligned}
$$

$$
\begin{aligned}
\hat{V} &= V_{DOM.CSA} + CVA(\lambda_{DOM}^C) + DVA(\lambda_{DOM}^B) \\
&= V_{FOR.CSA} + CVA(\lambda_{FOR}^C) + DVA(\lambda_{FOR}^B)
\end{aligned}
$$

$$
\begin{aligned}
\lambda_{FOR}^C &= (1-\alpha)\lambda_{DOM}^C \\
\lambda_{DOM}^B &= (1-\alpha')\lambda_{FOR}^B
\end{aligned}
$$

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Multi-currency multi-curve framework (mc²)

- Collateralized deals
  - The currently computed implied rates is a good approximation for deals collateralized in a strong currency.
- Uncollateralized single currency deals
  - Default-free value and exposure should be computed with local currency CSA.
  - This is in agreement with the recently proposed SCSA
  - CDS quotes should be used accordingly for this particular currency.
- Uncollateralized multi-currency deals, there is a choice
  - Default-free value with CSA and CDS rates in domestic currency
  - Default-free value with CSA and CDS rates in foreign currency
- Emerging markets
  - Local OIS curve can be proxied from the implied OIS curve and CDS curves of the domestic and foreign currency.

$$r^1_{OIS}(T) = r^1_{imp}(T) + \lambda^1(T) - \lambda^2(T)$$

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Conclusions

- A simple model is introduced to account explicitly for currency event risk.
- It provides a natural explanation for
  - CIP violation through additional default probability factors
  - Negative implied rates
  - Appears to be supported by historical data
  - Justifies the currently used practice of implied rates for collateralized deals
- Provides a consistent framework for uncollateralized deals in agreement with SCSA

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