Wrong Way Exposure -
Are Firms Underestimating Their Credit Risk?
Assessing Credit Risk when Default and Market Risk are Adversely Related

Introducing wrong way exposure - Unlike loans, swaps and other forward trades have uncertain credit exposure that depends on the movement of market rates. To place these deals on a comparable basis to loans we need to determine the expected exposure to the counterparty for each future period.

The Expected exposure for a deal at a given future point, is the expected value of \( \text{MAX} (\text{deal value}, 0) \). Market practice is to compute this under the standard distribution assumed when valuing options on underlying rates. Under this distribution, the expected value of the deal is its forward value. This assumption is valid only as long as the solvency of the counterparty has no relation to the deal’s underlying market rates.

For many deals, however, the market rates are correlated to the financial well being of the counterparty. In these cases, the above choice of distribution can lead to a gross underestimation of the exposure and expected loss. Many financial institutions were caught by surprise during the financial crises in South-east Asia and Russia when corporate and sovereign defaults as well as downgrades were accompanied by severe declines in currency values, thus driving exposures and losses well beyond their anticipations.

Consider for example a hypothetical three-year floating rate cross currency swap executed in January of 1997 between a financial institution and a Thai Bank. After the initial exchange, the financial institution paid Thai Baht and received dollars in return. In January 1998, during Thailand’s banking crisis, the Thai bank defaulted. At that time the Baht had devalued by about 50% relative to its expected value at the inception of the swap. Thus the exposure on the swap when it defaulted was approximately 50% of notional. At the inception of the deal, standard market practice would have estimated the expected exposure on January of 1998 to be around 4.5% of notional. Thus the realized exposure upon default was about 11 times the standard expected exposure estimate. The dramatic size of the actual exposure vs. the standard expected one is the norm rather than the exception and is driven by correlation and not bad luck.

The intuition behind this observation is that the swap, in effect, is a dollar loan collateralized by a foreign currency. If we anticipate a 40% percent decline in the currency if the counterparty defaults, then effectively the loan is 40% uncollateralized.

We refer to trades in which there is an adverse relationship between exposure size and counterparty default as “wrong way” deals. Although wrong way deals are common in

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1 This article originally appeared in Risk (July 1999), and was written jointly with Ronald Levin.
2 See [CM] and [H] for more discussion of exposure on derivatives.
3 1 year implied FX volatility was around 6.5% in January of 1997, and the 1 year forward FX was about 97% of spot.
the market, their impact does not seem to be generally understood. This is evidenced by our observation that many market participants do not seem to be adjusting their pricing of wrong way deals to account for the much higher expected credit exposure.

The goal of this article is to describe a simple methodology for valuing wrong way credit risk. The major step needed for this is to estimate the expected exposure *conditional on counterparty default*. 

Wrong way exposure occurs across all asset classes – foreign exchange, interest rates, equities and commodities. An obvious example is a company selling a put on its own stock. While the methodology described in this paper applies to all derivative transactions, we concentrate for illustration purposes on foreign exchange related “wrong way” transactions. In particular, “wrong way” cross currency swaps typically possess substantial amounts of credit risk due to their long maturities and large notionals.

**Exposure conditional on default**

There are two scenarios that need to be considered in order to calculate corporate “wrong-way” exposure:

- The sovereign defaults (discussed in Case I below).
- The corporation defaults, but the sovereign does not (discussed in Case II below).

In calculating the conditional exposure, these two scenarios will be weighted according to their relative probabilities.

In Case I, for simplicity, we will consider a sovereign counterparty. The results of this case will be used later in conjunction with case II, when the counterparty is a corporation.

**Case I: “Wrong-way” risk for a sovereign counterparty**

Given a default of the sovereign at time $t$, we express the expected value of the currency as a percentage adjustment to the initial forward rate:

$$ E[FX(t) \mid \text{sovereign default}] = RV_s \overline{FX}(t). $$

Where:

- $\overline{FX}(t)$ - Initial forward currency value for time $t$ (in dollars).
- $FX(t)$ - Realized currency value at time $t$ (in dollars).
- $RV_s$ - Residual value factor for the currency upon default.

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4 For discussion of other types of transactions, see [LL].

5 For illustration purposes, we use dollars. The same would apply to any other currency. The residual value factors might be different, however. See [LL].
The rationale for this assumption is that the unconditional expected value for the currency is given by the forward rate. The effect of default is then to reduce the expected value by a fixed percentage as reflected by the factor $RV_s$. (For example, if, upon default, the expected currency value is reduced by 60%, then $RV_s = 0.4$.)

In general, one needs to make an assumption about the distribution of the FX around this expected value. This is due to the fact that, to calculate the expected value of the $\text{MAX}(\text{deal value},0)$, one needs to know the distribution of the deal value, not just its expected value.

**Example:**
Consider a par $100$ million floating-to-floating three-year cross-currency swap with a BBB sovereign, where, after the initial exchange, we are receiving dollars and paying the sovereign’s currency.

- The residual value factor using the residual value table is 27%.
- The implied FX volatility is a flat 15%.
- Current interest rates are the same for dollars and the currency.

From these assumptions one can calculate the exposure at any future point.

**Expected Exposure Profile**

<table>
<thead>
<tr>
<th>Year</th>
<th>Market practice</th>
<th>Wrong-way</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$6m</td>
<td>$73m</td>
</tr>
<tr>
<td>2</td>
<td>$8.4m</td>
<td>$73m</td>
</tr>
<tr>
<td>3</td>
<td>$10.3m</td>
<td>$73m</td>
</tr>
</tbody>
</table>

The “wrong-way” computation gives, on average, an exposure that is 9 times higher than the standard method. If the sovereign spread is 100bp, and the discount rate is 5%, the upfront credit charge would be approximately $218,000 using the market practice calculation and $1.95 million using the wrong way methodology.

The exposures above are calculated as follows:
- Given $FX(t)$, the value of the swap is $100m(1 - \frac{FX(t)}{FX(0)})$. This is so since the value of each leg of the swap is par in its own currency. The swap value is then just the difference between the value of the dollar leg, which is $100$ million, and the value of the foreign currency leg. The notional of the foreign currency leg is $\frac{100m}{FX(0)}$ since it was a par swap at inception. Thus the value of the foreign currency leg at any point in time $t$ is given by $\frac{100m}{FX(0)}FX(t).

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6 We have assumed here that the decline in currency value relative to the forward rate does not depend on the timing of default.

7 For credit charge calculation, see appendix B – calculating credit charge.
• The exposure on the swap at time $t$ is given by $\text{MAX}(100m \cdot (1 - \frac{FX(t)}{FX(0)}), 0)$.

• In the standard approach we computed the expected value of this exposure where $FX(t)$ is log-normally distributed with mean of $FX(t) = FX(0)$ and annual volatility of 15%.

• The wrong-way approach assumes that, given default, the mean of the distribution for $FX(t)$ is 27% of $FX(0)$, with some distribution around it. Given this mean, the probability that the swap is out-of-the-money is negligible. Thus, since the swap value is linear in $FX(t)$, the expected exposure in this case is just $100m \cdot (1 - 0.27 \cdot \frac{FX(0)}{FX(0)}) = 73m$.

Case II: “Wrong way” risk for a corporate counterparty

Step 1: Default probability computations.

As noted above, the expected exposure for corporations depends on two potential types of default events and their associated distributions weighted by their relative probabilities:

• The sovereign defaults. We assume that when the sovereign defaults it forces the corporation into default on its cross-border obligations. This case is denoted by subscript $s,c$.

• The corporation defaults but the sovereign does not. This case is denoted by the subscript $c,s$.

Given the sovereign and corporate spreads on dollar-denominated debt together with a recovery rate assumption, we can extract the (risk-neutral) default probability for the sovereign $q_s(t)$, and the corporation $q_c(t)$, for the period $[t-1,t]$\(^9\). This, however, is not sufficient for our purposes. For corporate wrong-way exposure, we need to know in each period $[t-1,t]$ the following two probabilities:

$q_{s,c}(t)$ - Probability that the sovereign has defaulted during the period $[t-1,t]$, and the corporation has not defaulted before $t-1$. The sovereign might default in the period $[t-1,t]$, in scenarios where the corporation has defaulted before time $t-1$. We cannot consider those cases as cases where the sovereign forced default on the corporation.

$q_{c,s}(t)$ – Probability that the corporation defaulted during the period $[t-1,t]$ but the sovereign did not default.

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\(^8\)This is the general case. There are exceptions, however, such as gold producers which might not be forced into technical default by the sovereign.

\(^9\) This is the probability as of today that the name survived up to time $t-1$ and defaulted between $t-1$ and $t$. For a detailed discussion of how these probabilities are bootstrapped see [LL].
To calculate $q_{s,c}(t)$, one needs to make some further assumptions. We make a simplifying assumption, that the probability of a sovereign default is independent of prior corporate default\(^{10}\). This assumption is conservative from the wrong-way perspective.

Under this assumption the required probabilities are given by:

\[(2a) \quad q_{s,c}(t) = [1 - Q_c(t-1)] * \frac{q_s(t)}{[1 - Q_s(t-1)]}\]

\[(2b) \quad q_{c\mid s}(t) = q_c(t) - q_{s,c}(t)\]

$Q_c(t-1)$ - The cumulative (risk-neutral) probability that the corporation defaults between 0 and t-1. ($Q_c(t) = Q_c(t-1) + q_c(t)$.)

$Q_s(t-1)$ – The Cumulative (risk-neutral) probability that the sovereign defaults between 0 and t-1.

We may interpret equation (2a) as follows: the first factor $[1-Q_c(t-1)]$ is the probability that the corporation survives through to time t-1. The second factor $[q_s(t)/(1-Q_s(t-1))]$ is the probability that the sovereign will default between t-1 and t given that it has survived to time t-1. Since, by assumption, the sovereign default probability is independent of the corporation remaining solvent, the probability of a sovereign driven default in period t is then just the product of the two factors.

When calculating the expected exposure conditional on default, the exposures conditional on the two default scenarios are weighted by their relative probabilities. The weight for the sovereign default in the time period [t-1,t] is $q_{s,c}(t)/q_c(t)$, while the weight of the corporate-only default in that time period is $q_{c\mid s}(t)/q_c(t)$.

In cases where $Q_c(t)$ is small during the life of the deal a good approximation is:

$q_{s,c}(t) = q_s(t)$ and $q_{c\mid s}(t) = q_c(t) - q_s(t)$.

**Step 2: Residual value given corporate but not sovereign default**

Before we discuss in detail the foreign-exchange adjustment in the case of corporate but not sovereign default, it is important to note that we have two pieces of information here that generally drive the expected value of the currency in opposite directions:

- The sovereign did not default (which increases expected value of currency).
- The corporation defaulted (which generally decreases expected value of currency).

*Non-default of sovereign* - The forward $\overline{FX}(t)$ is an expected value of the possible outcomes for $FX(t)$. Under our assumptions if the sovereign defaulted at time t, the
expected value of the currency is \( RV \), which is considerably lower than \( \overline{FX}(t) \). Thus, conditional on non-default, the expected currency value should be higher than \( \overline{FX}(t) \). We denote by subscript \( s \) the fact that the sovereign did not default, and obtain

\[
(3) \quad \overline{FX}_s(t) \equiv E[FX(t) \mid \text{sovereign not defaulting}] = \overline{FX}(t) \frac{1 - Q_s(t)RV_s}{1 - Q_s(t)}.
\]

**Corporation defaulted** - The default of a corporation could have been either idiosyncratic or due to adverse economic conditions (systemic risk). If we knew that the default is always idiosyncratic, the knowledge that the counterparty defaulted wouldn’t add any information, and we would conclude that the expected value of \( FX(t) \) is \( \overline{FX}_s(t) \). In general, however, the probability of corporate default increases when economic conditions in the market deteriorate. When this happens, the value of the currency usually falls as well. Thus, in general, the expected currency value conditional on corporate but not sovereign default, is lower than \( \overline{FX}_s(t) \).

**Simple model for estimating impact of corporate default**

Unlike the sovereign case, we are unable to observe directly the relationship between corporate default and the currency value. A reasonable model for estimating this relationship will need to take into account the following two considerations:

**Correlation of share price with local currency** - Historical correlation computations, as well as theoretical economic considerations, suggest that exporting firms typically have low or even negative correlation with the currency value, while banks generally show a high correlation with currency value. Exporters with foreign currency income and local currency liabilities and expenses will benefit from decline in currency value. Banks, who’s performance, is in general, tied in a leveraged way, to the well being of the economy, will generally suffer when the economy and currency decline. Thus the knowledge that an exporter defaulted might have almost no effect or even a positive effect on the estimated FX expected value, while the knowledge that a bank defaulted will have a substantial negative effect on this FX estimation.

**Rating of the corporation** - The default of a highly rated corporation is a more significant event than that of one with a lower rating. We expect, then, a correspondingly greater currency decline in conjunction with its default.

Realizing its imperfection, we nevertheless present here a simple approach to estimate the corporate residual value factor \( RV_c \), which accounts for both of the above considerations. In Merton’s bankruptcy model\(^{11}\), the assets of the firm are assumed to be stochastic, while the liabilities are fixed. Following this model, we assume that the assets follow a driftless random walk and default occurs as soon as the assets hit the liability level.

\(^{11}\) see [ M]
Denote
\( A(t) \) - Asset value at time t.
\( \sigma_A \) - Annualized standard deviation of asset value.
\( L(t) \) - Liability.\(^{12}\)

Under our assumptions the default probability\(^{13}\) is
\[
Q_c(t) = 2N^{-1}\left( \frac{L(t) - A(0)}{\sigma_A \sqrt{t}} \right)
\]
where:
\( N^{-1} \) - Inverse cumulative standard normal distribution.\(^{16}\)

Since \( Q_c(t) \)\(^{14}\) is known, we can solve for the liability
\[
L(t) = A(0) + N^{-1}\left( \frac{Q_c(t)}{2} \right) \sigma_A \sqrt{t}.
\]

Default occurs when the assets move by \( N^{-1}\left( \frac{Q_c(t)}{2} \right) \sqrt{t} \) annual asset standard deviations. We can now express the expected change in exchange rate, conditional on default, in terms of the asset move, the chosen asset-FX correlation \( \rho \) and the FX volatility \( \sigma_{FX} \).

(4) \( RV_c = 1 + \rho \sigma_{FX} N^{-1}\left( \frac{Q_c(t)}{2} \right) \sqrt{t} \)\(^{15}\)

Intuitively, the corporate residual value should not depend on time in any significant way for longer maturities\(^{16}\). To recognize this in the model, we need to (somewhat arbitrarily) fix the horizon, independent of the actual exposure date. We choose that horizon to be four years.

Our expression for \( RV_c \) takes into account the two considerations described above:
- The higher the correlation, the smaller the residual value factor.
- The stronger the credit, the lower the residual value factor.

Combining equations (3) and (4) we obtain the expected currency value at time t, conditional on corporate but not sovereign defaulting:

(5) \( \overline{FX}_{RV_c}(t) = \overline{FX}_{RV}(t) * RV_c \).

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\(^{12}\) Although the model assumes a fixed liability, the cumulative probability of default is in general inconsistent with a constant barrier. The barrier here is chosen to be consistent with the four-year default probability, independent of the actual maturity of the deal. The reason for this is described shortly in the text.

\(^{13}\) This is a consequence of the reflection principle see [KS].

\(^{14}\) Theoretically here we should use here the probability of default of the corporation on its local debt. If the sovereign forced the corporation into default, its assets may well be above the liabilities.

\(^{15}\) Note that \( N^{-1}\left( \frac{Q_c(t)}{2} \right) < 0 \).

\(^{16}\) The default of a firm over a short period of time, is not an indicator of a deteriorating market. Thus the knowledge of its default will not alter the currency’s expected value.
We are now in a position to give an example of a corporate “wrong-way” swap exposure.

Example

Consider a par $100 million floating-to-floating three-year cross-currency swap with a BBB rated bank in a AA rated country. After the initial exchange, we are receiving dollars and paying the sovereign’s currency.

Assume:
- Sovereign spread is 25bp with 50% recovery rate.
- Bank’s spread is 100bp with 50% recovery rate.
- 40% correlation between the bank’s stock and the FX.
- Implied FX volatility is a flat 10%.
- Current interest rates for dollars and the currency are 5%.

Calculation steps
- The residual value factor for the sovereign using the RV table (see appendix A) is 17%.
- The four-year risk-neutral probability of default for the bank is approximately $Q_c(4) = 1-(1\text{-spread}/(1\text{-recovery}))^4 = 7.8\%$.
- Since the sovereign default is very low and the interest rates are identical $FX_{so}(t) = FX(0)$.
- From equation (4) $RV_c = 86\%$.
- From equation (5) we obtain $FX_{cc}(t) = FX_{sc}(t)RV_c = 0.86 FX(0)$.
- The relative weights of sovereign and corporate defaults are approximately 25% and 75% respectively. (For low default probability the sovereign weighting is estimated by the spread ratio.)
- Exposure for the case of bank defaulting but not sovereign assumes that the FX distribution is lognormal with mean at 0.86 $FX(0)$ and standard deviation of $0.1 \sqrt{t}$.
- Exposure in the unconditional case assumes a log-normal distribution with mean of $FX(0)$ and standard deviation of $0.1 \sqrt{t}$.
- As mentioned in the sovereign case, conditional on sovereign default the swap is deeply in-the-money, and thus the expected exposure is just $(1-0.17)\cdot 100m = 83m$. 

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17 For simplicity we assumed the same volatility for both conditional and unconditional distributions.
Expected exposure profile for corporate case.

<table>
<thead>
<tr>
<th>Year</th>
<th>Sovereign default</th>
<th>Bank but not Sovereign default</th>
<th>Wrong-way exposure</th>
<th>Market practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$83m</td>
<td>$14.3m</td>
<td>$31.4m</td>
<td>$4m</td>
</tr>
<tr>
<td>2</td>
<td>$83m</td>
<td>$15.0m</td>
<td>$32.0m</td>
<td>$5.6m</td>
</tr>
<tr>
<td>3</td>
<td>$83m</td>
<td>$15.7m</td>
<td>$32.5m</td>
<td>$6.9m</td>
</tr>
</tbody>
</table>

Applying the 100bp spread to these exposure profiles, will give a credit charge of approximately $854,000 for the “wrong-way” calculation and $146,000 for the standard method.

Concluding remarks

“Right-way” exposure - While we concentrated on “wrong-way” transactions, some transactions are actually “right-way”, since they benefit from the correlation between default and the underlying rates. For example, if one reverses the flows in the sovereign default example, the conditional credit charge would be zero.18

It is tempting to think that the underestimation on “wrong-way” deals, is offset by the over estimation of “right-way” deals. However, this is not the case, since they are typically not with the same counterparty. If we view the unconditional exposure as one unit of credit risk, “wrong-way” exposure is on the order of 10 units, and “right-way” exposure is on the order zero units. So a “right-way” deal and a “wrong-way” deal, with different counterparties, will constitute two units of credit risk in the standard approach versus 10 units of credit risk when taking correlation into account.

Netting – Obviously, when dealing with counterparty exposure, one should take into account netting when it is legally enforceable. The methodology set forth in this paper applies equally well to this case.

Collateral agreements - Collateral agreements can go a long way to mitigate wrong way risk, especially for corporate defaults where the sovereign remains solvent. For sovereign defaults, or when the currency is pegged or managed, we are subject to the risk of a sudden major devaluation in the currency. During those periods, it is very likely that corporations will have a hard time delivering the extra collateral required, and thus the exposure and credit losses can become very substantial.

In this paper we have demonstrated the importance of calculating credit exposures conditional on the counterparty defaulting. Calculating exposures on a conditional basis will help avoid costly exposure surprises.

18 For other right-way examples see [LL].
References:


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Appendix A: Estimating the Residual Currency Value upon Sovereign default

**Empirical approach**— We studied depreciation over 92 sovereign defaults and 18 significant downgrades\(^{19}\). 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.

<table>
<thead>
<tr>
<th>Rating</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAA</td>
<td>17%</td>
</tr>
<tr>
<td>AA</td>
<td>17%</td>
</tr>
<tr>
<td>A</td>
<td>22%</td>
</tr>
<tr>
<td>BBB</td>
<td>27%</td>
</tr>
<tr>
<td>BB</td>
<td>41%</td>
</tr>
<tr>
<td>B</td>
<td>62%</td>
</tr>
</tbody>
</table>

Note that the higher the rating, the lower the residual value factor, i.e. upon default the expected devaluation of the currency is higher. This is consistent with the following facts: A larger shock to the economy is needed to drive a better rated sovereign into default; and the higher rated the sovereign, the less devaluation is already built into the forward rate.

**Implied approach** — One can obtain an “implied” residual value factor using the probability of default implied by the credit market; an estimate on the shape of the distribution of the FX upon default; and prices of extremely out-of-the money forex options. In general, this approach leads to higher residual value factors. However, for long maturities or illiquid option markets, one would be hard pressed to find the necessary option prices.

\(^{19}\) See [MP].
Appendix B: Calculating Credit Charge

The basic idea in calculating the up front credit charge is fairly simple:
- We add up the PV of (risk-neutral) expected losses for each future period.
- The (risk-neutral) expected loss associated with a given period is the product of the expected loss given default in that period and the (risk-neutral) probability that the counterparty defaults in that period.

Mathematically we express this as:

\[ CC = (1-RR) \times \left( \sum t q(t) Z(t) LEE(t) \right) \]

- \( RR \) - Recovery rate, which is the fraction of the exposure amount received in the event of default.
- \( q(t) \) - The (risk-neutral) default probability for period \( t \), that is, the probability that the counterparty will survive to time \( t-1 \) and then go into default between \( t-1 \) and \( t \).
- \( Z(t) \) - The risk-free discount factor for period \( t \).
- \( LEE(t) \) - The loan equivalent exposure (or expected exposure) given default in period \( t \) (the expected loss given default in period \( t \) is then \( (1 - RR) LEE(t) \)).

If the credit spread \( S \) is small and the spread term structure is flat, \( S/(1-RR) \) is a reasonable approximation for \( q(t) \), and thus \( CC = S \times \left( \sum t Z(t) LEE(t) \right) \).