

FX Exposure

1. Measuring Exposure

FX Risk Management

- **Exposure**

At the firm level, currency risk is called *exposure*.

Three areas

(1) *Transaction exposure*: Risk of transactions denominated in FX with a payment date or maturity.

(2) *Economic exposure*: Degree to which a firm's expected cash flows are affected by unexpected changes in S_t .

(3) *Translation exposure*: Accounting-based changes in a firm's consolidated statements that result from a change in S_t . Translation rules are complicated: not all items are translated using the same S_t . These rules create accounting gains/losses due to changes in S_t .

We will say a firm is “exposed” or has exposure if it faces currency risk.

Q: How can FX changes affect the firm?

- *Transaction Exposure*

- Short-term CFs: Existing contract obligations.

- *Economic Exposure*

- Future CFs: Erosion of competitive position.

- *Translation Exposure*

- Revaluation of balance sheet (Book Value vs Market Value).

Example: Exposure.

A. *Transaction exposure.*

Swiss Cruises, a Swiss firm, sells cruise packages priced in USD to a broker. Payment in 30 days.

B. *Economic exposure.*

Swiss Cruises has 50% of its revenue denominated in USD and only 20% of its cost denominated in USD. A depreciation of the USD will affect future CHF cash flows.

C. *Translation exposure.*

Swiss Cruises obtains a USD loan from a U.S. bank. This liability has to be translated into CHF. ¶

Measuring Transaction Exposure

Transaction exposure (TE) is very easy to identify and measure:

$$TE = \text{Value of a fixed future transaction in FC with a certain date} \times S_t$$

For a MNC \Rightarrow TE: consolidation of contractually fixed future currency inflows and outflows for all subsidiaries, by currency. (Net TE!)

Example: Swiss Cruises.

Sold cruise packages for USD 2.5 million. Payment: 30 days.

Bought fuel oil for USD 1.5 million. Payment: 30 days.

$S_t = 1.0282 \text{ CHF/USD}$.

Thus, the net transaction exposure in USD is:

$$NTE = (\text{USD } 2.5\text{M} - \text{USD } 1.5\text{M}) \times 1.0282 \text{ CHF/USD} = \text{CHF } 1.0282\text{M.}\uparrow$$

• Netting

MNC take into account the correlations among the major currencies to calculate Net TE \Rightarrow Portfolio Approach.

A U.S. MNC: Subsidiary A with CF(in EUR) > 0
 Subsidiary B with CF(in GBP) < 0
 $\rho_{\text{GBP, EUR}}$ is very high and positive.
 Net TE might be very low for this MNC.

- Hedging decisions are usually not made transaction by transaction. Rather, they are made based on the exposure of the portfolio.
- Usually, companies aggregate and report the company's NTE by maturity date, say "less than 90 days," and "more than 90 days."

Example: Swiss Cruises.

Net TE (in USD): USD 1 million. Due: 30 days.

Loan repayment: CAD 0.80 million. Due: 30 days.

$S_t = 1.282$ CAD/USD.

$\rho_{CAD,USD} = .924$ (from 1990 to 2001)

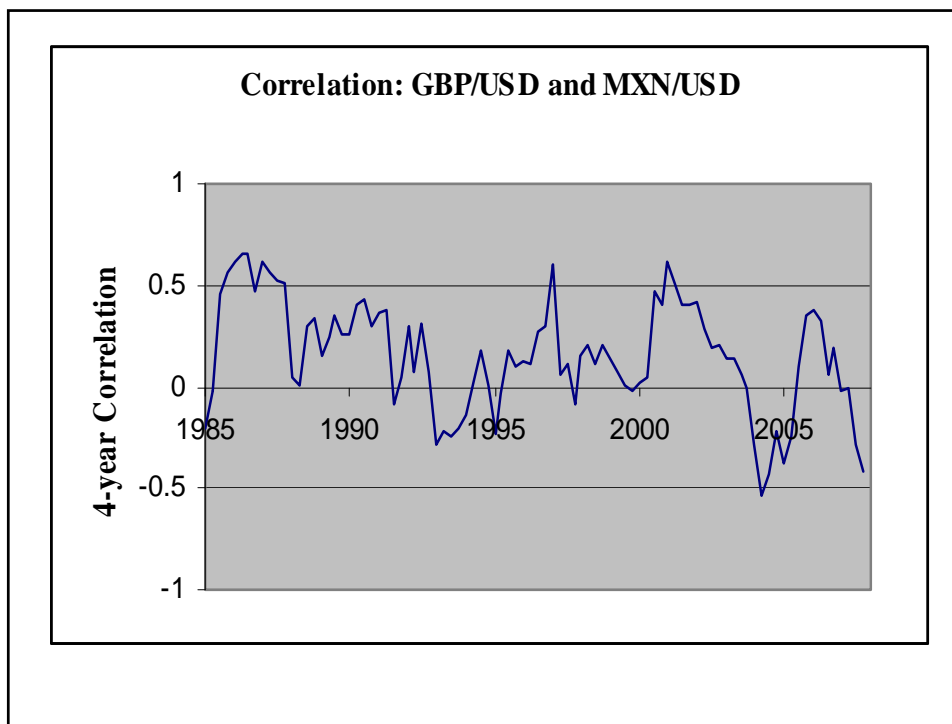
Swiss Cruises considers the Net TE (up to 30 days) to be close to zero. ¶

Note 1: Correlations vary a lot across currencies. In general, regional currencies are highly correlated. From 2000-2007, the GBP and EUR had an average correlation of .71, while the GBP and the MXN had an average correlation of -.01.

Note 2: Correlations also vary over time.

Currencies from developed countries tend to move together... But, not always!





• Q: How does TE affect a firm in the future?

MNCs are interested in how TE will change in the future (T days). After all, it is in the future that the transaction will be settled.

- MNCs do not know the future S_{t+T} , they need to forecast S_{t+T} .
- S_{t+T} is difficult to forecast. The forecast has an associated standard error, which produces a range for (or an interval around) S_{t+T} and, thus, TE.
- From a risk management perspective, it is important to know how much is likely to be received from a FC inflow or how much is likely to be needed to cover a FC outflow.

Range Estimates of TE

- Exchange rates are very difficult to forecast. According to the RWM, Net TE is the best forecast for the value of the transaction at time T. But, not very precise.
- From a risk management point of view, a firm would like to have know: How much can the firm spend (should the firm have on the bank) on account of the receivable (payable) at time T?
- Given that a point estimate (Net TE) is not very precise, a range estimate of the Net TE will provide a more useful number for risk managers.

The smaller the range, the lower the sensitivity of the Net TE. (The lower the risk.)

- Three popular methods for estimating a range for TE:
 - (1) Ad-hoc rule ($\pm 10\%$)
 - (2) Sensitivity Analysis (or simulating exchange rates)
 - (3) Assuming a statistical distribution for exchange rates.

- **Ad-hoc Rule**

Instead of using a specific confidence interval (C.I.), which requires (complicated calculations and/or unrealistic assumptions) many firms use an ad-hoc rule to get a range: $\pm 10\%$ rule

It is a simple and easy to understand: Get TE and add/subtract $\pm 10\%$.

Example: Swiss Cruises has a Net TE= CHF 1.0282 M due in 30 days
 \Rightarrow if S_t changes by $\pm 10\%$, Net TE changes by \pm CHF 102,820. ¶

Note: This example gives a range for NTE:

$$\text{NTE} \in [\text{CHF } 0.92538 \text{ M}; \text{CHF } 1.13102 \text{ M}]$$

\Rightarrow the wider the range, the riskier an exposure is.

Risk Management Interpretation: If SC is counting on the USD 1M to pay CHF expenses, these expenses should not exceed **CHF .9254 M.** ¶

- **Sensitivity Analysis**

Goal: Measure the sensitivity of TE to different exchange rates.

Examples: Sensitivity of TE to extreme forecasts of S_t .

Sensitivity of TE to randomly simulate thousands of S_t .

Data: 45-years of monthly CHF/USD percentage changes

<i>1-mo Changes in CHF/USD</i>	
Mean	-0.002052
Standard Error	0.0015034
Median	-0.003271
Mode	#N/A
Standard Deviation	0.03470942
Sample Variance	0.0012047
Kurtosis	0.4632713
Skewness	0.4298708
Range	0.283689
Minimum	-0.131765
Maximum	0.150924
Sum	0.0576765
Count	533

Example: Sensitivity analysis of Swiss Cruises Net TE (CHF/USD) Empirical distribution (ED) of S_t monthly changes over the past 45 years. Extremes: **15.09%** (on October 2011) and **-13.18%** (on March 1973).

(A) Best case scenario.

Net TE: USD 1M x **1.0282 CHF/USD** x (1 + **0.1509**) = **CHF 1,183,355**.

(B) Worst case scenario.

Net TE: USD 1M x **1.0282 CHF/USD** x (1 - **0.1318**) = **CHF 896,400**.

Note: If Swiss Cruises is counting on the USD 1M to cover CHF expenses, from a risk management perspective, the expenses to cover should not exceed **CHF 896,400**. ¶

Note: Some managers may consider the range, based on extremes, too conservative: NTE \in [**CHF 896,400; CHF 1,183,355**].

⇒ The probability of the worst case scenario to happen is very low (only once in 533 months!)

Under more likely scenarios, we may be able to cover more expenses with the lower bound.

- A different range can be constructed through sampling from the ED.

Example: Simulation for SC's Net TE (CHF/USD) over one month.

(i) Randomly draw *1,000* monthly $e_{f,t+30}$'s from the ED.

(ii) Calculate S_{t+30} for each $e_{f,t+30}$ selected in (i).

(Recall: $S_{t+30} = 1.0282 \text{ CHF/USD} \times (1 + e_{f,t+30})$)

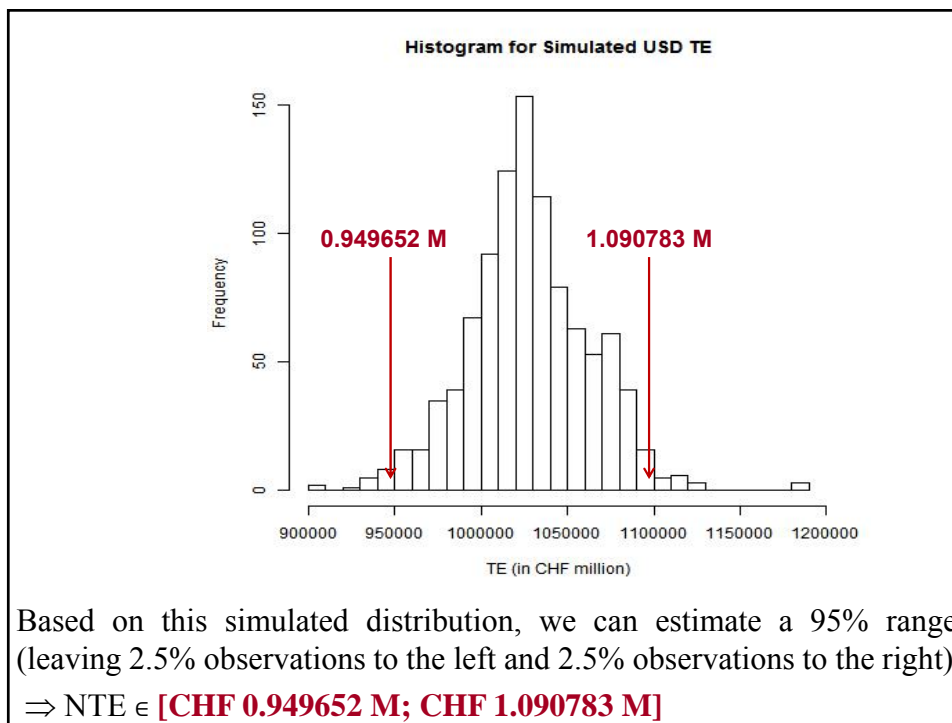
(iii) Calculate **TE** for each S_{t+30} . (Recall: **TE** = USD 1M x S_{t+30})

(iv) Plot the 1,000 **TE**'s in a histogram. (Simulated TE distribution.)

Example (continuation): In excel, using Vlookup function

- (i) Randomly draw $s_t = s_{sim,1}$ from ED: Observation 519: $s_{t+30} = 0.0034$.
(ii) Calculate $S_{sim,1}$: $S_{t+30} = 1.0282 \text{ CHF/USD} \times (1 + .0034) = 1.0317$
(iii) Calculate $TE_{sim,1}$: $TE = \text{USD } 1\text{M} \times S_{t+30} = 1,031,701.25$
(iv) Repeat (i)-(iii) 1,000 times. Plot histogram. Construct a $(1-\alpha)\%$ C.I.

Lookup cell	s_t	Random Draw		S_sim	TE(sim)
		with Randbetween	with Vlookup		
1					
2	0.0025	519	0.0034	1.0317	1,031,701.25
3	-0.0027	147	-0.0104	1.0175	1,017,489.58
4	0.0001	99	0.0125	1.0411	1,041,098.57
5	-0.0443	203	-0.0584	0.9681	968,119.73
6	-0.0017	482	-0.0727	0.9535	953,458.55
7	-0.0031	4	0.0001	1.0283	1,028,319.69
8	-0.0227	67	-0.0226	1.0050	1,004,954.33
9	-0.0099	136	0.0095	1.0380	1,038,012.59
10	0.0098	232	0.0191	1.0479	1,047,877.24



Based on this simulated distribution, we can estimate a 95% range (leaving 2.5% observations to the left and 2.5% observations to the right)

=> NTE \in **[CHF 0.949652 M; CHF 1.090783 M]**

Practical Application: If SC expects to cover expenses with this USD inflow, the maximum amount in CHF to cover, using this 95% CI, should be **CHF 949,652**. ¶

• **Aside: How many draws in the simulations?**

Usually, we draw until the histograms –i.e., CIs– do not change a lot.

Example: 1,000 and 10,000 draws

For the SC example, we drew 1,000 scenarios to get a 95% C.I.:

=> NTE \in **[CHF 0.949652 M; CHF 1.090783 M]**.

Now, we draw 10,000 scenarios and determined the following 95% C.I.:

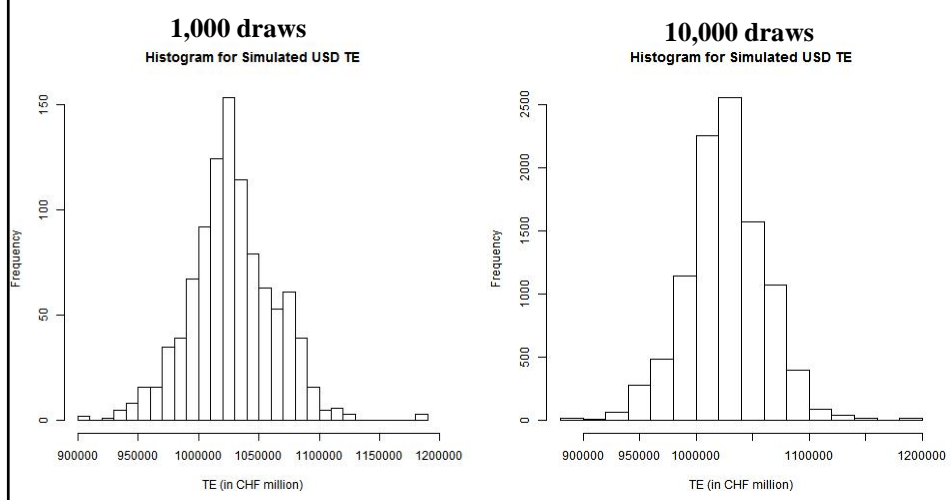
=> NTE \in **[CHF 0.952202 M; CHF 1.093762 M]**

Example (continuation): Different 95% C.I.

1,000 draws: **[CHF 0.949652 M; CHF 1.090783 M]**

10,000 draws: **[CHF 0.952202 M; CHF 1.093762 M]**

=> Not that different: 1,000 simulations seem enough!



• **Assuming a Distribution**

Confidence intervals (CI) based on an assumed distribution provide a range for TE.

For example, a firm can assume that S_t changes, s_t , follow a normal distribution and based on this distribution construct a 95% CI.

Recall that a $(1 - \alpha)\%$ confidence interval for the mean is given by:

$$[\mu \pm z_{\alpha/2} \sigma],$$

where μ = Estimated mean

σ^2 = Estimated variance

Popular $z_{\alpha/2}$:	$\alpha=.01$	$z_{\alpha/2=.005} = 2.58$
	$\alpha=.05$	$z_{\alpha/2=.025} = 1.96 (\approx 2)$.
	$\alpha=.10$	$z_{\alpha/2=.050} = 1.645$

Interpretation: If $\alpha = .05$, the probability is about .95 that the 95% confidence interval will include the true population parameter.

Example: CI range based on a Normal distribution.

Assume Swiss Cruises believes that CHF/USD monthly changes follow a normal distribution. Swiss Cruises estimates the mean and the variance.

μ = Monthly mean = $-0.002 \approx 0$

σ^2 = Monthly variance = $0.0012947 \Rightarrow \sigma = 0.03471$ (3.47%)

$e_{f,t} \sim N(0, 0.0012947)$. $e_{f,t}$ = CHF/USD monthly changes.

Swiss Cruises constructs a 95% CI for CHF/USD monthly changes.

Recall that a 95% confidence interval is given by $[\mu \pm 1.96 \sigma]$.

Thus, $e_{f,t}$ will be between -0.068 and 0.068 (with 95% confidence).

Based on this range for s_t , we derive bounds for the net TE:

(A) Lower bound

Net TE: USD 1M x 1.0282 CHF/USD x $(1 - 0.068)$ = **CHF 958,251.9**.

(B) Upper bound

Net TE: USD 1M x 1.0282 CHF/USD x $(1 + 0.068)$ = **CHF 1,098,148**.

=> TE ∈ [CHF 958,252; CHF 1,098,148]

- The lower bound, for a receivable, represents the worst case scenario within the confidence interval.

There is a *Value-at-Risk* (VaR) interpretation:

VaR: Maximum expected loss in a given time interval within a (one-sided) confidence interval.

Going back to the previous example.

CHF 958,252 is the minimum revenue to be received by Swiss Cruises in the next 30 days, within a 97.5% CI.

If Swiss Cruises expects to cover expenses with this USD inflow, the maximum amount in CHF to cover, within a 97.5% CI, should be CHF 958,252. ¶

• **Summary NTE for Swiss francs:**

- NTE = CHF 1.0282 M

- NTE Range:

- Ad-hoc:

NTE ∈ [CHF 0.92538 M; CHF 1.13102 M]

- Simulation:

- Extremes: NTE ∈ [CHF 896,400; CHF 1,183,355].

- Simulation: NTE ∈ [CHF 949,652 M; CHF 1,090,783 M]

- Statistical Distribution (normal):

NTE ∈ [CHF 958,252; CHF 1,098,148]

◆ **Approximating returns to create CIs for different T.**

In general, we use *arithmetic returns*: $e_{f,t} = S_t/S_{t-1} - 1$. Changing the frequency is not straightforward.

But, if we use *logarithmic returns* –i.e., $e_{f,t} = \log(S_t) - \log(S_{t-1})$ –, changing the frequency of the mean return (μ) and return variance (σ^2) is simple. Let μ and σ^2 be measured in a given base frequency. Then,

$$\begin{aligned}\mu_f &= \mu T, \\ \sigma_f^2 &= \sigma^2 T,\end{aligned}$$

Example: From Table for CHF/USD: $\mu_m = 0.0004$ and $\sigma_m = .0329961$. (These are arithmetic returns.) We want to calculate the daily and annual percentage mean change and standard deviation for S_t .

We will approximate them using the logarithmic rule.

(1) Daily (i.e., $f=d$ =daily and $T=1/30$)

$$\mu_d = (0.0004005) \times (1/30) = .000013 \quad (0.0013\%)$$

$$\sigma_d = (0.0329961) \times (1/30)^{1/2} = .00602 \quad (0.60\%)$$

◆ **Approximating returns to create CIs for different T.**

(2) Annual (i.e., $f=a$ =annual and $T=12$)

$$\mu_a = (-0.002052) \times (12) = -0.024624 \quad (-2.46\%)$$

$$\sigma_a = (0.03471) \times (12)^{1/2} = .12024 \quad (12.02\%)$$

The annual compounded arithmetic return is $.004817 = (1 + .0004005)^{12} - 1$. When the arithmetic returns are low, these approximations work well. ¶

Note I: Using these annualized numbers, we can approximate an annualized VaR(97.5), if needed:

$$\begin{aligned}\text{USD } 1\text{M} \times 1.0282 \text{ CHF/USD} \times [1 + (-0.024624 - 1.96 \times 0.12024)] &= \\ &= \text{CHF } 760,5653. \quad \text{¶}\end{aligned}$$

Note II: Using logarithmic returns rules, we can approximate USD/CHF monthly changes by changing the sign of the CHF/USD. The variance remains the same. Then, annual USD/CHF mean percentage change is approximately 2.46%, with an 12.02% annualized volatility.

● **Sensitivity Analysis for portfolio approach**

Do a simulation: assume different scenarios -- attention to correlations!

Example: IBM has the following CFs in the next 90 days

FC	Outflows	Inflows	S_t	Net Inflows
GBP	100,000	25,000	1.60 USD/GBP	(75,000)
EUR	80,000	200,000	1.05 USD/EUR	120,000

$$\text{NTE (USD)} = \text{EUR } 120\text{K} * 1.05 \text{ USD/EUR} + (\text{GBP } 75\text{K}) * 1.60 \text{ USD/GBP}$$

$$= \text{USD } 6,000 \text{ (this is our baseline case)}$$

Situation 1: Assume $\rho_{\text{GBP, EUR}} = 1$. (EUR and GBP correlation is high.)

Scenario (i): EUR appreciates by 10% against the USD ($e_{f, \text{EUR}, t} = .10$).

$$S_t = 1.05 \text{ USD/EUR} * (1 + .10) = 1.155 \text{ USD/EUR}$$

$$\text{Since } \rho_{\text{GBP, EUR}} = 1 \Rightarrow S_t = 1.60 \text{ USD/GBP} * (1 + .10) = 1.76 \text{ USD/GBP}$$

$$\text{NTE (USD)} = \text{EUR } 120\text{K} * 1.155 \text{ USD/EUR} + (\text{GBP } 75\text{K}) * 1.76 \text{ USD/GBP}$$

$$= \text{USD } 6,600. \text{ (10\% change)}$$

Example (continuation):

Scenario (ii): EUR depreciates by 10% against the USD ($e_{f, \text{EUR}, t} = -.10$).

$$S_t = 1.05 \text{ USD/EUR} * (1 - .10) = 0.945 \text{ USD/EUR}$$

$$\text{Since } \rho_{\text{GBP, EUR}} = 1 \Rightarrow S_t = 1.60 \text{ USD/GBP} * (1 - .10) = 1.44 \text{ USD/GBP}$$

$$\text{NTE (USD)} = \text{EUR } 120\text{K} * 0.945 \text{ USD/EUR} + (\text{GBP } 75\text{K}) * 1.44 \text{ USD/GBP}$$

$$= \text{USD } 5,400. \text{ (-10\% change)}$$

Now, we can specify a range for NTE

$$\Rightarrow \text{NTE} \in [\text{USD } 5,400, \text{USD } 6,600]$$

Note: The NTE change is exactly the same as the change in S_t . If a firm has matching inflows and outflows in highly positively correlated currencies --i.e., the NTE is equal to zero--, then changes in S_t do not affect NTE. That's very good.

Example (continuation):

Situation 2: Suppose the $\rho_{\text{GBP, EUR}} = -1$ (NOT a realistic assumption!)

Scenario (i): EUR appreciates by 10% against the USD ($e_{\text{f, EUR, t}} = .10$).

$$S_t = 1.05 \text{ USD/EUR} * (1 + .10) = 1.155 \text{ USD/EUR}$$

$$\text{Since } \rho_{\text{GBP, EUR}} = -1 \Rightarrow S_t = 1.60 \text{ USD/GBP} * (1 - .10) = 1.44 \text{ USD/GBP}$$

$$\begin{aligned} \text{NTE (USD)} &= \text{EUR } 120\text{K} * 1.155 \text{ USD/EUR} + (\text{GBP } 75\text{K}) * 1.44 \text{ USD/GBP} \\ &= \text{USD } 30,600. \text{ (410\% change)} \end{aligned}$$

Scenario (ii): EUR depreciates by 10% against the USD ($e_{\text{f, EUR, t}} = -.10$).

$$S_t = 1.05 \text{ USD/EUR} * (1 - .10) = 0.945 \text{ USD/EUR}$$

$$\text{Since } \rho_{\text{GBP, EUR}} = -1 \Rightarrow S_t = 1.60 \text{ USD/GBP} * (1 + .10) = 1.76 \text{ USD/GBP}$$

$$\begin{aligned} \text{NTE (USD)} &= \text{EUR } 120\text{K} * 0.945 \text{ USD/EUR} + (\text{GBP } 75\text{K}) * 1.76 \text{ USD/GBP} \\ &= \text{(USD } 18,600). \text{ (-410\% change)} \end{aligned}$$

Now, we can specify a range for NTE

$$\Rightarrow \text{NTE} \in [\text{USD } 18,600, \text{USD } 30,600]$$

Example (continuation):

Note: The NTE has ballooned. A 10% change in exchange rates produces a dramatic increase in the NTE range.

\Rightarrow Having non-matching exposures in different currencies with negative correlation is very dangerous.

IBM will assume a correlation from the data and, then, jointly draw –i.e., draw together a pair, $e_{\text{f, GBP, t}}$ & $e_{\text{f, EUR, t}}$ – many scenarios for S_t to generate an empirical distribution for the NTE.

From this ED, IBM will get a range –and a VaR– for the NTE. ¶