FX Exposure

1. Measuring Exposure

FX Exposure

• Exposure (Risk)

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

• Three areas

(1) *Transaction exposure*: Risk of transactions denominated in FC 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 create accounting gains/losses due to changes in S_t.

We say a firm is "*exposed*" or has exposure if it faces currency risk.

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 following Swiss accounting rules. ¶

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).

Measuring Transaction Exposure

• Transaction exposure (TE) is easy to identify and measure.
- Identification: Transactions denominated in FC with a fixed future date
- Measure: Translate identified FC transactions to DC using S_t.

$$TE_{j,t} = \textbf{Value of a fixed future transaction in } \textbf{FC}_j * S_t$$

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 CHF/USD**.
Thus, the net transaction exposure in USD 30 days is:

Net $TE_{j=USD}$ = (USD 2.5M – USD 1.5M) * **1.0282 CHF/USD**
= **USD 1M** * **1.0282 CHF/USD**= CHF 1.0282M. ¶

• **Netting**
An MNC has many transactions, in different currencies, with fixed futures dates. Since TE is denominated in DC, all exposures are easy to consolidate in one single number: Net TE (NTE).

$$\text{NTE} = \text{Net } TE_t = \sum_{J=1}^{J} TE_{j,t} \qquad j = \text{EUR, GBP, JPY, BRL, MXN,...}$$

• NTE is reported by fixed date: up to 90 days, more than 90-days, etc.

Note: Since currencies are correlated, firms take into account **correlations** to calculate how changes in S_t affect Net TE $\Rightarrow$ **Portfolio Approach**.

Example: A U.S. MNC: Subsidiary A with CF(in EUR) > 0
Subsidiary B with CF(in GBP) < 0
Since $\rho_{GBP,EUR}$ is very high and positive, NTE may be very low. ¶

$\Rightarrow$ Hedging decisions are usually made based on exposure of the **portfolio**.

• **Netting - Correlations**

Example: Swiss Cruises.

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

Loan repayment: **CAD 1.40 million**. Due: 30 days.

S_t = **1.3692 CAD/USD.**

$\rho_{CAD,USD}$ = .843 (monthly from 1971 to 2017)

Swiss Cruises considers NTE to be close to zero. ¶

Note 1: Correlations vary a lot across currencies. In general, **regional** currencies are highly correlated.

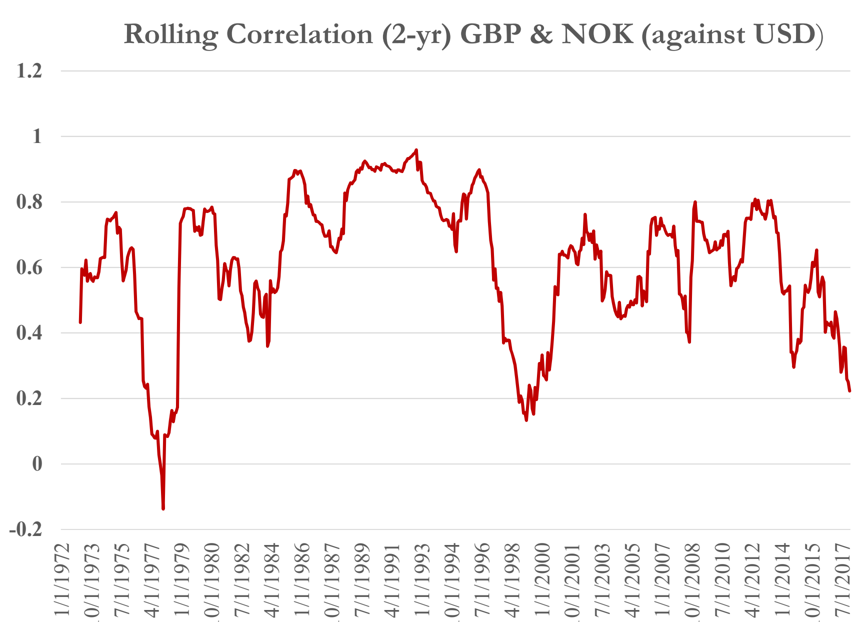
From **2000-2017**,

$\rho_{GBP,NOK}$ = **0.58**

$\rho_{GBP,JPY}$ = **0.04**

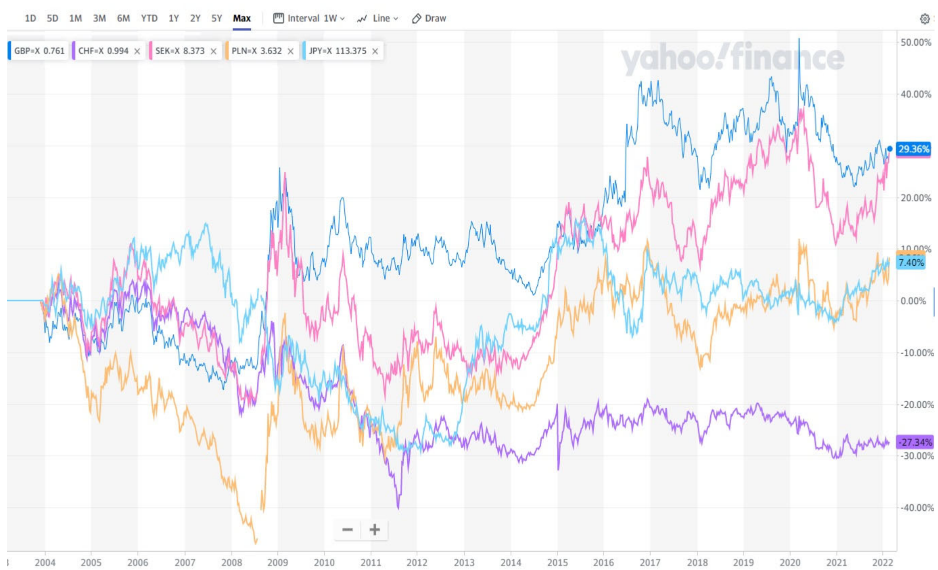
Note 2: Correlations also vary over time.

• **Netting - Correlations**



• Netting - Correlations

On average, currencies from developed countries tend to move together... But, not all and not always.



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

Firms are interested in how TE will change in the future, say, in T days when transaction will be settled.

- Firms do not know S_{t+T}, they need to forecast S_{t+T} $\Rightarrow$ $E_t[S_{t+T}]$

- Once we forecast $E_t[S_{t+T}]$, we can forecast $E_t[TE_{t+T}]$:

$E_t[TE_{t+T}]$ = **Value of a fixed future transaction in FC** * $E_t[S_{t+T}]$

- $E_t[S_{t+T}]$ has an associated standard error, which can be used to create a range (or interval) for S_{t+T} & TE.

- Risk management perspective:

How much DC can the firm spend on account of a FC inflow in T days?

How much DC will be needed to cover a FC outflow in T days?.

Range Estimates of TE

• S_t is very difficult to forecast. Thus, a range estimate for NTE provides a useful number for risk managers.

The smaller the range, the lower the sensitivity of NTE.

• Three popular methods for estimating a range for NTE:

(1) Ad-hoc rule (say, **±10%**)

(2) Sensitivity Analysis (or simulating exchange rates)

(3) Assuming a statistical distribution for exchange rates.

• **Ad-hoc Rule**

Many firms use an *ad-hoc* ("arbitrary") rule to get a range: **±X%** (for example, a 10% rule)

Simple and easy to understand: Get TE and add/subtract ±X%.

Example: 10% Rule.

SC has a Net TE = **CHF 1.0282M** due in 30 days

⇒ if S_t changes by **±10%**, NTE changes by ± **CHF 102,820**. ¶

Note: This example gives a range for NTE:

NTE ∈ **[CHF 0.92538 M; CHF 1.13102 M]**

Risk Management Interpretation: A risk manager will only care about the lower bound. If SC is counting on the **USD 1M** inflow 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

1-mo Changes in CHF/USD	
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

μ_m = -0.2052%

σ_m = 3.47%

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 * **1.0282 CHF/USD** * (1 + **0.1509**) = **CHF 1,183,355**.

(B) Worst case scenario.
Net TE: USD 1M * **1.0282 CHF/USD** * (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**. ¶

- **Sensitivity Analysis – Simulation**

Managers may consider the previous range, based on extremes, too conservative:

NTE ∈ **[CHF 896,400; CHF 1,183,355].** .

⇒ Probability of worst case scenario is low: Only once in 533 months!

Under more likely scenarios, a firm may be able to cover more expenses.

A more realistic range can be constructed through sampling from the ED.

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

(i) Randomly pick 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 CHF/USD** * (1 + $e_{f,t+30}$))

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

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

Example (continuation): In excel, using Vlookup function

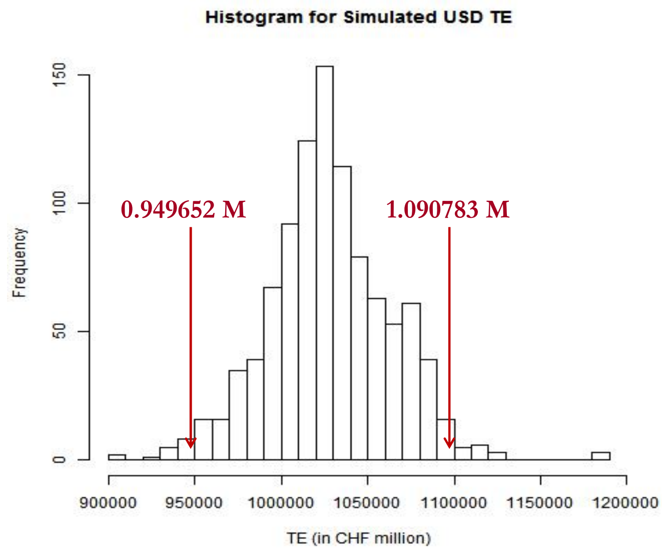
(i) Randomly draw $e_{f,t}$= $e_{f,sim,1}$ from ED: Observation 519: $e_{f,t+30}$= **0.0034**

(ii) Calculate $S_{sim,1}$: S_{t+30} = **1.0282 CHF/USD** * (1 + **.0034**) = **1.0317**

(iii) Calculate $TE_{sim,1}$: **TE** = **USD 1M** * S_{t+30} = **1,031,701.25**

(iv) Repeat (i)-(iii) 1,000 times. Plot histogram. Construct a (1-α)% C.I.

Lookup cell	$e_{f,t}$	Random Draw with Randbetween	Draw $e_{f,sim}$ with Vlookup	S_sim	TE(sim)
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 ∊ **[CHF 0.949652 M; CHF 1.090783 M]**

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⇒ NTE ∊ **[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 ∈ **[CHF 0.949652 M; CHF 1.090783 M]**).

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

⇒ NTE ∈ **[CHF 0.952202 M; CHF 1.093762 M]**

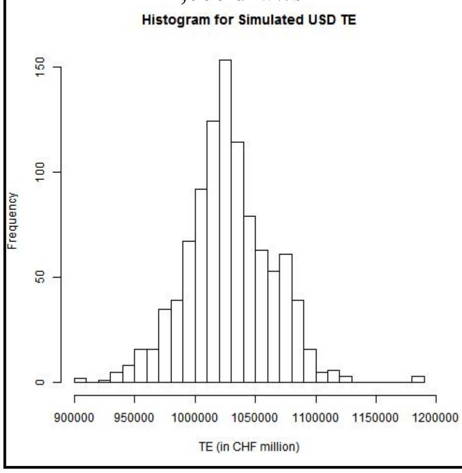
Example (continuation): Different 95% C.I.

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

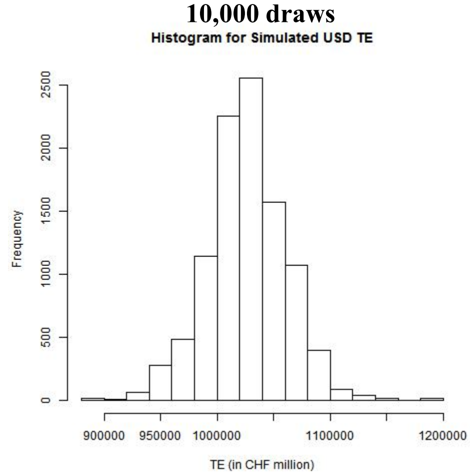
10,000 draws: **[CHF 0.952202 M; CHF 1.093762 M]**

⇒ Not that different: 1,000 simulations seem enough!

1,000 draws



10,000 draws



• Assuming a Distribution

A range based on an assumed distribution provide a range for TE.

For example, a firm assumes that $e_{f,t} \sim N(\mu, \sigma^2)$. ("~" = follows)

Recall that based on a distribution, we can build a confidence interval (CI). For the normal distribution we have:

⇒ a $(1 - \alpha)\%$ CI: $[\mu \pm z_{\alpha/2}\, \sigma]$

where μ = Estimated mean

σ^2 = Estimated variance

Note: To be precise, since the normal distribution is symmetric $|z_{1-\alpha/2}| = |z_{\alpha/2}|$. We just use the absolute value for the z_α.

Usual α's: $\alpha = .05$ ⇒ $z_{.025} = 1.96$ (≈2)

$\alpha = .02$ ⇒ $z_{.01} = 2.33$

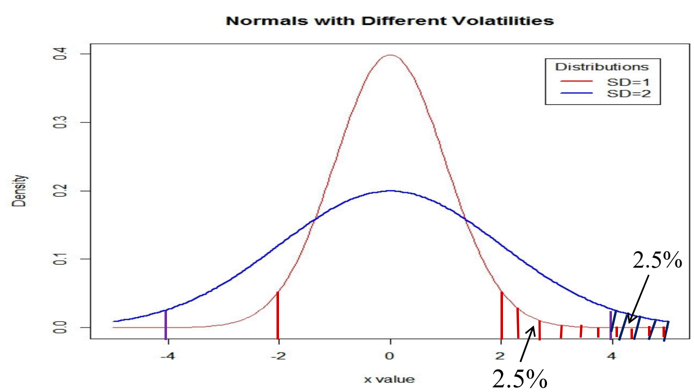
Interpretation: If $\alpha = .05$, the probability is about .95 that the 95% confidence interval will include the true population parameter.

• **Assuming a Distribution**

Below, we plot two different (1 - α)% Confidence Intervals for two different SD (σ = 1 & 2), where α = 5%:

95% Confidence Interval: [μ ± **1.96** σ].

Bigger SD, wider CI. We associate a wider CI with more uncertainty.



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**

σ^2 = Monthly variance = **0.03471^2 =** 0.0012947 ⇒ **σ = 0.03471** (**3.47%**)

$e_{f,t}$ ~ 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 [μ ± **1.96** σ].

Thus, $e_{f,t}$∈ [**-0.002** ± **1.96** **0.03471**] =[**-0.070**, **0.066**] (with 95% confidence)

Based on this range for $e_{f,t}$, we derive bounds for the net TE:

(A) Lower bound

Net TE: **USD 1M** * **1.0282 CHF/USD** * (1 **– 0.070**) = **CHF 956,226**.

(B) Upper bound

Net TE: **USD 1M** * **1.0282 CHF/USD** * (1 + **0.066**) = **CHF 1,096,061**.

⇒ TE ∊ **[CHF 956,226; CHF 1,096,601]**

• 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 previous example: **CHF 956,226** is the minimum revenue to be received by Swiss Cruises in the next 30 days, within a 97.5% CI.

The VaR is usually expressed as an expected loss, in this case, the loss relative to today's valuation of receivable (TE). We will call this VaR(mean):

VaR(mean, 97.5%) = **CHF 1.0282M** - **CHF 956,226** = **CHF 71,974**

Interpretation: With 97.5% confidence, the maximum expected loss of value (in CHF) of today's Swiss Cruises **USD 1M** receivable is **CHF 71,974.** ¶

● **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 956,226; CHF 1,096,601]**

♦ **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,

$\mu_f = \mu$ T,

$\sigma^2_f = \sigma^2$ T,

Example: From Table for CHF/USD: μ_m= **-0.002052** and σ_m= **0.03471**. (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)

μ_d = (**-0.002052**) * (1/30) = -.000375 (0.038%)

σ_d = (**0.03471**) * $(1/30)^{1/2}$ = .00634 (0.63%)

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

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

μ_a = (**-0.002052**) * (12) = -0.024624 (-2.46%)

σ_a = (**0.03471**) * $(12)^{1/2}$ = .12024 (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:

USD 1M * **1.0282 CHF/USD** * [1 + (-0.024624 – **1.96** * 0.12024)] =

= **CHF 760,5653**. ¶

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

NTE (USD) = EUR 120,000 * **1.05 USD/EUR**
+ (GBP 75,000) * **1.60 USD/GBP**
= USD 6,000 (this is our baseline case)

We are going to consider two extreme situations for the EUR & GBP:
- **Situation 1:** Perfect positive correlation, $\rho_{GBP,EUR} = 1$.
- **Situation 2:** Perfect negative correlation, $\rho_{GBP,EUR} = -1$.

We use these extreme situations to illustrate the benefits/costs of having currency positions that co-move.

Example (continuation):
Situation 1: Assume $\rho_{GBP,EUR} = 1$. (EUR and GBP correlation is high.)
Scenario (i): EUR appreciates by 10% against the USD ($e_{f,EUR,t} = 0.10$).
S_t = **1.05 USD/EUR** * (1 + **0.10**) = **1.155 USD/EUR**

Since $\rho_{GBP,EUR} = 1 \Rightarrow$ S_t= **1.60 USD/GBP** * (1 + **0.10**)= **1.76 USD/GBP**

NTE (USD) = EUR 120,000 * **1.115 USD/EUR**
+ (GBP 75,000) * **1.76 USD/GBP**
= **USD 6,600**

⇒ This new NTE represents a 10% change with respect to baseline case.

Example (continuation):
Scenario (ii): EUR depreciates by 10% against the USD ($e_{f,EUR,t}$ = -0.10).

S_t = **1.05 USD/EUR** * (1 – **0.10**) = **0.945 USD/EUR**

Since $\rho_{GBP,EUR}$ = 1 ⇒ S_t= **1.60 USD/GBP** * (1 – **0.10**)= **1.44 USD/GBP**

NTE (USD) = EUR 120,000 * **0.945 USD/EUR**
+ (GBP 75,000) * **1.44 USD/GBP**
= **USD 5,400**

⇒ This new NTE represents a **-10%** change with respect to baseline case.

Now, we can specify a range for NTE
⇒ NTE ∊ **[USD 5,400, 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 or close to zero-, then changes in S_t do not affect NTE. That's very good.

Example (continuation):
Situation 2: Suppose the $\rho_{GBP,EUR}$ = -1 (NOT a realistic assumption!)
Scenario (i): EUR appreciates by **10%** against the USD ($e_{f,EUR,t}$ = **0.10**).
S_t = **1.05 USD/EUR** * (1 + **0.10**) = 1.155 USD/EUR

Since $\rho_{GBP,EUR}$ = -1 ⇒ S_t = **1.60 USD/GBP** * (1– **0.10**) = 1.44 USD/GBP

NTE (USD) = EUR 120,000 * 1.155 USD/EUR
+ (GBP 75,000) * 1.44 USD/GBP = **USD 30,600**. (410% ↑)

Scenario (ii): EUR depreciates by **10%** against the USD ($e_{f,EUR,t}$ = **-0.10**).
S_t = **1.05 USD/EUR** * (1 – **0.10**) = 0.945 USD/EUR

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

NTE (USD) = EUR 120,000 * 0.945 USD/EUR
+ (GBP 75,000) * 1.76 USD/GBP = **-USD 18,600**. (-410% ↓)

Now, we can specify a range for NTE
⇒ NTE ∊ **[(USD 18,600), USD 30,600]**

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

⇒ 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, $e_{f,EUR,t}$ & $e_{f,GBP,t}$ – 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. ¶