FX Exposure

1. Measuring Exposure

FX Risk Management

• 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.

$TE_{j,t}$ = **Value of a fixed future transaction in 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 = **1.45 CHF/USD**.

Thus, the net transaction exposure in USD 30 days is:

Net $TE_{j=USD}$ = (USD 2.5M – USD 1.5M) * **1.45 CHF/USD**
= **USD 1M** * **1.45 CHF/USD** = CHF 1.45M. ¶

• **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 ⇒ **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. ¶

⇒ 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 1.50 million**. Due: 30 days.

S_t = **1.47 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.

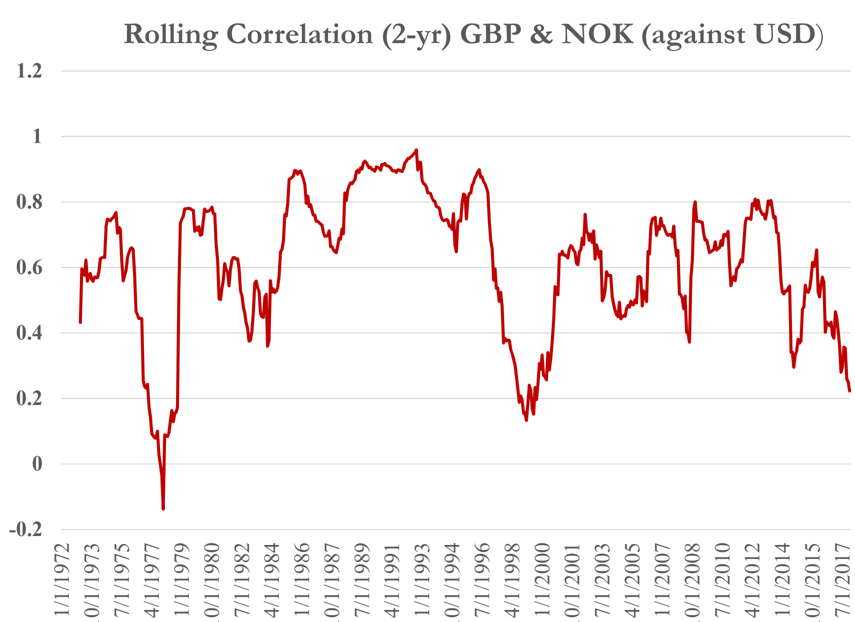
From **2000-2017**,

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

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

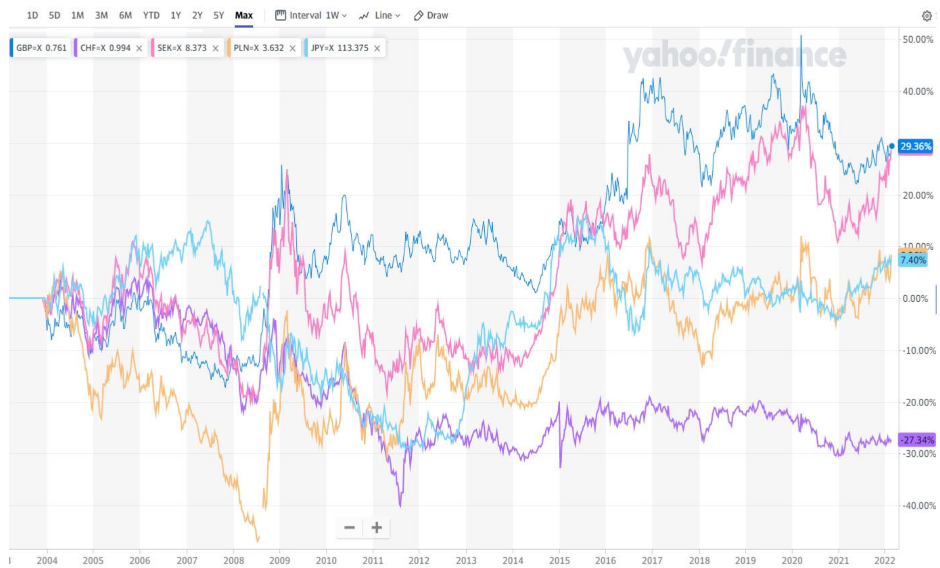
Note 2: Correlations also vary over time.

• **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 1.45M** due in 30 days

⇒ if S_t changes by **±10%**, NTE changes by ± **CHF 145,000**. ¶

Note: This example gives a range for NTE:

NTE ∈ **[CHF 1.305M; CHF 1.595M]**

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 1.305M**. ¶

- **Sensitivity Analysis**

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

Example: Sensitivity of TE to extreme forecasts of S_t.

Sensitivity of TE to randomly simulate thousands of S_t.

Data: 20 years of monthly CHF/USD % changes (ED)

Mean (μ)	-0.00152	μ_m = **-0.152%**
Standard Error	0.00202	
Median	-0.00363	
Mode	#N/A	
Stand Deviation (σ)	0.03184	σ_m = **3.184%**
Sample Variance (σ^2)	0.00101	
Kurtosis	0.46327	
Skewness	0.42987	
Range	0.27710	
Minimum	**-0.11618**	
Maximum	**0.15092**	
Sum	0.0576765	
Count	248	

- **Sensitivity Analysis – Extremes (Worst Case & Best Case)**

Example: Extremes for Swiss Cruises Net TE (CHF/USD)

ED of S_t monthly changes over the past 20 years (1994-2014).

Extremes: **15.09%** (on October 2011) and **–11.62%** (on Jan 2009).

SC's net receivables in FC: **USD 1M**.

(A) *Best case scenario*: largest appreciation of USD: **0.1509**

NTE: **USD 1M** * **1.45 CHF/USD** * (1 + **0.1509**) = **CHF 1,668,805**.

(B) *Worst case scenario*: largest depreciation of USD: **-0.1162**

NTE: **USD 1M** * **1.45 CHF/USD** * (1 + (**–0.1162**)) = **CHF 1,281,510**.

That is,

NTE ∈ **[CHF 1,281,510; CHF 1,668,805]**

Note: If Swiss Cruises is counting on the USD 1M to cover CHF expenses, the expenses to cover should not exceed **CHF 1,281,510**. ¶

- **Sensitivity Analysis – Simulation**

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

NTE ∈ [**CHF 1,281,510; CHF 1,668,805**].

⇒ Probability of worst case scenario is low: Only once in 240 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} = **1.45 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

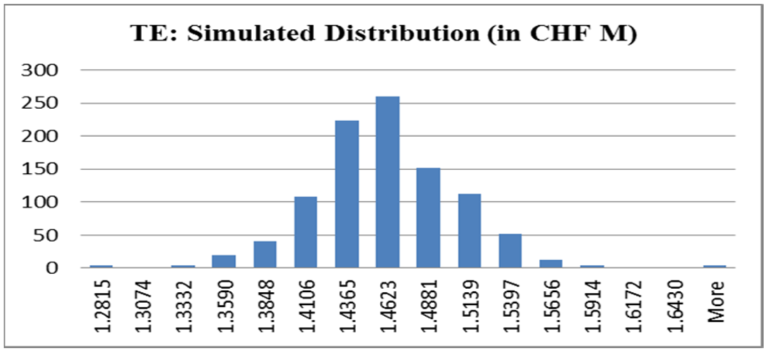
(i) Randomly draw $e_{f,t}$=$e_{f,sim,1}$ from ED: Observation 19: $e_{f,t+30}$ = **0.0034**

(ii) Calculate $S_{sim,1}$: S_{t+30} = **1.45 CHF/USD** * (1 + **.0034**) = **1.4549**

(iii) Calculate $TE_{sim,1}$: **TE** = **USD 1M** * S_{t+30} = **1,454,937.57**

(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 s_sim with Vlookup	S_sim	TE(sim)
1					
2	0.0025	19	**0.0034**	**1.4549**	**1,454,937.57**
3	-0.0027	147	-0.0104	1.4349	1,434,895.83
4	**0.0001**	99	0.0125	1.4682	1,468,189.96
5	-0.0443	203	-0.0584	1.3653	1,365,272.92
6	-0.0017	82	-0.0727	1.3446	1,344,597.25
7	-0.0031	**4**	**0.0001**	1.4502	1,450,168.79
8	-0.0227	67	-0.0226	1.4172	1,417,218.22
9	-0.0099	136	0.0095	1.4638	1,463,838.02
10	0.0098	232	0.0191	1.4777	1,477,749.46



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 1.3661 M**; **CHF 1.5443 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 1,366,100**. ¶

• **Aside: How many draws in the simulations?**
Usually, we draw until the 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 1.3661 M**; **CHF 1.5443 M**]

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

⇒ NTE ∈ [**CHF 1.3670 M**; **CHF 1.5446 M**]

• Not a significant change in the range: 1,000 simulations seem enough.

• Assuming a Distribution

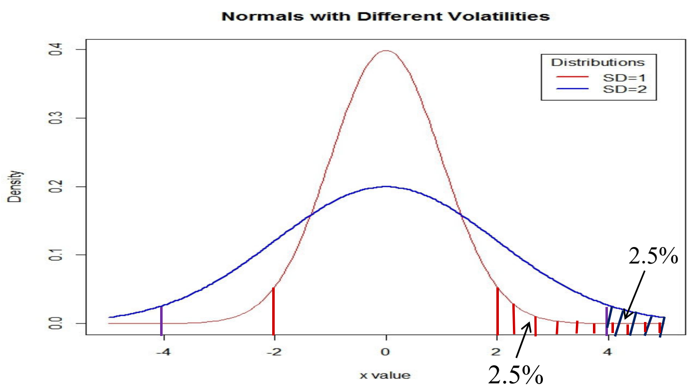
CIs based on an assumed distribution provide a range for TE.

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

$\Rightarrow$ construct a $(1 - \alpha)\%$ CI: $[\mu \pm |z_{\alpha/2}|\ \sigma]$. $(|z_{\alpha/2}| = z_{1-\alpha/2})$

Usual α's: $\alpha = .05 \Rightarrow |z_{.025}| = \mathbf{1.96}\ (\approx 2)$

$\alpha = .02 \Rightarrow |z_{.01}| = \mathbf{2.33}$



• Assuming a Distribution – Normal for $e_{f,t}$

Example: CI range based on a Normal distribution.

Swiss Cruises believes that CHF/USD monthly changes follow a normal distribution. SC estimates:

μ = Monthly mean = **-0.00152** ≈ -0.15%

σ^2 = Monthly variance = 0.001014 $(\Rightarrow \sigma = \mathbf{0.03184}$, or 3.18%)

$e_{f,t} \sim N(\mathbf{-0.00152}, \mathbf{0.03184}^2)$ $e_{f,t}$ = CHF/USD monthly changes.

SC builds a 95% CI for CHF/USD monthly changes:

[**-0.00152** ± **1.96** * **0.03184**] = [-0.06393; 0.06089].

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

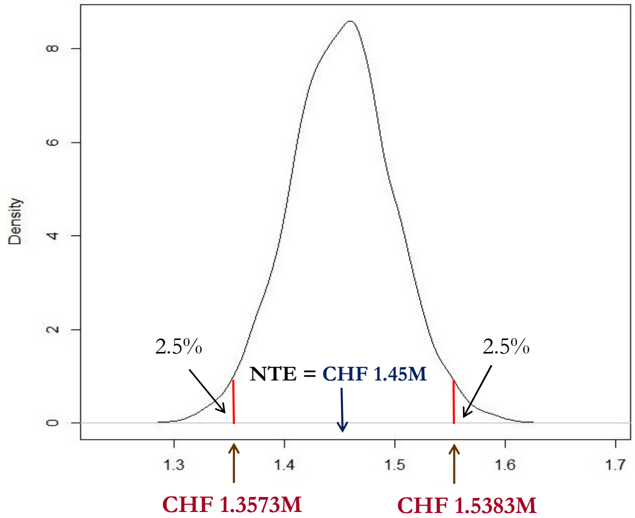
(A) Upper bound

NTE: **USD 1M** * **1.45 CHF/USD** * (1 + 0.06089) = **CHF 1,538,291**.

(B) **Lower bound**

NTE: **USD 1M** * **1.45 CHF/USD** * (1 + (-0.06393)) = **CHF 1,357,302**.

95% CI range based on a Normal Distribution and VaR(97.5%)



VaR(97.5%): Minimum revenue within a 97.5% C.I.

⇒ NTE ∈ [**CHF 1.357 M**; **CHF 1.538 M**]

• 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) CI.

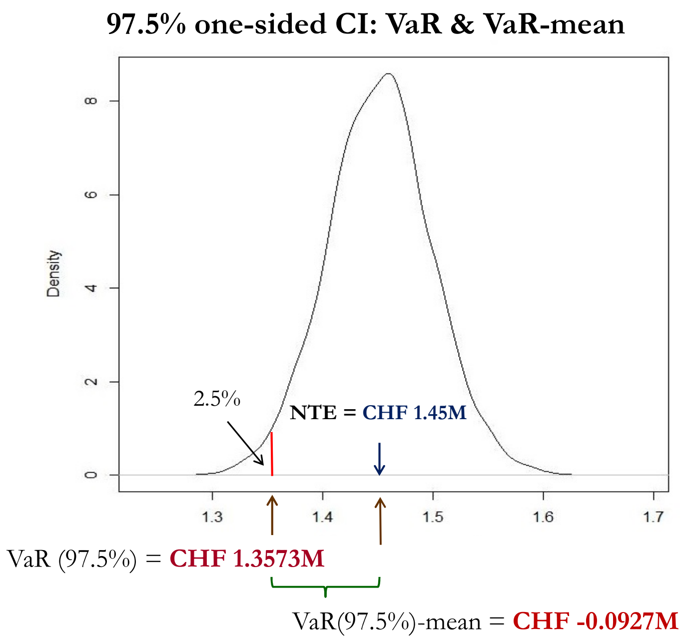
In our case, we can express the "*expected loss*" relative to today's value:

VaR-mean = **VaR** – **NTE**

Example (continuation): The minimum revenue to be received by SC in the next 30 days, within a 97.5% CI (⇒ $|z_{.025}| = 1.96$):

VaR(97.5%) = **CHF 1.45M** [1 + (**-0.00152** – **1.96** * **0.03184**)]
= **CHF 1,357,302**.

⇒ VaR-mean (.975) = **CHF 1.3573M** – **CHF 1.45M** = **CHF -0.0927M**



Example (continuation): ⇒ NTE ∈ [**CHF 1.357 M**; **CHF 1.538 M**]

VaR(97.5%) = **CHF 1,357,302**

If SC expects to cover expenses with this USD inflow, the maximum amount in CHF to cover, within a 97.5% CI, should be **CHF 1,357,302**.

VaR-mean (97.5%) = **CHF -0.0927M**

Relative to today's valuation (or *expected valuation*, according to RWM), the maximum *expected loss* with a 97.5% "chance" is **CHF -0.0927M**. ¶

Note: We could have used a different significance level to calculate the VaR, for example 99% (⇒ $|z_{.01}|$ = 2.33). Then,

VaR(99%) = **CHF 1.45M** [1 + (-0.00152 – 2.33 * 0.03184)]
= **CHF 1.34023**. (A more *conservative* bound.)

⇒ VaR-mean (.99) = **CHF 1.34023M** – **CHF 1.45M** = **CHF -0.1098M**

● **Summary NTE for Swiss Cruises:**

- **NTE = CHF 1.45M**

• **NTE Range:**

◇ **Ad-hoc:**

NTE ∈ [**CHF 1.305M**; **CHF 1.595 M**].

◇ **Sensitivity Analysis:**

- Extremes: NTE ∈ [**CHF 1.281 M**; **CHF 1,6688 M**]
- Simulation: NTE ∈ [**CHF 1.3661 M**; **CHF 1.5443 M**]

◇ **Statistical Distribution (normal):**

NTE ∈ [**CHF 1.357 M**; **CHF 1.538 M**]

♦ **Approximating Returns**

In general, we use *arithmetic returns*: $e_{f,t} = S_t/S_{t-1} - 1$. To change the frequency, compounding is needed.

But, if we use *logarithmic returns* –i.e., $e_{f,t} = \log(S_t) - \log(S_{t-1})$–, changing the frequency of mean returns (μ) and return variances (σ^2) is simpler.

Let μ_b & σ_b^2 be measured in a given base frequency, say, b. Then,

$\mu_f = \mu_b * T$,

$\sigma_f^2 = \sigma_b^2 * T$ $\Rightarrow \sigma_f = \sigma_b * \text{sqrt}(T)$

T = # periods of base frequency b in new frequency, f.

♦ Approximating Returns – From monthly to daily & annual

Example: Using monthly data, compute daily and annual mean & SD.

From previous Table (base frequency: b = monthly, arithmetic computed):

μ_m= -**0.00152**

σ_m= **0.03184**

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

μ_d = (-**0.00152**) * (1/30) = .0000507 (0.006%)

σ_d = (**0.03184**) * $(1/30)^{1/2}$ = .00602 (0.60%)

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

μ_a = (-**0.00152**) * (12) = **-0.01824** (-1.82%)

σ_a = (**0.03184**) * $(12)^{1/2}$ = **0.110297** (11.03%)

Check: The annual compounded arithmetic return:

$$(1 - \mathbf{0.00152})^{12} - 1 = -0.01809.$$

When arithmetic returns are low, these approximations work well. ¶

♦ Approximating Returns – From monthly VaR to annualized VaR

Example: Using the annualized approximation, we can also approximate an annualized VaR(97.5%) for Swiss Cruises:

VaR(97.5%) = **USD 1M** * **1.45 CHF/USD** * [1 +(-**.01824** – 1.96***0.1103**)]

= **CHF 1,101,374**. ¶

Note II: Using logarithmic returns rules, we can approximate USD/CHF monthly changes by changing the sign of the CHF/USD, while the variance remains the same.

Then,

- Annualized USD/CHF mean percentage change ≈ **1.82%**,
- Annualized USD/CHF volatility ≈ **11.03%**

● Sensitivity Analysis – Portfolio Approach

A simulation: Draw different scenarios, pay attention to *correlations*!

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

	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_0 = EUR 120K * 1.05 USD/EUR + (GBP 75K) * 1.60 USD/GBP
= **USD 6,000** (this is our baseline case)

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

Scenario (i): EUR appreciates by **10%** against the USD

Since $\rho_{GBP,EUR} = 1$, S_t = 1.05 USD/EUR * (1 + .10) = 1.155 USD/EUR
S_t = 1.60 USD/GBP * (1 + .10) = 1.76 USD/GBP

NTE = EUR 120K * 1.155 USD/EUR + (GBP 75K) * 1.76 USD/GBP
= **USD 6,600**. (**+10% change** = **USD -600**)

● Sensitivity Analysis – Portfolio Approach

Example (continuation): with $\rho_{GBP,EUR} = 1$.

Scenario (ii): EUR depreciates by **10%** against the USD

Since $\rho_{GBP,EUR} = 1$, S_t = 1.05 USD/EUR * (1 – .10) = 0.945 USD/EUR
S_t = 1.60 USD/GBP * (1 – .10) = 1.44 USD/GBP

NTE = EUR 120K * 0.945 USD/EUR + (GBP 75K) * 1.44 USD/GBP
= **USD 5,400**. (**-10% change** = **USD -600**)

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. Then,

if $NTE_0 \approx 0$ ⇒ $e_{f,t}$ has very small effect on NTE.

That is, if a firm has matching inflows and outflows in highly positively correlated currencies, then changes in S_t do not affect NTE. From a risk management perspective, this is very good.

- **Sensitivity Analysis – Portfolio Approach**

Example (continuation):

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

Scenario (i): EUR **appreciates** by **10%** against the USD

Since $\rho_{GBP,EUR}$ = -1, S_t = **1.05 USD/EUR** * (1 + .10) = **1.155 USD/EUR**

S_t = **1.60 USD/GBP** * (1 – .10) = **1.44 USD/GBP**

NTE = **EUR 120K** * **1.155 USD/EUR** + **(GBP 75K)** * **1.44 USD/GBP**
= **USD 30,600**. (**410% change** = **USD 24,600**)

Scenario (ii): EUR **depreciates** by **10%** against the USD

Since $\rho_{GBP,EUR}$ = -1, S_t = **1.05 USD/EUR** * (1 - .10) = **0.945 USD/EUR**

S_t = **1.60 USD/GBP** * (1 + .10) = **1.76 USD/GBP**

NTE = **EUR 120K** * **0.945 USD/EUR** + **(GBP 75K)** * **1.76 USD/GBP**
= **(USD 18,600).** (**-410% change** = **USD -24,600**)

Now, we can specify a range for NTE

⇒ NTE ∈ [**(USD 18,600)**; **USD 30,600**]

- **Sensitivity Analysis – Portfolio Approach**

Example (continuation):

Note: The NTE has ballooned. A **10% change** in S_t a dramatic increase in the NTE range.

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

Remarks:

- IBM can assume a correlation (estimated from the data). Then, draw many scenarios from a *bivariate normal distribution* to generate a simulated distribution for the NTE.

- Alternatively, IBM can just draw joint pairs from the ED. From this ED, IBM will get a range –and a VaR– for the NTE. ¶