Measuring FX Exposure

Transaction Exposure 1

FX Risk Management

• **FX Exposure: Review**

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

• TE is simply to calculate: Value in DC of a specific transaction wit a certain date/maturity denominated in FC.

• We can measure TE, and analyze the sensitivity of TE to changes in S_t.
- Use a statistical distribution or a simulation.
The less sensitive TE is to S_t, the lower the need to pay attention to $e_{f,t}$.

• MNCs have measures for NTE for:
- a single transaction
- all transactions (Netting, where co-movements of S_t's are incorporated

• The last measure approaches TE with a portfolio approach, where currency correlations are taken into account.

• **Correlations: Brief Review**

Recall that the co-movement between two random variables can be measured by the correlation coefficient. The correlation between the random variables X and Y is given by:

$Corr(X,Y) = \rho_{XY} = \sigma_{XY}/(\sigma_Y\sigma_Y)$.

Interpretation of the correlation coefficient ($\rho_{xy} \in [-1, 1]$):
If $\rho_{xy} = 1$, X changes by 10%, Y also changes by 10%.
If $\rho_{xy} = 0$, X changes by 10%, Y is not affected –(linearly) independent.
If $\rho_{xy} = -1$, X changes by 10%, Y also changes by -10%.

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

• **Netting**

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

A U.S. MNC: Subsidiary A with CF(in EUR) > 0
Subsidiary B with CF(in GBP) < 0
$\rho_{GBP,EUR}$ 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.

Example: Swiss Cruises.

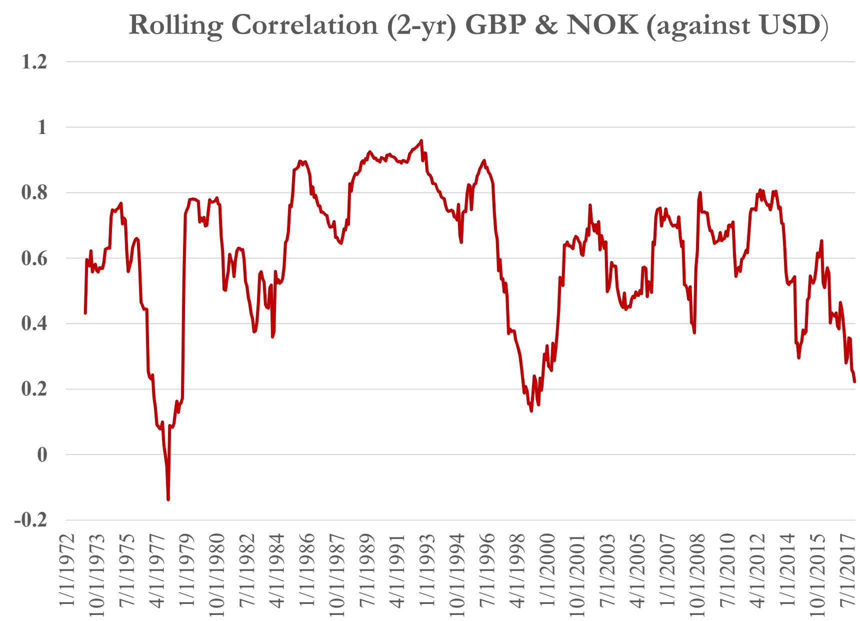
Net TE (in USD): USD 1 million. Due: 30 days.
Loan repayment: CAD 1.50 million. Due: 30 days.
S_t = 1.47 CAD/USD.
$\rho_{CAD,USD}$ = .924

Swiss Cruises considers the Net TE (overall) to be close to zero. ¶

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

Note 2: Correlations also vary over time.

• **Netting - Correlations**



• **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 $NTE_0 \approx 0$ ⇒ s_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. ¶

Managing TE

- **A Comparison of External Hedging Tools**

Transaction exposure: Risk from the settlement of transactions in FC.

Example: Imports, exports, acquisition of foreign assets.

• Tools: Futures/forwards (FH)
Options (OH)
Money market (MMH)

• Q: Which hedging tool is better?

- New tool: MMH

Money market hedge: Based on a replication of **IRPT** arbitrage.

Let's take the case of *receivables* denominated in FC:

1) **Borrow FC**
2) Convert to DC
3) Deposit DC in domestic bank
4) **Transfer FC receivable** to cover loan (+ interest) from (1).

Under IRPT, step 4) involves buying FC forward, to repay loan in (1)

⇒ This step is not needed, instead, we just transfer the FC receivable.

Q: Why MMH instead of FH?

- Under perfect market conditions ⇒ MMH = FH
- Under less than perfect conditions ⇒ MMH ≠ FH

- New tool: MMH

Now, let's take the case of *payables* denominated in FC:

1) **Borrow DC**
2) Convert to FC
3) Deposit FC in domestic bank
4) **Transfer FC deposit** (+ interest) to cover payable in FC.

Under IRPT, step 4) involves selling FC/buying DC forward, to repay loan in (1)

⇒ This step is not needed, instead, we just transfer the FC deposit.

Q: Why MMH instead of FH?

- Under perfect markets ⇒ MMH = FH
- Under less than perfect markets ⇒ MMH ≠ FH

• Comparison of Hedging Strategies

Example: Iris Oil Inc. has a large FC exposure in the form of a CAD cash flow from its Canadian operations. Iris decides to transfer **CAD 300M** to its USD account in 90 days.

FX risk to Iris: CAD may depreciate against the USD.

Data:
S_t = 0.8451 USD/CAD
$F_{t,90\text{-day}}$ = 0.8493 USD/CAD
i_{USD} = **3.92%**
i_{CAD} = **2.03%**

X	Calls	Puts
.82 USD/CAD	----	0.21
.84 USD/CAD	1.58	0.68
.88 USD/CAD	0.23	----

Example (continuation):

Date	Spot market	Forward market	Money market
t	S_t = .8451 USD/CAD	$F_{t,90\text{-day}}$ = .8493 USD/CAD	i_{USD} = 3.92% i_{CAD} = 2.03%
$t+90$	Receive **CAD 300M** and transfer into USD.		

NTE = **CAD 300M** * .8451 USD/CAD = **USD 253.53M**

• Hedging Strategies:

1. Do Nothing

Do not hedge and exchange the **CAD 300M** at S_{t+90}.

2. Forward Market

At t, sell the **CAD 300M** forward and at time $t+90$ guarantee:

CAD 300M * **.8493 USD/CAD** = **USD 254,790,000**

Example (continuation):

3. Money Market

At t, Iris Oil takes the following three steps, simultaneously:

1) Borrow from Canadian bank at **2.03%** for 90 days :

CAD 300M / [1 + **.0203** * (90/360)] = **CAD 298,485,188**.

2) Convert to USD at S_t:

CAD 298,485,188 * **0.8451 USD/CAD** = **USD 252,249,832**

3) Deposit in US bank at **3.92%** for 90 days to guarantee at time t+90:

USD 252,249,832 * [1 + **.0392** * (90/360)] = **USD 254,721,880**.

Note: Both the FH and the MMH guarantee certainty at time t+90

FH delivers to Iris Oil: **USD 254,790,000**

MMH delivers to Iris Oil: **USD 254,721,880**

⇒ Iris Oil selects the FH. (MMH is a *dominated* strategy.)

Example (continuation):

4. Option Market

At t, buy a **put**. Available 90-day options:

X	Calls	Puts
.82 USD/CAD	----	0.21
.84 USD/CAD	1.58	**0.68**
.88 USD/CAD	**0.23**	----

Buy the **.84 USD/CAD put** ⇒ Total premium cost of **USD 2.04M**.

Position	**Initial CF**	**Cash flows at t+90**	
		S_{t+90} < .84 USD/CAD	**S_{t+90} >.84 USD/CAD**
Option (HP)	**USD 2.04M**	(.84 – S_{t+90}) * **CAD 300M**	0
Underlying (UP)	0	S_{t+90} * **CAD 300M**	S_{t+90} * **CAD 300M**
Total CF	**USD 2.04M**	USD 252M	S_{t+90} CAD 300M

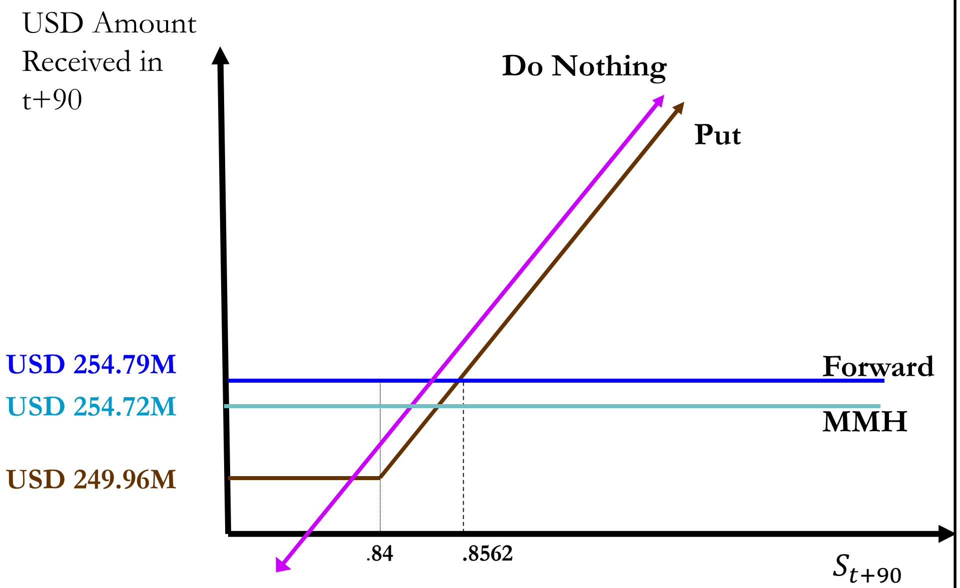
Net CF at $t + 90$:

USD 249,960,000 for S_{t+90} < **.84 USD/CAD**

or S_{t+90} * **CAD 300M** – **USD 2.04M** for S_{t+90} > **.84 USD/CAD**

Example (continuation):

- Let's plot all strategies:



Example (continuation): Companies do not like paying premiums.

5. Collar

At time t, *buy* a **put** and *sell* a **call**.

Buy **.84** put at **USD 0.0068**

Sell **.88** call at **USD 0.0023**. ⇒ Initial cost = **USD 0.0045** per collar

⇒ Total cost: **USD 1.35M**

Position	Initial CF	Cash flows at t+90		
		S_{t+90} < .84	.84 < S_{t+90} < .88	S_{t+90} > .88
Put	USD 2.04M	(.84 – S_{t+90}) * CAD 300M	0	0
Call	-USD 0.69M	0	0	(.88 – S_{t+90}) * CAD 300M
UP	0	S_{t+90} * CAD 300M	S_{t+90} * CAD 300M	S_{t+90} * CAD 300M
Total CF	USD 1.35M	USD 252M	S_{t+90} CAD 300M	USD 264M

Net CF at $t + 90$:

USD 250.65M for S_{t+90} < .84 USD/CAD

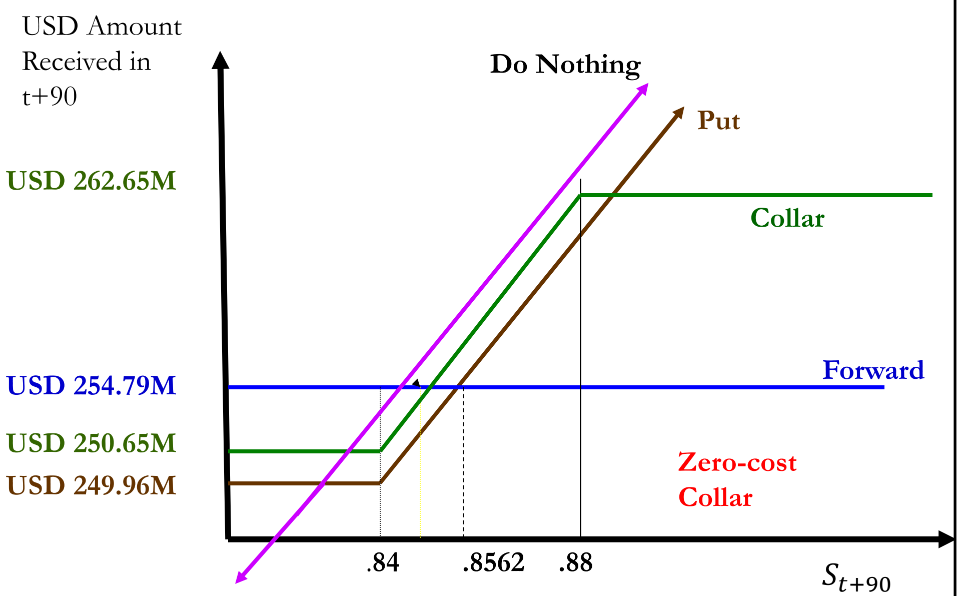
or S_{t+90} **CAD 300M – USD 1.35M** for .84 USD/CAD < S_{t+90} < .88 USD/CAD

or USD 262.65M for S_{t+90} > .88 USD/CAD

Note: This collar reduces the upside: establishes a floor and a cap.

Example (continuation):

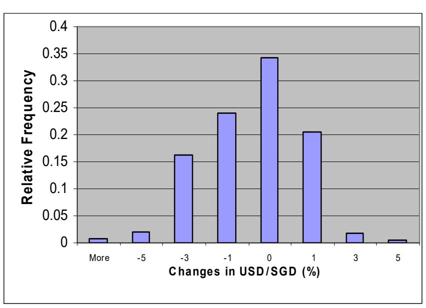
Let's plot all strategies:

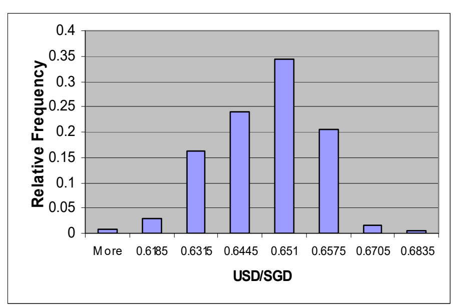


• Optimal Hedging Strategies?

Q: Which strategy is better? We need to say something about S_{t+90}. For example, we can assume a distribution (normal) or use the ED to say something about future changes in S_t.

Example: Suppose we have a **receivable in SGD** in 30 days. We can use the **distribution** for monthly USD/SGD changes from the past 30 years. Then, we get the distribution for S_{t+30} (USD/SGD).





Example (continuation): Distribution of monthly USD/SGD changes from past 30 years. Raw data & relative frequency for S_{t+30} (USD/SGD).

s_t (SGD/USD)	*Frequency*	*Rel frequency*	S_t =1/.65*(1+s_t)	
-0.0494 or less	2	0.0058	1.462	0.6838
-0.0431	2	0.0058	1.472	0.6793
-0.0369	1	0.0029	1.482	0.6749
-0.0306	3	0.0087	1.491	0.6705
-0.0243	6	0.0174	1.501	0.6662
-0.0181	20	0.0580	1.511	0.6620
-0.0118	36	0.1043	1.520	0.6578
-0.0056	49	0.1420	1.530	0.6536
0.0007	86	**0.2493**	1.540	**0.6495**
0.0070	52	0.1507	1.549	0.6455
0.0132	41	0.1188	1.559	0.6415
0.0195	29	0.0841	1.568	0.6376
0.0258	5	0.0145	1.578	0.6337
0.0320	7	0.0203	1.588	0.6298
0.0383	5	0.0145	1.597	0.6260
0.0446	0	0.0000	1.607	0.6223
0.0508 or +	3	0.0058	1.617	0.6186

• **Examples assuming an explicit distribution for S_{t+T}**

Example – Receivables: Evaluate (1) FH, (2) MMH, (3) OH & (4) NH.

Cud Corp will receive **SGD 500,000** in 30 days. (SGD Receivable.)

Data:

• S_t = **.6500 - .6507 USD/SGD**.

• $F_{t,30}$ = **.6510 - .6519 USD/SGD**.

• 30-day interest rates: i_{SGD}: **2.65% - 2.75%** & i_{USD}: **3.20% - 3.25%**

• A 30-day put option on SGD: **X = .65 USD/SGD** and P_t= **USD.01**.

• Forecasted S_{t+30}:

Possible Outcomes	**Probability**
USD .63	18%
USD .64	24%
USD .65	34%
USD .66	21%
USD .68	3%

(1) FH: Sell SGD 30 days forward
USD received in 30 days = Receivables in SGD * $F_{t,30}$
= **SGD 500,000** * **.651 USD/SGD** = **USD 325,500**.

(2) MMH:
- Borrow SGD at **2.75%** for 30 days,
- Convert to USD at **.65 USD/SGD,**
- Deposit USD at **3.2%** for 30 days,
- Repay SGD loan in 30 days with SGD 500,000 receivable

Amount to borrow = **SGD 500,000**/(1 + **.0275** * 30/360) =
= SGD 498,856.79

Convert to USD (Amount to deposit in U.S. bank) =
= SGD 498,856.79 * **.65 USD/SGD** = USD 324,256.91

Amount received in 30 days from U.S. bank deposit =
= USD 324,256.91 * (1 + **.032** * 30/360) = **USD 325,121.60**

(3) OH: Purchase put option. **X = .65 USD/CHF**
P_t = premium = **USD .01**

Possible S_{t+30}	**Premium per SGD + Op Cost**	**Exercise?**	**Net USD Received for SGD 0.5M**	**Prob**
.63 USD/SGD	USD .010027	Yes	**USD 319,986.5**	18%
.64 USD/SGD	USD .010027	Yes	**USD 319,986.5**	24%
.65 USD/SGD	USD .010027	No	**USD 319,986.5**	34%
.66 USD/SGD	USD .010027	No	**USD 324,986.5**	21%
.68 USD/SGD	USD .010027	No	**USD 334,986.5**	3%

Note: In the Total Amount Received (in USD) we have subtracted the *opportunity cost* involved in the upfront payment of a premium:
USD .01 * **.032** * 30/360 = **USD .000027** (Total = **USD 13.50**)
⇒ Total Premium Cost: **USD 5,013.50**
E[Amount Received in USD] = **319,986.5** * .76 + **324,986.50** * .21 +
+ **334,986.50** * .03 = **USD 321,486.5**

(4) No Hedge (NH): Sell **SGD 500,000** in the spot market in 30 days.

Possible S_{t+30}	**USD Received for SGD 0.5M**	**Probability**
.63 USD/SGD	USD 0.315M	18%
.64 USD/SGD	USD 0.320M	24%
.65 USD/SGD	USD 0.325M	34%
.66 USD/SGD	USD 0.330M	21%
.68 USD/SGD	USD 0.340M	3%

Note: When we compare (1) to (4), it's not clear which one is better. Preferences will matter. We can calculate and expected value:

E[Amount Received in USD] = 315K * .18 + 320K * .24 + 325K * .34+ + 330K * .21 + 335K * . 03 = **USD 323,500**

Conclusion: Cud Corporation is likely to choose the FH. But, risk preferences matter. ¶

Example – Payables: Evaluate (1) FH, (2) MMH, (3) OH, (4) No Hedge

Situation: Cud Corp needs **CHF 100,000** in 180 days. (CHF Payable.)

Data:

- **S_t = .675 - .680 USD/CHF.**
- **$F_{t,180}$ = .695 - .700 USD/CHF.**
- 180-day interest rates are as follows:
  - i_{CHF}: **9% - 10%;**
  - i_{USD}: **13% - 14.0%**
- A 180-day call option on CHF: **X = .70 USD/CHF** and P_t = **USD.02**.

- Cud forecasted S_{t+180}:

Possible Outcomes	**Probability**
USD .67	30%
USD .70	50%
USD .75	20%

(1) FH: Purchase CHF 180 days forward
USD needed in 180 days = Payables in CHF x $F_{t,180}$
= **CHF 100,000** * **.70 USD/CHF** = **USD 70,000**.

(2) MMH:
- Borrow USD at **14%** for 180 days,
- Convert to CHF at **.680 USD/CHF** ,
- Invest CHF at **9%** for 180 days,
- Repay USD loan in 180 days & transfer CHF deposit to cover payable

Amount in CHF to be invested = **CHF 100,000**/(1 + **.09** * 180/360)
= **CHF 95,693.78**

Amount in USD needed to convert into CHF for deposit =
= **CHF 95,693.78** * **.680 USD/CHF** = **USD 65,071.77**

Interest and principal owed on USD loan after 180 days =
= **USD 65,071.77** * (1 + **.14** * 180/360) = **USD 69,626.79**

(3) OH: Purchase call option. **X = .70 USD/CHF**
C_t = premium = **USD .02**.

Possible S_{t+180}	**Premium per CHF + Op Cost**	**Exercise?**	**Net Paid for CHF 0.1M**	**Prob**
.67 USD/SGD	USD .0213	No	USD 69,130	30%
.70 USD/SGD	USD .0213	No	USD 72,130	50%
.75 USD/SGD	USD .0213	Yes	USD 72,130	20%

Note: In the Total USD Cost we have included the opportunity cost involved in the upfront payment of a premium = **USD 130**.

E[Amount to Pay in USD] = **USD 71,230**

• *Preferences matter*: A risk taker may like the 30% chance of doing better with the OH than with the MMH.

(4) Remain Unhedged: Purchase **CHF 100,000** in 180 days.

Possible S_{t+180}	Net Paid for CHF 0.1M	Probability
.67 USD/SGD	USD 67,000	30%
.70 USD/SGD	USD 70,000	50%
.75 USD/SGD	USD 75,000	20%

Preferences matter: Again, a risk taker may like the **30% chance** of doing better with the NH than with the MMH. (Actually, there is also an additional 50% chance of being very close to the MMH.)

E[Amount to Pay in USD] = **USD 70,100**

Conclusion: Cud Corporation is likely to choose the MMH. ¶

Internal Methods

• These are hedging methods that do not involve financial instruments.

• **Risk Shifting**

Q: Can firms completely avoid FX exposure?

A: Yes! By **pricing** all foreign transactions in **domestic currency**.

Example: Bossio Co., a U.S. firm, sells naturally colored cotton. Asuni, a Japanese company, buys Bossio's cotton. Bossio Co. prices all exports in USD. ¶

⇒ Currency risk is not eliminated. The foreign company bears it.

• Problem with risk-shifting: Reduces firm flexibility.