Foreign Exchange: Markets, Products, and Pricing

Winter Quarter 2023

Week #1

Foreign Exchange Markets

Foreign exchange

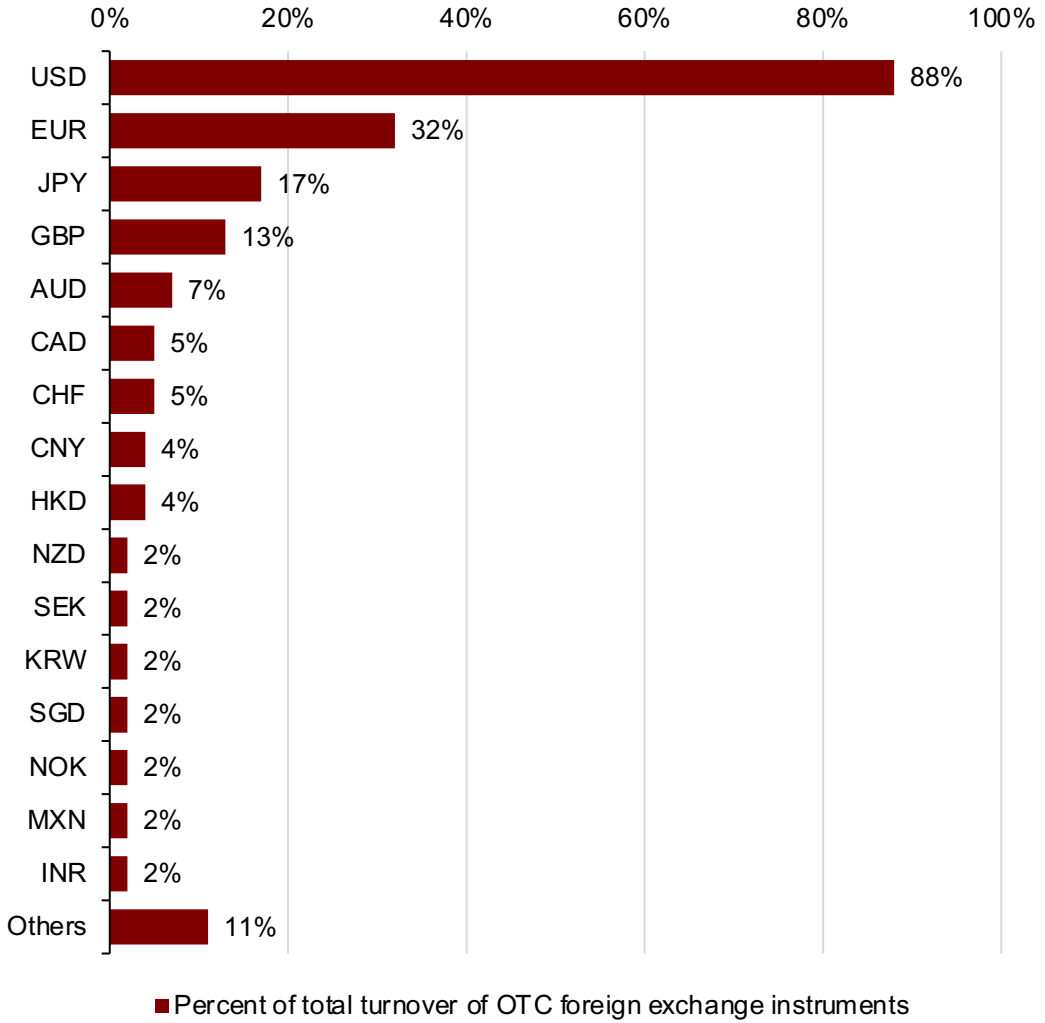
What is foreign exchange?

- Buying and selling currency
- Every FX transaction is both a purchase and a sale!
  - Buying (receiving) one currency
  - Selling (paying) another currency

Transactions happen globally, decentralized market

- Transactions are typically bilateral, agreed between two institutions
- No centralized exchange acting as a counterparty to transactions
- Transactions occur in many nations, subject to local laws and regulations

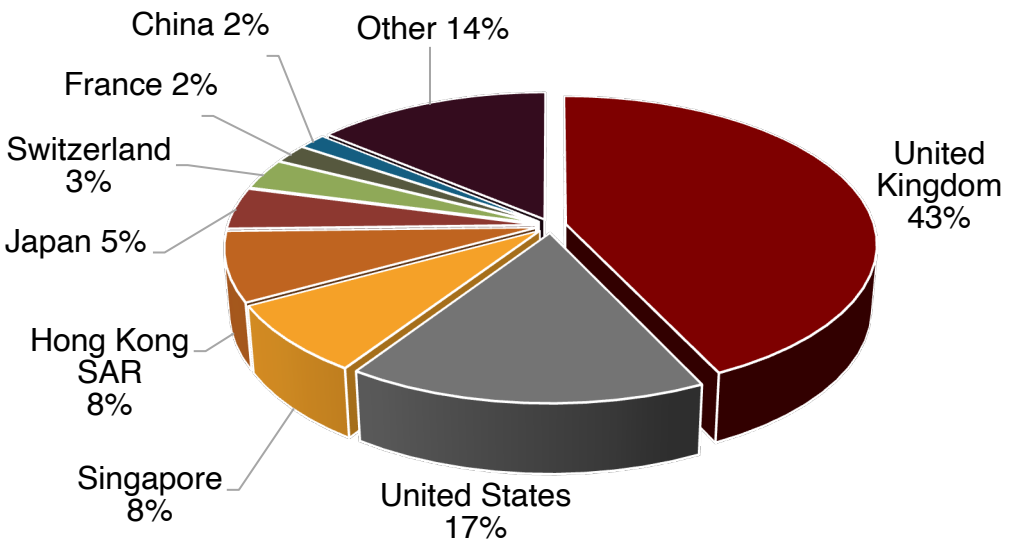
Which currencies are traded?



- USD - US dollar
- EUR - Euro
- JPY - Japanese yen
- GBP - British pound
- AUD - Australian dollar
- CAD - Canadian dollar
- CHF - Swiss franc
- CNY - Chinese yuan
- HKD - Hong Kong dollar
- NZD - New Zealand dollar
- SEK - Swedish krona
- KRW - South Korean won
- SGD - Singapore dollar
- NOK - Norwegian krona
- MXN - Mexican new peso
- INR - Indian rupee

Where does FX trading happen?

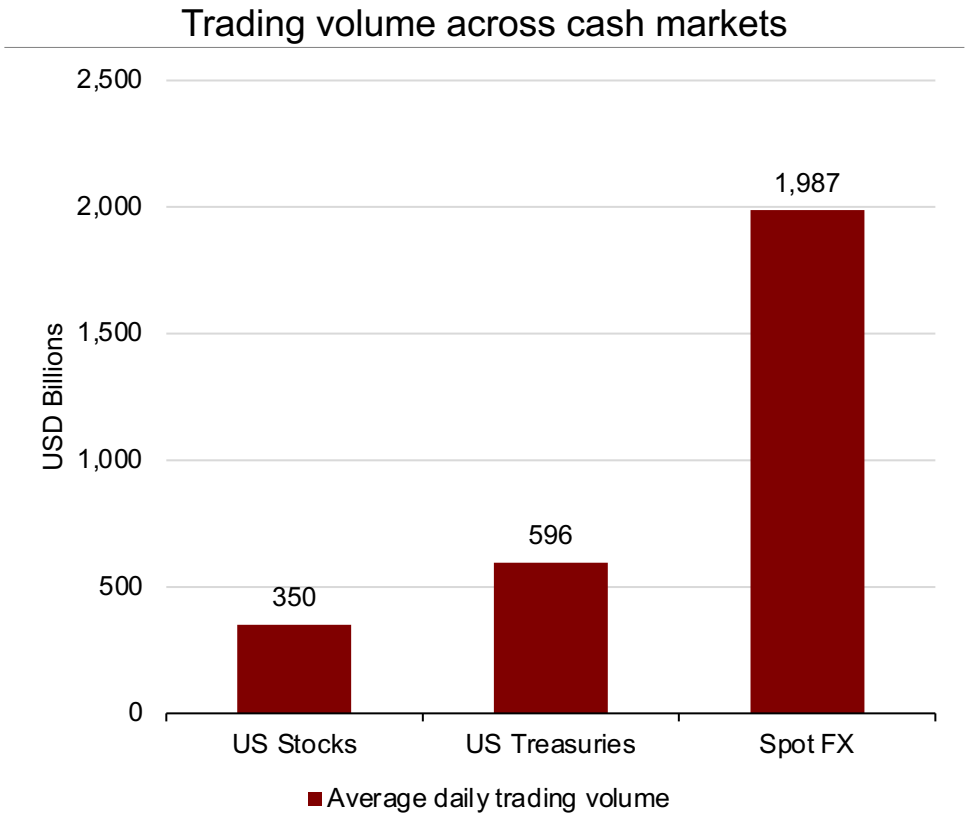
Geographical distribution of global FX turnover



- A “24/5” market
- Monday morning Sydney, Australia to Friday evening New York, USA

Size of the FX market (cash trading)

- Very high volume for foreign exchange as a cash product…

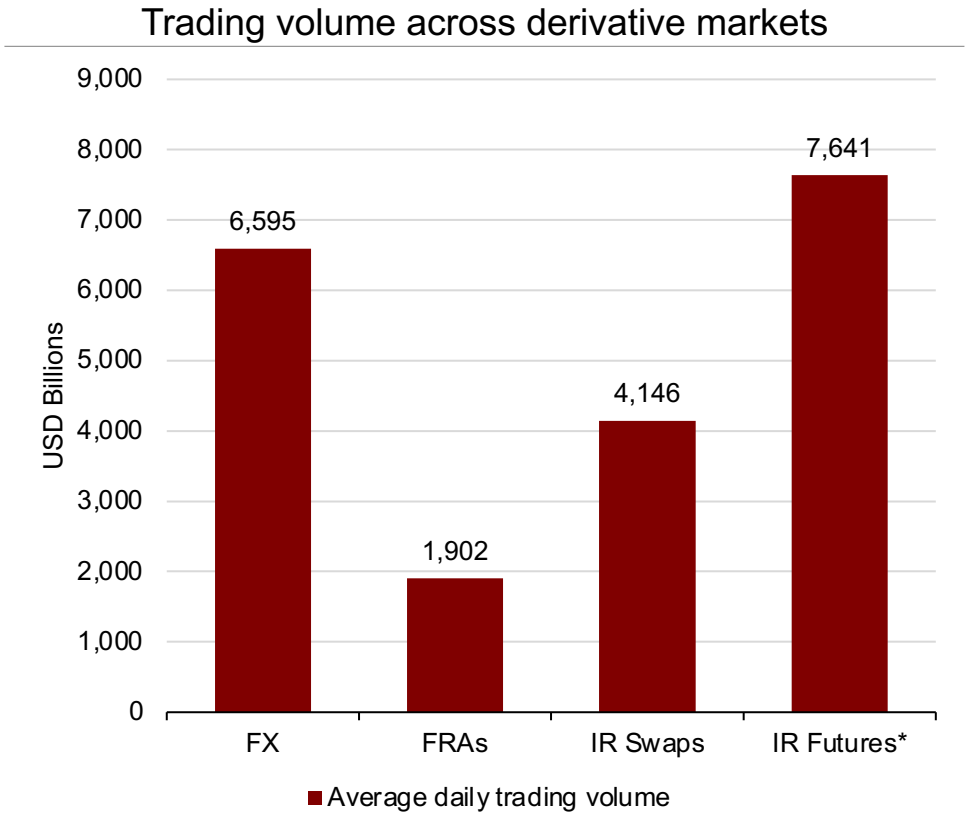


- This is a popular graphic used to show that the foreign exchange market is significantly larger than other well-known markets
- The comparison may be somewhat misleading, since the FX market is traded around the world, and although US stocks and US treasuries are owned by international investors the majority of trading occurs in the United States

Source: SIFMA and BIS

Size compared to derivative markets

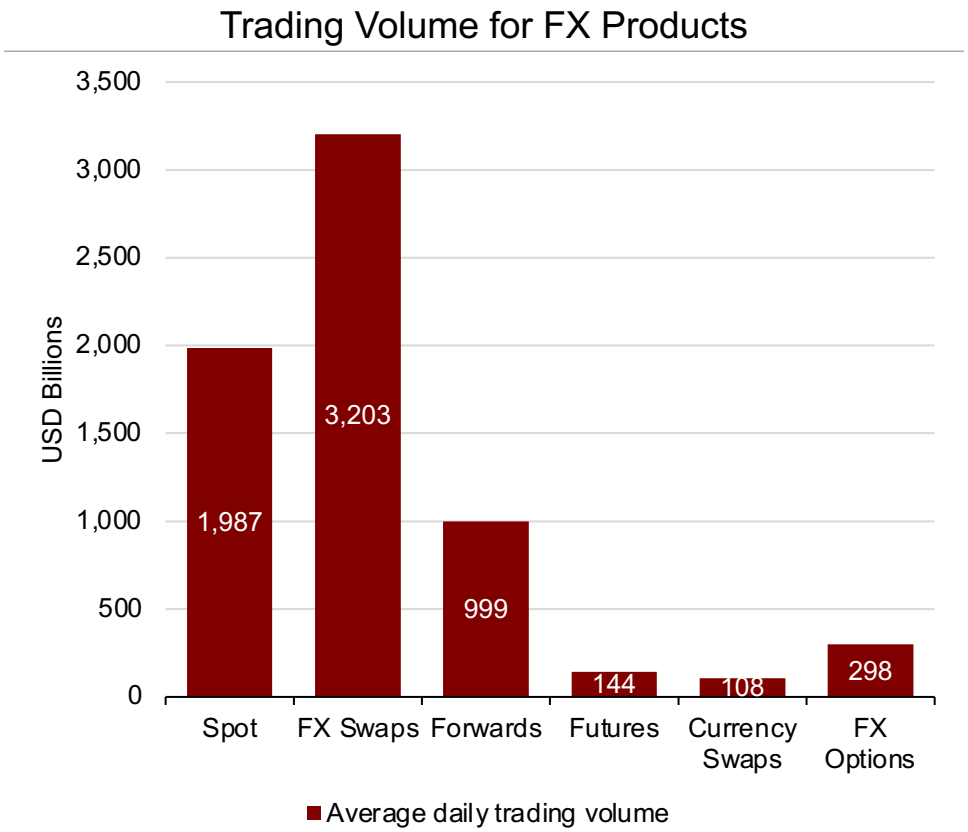
- …comparable in size to the interest rate market when derivative markets are included



- Note that for the interest derivatives market, futures trading volume is large relative to the Over-the-counter ("OTC") market
- This is because interest rate futures are very important hedging instruments for liquidity providers (market makers)

* Exchange-traded interest rate derivatives

Market size by type of FX product

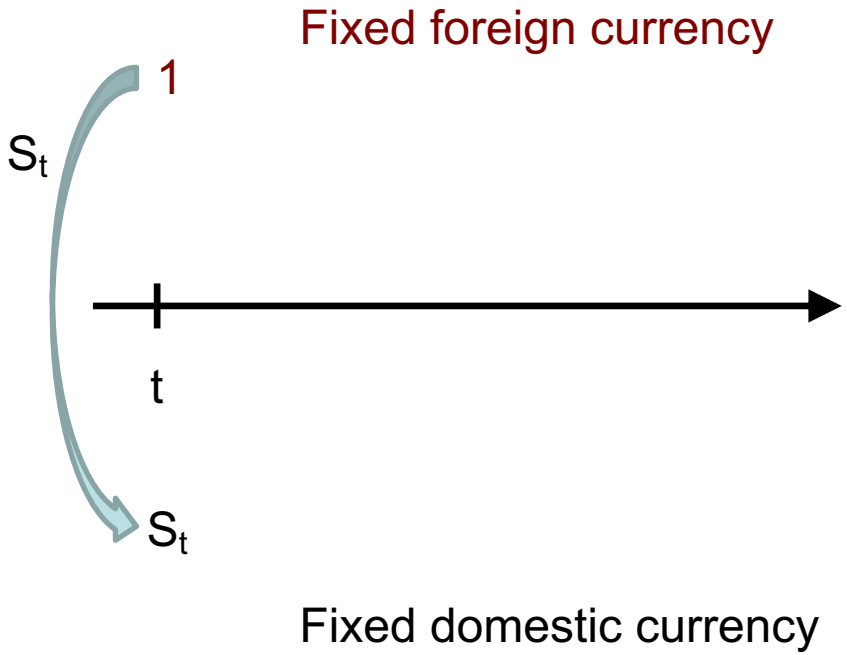


- For the FX markets, unlike the interest rate derivatives markets, futures trading volume is relatively small relative to the Over-the-counter ("OTC") market
- The underlying cash products (spot, forwards and deposits) are readily available to liquidity providers and are the preferred hedging instruments

Spot rates

Spot rate

- The spot rate, S_t , is the unique transformation from foreign currency value to domestic currency value (at time *t*)



What is the FX spot rate?

- "Spot rate"
  - The market price (in domestic currency) for 1 unit of foreign currency
- Notation – Financial math
  - S_t is the price of 1 unit of foreign currency at time t
- Notation – Market practice
  - Currency pairs are denoted as "CCY1/CCY2",
    - For example, "EUR/USD"
  - Better notation is "EURUSD" instead of "EUR/USD" (i.e., omit the "/")

Spot rate

- The spot rate is:
  - Observable: it is the market price, or fair value of foreign currency
  - Not a derivative: the price is not derived from another asset
  - Stochastic: the true dynamics of S_t are difficult to model

- If S_t is the price of 1 unit of foreign currency at time *t,* then the price for *N* units of foreign currency must be: $N * S_t$
  - Note that this may not be exact in practice due to transaction costs, bid/offer spreads

Domestic and foreign currency viewpoints

- Spot price: 1 unit of foreign currency *(in terms of domestic currency)*
  - *1 (of foreign)* = S_t *(of domestic)*
  - *1* / S_t *(of foreign)* = *1 (of domestic)*

- Terminology used in academic papers and in theoretical pricing:
  - S_t is the price "in domestic terms",
  - *1* / S_t is the price "in foreign terms"

- Note that the term "domestic" currency may have a different meaning in market terminology. (We will discuss this in the following slides.)

Market terminology – Quoting spot rates

- Every FX quotation has two components:
  - Fixed currency (set to 1 unit in the quote)
  - Variable currency (i.e., the “numeraire” currency)
  - “CCY1 / CCY2”

CCY1	CCY2
Base currency	Terms currency
Fixed currency	Variable currency
Home currency	Overseas currency

Quoting spot rates – Example

$$EURUSD = 1.0622$$

CCY1
"Fixed", "Base"

CCY2
"Variable", "Terms"

CCY1 in units of CCY2
1 EUR = $1.0622

CCY1	CCY2
Base currency	Terms currency
Fixed currency	Variable currency
Home currency	Overseas currency

Potential confusion: “Domestic” currency

- “Domestic” currency can be a confusing phrase
  - FX spot traders may consider “base” currency to be “domestic”
  - In mathematics, since the “terms” currency is the numeraire, it seems the right choice for “domestic” currency

- Every FX quotation has two components:
  - Fixed currency (set to 1 unit in the quote)
  - Variable currency (i.e., the “numeraire” currency)

- No matter which phrase is used, remember that a quote of “EURUSD” refers to EUR 1 in terms of USD
- …and <u>not</u> EUR’s per USD

Base currency conventions

- *EUR* > Market convention has EUR as base currency when quoted versus any other currency
- *EUR* > *GBP* > The British pound will be quoted as the base currency versus and currency other than EUR
- This order of precedence is followed by Australian, New Zealand, US and Canadian dollars, Swiss franc and Japanese yen:
- *EUR* > *GBP* > *AUD* > *NZD* > *USD* > *CAD* > *CHF* > *JPY* >
- The order of precedence for the 8 currencies above is common knowledge among market participants

  (For currency quotes not involving the 8 currencies listed above, it's most common to rely on local currency dealers or market services like Bloomberg as references for market quoting conventions)

Direct and indirect quotes (versus the USD)

- Direct quote
  - AUDUSD, EURUSD, GBPUSD, NZDUSD
  - An increasing price implies a stronger AUD (versus the USD)

- Indirect quote
  - USDBRL, USDCAD, USDCHF… all others
  - An increasing price implies a stronger USD (e.g., versus BRL)

Spot market trade date

Trade date

- Trade date is when the terms of the transaction are agreed
- Currency trading is a global, 24-hour market
- The “trading day” ends at 5pm New York time

Spot market – “When do I get my money?”

Spot settlement date (“Value date”)

- The spot settlement date, also called the “value date”, is when cash flows occur, i.e., when currencies are delivered
- Value date for spot transactions = “T + 2” for most currency pairs
- Spot value date = T+1 for USD versus CAD, TRY, PHP, and certain other currencies
- Proposals in the US and Europe to move all settlements, including foreign exchange transactions, to T+1

- The spot settlement date becomes a reference point, “ time t ” for spot and forward quoting and pricing

Value date for spot contracts

- T+1 must be a “good day” in both currencies, but not necessarily for USD
- T+2 must be a “good day” in both currencies, and for USD

Trade date (T+0)	T+1	Value date (T+2)
Trade terms are agreed		Two currency payments are delivered
	Good day for CCY1 and CCY2 if non-USD	Good day for CCY1 and CCY2
	Can be a USD holiday	Cannot be a USD holiday

Bid/Offer Spreads (for Spot Rates)

Bid offer spreads

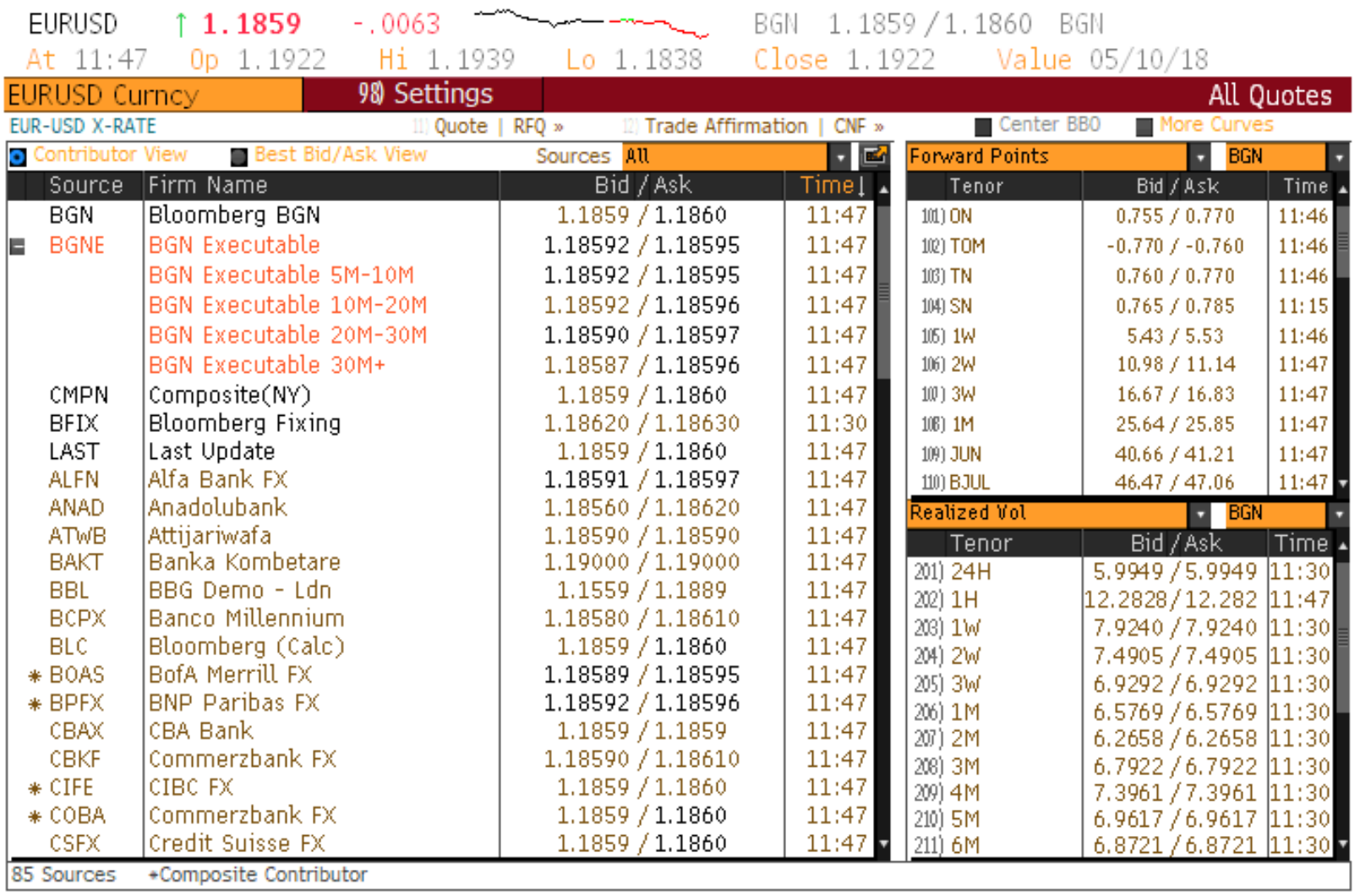
- Market makers (liquidity providers, “dealers”)
- Market takers (liquidity seekers, “customers”)

$$EURUSD = \underbrace{1.0622}_{Bid} / \underbrace{1.0624}_{Offer}$$

Bid
Dealer is willing to buy one EUR for $1.0622

Offer
Dealer is willing to sell one EUR for $1.0624

Bid offer spreads



Bid/Offer – Example

- A US Corporation is paid GBP 10m for a shipment of products to the UK
- Since the company is domiciled in the US and produces financial statements denominated in USD, it has no need for GBP and must convert back to USD. Thus, the corporation needs to sell the GBP against USD
- The bank quote for GBPUSD is 1.2066 / 68
  - Is the client on the bid or the offer?
  - How do you determine the resulting USD proceeds?

Bid/Offer – Example

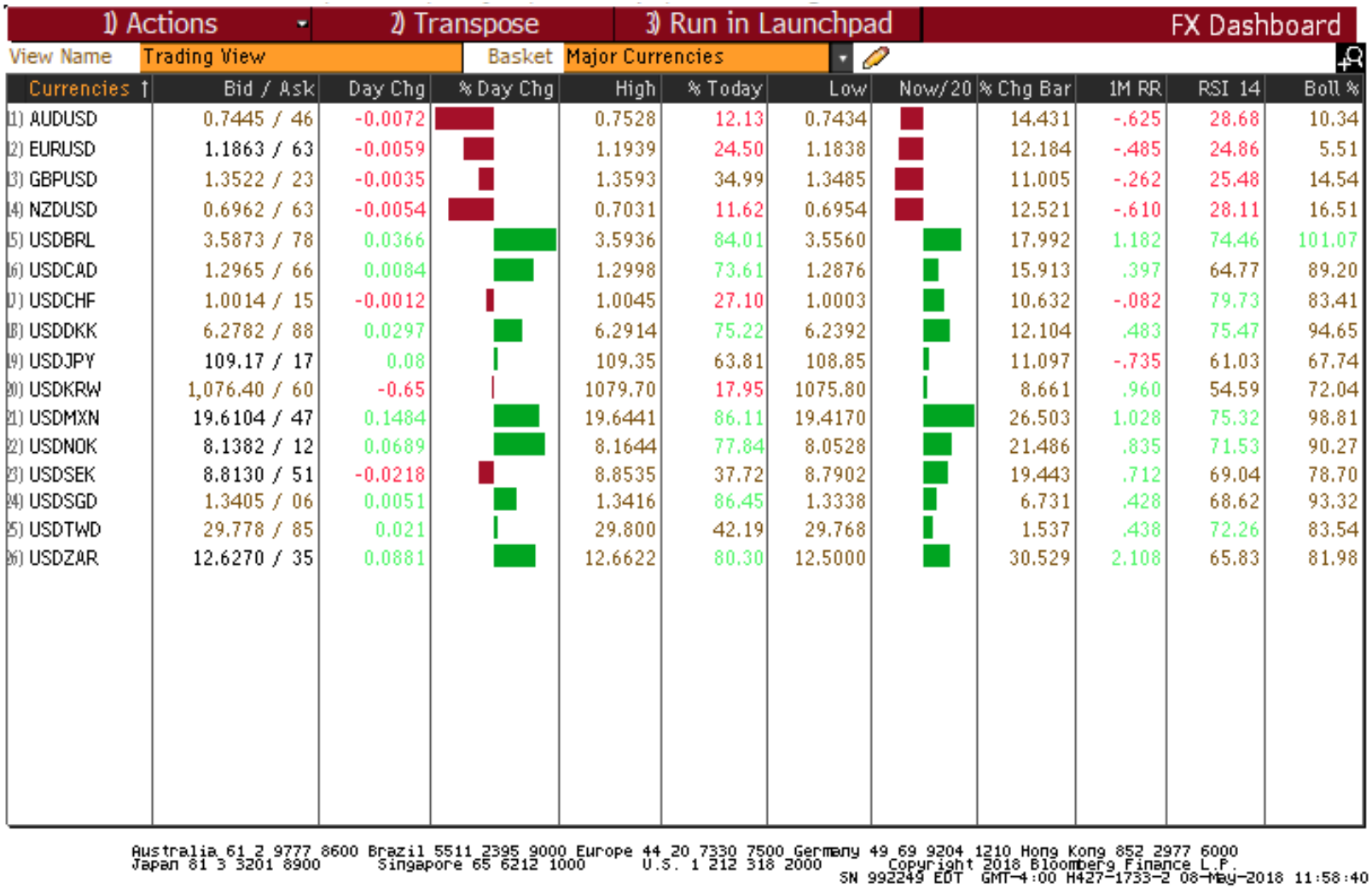
- The question is from the client's perspective, but let's first think in terms of the bank.
- The Bank is going to receive GBPUSD, so it is buying them on the 'bid'. The Bank buys low at 1.2066
- The bank will transact at 1.2066, giving the client US$12,066,000 in exchange for GBP 10,000,000

Bid/Offer – Direct and indirect quotes

- Direct quote
  - AUDUSD, EURUSD, GBPUSD, NZDUSD
  - Market makers buy AUD (sell USD) on the bid, sell AUD (buy USD) on the offer
  - Bid offer = 0.6720 / 0.6721

- Indirect quote
  - USDBRL, USDCAD, USDCHF… all others
  - Market makers buy USD (sell BRL) on the bid, sell USD (buy BRL) on the offer
  - Bid offer = 5.1430 / 5.1435

Bid/Offer – Direct and indirect quotes



Currencies	Bid / Ask	Day Chg	% Day Chg	High	% Today	Low	Now/20	% Chg Bar	1M RR	RSI 14	Boll %
1) AUDUSD	0.7445 / 46	-0.0072		0.7528	12.13	0.7434		14.431	-.625	28.68	10.34
2) EURUSD	1.1863 / 63	-0.0059		1.1939	24.50	1.1838		12.184	-.485	24.86	5.51
3) GBPUSD	1.3522 / 23	-0.0035		1.3593	34.99	1.3485		11.005	-.262	25.48	14.54
4) NZDUSD	0.6962 / 63	-0.0054		0.7031	11.62	0.6954		12.521	-.610	28.11	16.51
5) USDBRL	3.5873 / 78	0.0366		3.5936	84.01	3.5560		17.992	1.182	74.46	101.07
6) USDCAD	1.2965 / 66	0.0084		1.2998	73.61	1.2876		15.913	.397	64.77	89.20
7) USDCHF	1.0014 / 15	-0.0012		1.0045	27.10	1.0003		10.632	-.082	79.73	83.41
8) USDDKK	6.2782 / 88	0.0297		6.2914	75.22	6.2392		12.104	.483	75.47	94.65
9) USDJPY	109.17 / 17	0.08		109.35	63.81	108.85		11.097	-.735	61.03	67.74
10) USDKRW	1,076.40 / 60	-0.65		1079.70	17.95	1075.80		8.661	.960	54.59	72.04
11) USDMXN	19.6104 / 47	0.1484		19.6441	86.11	19.4170		26.503	1.028	75.32	98.81
12) USDNOK	8.1382 / 12	0.0689		8.1644	77.84	8.0528		21.486	.835	71.53	90.27
13) USDSEK	8.8130 / 51	-0.0218		8.8535	37.72	8.7902		19.443	.712	69.04	78.70
14) USDSGD	1.3405 / 06	0.0051		1.3416	86.45	1.3338		6.731	.428	68.62	93.32
15) USDTWD	29.778 / 85	0.021		29.800	42.19	29.768		1.537	.438	72.26	83.54
16) USDZAR	12.6270 / 35	0.0881		12.6622	80.30	12.5000		30.529	2.108	65.83	81.98

“Left-hand side” or “Right-hand side”

- Simple terminology for bid / offer
  - Left-hand side / Right hand side
  - Avoids potential confusion over which currency is being bought or sold, and by which party
- Left-hand side always refers to the market-maker’s bid
- Right-hand side always refers to the market-maker’s offer

Spot contracts

What is an FX spot contract?

- Spot contract
  - An agreement to exchange *N* units of foreign currency for domestic currency at a fixed rate, *R*

  Example: you pay me *N* units of foreign currency, and I pay you *N* * *R* units of domestic currency

  - I “buy” foreign currency, you “sell” foreign currency

Spot contract: Calculating value

- Market value, “mark-to-market” value, profit or loss
- A spot contract with notional amount, *N*, and contract rate, *R*
- Value to the buyer *(measured in domestic currency)*
  - $N * (S_t - R)$

- This is because there are two cash flows

  (1) *N (of foreign currency)* and (2) - *N * R (of domestic currency)*
  - And the market value of *N (of foreign currency)* is $N * S_t$

Profit and loss

- Mark to market an existing position using current mid-market rates

USD example #1	Buy/sell	Currency	Amount	Rate	Buy/sell	Currency	Amount	P/L
Initial trade	BUY	EUR	10,000,000	1.2050	SELL	USD	-12,050,000	0
Revaluation rate				1.1885				
Market value	SELL	EUR	-10,000,000	1.1885	BUY	USD	11,885,000	-165,000
Percent changes				*-1.37%*				*-1.37%*

USD example #2	Buy/sell	Currency	Amount	Rate	Buy/sell	Currency	Amount	P/L
Initial trade	BUY	CHF	10,000,000	1.0150	SELL	USD	-9,852,217	0
Revaluation rate				1.0020				
Market value	SELL	CHF	-10,000,000	1.0020	BUY	USD	9,980,040	127,823
Percent changes				*-1.28%*				*1.30%*

Cross rates

Spot price: Cross rates

- Cross rates, two foreign currencies
  - If *1 (of foreign currency #1)* = S_t *(of domestic)*
  - and *1 (of foreign currency #2)* = U_t *(of domestic)*
  - Then *1 (of foreign currency #1)* = S_t / U_t *(of foreign currency #2)*

Cross rates

EURUSD = 1.1882 bid

€1.00 = $1.1882

USDJPY = 109.14 bid

$1.00 = ¥109.14

- Crossing two bid offer spreads,

EURJPY = 129.68 bid

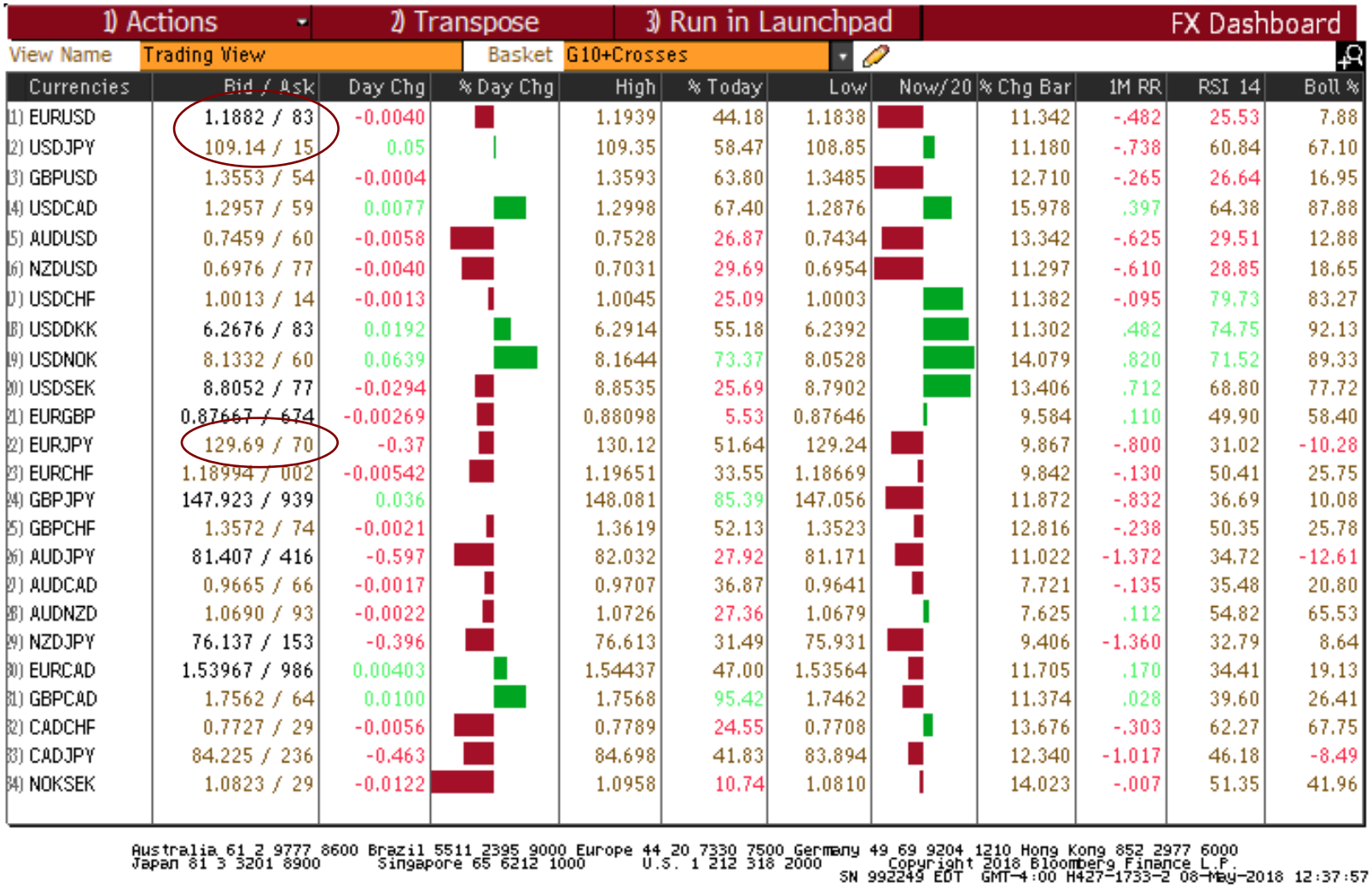
€1.00 = ¥129.68

versus bid offer in a directly traded market

EURJPY = 129.69 bid

€1.00 = ¥129.69

Cross rates



1) Actions | 2) Transpose | 3) Run in Launchpad | FX Dashboard

View Name: Trading View | Basket: G10+Crosses

Currencies	Bid / Ask	Day Chg	% Day Chg	High	% Today	Low	Now/20	% Chg Bar	1M RR	RSI 14	Boll %
1) EURUSD	1.1882 / 83	-0.0040		1.1939	44.18	1.1838		11.342	-.482	25.53	7.88
2) USDJPY	109.14 / 15	0.05		109.35	58.47	108.85		11.180	-.738	60.84	67.10
3) GBPUSD	1.3553 / 54	-0.0004		1.3593	63.80	1.3485		12.710	-.265	26.64	16.95
4) USDCAD	1.2957 / 59	0.0077		1.2998	67.40	1.2876		15.978	.397	64.38	87.88
5) AUDUSD	0.7459 / 60	-0.0058		0.7528	26.87	0.7434		13.342	-.625	29.51	12.88
6) NZDUSD	0.6976 / 77	-0.0040		0.7031	29.69	0.6954		11.297	-.610	28.85	18.65
7) USDCHF	1.0013 / 14	-0.0013		1.0045	25.09	1.0003		11.382	-.095	79.73	83.27
8) USDDKK	6.2676 / 83	0.0192		6.2914	55.18	6.2392		11.302	.482	74.75	92.13
9) USDNOK	8.1332 / 60	0.0639		8.1644	73.37	8.0528		14.079	.820	71.52	89.33
10) USDSEK	8.8052 / 77	-0.0294		8.8535	25.69	8.7902		13.406	.712	68.80	77.72
11) EURGBP	0.87667 / 674	-0.00269		0.88098	5.53	0.87646		9.584	.110	49.90	58.40
12) EURJPY	129.69 / 70	-0.37		130.12	51.64	129.24		9.867	-.800	31.02	-10.28
13) EURCHF	1.18994 / 002	-0.00542		1.19651	33.55	1.18669		9.842	-.130	50.41	25.75
14) GBPJPY	147.923 / 939	0.036		148.081	85.39	147.056		11.872	-.832	36.69	10.08
15) GBPCHF	1.3572 / 74	-0.0021		1.3619	52.13	1.3523		12.816	-.238	50.35	25.78
16) AUDJPY	81.407 / 416	-0.597		82.032	27.92	81.171		11.022	-1.372	34.72	-12.61
17) AUDCAD	0.9665 / 66	-0.0017		0.9707	36.87	0.9641		7.721	-.135	35.48	20.80
18) AUDNZD	1.0690 / 93	-0.0022		1.0726	27.36	1.0679		7.625	.112	54.82	65.53
19) NZDJPY	76.137 / 153	-0.396		76.613	31.49	75.931		9.406	-1.360	32.79	8.64
20) EURCAD	1.53967 / 986	0.00403		1.54437	47.00	1.53564		11.705	.170	34.41	19.13
21) GBPCAD	1.7562 / 64	0.0100		1.7568	95.42	1.7462		11.374	.028	39.60	26.41
22) CADCHF	0.7727 / 29	-0.0056		0.7789	24.55	0.7708		13.676	-.303	62.27	67.75
23) CADJPY	84.225 / 236	-0.463		84.698	41.83	83.894		12.340	-1.017	46.18	-8.49
24) NOKSEK	1.0823 / 29	-0.0122		1.0958	10.74	1.0810		14.023	-.007	51.35	41.96

Profit and loss: cross-currency

- Market value can be measured in either currency

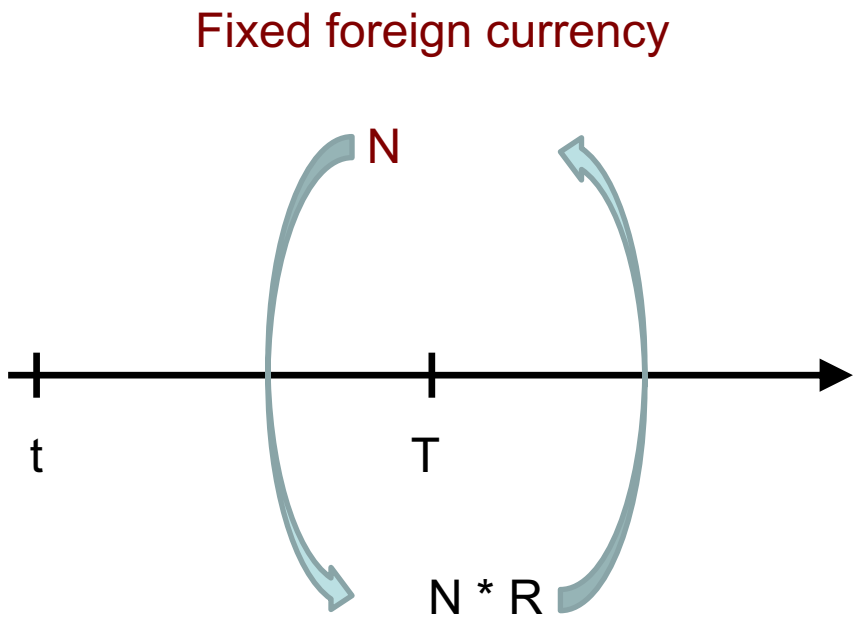
Cross example #1	Buy/sell	Currency1	Amount	Rate	Buy/sell	Currency2	Amount	P/L CCY2
Initial trade	BUY	EUR	10,000,000	0.8650	SELL	GBP	-8,650,000	0
Revaluation rate				0.8767				
Market value	SELL	EUR	-10,000,000	0.8767	BUY	GBP	8,767,000	117,000

Cross example #2	Buy/sell	Currency	Amount	Rate	Buy/sell	Currency	Amount	P/L CCY1
Initial trade	BUY	EUR	10,000,000	0.8650	SELL	GBP	-8,650,000	0
Revaluation rate				0.8767				
Market value	SELL	EUR	9,866,545	0.8767	BUY	GBP	8,650,000	133,455

- Profit and loss from the US dollar viewpoint will depend on additional spot rates
  - In this example either EURUSD or GBPUSD

Forward contracts

FX forward contract: Cash flows



t = Trade Date T = Delivery Date

What is an FX forward contract?

Forward contract

- Exchange *N* units of foreign currency for domestic currency at a contract rate of *R*
- Delivery at a future date, *T*
- Exchange amount, *N,* and rate*, R,* are fixed at time *t*

Cash flows

- For a forward contract to BUY foreign currency, there will be two cash flows at time *T*

  (1) + *N (of foreign currency)*, and

  (2) - *N* * *R (of domestic currency)*

- Signs are opposite for a forward contract to SELL foreign currency

Forward points

Forward points

Definition

- "Forward points" = Forward rate - Spot rate
- Forward rate = Spot Rate + *multiplier* * Quoted forward points

"Multiplier"

- When forward points are quoted (or shown on market data screens), the amount is scaled by a power of 10
  - Each currency pair follows a market convention that states how many decimal places are used to adjust forward points
  - *(for most currencies) Multiplier = 10,000*
  - *(for USDJPY) Multiplier = 100*

Forwards – Terminology

Forward points

- Premium, discount
  - Premium means the quoted forward rate is higher than the quoted spot rate (forward points are positive). Discount means it is lower (forward points are negative)
- “Up”, “down” (add or subtract points)
  - Forward points are sometimes quoted as positive numbers for simplicity. The designation “up” or “down” would be used to indicated whether quoted forward points are positive or negative.

“All-in rate”, “forward outright”

- Words used to describe the forward rate to make clear that forward points have been included and scaled to market conventions

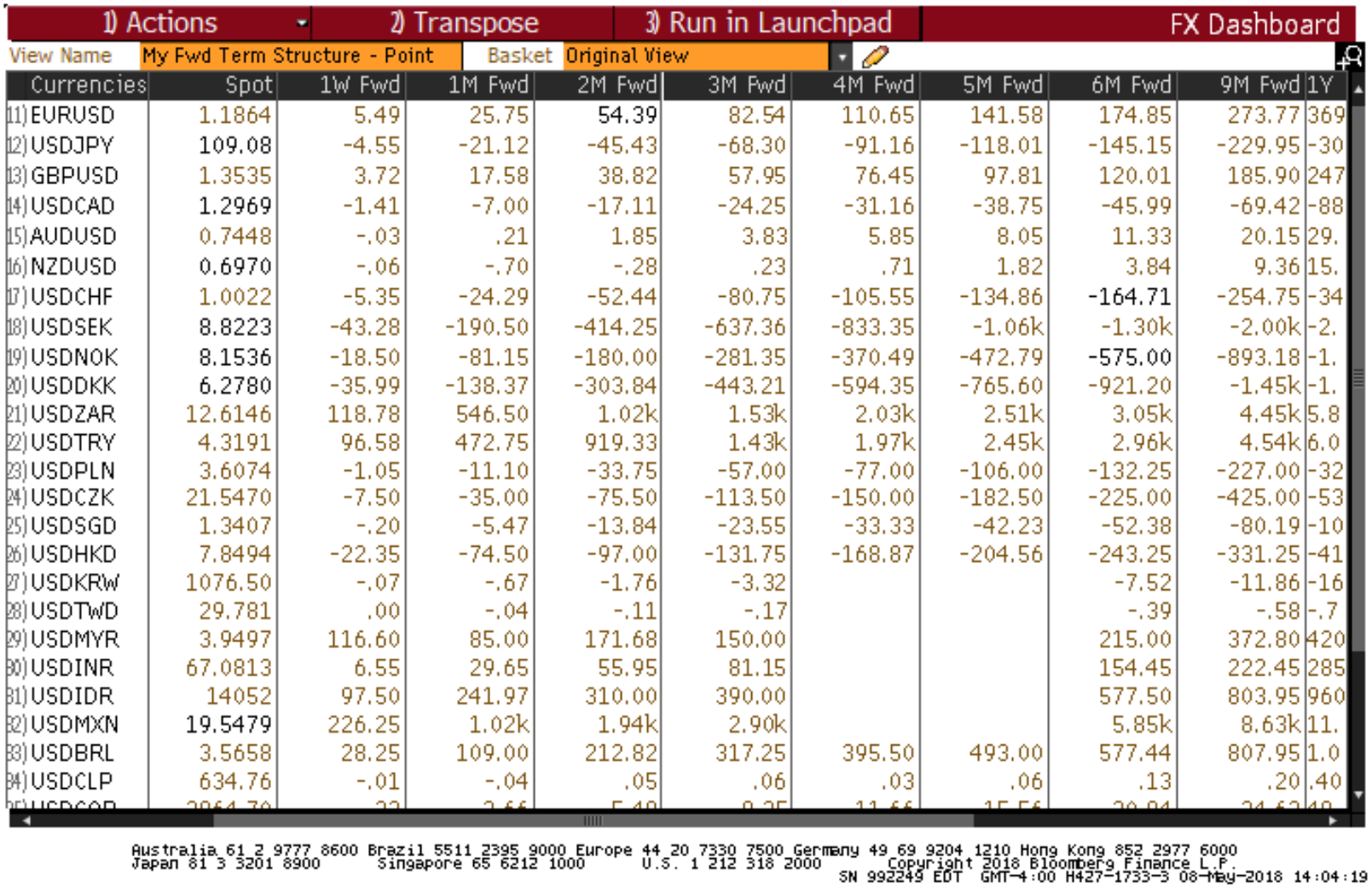
Delivery date (“value”)

- Spot date rules
  - T+2 delivery
  - Exceptions, T+1 for some currency pairs
- Contracts with any delivery date other that spot are considered forward contracts
- Over-the-counter market, in practice any delivery date is available, as long as physical delivery is available on that date for both currencies

Value dates

- “Standard” dates (most frequently traded, greatest liquidity)
  - 1 week, 1 month, 3 months, 6 months, 9 months, 1 year
- “Broken” dates: when the delivery date does not correspond to an exact monthly interval (or to 1 week)
- Special cases
  - Current trading day (“cash”)
  - Next trading day (“tom”)

Example: FX forward points



1) Actions | 2) Transpose | 3) Run in Launchpad | FX Dashboard

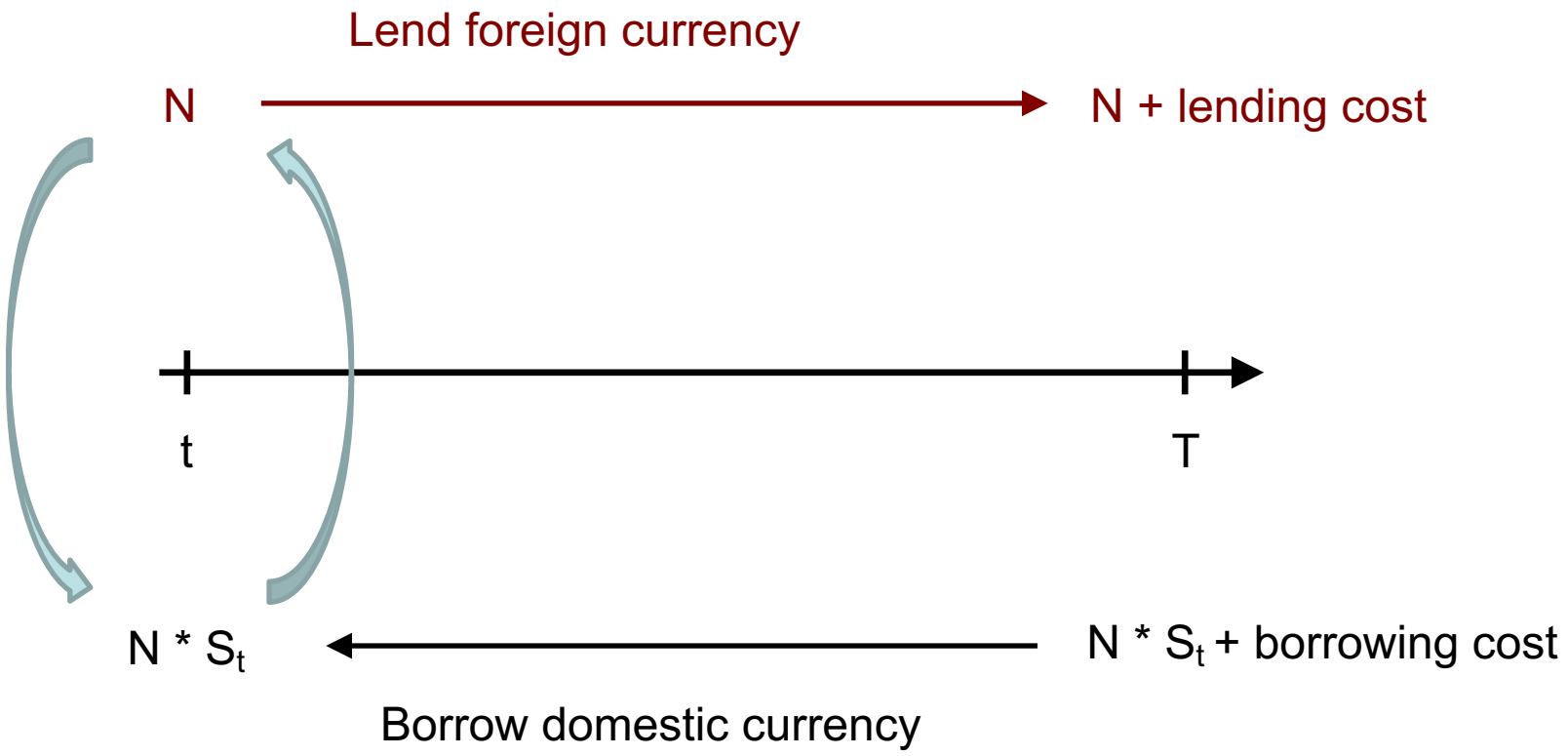
View Name: My Fwd Term Structure - Point | Basket: Original View

Currencies	Spot	1W Fwd	1M Fwd	2M Fwd	3M Fwd	4M Fwd	5M Fwd	6M Fwd	9M Fwd	1Y
11) EURUSD	1.1864	5.49	25.75	54.39	82.54	110.65	141.58	174.85	273.77	369
12) USDJPY	109.08	-4.55	-21.12	-45.43	-68.30	-91.16	-118.01	-145.15	-229.95	-30
13) GBPUSD	1.3535	3.72	17.58	38.82	57.95	76.45	97.81	120.01	185.90	247
14) USDCAD	1.2969	-1.41	-7.00	-17.11	-24.25	-31.16	-38.75	-45.99	-69.42	-88
15) AUDUSD	0.7448	-.03	.21	1.85	3.83	5.85	8.05	11.33	20.15	29.
16) NZDUSD	0.6970	-.06	-.70	-.28	.23	.71	1.82	3.84	9.36	15.
17) USDCHF	1.0022	-5.35	-24.29	-52.44	-80.75	-105.55	-134.86	-164.71	-254.75	-34
18) USDSEK	8.8223	-43.28	-190.50	-414.25	-637.36	-833.35	-1.06k	-1.30k	-2.00k	-2.
19) USDNOK	8.1536	-18.50	-81.15	-180.00	-281.35	-370.49	-472.79	-575.00	-893.18	-1.
20) USDDKK	6.2780	-35.99	-138.37	-303.84	-443.21	-594.35	-765.60	-921.20	-1.45k	-1.
21) USDZAR	12.6146	118.78	546.50	1.02k	1.53k	2.03k	2.51k	3.05k	4.45k	5.8
22) USDTRY	4.3191	96.58	472.75	919.33	1.43k	1.97k	2.45k	2.96k	4.54k	6.0
23) USDPLN	3.6074	-1.05	-11.10	-33.75	-57.00	-77.00	-106.00	-132.25	-227.00	-32
24) USDCZK	21.5470	-7.50	-35.00	-75.50	-113.50	-150.00	-182.50	-225.00	-425.00	-53
25) USDSGD	1.3407	-.20	-5.47	-13.84	-23.55	-33.33	-42.23	-52.38	-80.19	-10
26) USDHKD	7.8494	-22.35	-74.50	-97.00	-131.75	-168.87	-204.56	-243.25	-331.25	-41
27) USDKRW	1076.50	-.07	-.67	-1.76	-3.32			-7.52	-11.86	-16
28) USDTWD	29.781	.00	-.04	-.11	-.17			-.39	-.58	-.7
29) USDMYR	3.9497	116.60	85.00	171.68	150.00			215.00	372.80	420
30) USDINR	67.0813	6.55	29.65	55.95	81.15			154.45	222.45	285
31) USDIDR	14052	97.50	241.97	310.00	390.00			577.50	803.95	960
32) USDMXN	19.5479	226.25	1.02k	1.94k	2.90k			5.85k	8.63k	11.
33) USDBRL	3.5658	28.25	109.00	212.82	317.25	395.50	493.00	577.44	807.95	1.0
34) USDCLP	634.76	-.01	-.04	.05	.06	.03	.06	.13	.20	.40

Borrow and lend

Forward delivery: Borrow and lend

Spot transaction
Buy foreign currency



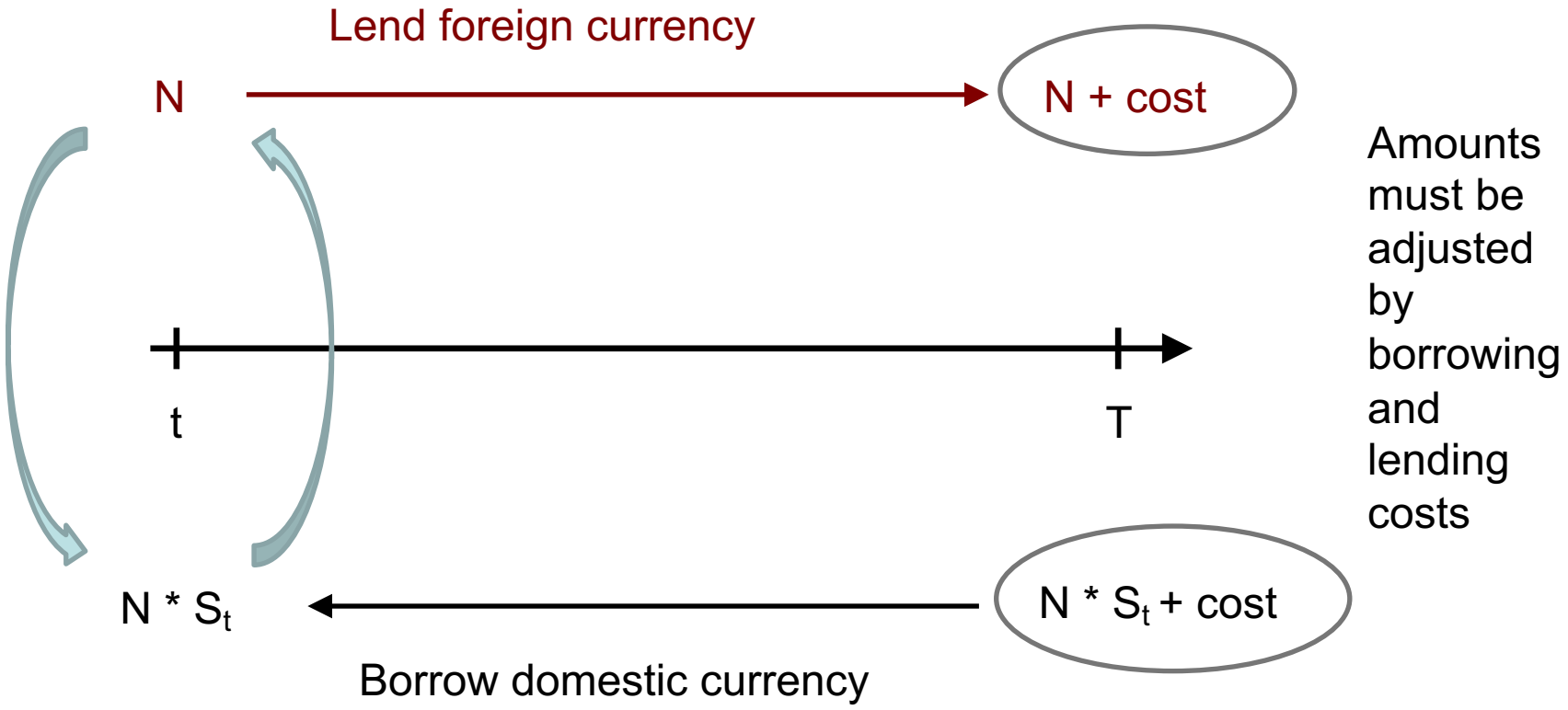
Spot transaction
Sell domestic currency

Forward delivery: Borrow and lend

- "Manufacture" forward delivery using the FX spot and financing markets
  - Execute at spot
  - Borrow the currency that has been sold at spot
    - Borrow the amount needed for spot delivery, with borrowing period equal to the desired time horizon
  - Lend the currency that has been purchased at spot
    - Lend the amount received at spot delivery, with borrowing period equal to the desired time horizon
  - There will be no net cash flows at the spot date, and a fixed exchange of currencies at the horizon date

Forward delivery: Borrow and lend

Spot transaction
Buy foreign currency



Amounts must be adjusted by borrowing and lending costs

Spot transaction
Sell domestic currency

Forward delivery: Borrow and lend

- Borrow and lend rates are in different currencies
- If the borrowing and lending costs in the two currencies are not equal, then the forward rate will not equal the spot rate

Covered Interest Rate Parity

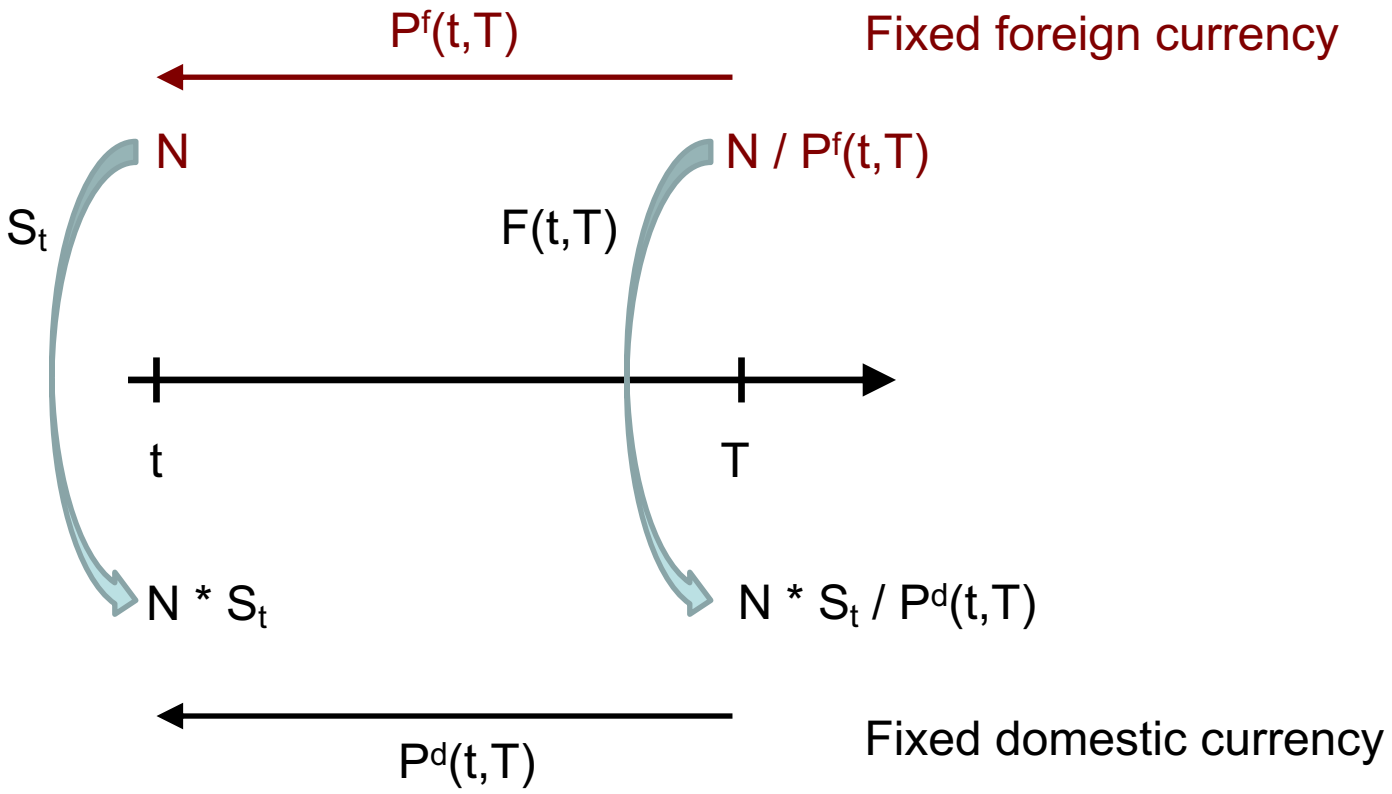
Notation

- Present value ("PV"), discounting a known cash flow from times T to t
  - $PV[\text{ known cash flow at } T] = P(t,T) * \text{ known cash flow at } T$
  - Where $P(t,T)$ is the price of a zero-coupon bond

- Zero coupon bonds:
  - Domestic $P^d(t,T)$
  - Foreign $P^f(t,T)$

- For simplicity, we write P^d, P^f, when t and T are understood

Covered interest rate parity: cash flows



Covered interest rate parity

- **Theoretical assumption:** all costs of borrowing or lending are captured in the price of zero-coupon bonds
  - Then zero-coupon bond prices in the two currencies give the correct adjustment between spot and forward rates

- Execute at spot, borrow and lend to the forward date:

Execute at spot:	(1) + *1 (of foreign, at t)*	(2) - S_t *(of domestic, at t)*
Borrow domestic:	(3) + S_t *(of domestic, at t)*	(4) - S_t / P^d *(of domestic, at T)*
Lend foreign:	(5) - *1 (of foreign, at t)*	(6) + $1 / P^f$ *(of foreign, at T)*

Covered interest rate parity (continued)

Execute at spot: (1) + *1 (of foreign, at t)* (2) - S_t *(of domestic, at t)*

Borrow domestic: (3) + S_t *(of domestic, at t)* (4) - S_t / P^d *(of domestic, at T)*

Lend foreign: (5) - *1 (of foreign, at t)* (6) + $1 / P^f$ *(of foreign, at T)*

(1) and (5) cancel, as do (2) and (3). So, (4) = (6) in domestic currency value

S_t / P^d *(of domestic, at T)* has value equal to $1 / P^f$ *(of foreign, at T)*

Which means:

$$S_t / P^d = F(t,T) * 1 / P^f$$

$$F(t,T) = S_t * P^f / P^d$$

Covered interest rate parity: Interpretation

- Interpretation: when adjusting a spot price to forward delivery
  - Borrower of the higher interest currency will want compensation
  - Lender of the higher interest currency can give compensation

- Higher interest rate currencies will be “weaker” on a forward basis

Continuously compounded zero-coupon rates

- Continuously compounded, zero-coupon interest rates, for times t to T
  - Domestic $r^d(t,T)$, Foreign $r^f(t,T)$
- For simplicity, we write r^d, r^f when t and T are understood

- Zero-coupon bond prices:
  - Domestic $P^d(t,T) = exp[\ -r^d(t,T)*(T-t)\ ]$
  - Foreign $P^f(t,T) = exp[\ -r^f(t,T)*(T-t)\ ]$

- Forward rate $F(t,T) = S_t * P^f / P^d = S_t * exp[(r_d-r_f)*(T-t)]$

Interest rate concepts needed to price FX forward contracts

- Money market conventions for tenors of 1 year and under
  - Day count: generally ACT/360 or ACT/365
  - Compounding: Simple interest
- Bond market conventions for tenors beyond 1 year
  - Day count: generally 30/360
  - Compounding: generally annual or semi-annual
- In practice, interest rate conventions may be specific to a single country

Covered interest rate parity

- When using interest rates quoted in the market, apply **that market's** interest rate convention
  - Money market conventions for 1 year and under (typically ACT/360, except for GBP, AUD, NZD, CAD and others which are ACT/365)
  - Swap or bond convention for maturities beyond 1 year (typically annual bond, semi-bond for US and others)

Forward = Spot * (1 + $R_{variable\ ccy}$*days/360) / (1 + $R_{fixed\ ccy}$*days/360)

…ACT/365 is used in practice for some currencies

***** Know the quoting convention for the interest rates you are using *****

Example: covered interest rate parity

Transaction	Value date	USD amount	NOK amount	FX Rate	Interest Rate
Spot trade	2/18/2014	(100,000,000)	610,590,000	6.1059	n/a
Borrow USD	2/18/2014	100,000,000	n/a	n/a	0.260%
	2/18/2015	(100,263,611)	n/a	n/a	
Lend NOK	2/18/2014	n/a	(610,590,000)	n/a	1.554%
	2/18/2015	n/a	620,210,354	n/a	
Equivalent cash flows	2/18/2014	(100,000,000)	610,590,000	6.1059	n/a
	2/18/2015	(100,263,611)	620,210,354	6.1858	n/a
Forward trade	2/18/2015	(100,000,000)	618,579,709	6.1858	n/a