

QF602: Derivatives

Lecture 1:

Introduction to Derivatives

What are Derivatives?

- Financial instrument that “derives” cash flows from price of some other asset.
- Typically, an agreement between two parties to exchange cash flows.
- Derivatives can be used to hedge against unfavorable price changes, or speculate on favorable price changes.
- Hedging means mitigate or reduce risks.

Types of Underlying Assets

- Physical assets such as agricultural products, precious metals, or fossil fuels.
- Financial assets such as stocks or bonds (or even other derivatives!).
- Intangible assets such as electricity or weather.
- Derivatives can also be written on an FX rate, or an interest rate.

Types of Derivatives

- Some Derivatives represent obligations. Both parties are required to follow through on transactions, irrespective of gain or loss.
- Other Derivatives represent options. One party has the right but not the obligation to buy or sell an asset. The other party receives a fee to sell that right.

Where can we trade them?

- Some Derivatives are traded on an exchange, such as Chicago Mercantile Exchange (CME).
- Exchange-traded Derivatives feature standardized terms and conditions, high liquidity, and price transparency.
- Clearing house operated by exchange serves as “central counterparty” to ensure that all transactions are completed.

Derivatives Exchanges

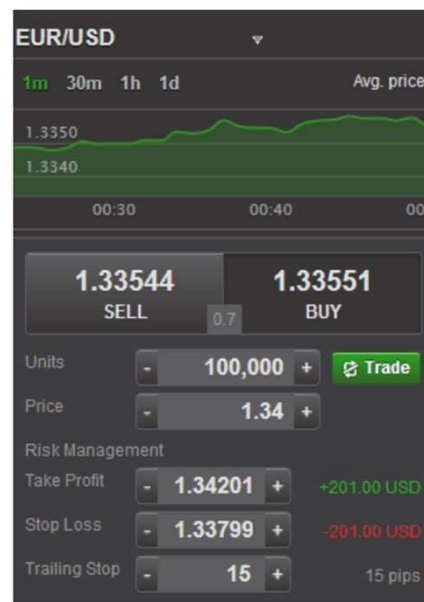
NYSE Euronext	Interest Rates and Bond Derivatives, Commodities, Equity Index Derivatives, Stock Options and Stock Futures and ETF Options
CME Group	Derivative product linked to Agriculture, Energy, Equity Index, FX, Interest Rate and Metals
Intercontinental Exchange, Inc.	Futures & Options based on Agriculture, Index, FX, Oil & Gas, Electricity
Tokyo Stock Exchange	Index Futures, JGB (Japan Government Bond) Futures and Options on JSG Futures, TOPIX (Tokyo stock Price Index) Options, Individual Options
OSAKA Securities Exchange	Index Futures, Index Options, Security Options, OSE-FX (OSAKA Securities Exchange-FX)
EUREX (owned by Deutsche Börse AG)	Derivative based on Interest Rate, Equity, Equity Index, Dividend, Volatility Index, Inflation, Commodity, Weather and Property
Hong Kong Exchanges and Clearing Limited	Equity Index Futures & Options, Stock Futures & Options, Currency Futures, Interest Rate and Fixed Income Futures, Gold Futures
Singapore Exchange	Interest Rate Futures & Options, Equity Index Futures & Options, Dividend Index Futures, Derivatives linked to Agriculture, Energy and Metal, FX Forward, Interest Rate Swaps
Australian Securities Exchange	Futures and Options linked to Equities, Interest Rates, Agriculture, Energy and Environmental Markets. CFDs for Equities, Indices and Commodities.

Types of Derivatives

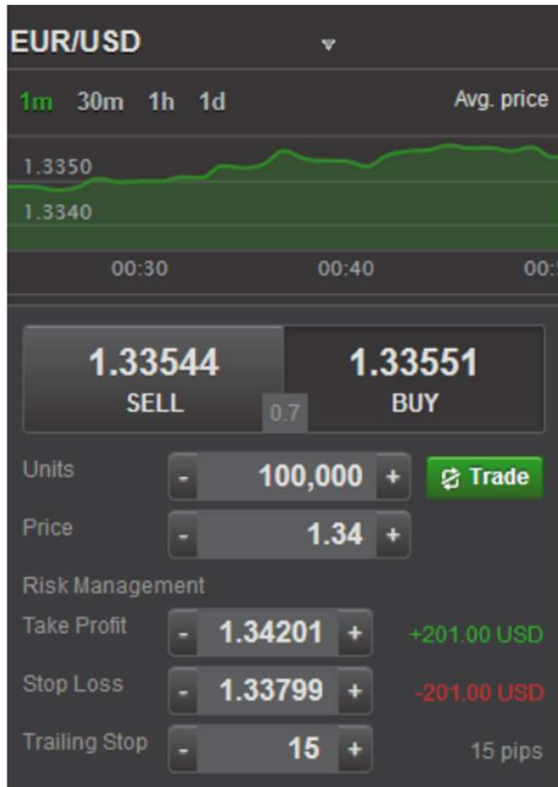
- Other Derivatives, known as “over-the-counter” (OTC) Derivatives, are direct bilateral agreements with no central counterparty.
- Generally, one party will be major financial institution acting as “marketmaker”.
- OTC Derivatives have more flexibility for terms and conditions, but less price transparency and no protection from credit risk.

Market Making

- If you want to long 100k EURUSD, what would you do?
- You find an FX broker, open an account, put some money into the account and then trade.
- Most of them will have a mobile app looks like below

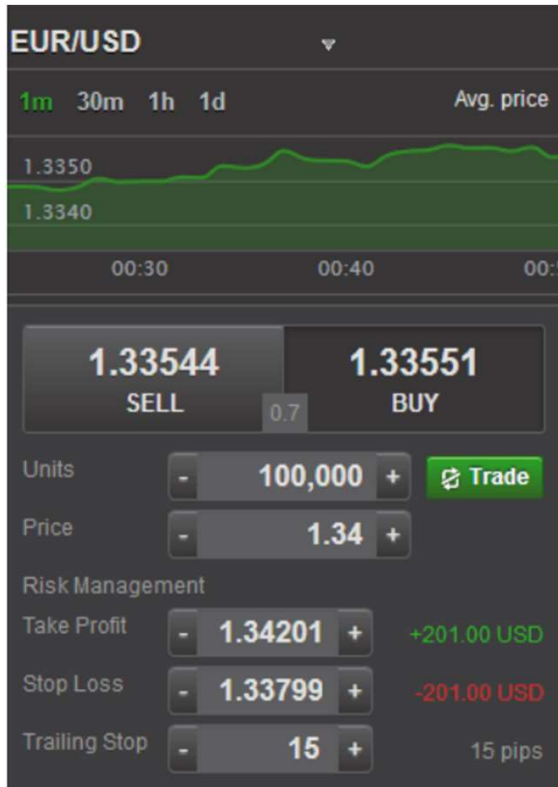


Market Making



- Some FX lingos
 - 1.3**3**54, the 3 in the middle is called the big figure/handle.
 - 1.335**4**, the 4th digit after the dot is called one pip.
 - 100 pips = 1 big figure
 - The last digit is 1/10 of a pip.

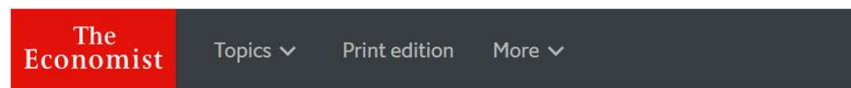
Market Making



- If you want to buy 100K EURUSD now, the price is 1.33551.
- But if you want to sell 100K EURUSD now, the price is 1.33544.
- Note that if you buy and sell simultaneously then you will guarantee to lose
$$100k * (1.33544 - 1.33551) = \$7$$
- Who earns that \$7? Market makers.
- The \$7 is the bid-offer spread.

Market Making

- Market makers are there to provide the liquidity to trade even in extreme market conditions, like the SNB unpegged CHF against EUR on 15 Jan 2015.
- On return, they charge a spread to provide that service.



The Economist explains

Why the Swiss unpegged the franc



Market Making

- EURCHF dropped to 0.85 from 1.2 in a matter of minutes.

#FINANCIALS

JANUARY 15, 2015 / 8:25 PM / 3 YEARS AGO

EBS confirms market low for euro/Swiss franc at 0.8500 francs



Market Making

- A few brokers went bust because of that event.

City forex broker and West Ham sponsor goes bust as clients suffer huge losses from Swiss currency bombshell

- Alpari UK applies for insolvency after clients rack up huge losses
- Swiss central bank shocked currency markets by removing euro peg
- Positions held by forex traders went haywire as Swiss franc soared 13-15% against euro, sterling and dollar



By [ADRIAN LOWERY FOR THISISMONEY.CO.UK](#)

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Types of Derivatives

- Forward contract is an OTC derivative that represents obligation.
- Futures contract is an exchange-traded derivative that represents obligation.
- Option contract is an OTC or exchange-traded derivative that represents option.
- Forward rate agreement (FRA) is forward contract on (short-term) interest rate.
- Interest rate swap (IRS) is sequence of FRAs.

Credit Risk

- Credit risk is a risk that counterparty will default on terms of agreement.
- If derivative represents obligations, then both parties will be exposed to credit risk (since either party could potentially incur loss).
- If derivative is an option, in general, only the party with the right (long the option) will be exposed to credit risk.

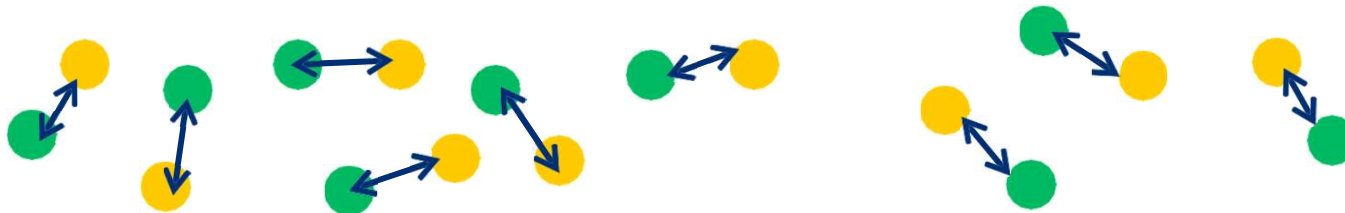
Credit Risk

- For OTC Derivatives, both parties are exposed to credit risk, although market maker is unlikely to default.
- In some cases, market maker might demand collateral or impose central counterparty.
- For exchange-traded Derivatives, central counterparty bears all credit risk while customers receive almost complete protection.

Exchange-Traded vs OTC



- Central counterparty eliminates credit (default) risk
- Standardized products and pricing transparency



- Both parties subject to credit (default) risk
- Flexible products but pricing opacity

Time Value of Money

- \$100 to be paid 1 year from now (Future Value)
- 5% interest rate per annum, denote as r .
- Present value (PV) can be computed as
$$PV = \text{Future Value} * \text{Discount Factor}.$$
- $DF(T) = \exp(-r*T) = 0.9512$, where $T=1$, $r=5\%$.
- We assume continuous compounding in this course unless otherwise stated.

Forward contract

- A forward contract is an agreement between 2 parties to buy or sell an asset at maturity.
- No cash flows until maturity.
- The price agreed to buy or sell the asset at maturity is call the strike price, K .
- The value of the forward contract V at t is computed as:

$$V(t) = (F(t,T) - K) * DF(T-t).$$

- Forward contract to have 0 value **at inception** has strike price equals to the **forward price at time 0**, i.e. $V(0) = 0$, if

$$F(0,T) = K.$$

Forward price

- $S(t)$ denotes the price of a stock at time t .
- $F(t,T)$ denotes the forward price at time t with maturity T , $t \leq T$.
- Consider a stock that pays no dividends and is worth \$50, $S(0) = \$50$.
- 6 month interest rate is 6% per annum, $r = 6\%$.
- Forward price of a stock can be viewed as equal to the spot price plus the cost of carrying it.
- The cost of carry is equal to the interest that might be received if he had immediately sold the stock and invested in a risk-free investment.

Forward price

- Forward price can be computed as:

$$F(t,T) = S(t) * \exp(r*(T-t)) = S(t) / DF(T-t)$$

- To compute a 6 month forward price, we can set $t=0$, $T=6/12$ and we get

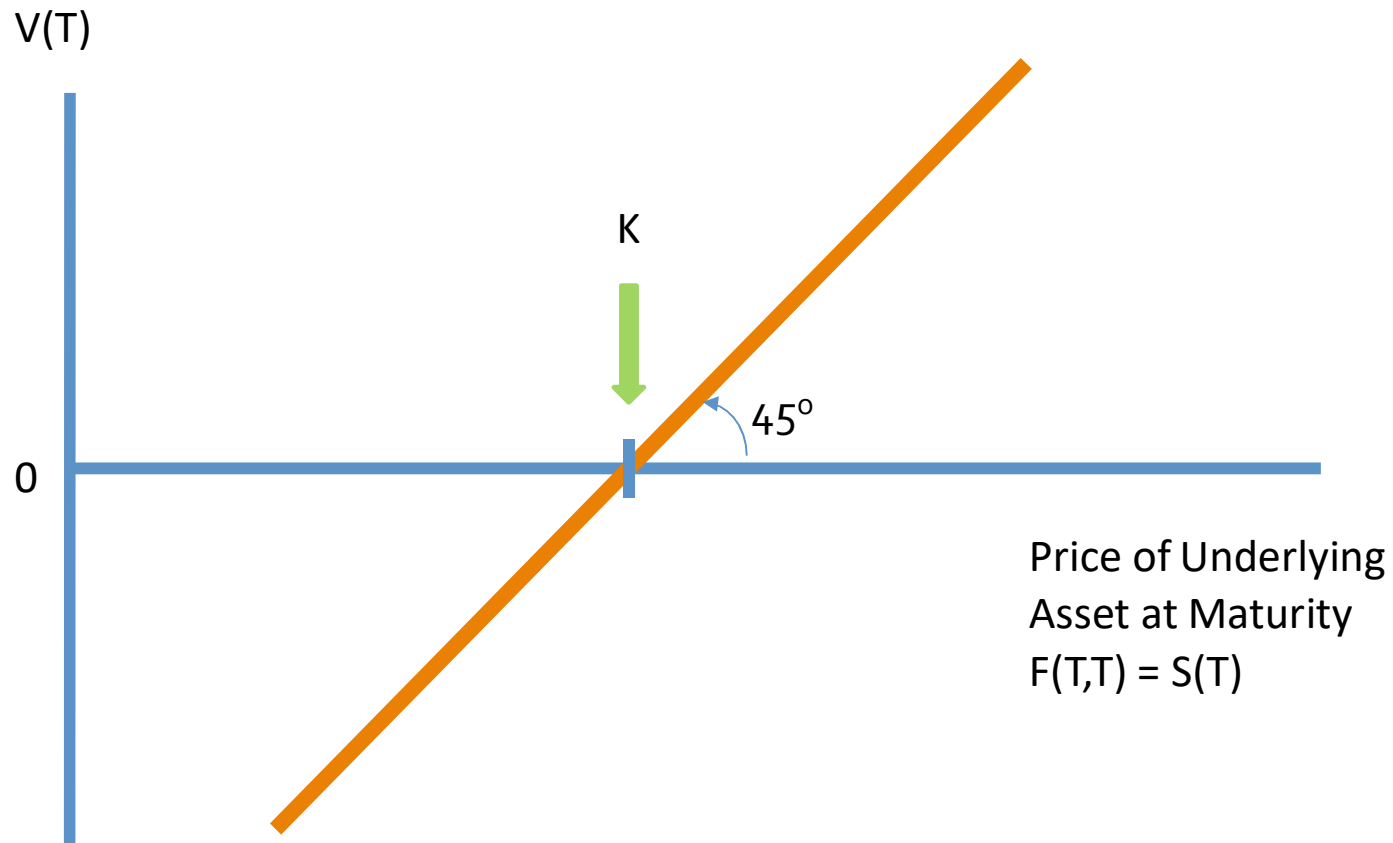
$$F(0, 6/12) = \$50 * \exp(6\% * 6/12) = \$51.52.$$

Forward price

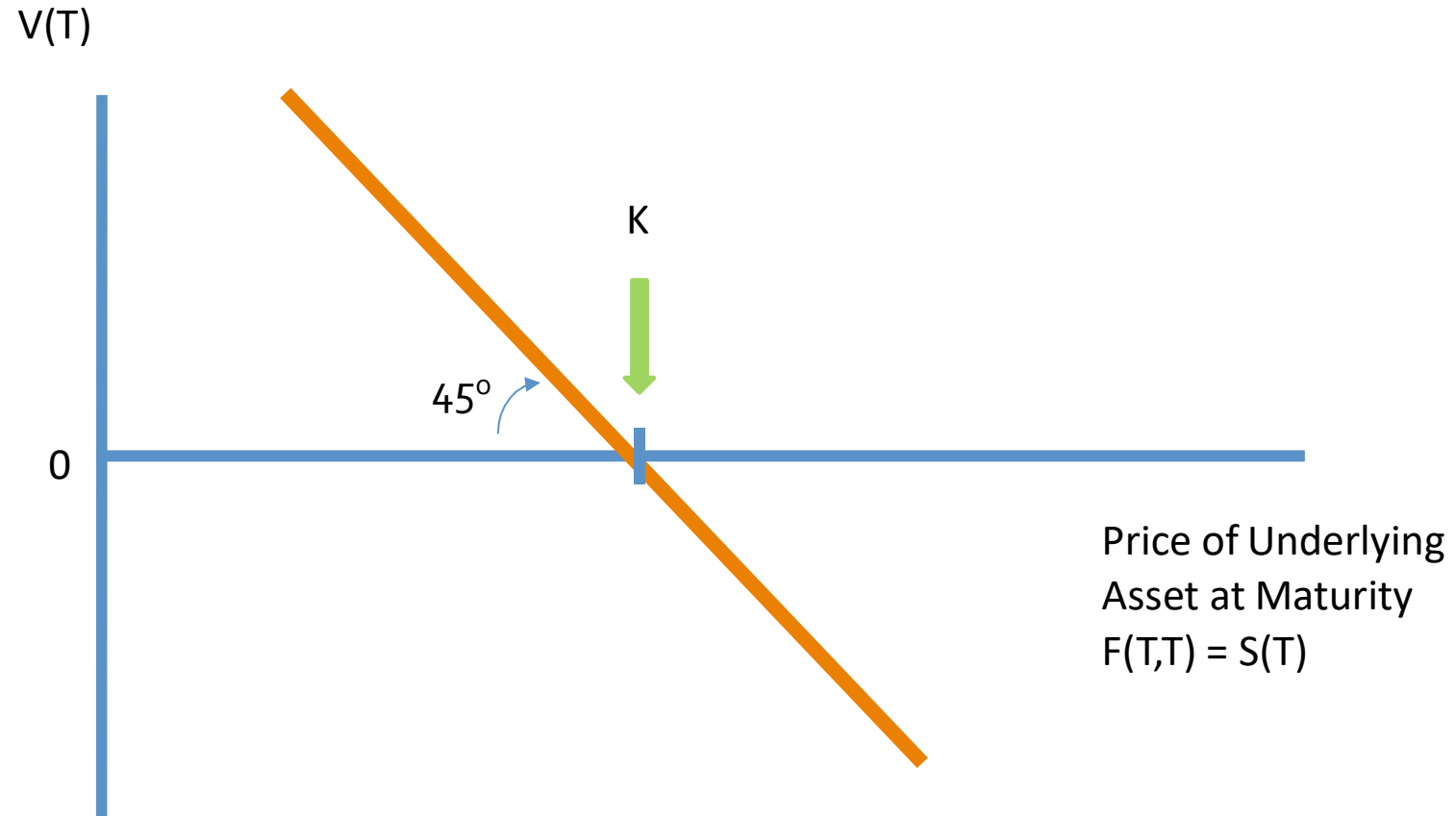
- So what if the stock provides an additional income to the stockholder?
- Stock pays dividend and one can also lend out the stock to earn an extra income via repurchasing agreement, aka repo.
- The cost of carry decreases.
- Dividend yield = 1% p.a., repo rate = 2% p.a. for 6 month period.
- The 6 month forward price now becomes

$$\$50 * \exp((6\%-1\%-2\%)* 6/12) = 50.76.$$

Payoff Diagram of Long Forward



Payoff Diagram of Short Forward



Futures contract

- A futures contract is an exchange-traded contract in which the holder has the obligation to buy/sell an asset on a future date at a market-determined price called the futures price.
- The contract specifications like quantity, time and place of delivery are determined by the exchange.
- The assets can be a commodity, a stock, an index, etc...
- Futures is considered safer than forward since the counterparty risk is almost totally eliminated.

Futures contract

- Futures contract are marked-to-market (mtm) on a daily basis.
- Every buyer/seller must maintain a certain amount with an account at the exchange.
- If the price movement is against you, the balance of your account reduces. If it drops below **the maintenance margin** then you will need to top up to **the initial margin**.

Futures vs Forward

FUTURES	FORWARD
Traded at Exchange	OTC
Standardized Contract Size, Minimum Price Change (1 Tick), Fixed Maturity Dates each year, and Fixed Settlement Terms	Customized
No Counter-Party Risk, Guarantee by Exchange. Exchange via a clearing member is de facto counter-party to both buyer and the seller	Counter-Party Risk
Fixed Trading Hours	No Fixed Trading Hours
Daily Price Limits may exist	No Daily Price Limits
Usually many contracts of different maturities are traded simultaneously	Not Applicable
Almost continuous multiple trader market-making in open outcry or electronic communications/trading network offers liquidity and ease to close out positions	Usually inter-bank or principal-to-principal price quotations. Market is less liquid.
Typically lower transaction costs due to standardization and trade volumes	High transaction costs
Contract is marked to market (revalued and settled) daily	Contract is not marked to market daily
Both long or short positions require posting of a margin (or collateral) in a margin account. The margin is revised continuously.	In general there is no margin requirement
Any minor trade dispute between buyer or seller can be settled quickly at the Exchange	Trade dispute can be quite troublesome

Example: Mark-to-Market

- Futures price: \$100
- Initial margin: \$7 per contract Maintenance margin: \$4 per contract
- Investor A buys 500 contracts, while investor B sells (shorts) 500 contracts
- Initial margin: $500 \times \$7 = \$3,500$ Maintenance margin: $500 \times \$4 = \$2,000$

Example: Mark-to-Market

<u>Trading Day</u>	<u>Settlement Price</u>
1	\$99
2	\$97
3	\$98
4	\$95

Settlement price is (average) closing price used for mark-to-market

Example: Mark-to-Market

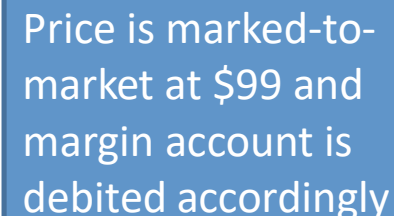
Investor A's Margin Account

Day 1: $P/L = (\$99 - \$100) \times 500 = -\$1 \times 500 = -\500
Balance = $\$3500 - \$500 = \$3000$

Day 2: $P/L = (\$97 - \$99) \times 500 = -\$2 \times 500 = -\1000
Balance = $\$3000 - \$1000 = \$2000$

Day 3: $P/L = (\$98 - \$97) \times 500 = +\$1 \times 500 = +\500
Balance = $\$2000 + \$500 = \$2500$

Day 4: $P/L = (\$95 - \$98) \times 500 = -\$3 \times 500 = -\1500
Balance = $\$2500 - \$1500 = \$1000$ Receive
margin call to deposit \$2500 to bring balance up
to initial margin



Price is marked-to-market at \$99 and margin account is debited accordingly



Variation margin

Example: Mark-to-Market

Investor B's Margin Account

Day 1: $P/L = (\$100 - \$99) \times 500 = +\$1 \times 500 = +\500
Balance = $\$3500 + \$500 = \$4000$ Withdraw
\$500 to bring balance to \$3500

Day 2: $P/L = (\$99 - \$97) \times 500 = +\$2 \times 500 = +\1000
Balance = $\$3500 + \$1000 = \$4500$ Withdraw
\$1000 to bring balance to \$3500

Day 3: $P/L = (\$97 - \$98) \times 500 = -\$1 \times 500 = -\500
Balance = $\$3500 - \$500 = \$3000$

Day 4: $P/L = (\$98 - \$95) \times 500 = +\$3 \times 500 = +\1500
Balance = $\$3000 + \$1500 = \$4500$ Withdraw
\$1000 to bring balance to \$3500

Futures Price vs Forward Price

- Futures price may be different from forward price when margin account earns interest
- If risk-free interest rate is constant, then futures price will be same as forward price

Futures Price vs Forward Price

- If risk-free interest tends to move in same direction as futures price (i.e. positively correlated), then long party tends to benefit at expense of short party.
- To compensate, futures price will be higher than corresponding forward price

Futures Price vs Forward Price

- Conversely, if risk-free interest tends to move in opposite direction as futures price (i.e., negatively correlated), then short party tends to benefit at expense of long party
- To compensate, futures price will be lower than corresponding forward price