Mathematics of Finance II: Derivative securities

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Forwards: Alternative derivation of formula

Spot transaction

Price agreed to.

Price paid/received.

Item exchanged.

Prepaid forward contract

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Price paid/received.

Item exchanged in T–years.

Forward contract

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Forward price when the underlying asset provides a known yield q: $F_p(0,t,T) = S_t e^{-q(T-t)}$:

$F_p(0,t,T)$ equals the investment required in the asset at time t (today) that will yield one unit of the asset in T–years when physical delivery occurs.

$e^{-q(T-t)}$ units of the asset will grow to
$e^{-q(T-t)} \times e^{q(T-t)} = 1$–unit of the asset in T–years, assuming that the income provided by the asset is reinvested in the asset.

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$F(0,t,T) = F_p(0,t,T)e^{r(T-t)} = S_t e^{(r-q)(T-t)}$

The forward contract allows the long position to delay payment for T–years and requires the short position to delay receipt.

The long position can earn interest on the cash that would otherwise have been paid.

The short position foregoes this interest. The forward price (which is arrived at by multiplying the prepaid forward price, equal to $S_t e^{-q(T-t)}$ by $e^{r(T-t)}$ compensates the short position for the delay.

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Futures: Definition

A future contract is a standardized agreement in which two counterparts agree to buy/sell an asset for a specified price at a specified period.

The buyer in the future contract is said to be in long position (LP) on futures.

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Difference between forwards and futures

Recall forward contracts are privately negotiated and are not standardized. Forward contracts are entirely flexible. Forward contracts are tailor–made contracts.

Futures contracts are standardized instruments and FC have clearing houses that guarantee the transactions, which drastically lowers the probability of default to almost never.

The specific details concerning settlement and delivery are quite distinct

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- Same underlying asset.
- Delivery date in two days.
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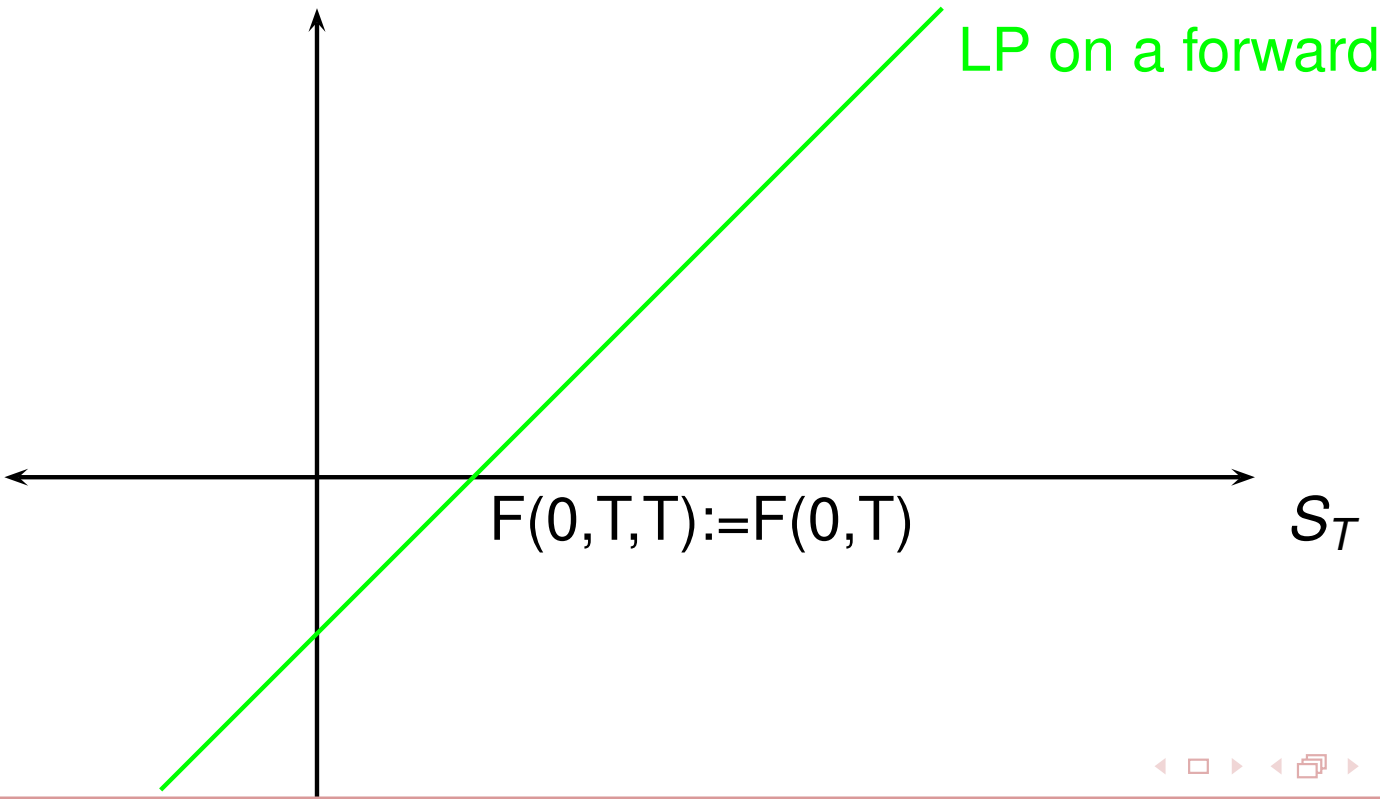
Forward prices & futures prices

Denote by $F(0,t,T)$ and $G(0,t,T)$ respectively the forward price and the futures price at time t.

Profit of LP on forward $= S_T - F(0,T,T)$



Forward prices & futures prices

Example: Suppose we have:

Day 0: $G(0,0,2) = 20$ SAR

Day 1: $G(0,1,T) = 10$ SAR with a 50% probability and $G(0,1,T) = 30$ SAR with a 50% probability

Day 2: $G(0,2,T) = S_2$ since the futures contract terminates.

Suppose that the interest rate is a constant 10% (effective per day).

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If on day 1 $G(0,1,T) = 10$ SAR, the P&L of the buyer is $G(0,1,T) - G(0,0,T) = -10$ SAR. She (He) would borrow this amount at $r = 10\%$ and have to repay 11 SAR **on day 2**.

If on day 1 $G(0,1,T) = 30$ SAR, the P&L of the buyer is $= G(0,1,T) - G(0,0,T) = 10$ SAR. She (He) would invest this amount at $r = 10\%$ and have 11 SAR **on day 2**.

Since there is a 50% chance of paying interest of 1 SAR and a 50% chance of earning interest of 1 SAR, there is no expected benefit from marking to market **on day 1**.

Since futures contract offers no benefit as compared to the forward contract $F(0,0,T) = G(0,0,T)$.

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Forward prices & futures prices

Now suppose that the interest rate is not constant.

Suppose that $r = 12\%$ on day 1 if $G(0,1,T) = 30$ SAR and $r = 8\%$ on day 1 if $G(0,1,T) = 10$ SAR.

If on day 1 $G(0,1,T) = 10$ SAR then the P&L of the buyer is $G(0,1,T) - G(0,0,T) = -10$ SAR.
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Now there is an expected gain from marking to market
$= (50\% \times 0.12 - 50\% \times 0.08) = 0.02$ SAR.

Since the futures contract offers a benefit as compared to the forward contract, $G(0,0,T)$ must exceed $F(0,0,T)$.

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With this reasoning situations:

1. $G(0,0,T) = F(0,0,T)$ when interest rates are uncorrelated with the futures price.
2. $G(0,0,T) \geq F(0,0,T)$ when interest rates are positively correlated with the futures price.
3. $G(0,0,T) \leq F(0,0,T)$ when interest rates are negatively correlated with the futures price.

Forward prices & futures prices

Empirical evidence:

1. Differences between the forward and futures prices are usually trivial once factors such as taxes, transaction costs, and the treatment of margin are controlled for.
2. Exceptions:
   - 2.1 Contracts on fixed income instruments, like T–bills. The prices of T–bills are highly negatively correlated with interest rates. $G(0,0,T) \leq F(0,0,T)$
   - 2.2 Long–lived contracts.

Formulas for $F(0,0,T)$: use to calculate both forward prices and futures prices.

Stock index futures contracts

Heavily traded. See National Post website.

Stock index: a weighted average of the prices of a selected number of stocks.

Underlying: the portfolio of stocks comprising the index.

Examples of stock indices (futures exchanges):

S&P/TSX Canada 60 Index (ME)
S&P 500 Composite Index (CME)
NYSE Composite Index (NYFE)

Where you buy and/or sell futures contracts

Futures are bought and sold in organized futures exchanges.
The biggest future exchanges are:

- South African Futures Exchange (SAFEX)
- China Financial Futures Exchange (CFFEX)
- Shanghai Futures Exchange (SHFE)
- International Petroleum Exchange of London
- New York Mercantile Exchange
- London Metal Exchange
- Tokyo Commodity Exchange

Where you buy and/or sell futures contracts

Hong Kong Futures Exchange (HKFE)

Taiwan Futures Exchange (TAIFEX)

Turkish Derivatives Exchange (TURDEX)

Agricultural Futures Exchange of Thailand (AFET)

Mercado Espaol de Futuros Financieros (MEFF)

ICE Futures Europe, formerly London International Financial Futures and Options Exchange (LIFFE)

Futures

Examples of underlying assets on which futures contracts are traded.

Category	**Description**
Stock index	S&P 500 index, Euro Stoxx 50 index, Nikkei 225, Dow-Jones Industrials, Dax, NASDAQ, Russell 2000, S&P Sectors (healthcare, utilities, technology)
Interest rate	30-year U.S. Treasury bond, 10-year U.S. Treasury notes, Fed funds rate, Euro-Bund, Euro-Bobl, LIBOR, Euribor
Foreign exchange	Euro, Japanese yen, British pound, Swiss franc, Australian dollar, Canadian dollar, Korean won
Commodity	Oil, natural gas, gold, silver, copper, aluminum, corn, wheat, lumber, hogs, cattle, milk

Futures

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The clearinghouse matches the purchases and the sales which take place during the day.

By matching trades, the clearinghouse never takes market risk because it always has offsetting positions with different counterparts.

By having the clearinghouse as counterpart, an individual entering a future contract does not face the possible credit risk of its counterpart.

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Futures and hedging

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Its traders will therefore seek to enter into a futures contract to lock in a purchase price closer to today's prices for jet fuel.

They may buy a futures contract agreeing to buy 1 million gallons of JP-8 fuel, taking delivery 90 days in the future, at a price of 3 dollars per gallon.

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Someone else naturally wants to ensure they have a steady market for fuel.

They also want to protect themselves against an unexpected decline in fuel prices, so they will gladly enter into either a futures contract.

In this example, both parties are hedgers, rather than speculators.

They are turning to the futures market as a way to manage their exposure to risk, rather than make money off of the deal directly.

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Futures: Arbitrage trade

There are also people who seek to make money off of changes in the price of the contract itself, when bought or sold to other investors.

Naturally, if the price of fuel rises, the contract itself becomes more valuable, and the owner of that contract could, if it chose, sell that contract for someone else who is willing to pay more for it.

It may make sense for another airline to pay 10 cents per gallon for a contract to save 20 cents. And so there is a lively and relatively liquid market for these contracts, and they are bought and sold daily on exchanges.

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