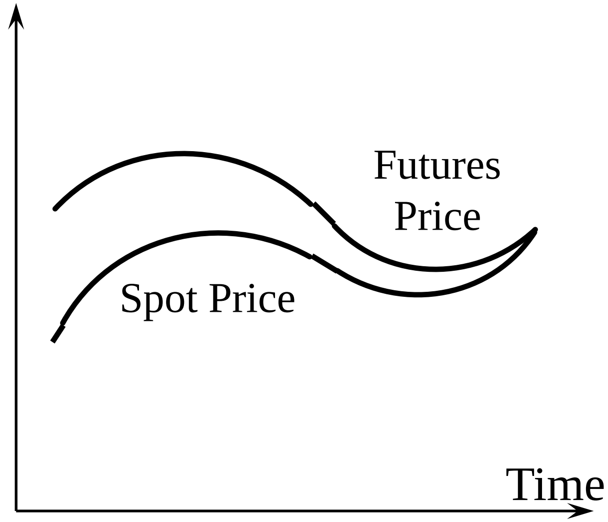
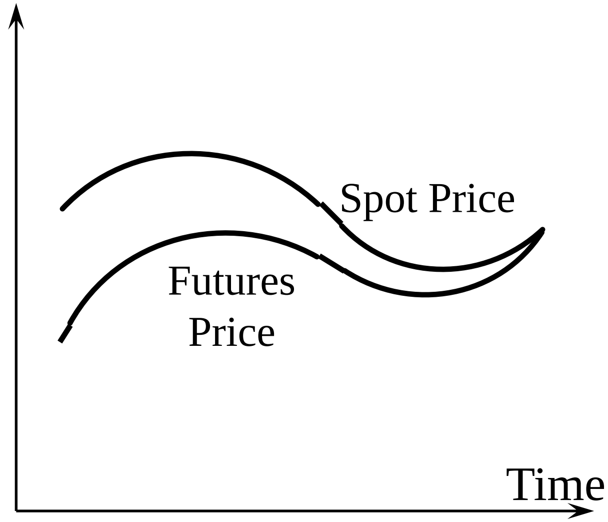
Futures Price Patterns

1. Futures Prices can be:
   a. An $\uparrow$ ing function of maturity: $F > S$; Contango; Normal.
   b. A $\downarrow$ ing function of maturity: $F < S$; Backwardation; Inverted.

2. Futures Price converges to Spot Price at maturity,
   if the spot asset is the same asset underlying the futures contract.



a. Contango



b. Backwardation

Pricing of Forwards on Investment Assets

1. **Forward price of any contract is based on cost of carry.**
   a) Cost of carry includes all cost an investor would incur if the investor would buy the asset today, and carries it till the maturity minus any carrying return.

   b) Carrying cost includes financing cost, storage and insurance charges, etc.

   c) Carrying return is the dividend or bonus an investor would receive during the maturity period by virtue of owning the underlying assets.

   d) Net carry cost is the difference between carrying cost and carrying return.

Pricing of Forwards on Investment Assets

1. **Forward price is the spot price plus the net carrying cost of the asset from today till the maturity of the contract.**

a) Underlying asset does not provide any return/income : $F_{(0,T)} = S_0 e^{RT}$

b) Underlying asset provides known cash return/income : $F_{(0,T)} = (S_0 - I)e^{RT}$

c) Underlying asset provides known yield : $F_{(0,T)} = S_0 e^{(R-q)T}$

These three formulas give the theoretical value of the contract.

where,

$F_{(0,T)}$ = Forward price of the contract on day for a contract maturing on day T.

T = Time to maturity in terms of years ($T = 0.5$ **means six month forward contract**).

R = Continuously compounded risk free rate of return

I = Present value of the known income (dividend) the underlying asset provides during the life of the contract.

q = Known yield the underlying asset provides during the life of the contract.

Pricing of Forwards on Investment Assets

1. If actual value of the contract in the forwards market $F_{(Actual)}$ is different than the $F_{(Thoeretical)}$ theoretical, then arbitrageurs undertake cash-and-carry or reverse-cash-and-carry arbitrage.

   a) Underlying asset does not provide any return/income = $F_{(0,T)} = S_0 e^{RT}$

   b) Underlying asset provides known cash return/income : $F_{(0,T)} = (S_0 - I)e^{RT}$

   c) Underlying asset provides known yield : $F_{(0,T)} = S_0 e^{(R-q)T}$

B. Pricing of Forwards on Investment Assets

1. **If actual value of the contract in the forwards market $F_{(Actual)}$ is different than the $F_{(Thoeretical)}$ theoretical, then arbitrageurs undertake cash-and-carry or reverse-cash-and-carry arbitrage.**

$F_{(Actual)}$ > $F_{(Thoeretical)}$ **Cash and carry arbitrage**	
<u>On day 0</u>	<u>On maturity day T</u>
Step 1: Borrow S_0	Step 1: Deliver underlying
Step 2: Buy underlying	Step 2: Receive $F_{(Actual)}$
Step 3: Sell forward	Step 3: Return S_0 with interest

$F_{(Actual)}$ < $F_{(Thoeretical)}$ Reverse-cash-and-carry-arbitrage	
Step 1: Short sell underlying asset at S_0	Step 1: Receive S_0 and interest
Step 2: Lend S_0 for a period equal to the maturity of the forward contract	Step 2: Take delivery of the underlying and pay F_0
Step 3: Buy forward	Step 3: Deliver the underlying asset to make up for the short sale.

Forward Prices for a security that provides no income.

Example 1: An investor would like to buy shares of a company after 6 months. The shares are quoted at Rs. 887 today. The investor can borrow money at continuously compounded rate of 8.16% per annum. The six months forward contract is quoted as Rs. 945. Find out what would be the arbitrage profit if arbitrage is possible.

Solution:

$F_{(Thoeretical)}$ **=** $F_{(0,T)}$**=** $S_0 e^{RT}$**= 887* e** $^{(8.16\%*0.5)}$ **= Rs. 924**

$F_{(Actual)}$ **= Rs. 945**

As $F_{(Actual)}$ **>** $F_{(Thoeretical)}$**, cash and carry arbitrage is possible.**

On day 0

Borrow S_0 = Rs. 887 for 6 months at 8.16%

Buy underlying, i.e. share of company

Sell forward at $F_{(Actual)}$ **= Rs. 945**

On maturity (after 4 months)

Deliver the underlying share

Receive 945 for selling the forward

Return 924 for borrowing Rs. 887 for 6 months

Profit = Rs. (945 – 924) = Rs. 21

Forward Prices for a security that provides no income.

Example 2: Spot price of gold (per 10 gram) is Rs. 10,550. The storage and insurance cost for 2 months is Rs. 275 for every 10 gram of gold. The investors can borrow/lend at Rs. 7.75% continuously compounded rate. If the two months gold forward is trading either at:

a) Rs. 11,230

b) Rs. 10, 453

Find out how arbitrageurs will be the able to make arbitrage profit:

Forward Prices for a security that provides no income.

Example 2: Spot price of gold (per 10 gram) is Rs. 10,550. The storage and insurance cost for 2 months is Rs. 275 for every 10 gram of gold. The investors can borrow/lend at Rs. 7.75% continuously compounded rate. If the two months gold forward is trading either at:

a) Rs. 11,230

b) Rs. 10, 453

Find out how arbitrageurs will be the able to make arbitrage profit:

Solution:

Spot price is given as Rs. 10, 550 **=** S_0

R = 7.75%, U = Rs. 275 paid at the beginning of the storage period

T = 0.1667 (2 months)

$\boldsymbol{F_{(Thoeretical)}} = \boldsymbol{F_{(0,T)}} = (\boldsymbol{S_0} + \boldsymbol{U})\boldsymbol{e^{RT}}$ **= (10550+275)* e $^{(0.0775*0.1667)}$ = Rs. 10, 965.75**

Case A: two months forward price on gold (per 10 gram) = Rs. 11,230 = F_0

Case B: Two month futures price on gold = Rs. 10,453 = F_0

Case A: $F_{(Actual)} > F_{(Thoeretical)}$, cash and carry arbitrage will be undertaken by the trader

Case B: $F_{(Actual)} < F_{(Thoeretical)}$, reverse cash and carry arbitrage will be undertaken by the trader

Forward Prices for a security that provides no income.

Cash and carry transactions

On day 0

Borrow = Rs. 10, 825 (Purchase cost + storage cost)

Buy gold at Rs. 10, 550

Pay storage cost of Rs. 275

Sell forward at Rs. 11, 230

On maturity (after 4 months)

Pay gold to forward counter party and receive Rs. 11, 230

Return Rs. 10, 965.73 for borrowing Rs. 10, 825

Earn a net profit of Rs. 264.27

Forward Prices for a security that provides no income.

Reverse Cash and carry transactions

On day 0

Sell gold (short sell)

Receive = Rs. 10, 550

Save Rs. 275 as a storage cost

Invest Rs. 10, 550 for two months

Buy forward at Rs. 10, 453

On maturity (after 4 months)

Receive gold from long forward position

Pay Rs. 10, 453 as payment for long forward

Receive Rs. 10, 965.75 from investment of Rs. 10, 825 for 2 months

Earn a net profit of Rs. 512. 75

Forward Prices for a security that provides no income.

Example 1: An investor would like to buy shares of a company after 4 months. The shares are quoted at Rs. 127 today. The investor can borrow money at continuously compounded rate of 8.55% per annum.

1. What would be the forward price of the share if there in no dividend income expected in these 4 months?
2. What would be the forward price of the share if there is Rs. 2.75 per share dividend after 2 months?

Solution:

1. Forward price of a company share without any income during the maturity

Maturity period = 4 months = 0.333 years

$F^* = S e^{rT} = 127 * e^{(8.55\% * 0.333)}$ = Rs. 130.80

2. Futures price of company share with income during the maturity

Dividend = 2.75

Dividend date 2 months = 0.1667 years

Present value of dividend $= 2.75 / e^{(8.55\% * 0.1667)} = 2.711$

With known income, the forward price is :

$\mathbf{F^* = (S - I) e^{rT}} = (127-2.711) * e^{(8.55\% * 0.333)} = 128.01$

General Formula for Valuation of Futures

a. security that provides no income.

$F^* = Se^{rT}$, so that $f = (Se^{rT} - K)\, e^{-rT}$ or $f = S - Ke^{-rT}$.

b. security that provides a known income.

$F^* = (S-I)e^{rT}$, so $f = [(S-I)e^{rT} - K]e^{-rT}$ or $f = S - I - Ke^{-rT}$.

c. security that pays a known dividend yield.

$F^* = Se^{(r-q)T}$, so $f = [Se^{(r-q)T} - K]\, e^{-rT}$ or $f = Se^{-qT} - Ke^{-rT}$.

d. Note: in each case, the forward price at the current time (F) is the value of K that makes $f = 0$.

Applications – Stock Index Futures

Problem:

- A one-year long forward contract on a non-dividend-paying stock is entered into when the stock price is Rs. 40 and the risk-free rate of interest is 10% per annum with continuous compounding.

a) What are the forward price and the initial value of the forward contract?
b) Six months later, the price of the stock is $45 and the risk-free interest rate is still 10%. What are the forward price and the value of the forward contract?

(a) $F = 40\, e^{(0.10) \times 1} = \text{Rs. } 44.21$

The initial value of the forward contract is zero.

(b) The delivery price K in the contract is Rs. 44.21. The value of futures contract after six months is

$F = 45 - 44.21e^{(-\ 0.10) \times 0.5} = \text{Rs. } 2.95$

The forward price is $40\, e^{(.0.1) \times 0.5} = \text{Rs. } 47.31$

Applications – Stock Index Futures

Problem:

The risk-free rate of interest is 7% per annum with continuous compounding, and the average dividend yield on a stock index is 3.2% p.a. The current value of the index is 150. What is the six-month futures price?

Using the above equation, the six-month futures price is

$$F^* = 150e^{(.07 - .032) \times 0.5} = \text{Rs. } 152.88.$$

Commodity Futures

- In case of consumable commodities like crude oil, copper, coal and agricultural products etc.

- Users of such commodities trade in commodity spot and forward/futures as they require these commodities to be either used in production process or for consumption

- Pricing of such commodities can be analyzed under two situations:
  - WITH and WITHOUT SUPPLY CONSTRAINTS

Commodity Futures

- **Without supply constraint**
  - If the commodity is available abundantly, i.e. there is no shortage currently or expected in future, then forward price will confirm to the cost-of-carry model as given below:

$$F_{(0,T)} = (S_0)e^{(R+U)T}$$

- Forward contracts are priced in a manner such that a trader can borrow (S_0) for a period of T at a rate of r to buy the commodity in spot and store it for period T by incurring storage/insurance costs at a rate of U.

- Cash and carry and reverse cash carry strategies are dependent upon actual and theoretical prices of forward/futures.

H. Commodity Futures

- **With supply constraint**
  - Pricing of forwards for consumption commodities in case of supply restrictions is also undertaken using cost of carry but with some adjustments. This adjustment is known as "*Convenience yield*"

  - Convenience yield arises from benefits of holding physical asset and such benefits are not available to forward/futures holders.

$$F_{(0,T)} = (S_0)e^{(R+U-Y)T}$$

where

R = continuously compounded risk free rate of return

U = present value of all costs, including storage, insurance, expressed as a percentage of the underlying spot price

Y = Convenience yield expressed as percentage of spot price

T = time to maturity in terms of years.

Commodity Futures

- Example:
  - Spot price of (S_0) Soybean oil = Rs. 93, 500 (per 1000 kg), R = 7.75% per annum continuously compounded. U = 0.35% per 1000 kg per annum continuously compounded, T = 0.333 (4 months), $F_{(0,4)}$ = Rs. 95,785 (per 1000 kg)
    a) Calculate the theoretical futures price based on cost of carry model
    b) Find out the convenience yield in absolute as well as percentage term?

Solution:

Theoretical price based on cost of carry model

(a)

$$F_{theoretical(0,T)} = S_0 e^{(R+U)T}$$

$$F_{theoretical(0,T)} = S_0 e^{(R+u)T} = 93550e^{(7.75\%+0.35\%)0.333} = 96{,}110.25$$

(b) **Convenience yield**

The theoretical futures price = 96,110.25

Actual futures price = 95,785

Convenience yield = 96,110.25 – 95,785 = 325.25

H. Commodity Futures

- **Example:**
  - Spot price of (S_0) Soybean oil = Rs. 93, 500 (per 1000 kg), R = 7.75% per annum continuously compounded. U = 0.35% per 1000 kg per annum continuously compounded, T = 0.333 (4 months), $F_{(0,4)}$ = Rs. 95,785 (per 1000 kg)

    a) Calculate the theoretical futures price based on cost of carry model

    b) Find out the convenience yield in absolute as well as percentage term?

Solution:

(b) **Convenience yield in percentage term**

The theoretical futures price = 96,110.25

Actual futures price = 95,785

Convenience yield = 96,110.25 – 95,785 = 325.25

$$F_{(0,T)} = S_0 e^{(R+u-Y)T}$$

$$Y = (R + u) - \frac{1}{T} \ln\left(\frac{F_{(0,T)}}{S_0}\right)$$

$$= (7.75\% + 0.35\%) - \frac{1}{0.333} \ln\left(\frac{95785}{93550}\right) = 1.01\%$$

Hence, the convenience yield is 1.01% per annum continuously compounded

Commodity Specific Features

- Soybean crush margin and soybean spot price
  - Soybean are crushed to produce Soyaoil and Soyameal.
  - Soyaoil is edible oil while soymeal is mostly used as the animal feed.
  - Soybean processors earn profit by buying beans and selling Soyaoil and soymeal.
  - Crush margin reflects the price difference between purchase price of soybeans and the sale price of extracted Soyaoil as well as Soyameal after adjusting for crushing and refining cost.

- **Crush margin** = Price of soyoil + price of Soyameal – {Price of Soyabean + crushing cost of Soyabean + refining cost of crude Soyaoil}

Commodity Specific Features

- Example:
- Spot price soybean (100 kg is Rs 4476 Soyaoil (per 10 kg) and soymeal (per 1000 kg) quotes at Rs. 801.25 and Rs. 40850, respectively. The cost of crushing and refining crude Soyaoil: Crushing cost: Rs. 750 per 1000 kg of soybean, refining cost: Rs. 2500 for 1000 kg of refined Soyaoil. Suppose Soyaoil production as a % of soybean crushed is 18%.
  - Calculate the crush margin for a soybean crusher
  - Calculate the crush margin if the soybean price (per 100 kg) increases by Rs. 200.

Commodity Specific Features

- Example:
  - Soybean price (per 1000 kg) = 4476*10 = Rs. 44760
  - Soyoil price (per 180kg) = 801.25*18 = Rs. 14422.5
  - Soymean price (per 820 kg) = Rs. 40.85*820 = 33497
  - Crush cost (per 1000 kg of soybean) = Rs. 750
  - Refining cost (per 180 kg of refined soyoil) = Rs. 2.5*180 = 450

- Crush margin = Price of Soyaoil (per 180 kg) + price of soymeal (per 820 kg) – {price of soybean (per 1000 kg)+crushing cost (per 1000 kg of soybean) + refining cost (per 180 kg of refined soyoil)

  = 14422.5+33497 – {44760+750+450}

  = 47919.5 - 47960 = -40.5

  The crusher incurs a loss of Rs. 40.5.

Commodity Specific Features

- **Crude oil futures**

LPG	Petrol	Diesel	Kerosene or Jet fuel	Fuel oil	Heating oil	Other residue like Paraffin Wax and Asphalt
2 gallons	19 gallons	10 gallons	4 gallons	2 gallons	1 gallons	7 gallons
		1 barrel = 42 gallons	1 gallon = 3.785 litre			

Commodity Specific Features

- **Crack spread futures**
  - Crack spread measures the price difference between the refined product and crude oil.
  - The crack spread price is a positive number if the price of the refined products is higher than that of crude oil.
  - If the refined products are priced lower than crude oil, then the crack spread is a negative number

Commodity Specific Features

- **Crack spread futures**

Example:

Spot crude oil is quoting at USD 103 per barrel while 1 gallon of diesel in spot market is quoting at USD 2.75. Find out the crack margin.

  - **Crack spread** = (USD 2.75 per gallon * 42 gallon per barrel) - USD 44.70 per barrel
  - USD 12.5 per barrel of crude oil

- Futures on crack spread can be for petrol/crude oil or for diesel/crude oil or jet fuel/crude oil or any refined product or crude oil combination.

- In a crack spread, one leg has to be crude oil with the other leg being any refined product.

- Crack spread futures are useful for price risk hedging for standalone oil refineries.

H. Commodity Specific Features

- **Crack spread futures**
- Types of crack spread futures contracts

1:1	1 crude oil contracts, 1 gasoline (or any other refined product) contract
2:1:1	2 crude oil contracts, 1 heating oil and 1 diesel contract
3:2:1	3 crude oil contracts, 2 heating oil and 1 diesel contract
5:3:2	5 crude oil contracts, 3 heating oil and 2 diesel contract

Commodity Specific Features

- **Crack spread futures**
  - Types of crack spread futures contracts
  - 2:1:1 means buying (selling) two crude oil futures contract and selling (buying) one contract each for two different kinds of refined products.
  - The choice of crack spread futures contracts depends on the refiner's output combination
  - If a refiner produces heating oil and diesel in equal proportion by refining crude oil, the refiner should choose 2:1:1 crack spread contract.

H. Commodity Specific Features

- **Crack spread futures: EXAMPLE**
- The petrol spot price is USD 2.30 per gallon and heating oil spot price is USD 2.14 per gallon and crude oil spot price is USD 82.5 per barrel. Find out the 3:2:1 crack spread margin when the refiner is producing gasoline and heating oil in the ratio 2:1

Solution:

- Price of one barrel of petrol = USD 2.30 * 42 = USD 96.6
- Price of one barrel of heating oil = USD 2.14*42 = USD 89.88
- Price of one barrel of crude oil = USD 82.5

3:2:1 crack spread = (2 gasoline +1 diesel) – 3 crude oil = USD (193.2+89.88-247.5)= 35.58

= USD 35.58 for 3 barrels of crude oil = USD 11.86 per barrel.

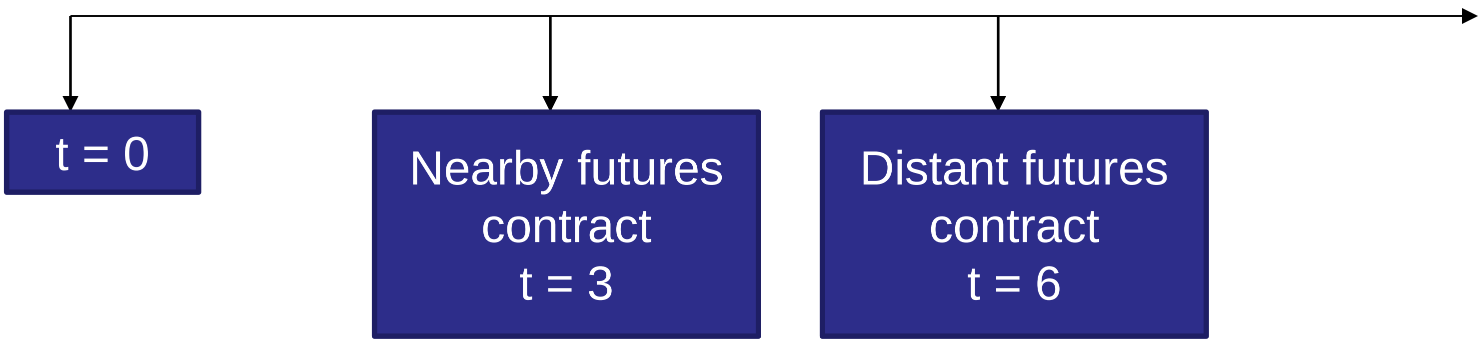
Commodity Specific Features

- Base metal derivatives
  - Like commodity futures market, base metals futures contracts exhibit contango and backwardation.
  - In contango market, futures prices are higher than spot price and distant maturity futures prices are higher than near maturity futures prices.
  - A market exhibits contango when there is an abundant supply of the underlying commodity.
  - In a backwardation market, spot price is higher than futures price or near maturity futures price is higher than distant futures price.
  - A market exhibits backwardation when there is supply scarcity in the underlying commodity
  - In contrast to agricultural commodities, crude oil and natural gas as well as base metals do not exhibit seasonality in consumption and production.
  - Base metals can also be stored for a long period of time without significant quality deterioration.
  - Hence, the amount of base metal inventory held in warehouses influences the spot and futures prices.

Commodity Futures

1. Spread Arbitrage

Cash and carry and reverse cash and carry can also happen among futures contracts with the same underlying asset but of different maturity. This is known as the spread arbitrage.



$$\boxed{F_{(0,dist.)} = F_{(0,nearby)} \times e^{CT}}$$

T = Time difference between nearby and distant futures contract

C = Continuously compounded cost of carrying the asset that includes storage, insurance and interest costs.

Commodity Futures

1. Spread Arbitrage

- Cash and carry and reverse cash and carry can also happen among futures contracts with the same underlying asset but of different maturity. This is known as the spread arbitrage.

$$\boxed{F_{(0,dist.)} = F_{(0,nearby)} \times e^{CT}}$$

- If the futures price prevailing in the market for the distant contract, $F_{(0,dist.),Actual}$ is not equal to the theoretical price, $F_{(0,dist.),Theoretical}$, arbitrage will happen.

- Spread arbitrage ensures that the price differential between two futures contracts must be equal to the cost of carrying the underlying asset from nearby contract delivery date to the distant contract delivery date.

Commodity Futures

1. Spread Arbitrage

EXAMPLE:

Suppose price of gold futures contract with three months maturity $F_{(\text{Actual}(0,3)}$ is Rs. 10, 715. The cost of carrying (in terms of interest rate) gold from 3 months to 6 months is 9% per annum continuously compounded. If the market price for $F_{(\text{Actual}(0,6)}$ is:

(a) Rs. 11, 072

(b) Rs. 10, 723, find out how arbitrage will take place?

H. Commodity Futures

1. Spread Arbitrage

Suppose price of gold futures contract with three months maturity $F_{(\text{Actual}(0,3)}$ is Rs. 10,715. The cost of carrying (in terms of interest rate) gold from 3 months to 6 months is 9% per annum continuously compounded. If the market price for $F_{(\text{Actual}(0,6)}$ is:

(a) Rs. 11, 072

(b) Rs. 10, 723, find out how arbitrage will take place?

Solution:

$$\boxed{F_{(0,dist.)} = F_{(0,nearby)} \times e^{CT}}$$

$$F_{(\text{Theoretical } 0,6)} = F_{Actual(0,3)} \times e^{CT}$$

$$F_{(\text{Theoretical } 0,6)} = 10{,}715 \times e^{0.09 \times 0.25} = 10{,}958.82$$

Case (a): Since $F_{Actual(0,6)} > F_{(\text{Theoretical } 0,6)}$ Cash-and-carry arbitrage would be undertaken by the traders.

Case (b): Since $F_{Actual(0,6)} < F_{(\text{Theoretical } 0,6)}$ Reverse Cash-and-carry arbitrage would be undertaken by the traders.

Commodity Futures.

Cash and carry transactions $F_{(\text{Actual}(0,6)}$ = Rs. 11, 072

On day 0

Go long in the nearby futures (3 months) at Rs. 10, 715

Sell the distance futures

Contract to borrow Rs. 10, 715 at 9% from t = 3 to t = 6

On maturity (after t = 3)

Borrow Rs. 10, 715 as contracted at t = 0

Pay Rs. 10, 715 to the long futures counter party

Take the delivery of gold store gold

On distant contract maturity day (t = 6)

Deliver gold as part of short futures contract

Receive Rs. 11, 072

Pay Rs. 10, 958.82 for borrowing Rs. 10, 715

Net profit = Rs. 11, 072 – Rs. 10, 958.82 = Rs. 113.8 = Rs. 114

H. Commodity Futures

Reverse Cash and carry transactions $F_{(\text{Actual}(0,6)}$ = Rs. 10, 723

On day 0

Go short in the nearby futures (3 months) at Rs. 10, 715

Buy the distant futures contract

Contract to lend Rs. 10, 715 at 9% from t = 3 to t = 6

On maturity (after t = 3)

Borrow gold for 3 months

Deliver gold to nearby short futures counterparty

Lend Rs. 10, 715 for three months

On distant contract maturity day (t = 6)

Receive Rs. 10, 958.82 as a lending receipt

Receive gold as part of long forward contract

Return gold to the lender

Pay Rs. 10, 723 to long futures counter party

Net profit of Rs. 235. 82

Non-Storable Commodity Derivatives

Electricity Derivatives

Exchange trading of electricity in India

There are three types of contracts:

1. Day-ahead-market (DAM) (also known as day-ahead-spot (DAS))
2. Day-ahead-contingency (DAC) market
3. Intra-day contracts

- In case of DAM and DAC market, buyers and sellers bid on D-1 day. Price is negotiated on D-1 day.
- Delivery of the electricity happens in day D.
- In intraday contracts, buyers and sellers bid on day D.
- Delivery also happens in day D.
- Futures trading in electricity is known as *Term-Ahead-Market (TAM).* The term can be for a day, a week, for a month, for a year or longer, depending on the buyers and sellers requirement and a availability of long maturity products in power exchanges.

I. Electricity Derivatives

Exchange trading of electricity in India

There are three types of contracts:

1. Day-ahead-market (DAM) / Day-Ahead-Spot (DAS)

- Day-ahead-market is also known as Day-ahead-spot (DAS) market**.**
- In a day-ahead market buyers and sellers can freeze the price of electricity on D-1 day, to be delivered on the following day, i.e., on day D.
- On day D-1, before a specific-cut-off time, buyers and sellers bid the volume of electricity they are willing to sell/buy and price.

- On exchange, a day is divided into 24 blocks of one hour each.
- Based on the demand and supply for each hour, a cut-off price and volume is determined.
- It means, on day D-1, 24 cut-off price and volume are determined.
- The cut-off price is known as **Market-Clearing Price (MCP)** or **unconstrained MCP**.
- The Cut-off volume is known as **Market volume (MCV).**

I. Electricity Derivatives

Exchange trading of electricity in India

Example MCP and MCV:

- The hypothetical buy and sell bid at different prices for a given hour (9 a.m. to 10 a.m.) is given below. In real life buyers and sellers can bid a minimum volume of MWh and multiples of 0.01 MWh thereafter. Determine the unconstrained MCP and unconstrained MCV.

Buy and sell bids at different price for 9 am to 10 am

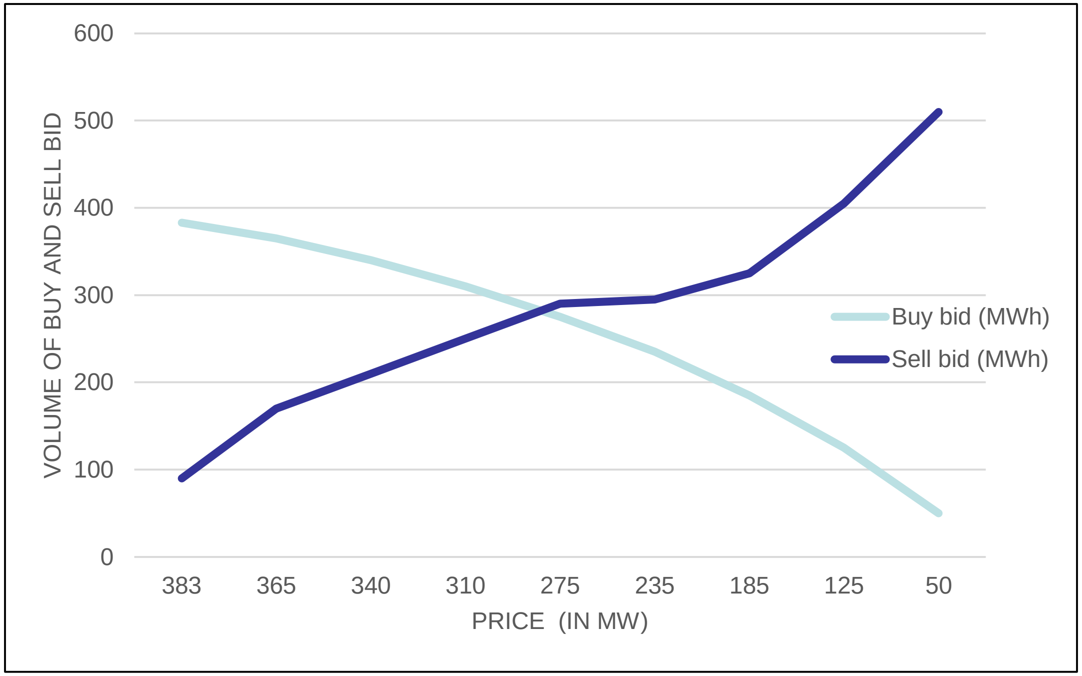
Price (INR/MW)	Buy bid (MWh)	Sell bid (MWh)
230	383	90
240	365	170
250	340	210
260	310	250
270	275	290
280	235	295
290	185	325
300	125	405
310	50	510

I. Electricity Derivatives

Exchange trading of electricity in India

Example MCP and MCV:

- The hypothetical buy and sell bid at different prices for a given hour (9 a.m. to 10 a.m.) is given below. In real life buyers and sellers can bid a minimum volume of MWh and multiples of 0.01 MWh thereafter. Determine the unconstrained MCP and unconstrained MCV.



I. Electricity Derivatives

Exchange trading of electricity in India

Example MCP and MCV:

- The hypothetical buy and sell bid at different prices for a given hour (9 a.m. to 10 a.m.) is given below. In real life buyers and sellers can bid a minimum volume of MWh and multiples of 0.01 MWh thereafter. Determine the unconstrained MCP and unconstrained MCV.
- Solution:
- At a certain price, the buy and sell bids should match.
- To do this, we can adopt the linear interpolation method.
- The thumb rule to these two price points in where the difference between buy and sell bid volume sign changes from positive to negative.
- At Rs. 260 difference between buy and sell is 60 MWh while at Rs. 270, the same is negative 15 MWh.

I. Electricity Derivatives

Exchange trading of electricity in India

Example MCP and MCV:

- The hypothetical buy and sell bid at different prices for a given hour (9 a.m. to 10 a.m.) is given below. In real life buyers and sellers can bid a minimum volume of MWh and multiples of 0.01 MWh thereafter. Determine the unconstrained MCP and unconstrained MCV.
- Solution:

$$\frac{x - x_a}{x_b - x_a} = \frac{y - y_a}{y_b - y_a}$$

$$\frac{x - 260}{270 - 260} = \frac{y - 250}{290 - 250}$$

$$y = 4x - 790$$

$$Similarly,$$

$$\frac{x - 260}{270 - 260} = \frac{y - 310}{275 - 310}$$

$$y = 1220 - 3.5x$$

$$Solving$$

$$x = 268$$

$$y = 282$$

Hence the MCP (for 9 am to 10 am) is Rs. 268 and MCV is 282 MWh