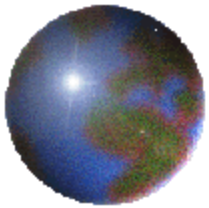
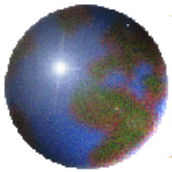
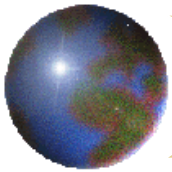


Energy and Commodity Derivatives



Outline

- Types of commodities
- Energy commodity futures
- Modeling commodity futures
- Simulation and implementation



What are commodities?

- Inputs to an industrial process
- Must be standardizable
- Involve some uncertainty: price/supply/inventory

Main types of commodities:

- Agricultural
- Metals
- Energy
- Other

Agricultural Commodities

- Grains: Corn, wheat, cocoa, coffee
- Oilseeds: soybeans, sunflower
- Foods: sugar, butter, cheese
- Livestock: cattle, pork bellies
- Fiber: cotton
- Tropicals: frozen orange juice

Seasonality and mean reversion in prices (farmers have a choice about what they produce)

Metals

- Base metals: copper, tin, lead, zinc, nickel, aluminum
- Strategic: uranium
- Precious: gold, silver
- Ferrous: iron ore and steel

Investment vs consumption metals

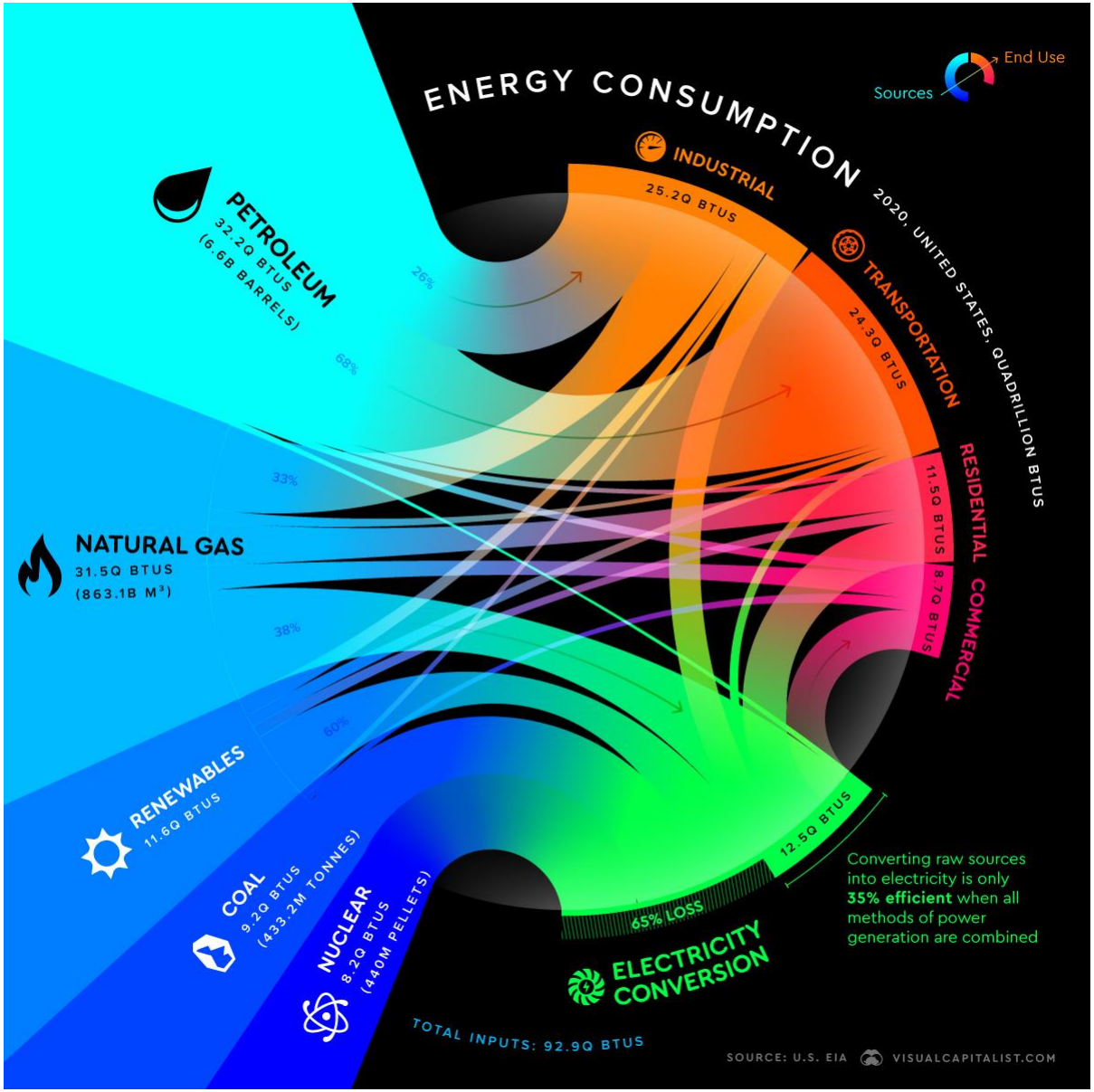
Some mean reversion (It can become uneconomic to extract some metals)

Energy Commodities

- Crude oil and their derivatives
  - Crude oil
  - Distillates: gasoline, kerosene,
  - Residuals: fuel oil, bunker oil
- Natural gas
- Power (electricity)

Other

- Coal
- Emissions (CO2)
- Minerals
- Weather
- Shipping/freight


ENERGY CONSUMPTION
2020, UNITED STATES, QUADRILLION BTUS
Sources
End Use
PETROLEUM
32.2Q BTUS
(6.6B BARRELS)
NATURAL GAS
31.5Q BTUS
(863.1B M³)
RENEWABLES
11.6Q BTUS
COAL
9.2Q BTUS
(433.2M TONNES)
NUCLEAR
8.2Q BTUS
(440M PELLETS)
INDUSTRIAL
25.2Q BTUS
TRANSPORTATION
24.3Q BTUS
RESIDENTIAL
11.5Q BTUS
COMMERCIAL
8.7Q BTUS
26%
68%
33%
38%
60%
12.5Q BTUS
65% LOSS
ELECTRICITY CONVERSION
Converting raw sources into electricity is only 35% efficient when all methods of power generation are combined
TOTAL INPUTS: 92.9Q BTUS
SOURCE: U.S. EIA
VISUALCAPITALIST.COM

Crude Oil

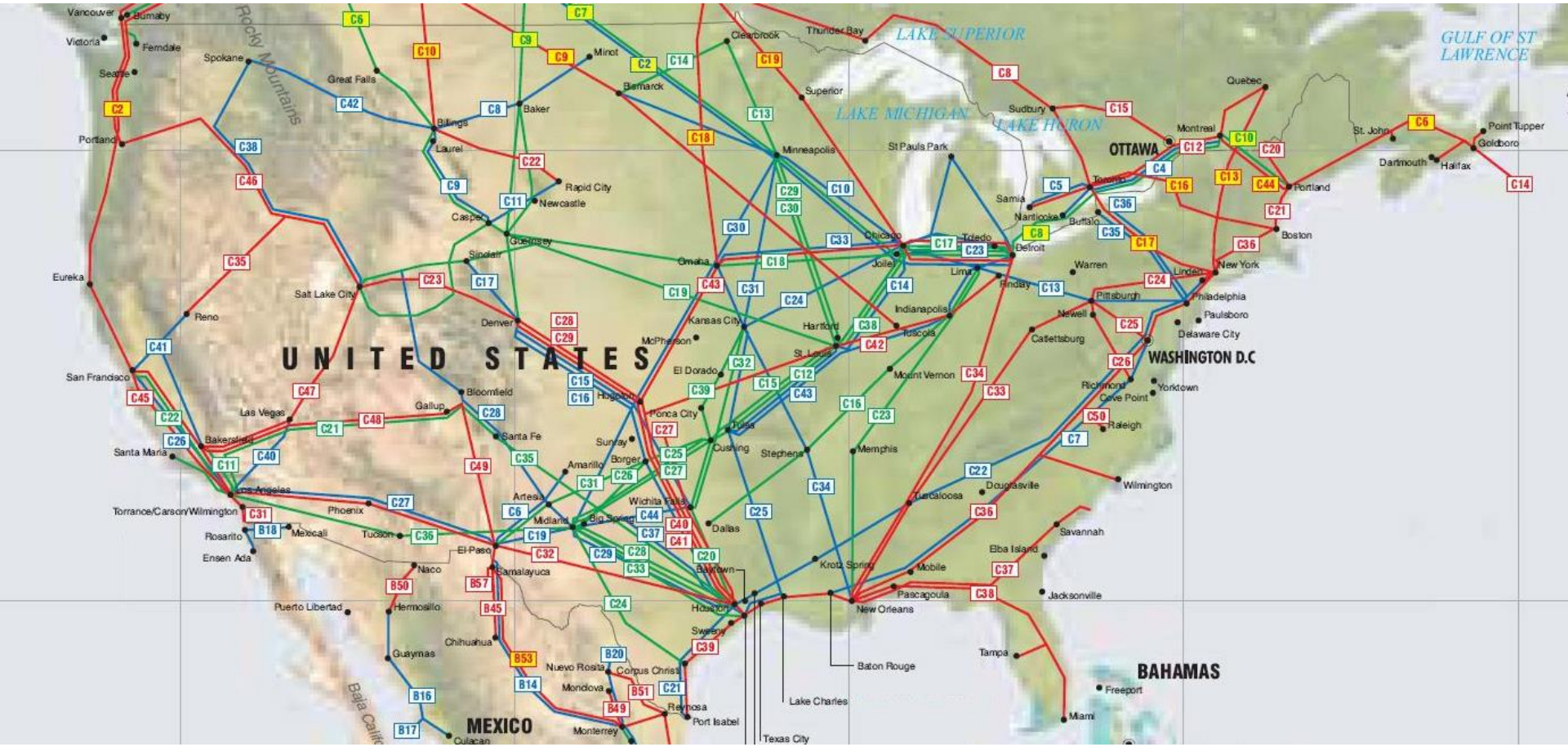
- Largest commodity market in the world
- Crude oil is the most non-standard commodity. Main criteria for listing:
  - Location of origin: West TX, Louisiana, Fateh
  - API: measure of density (heavy/light)
  - Sulfur content: sweet (<1% S), sour (>1% S)
- Three main benchmarks:
  - West Texas Intermediate (WTI): 38-40 API, 0.3% S
  - Brent: 38 API, 0.3% S
  - Dubai: 32 API, 2% S

Delivery and Futures

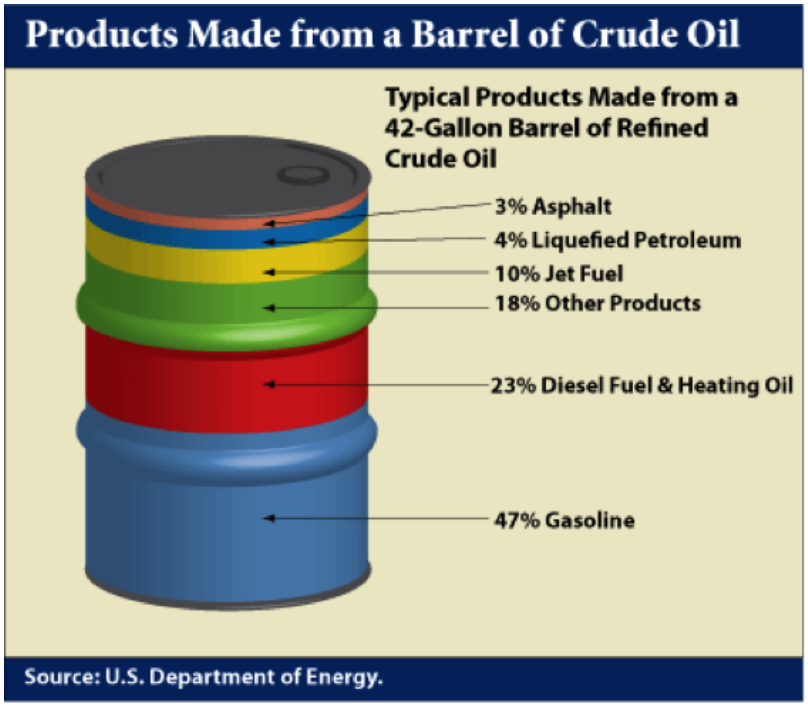
Standard delivery for futures is by pipeline, at specified locations

- CME: WTI = Cushing OK
- ICE Brent: Sullom Voe, UK
- Dubai Fateh: Dubai, UAE

US crude oil pipelines



Distillates



Fractional crude distillation produces a large number of derivatives:

- Gasoline.
- Kerosene/jet fuel
- Diesel fuel
- Bunker fuel

Main distillates futures

- RBOB (revised blendstock for oxygenate blending) Gasoline futures
- NY Harbor ULSD: Heating oil futures
- Residual fuel oil: USGC HSFO (3.5%)

Natural Gas

- Can be transported either by pipeline or in liquefied form (LNG) by tankers
- Futures traded on CME (delivery at Henry Hub), ICE (Europe), LNG on ICE (Japan/Korea)
- Propane is extracted from natgas. Futures on propane traded on CME.

Power - electricity

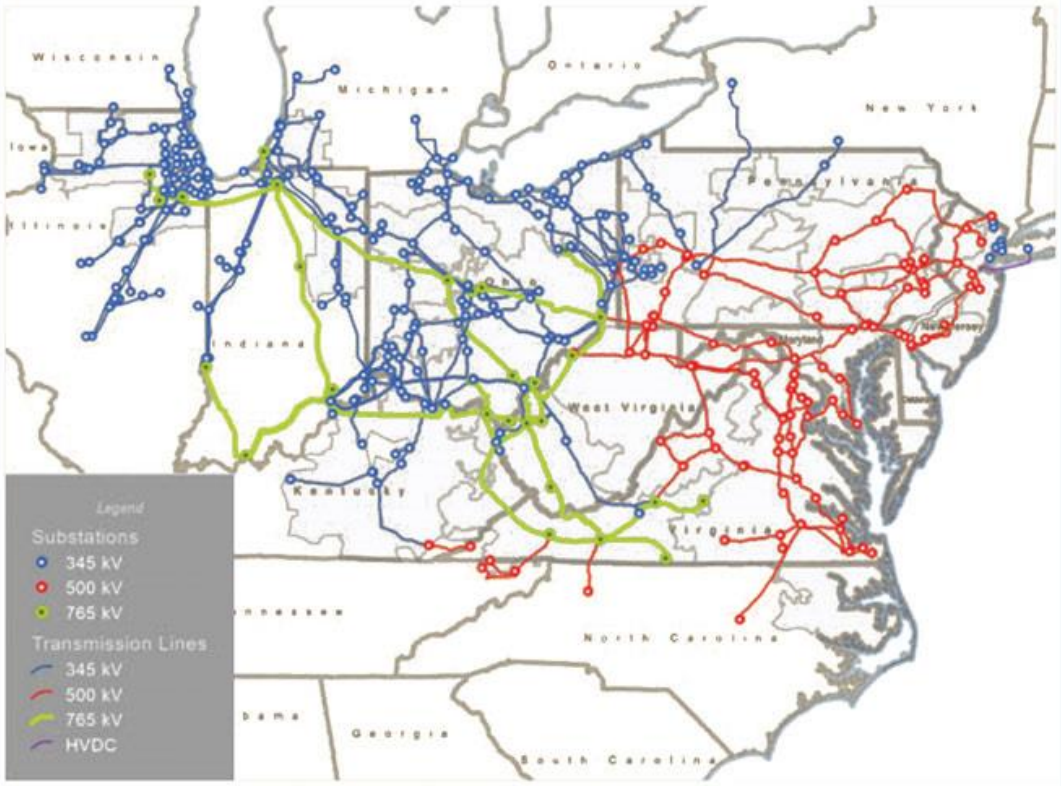
Special feature: very difficult to store

- Electricity markets are very local
- Markets are closely connected to generation plants.
- Supply and demand must be always in balance.
- Imbalances lead to spikes in prices.

- Recent trend towards deregulation. There is still a regulated sector with fixed prices

US Power Zones

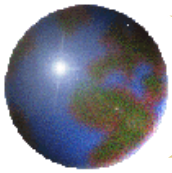
PJM zone map



Source: PJM

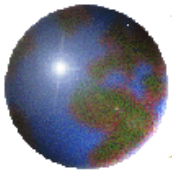
Power futures

- Electricity is traded as cash settled futures, giving the right to delivery over a specified period:
  - Monthly, e.g. PJM Monthly
  - Weekly
  - Daily, day-of and day-ahead futures.
  - Intraday: peak/base, hourly.

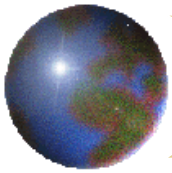


Power generation

- Coal power plants
- Nuclear plants
- Natural gas plants – very flexible, can be turned on/off quickly
- Hydro Power Plants
- Fuel Oil Plants
- Renewables power plants: wind, solar



Commodity derivatives



Commodity Derivatives

- Virtually all derivatives available on stocks and stock indices are also available in the commodity markets with futures as the underlying asset
- American options on futures are very common.
- Example: LO options – American options on WTI futures

Commodity swaps

- Swaps ensure delivery at regular time intervals in exchange for periodic payments
- Calendar Swap: cash settled at maturity in an amount equal to the sum/average of a futures price at regular intervals (typically daily).

Spread options

Spread options have a payoff linked to the spread between two assets

- Call spread pays max(S1 – S2 – K,0)
- Put spread pays max(K – S1 + S2, 0)

The two assets can be futures on different commodities or same commodity with different delivery dates.

WTI – Brent Crude Oil Spread Option

Calendar spread option: WTI Crude Oil 1 Month CS option

Natural Gas Derivatives *(page 774-775)*

- A typical OTC contract is for the delivery of a specified amount of natural gas at a roughly uniform rate to specified location during a month.
- NYMEX and IPE trade contracts that require delivery of 10,000 million British thermal units of natural gas to a specified location

Electricity Derivatives continued

- A typical contract allows one side to receive a specified number of megawatt hours for a specified price at a specified location during a particular month
- Types of contracts:

  5x8, 5x16, 7x24, daily or monthly exercise, swing options

Modeling Commodity Prices

- Futures prices can be used to define the process followed by a commodity price in a risk-neutral world.
- We can build in mean reversion and use the Ornstein-Uhlenbeck process

The Process for the Commodity Price

A simple mean reverting process is

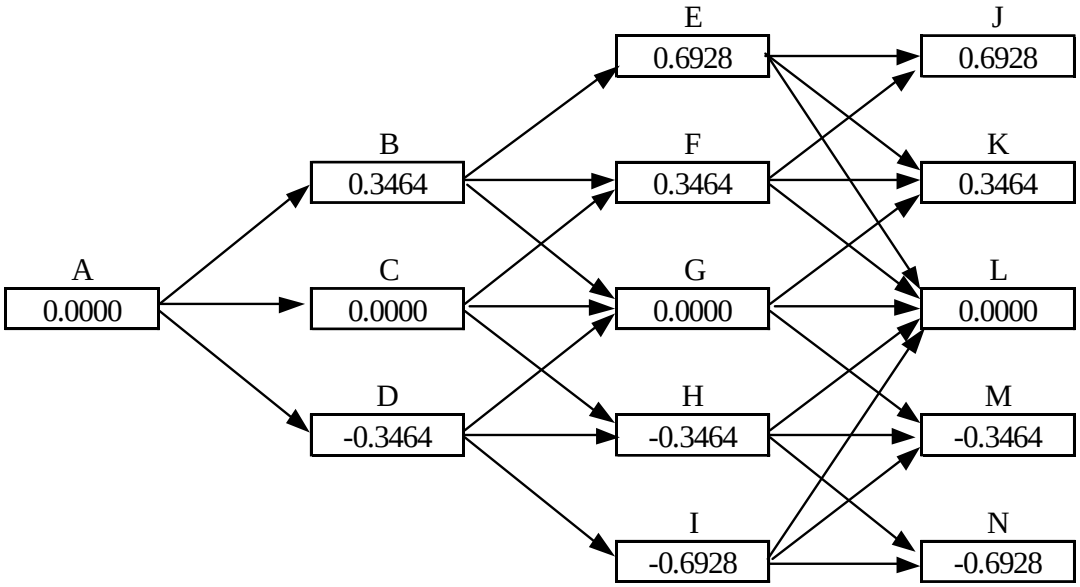
$$d\ln(S) = [\theta(t) - a\ln(S)]\,dt + \sigma\,dz$$

Can also be written

$$\frac{dS}{S} = \left[\theta^*(t) - a\ln S\right]dt + \sigma dz$$

Assume $a = 0.1$, $\sigma = 0.2$, and $\Delta t = 1$ year

Tree for $\ln(S)$ Assuming $\theta(t)=0$; Fig 35.1

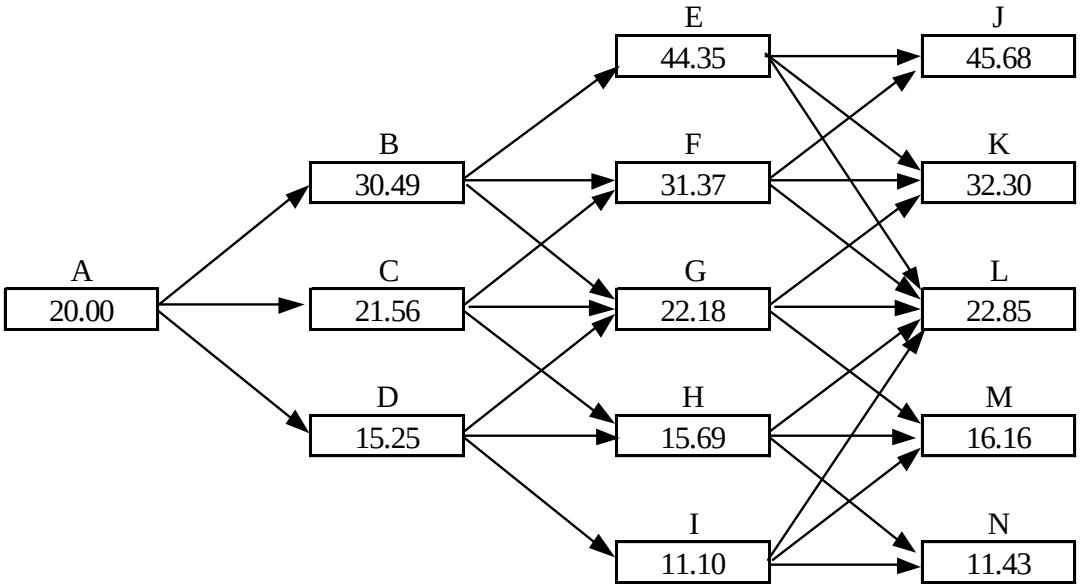


Node	A	B	C	D	E	F	G	H	I
p_u	0.1667	0.1217	0.1667	0.2217	0.8867	0.1217	0.1667	0.2217	0.0867
p_m	0.6666	0.6566	0.6666	0.6566	0.0266	0.6566	0.6666	0.6566	0.0266
p_d	0.1667	0.2217	0.1667	0.1217	0.0867	0.2217	0.1667	0.1217	0.8867

Determining $\theta(t)$

- The nodes on the tree are moved so that the expected commodity price equals the futures price
- Assume that the one-year, two-year and three-years futures price for the commodity are $22, $23, and $24, respectively

Final Tree; Fig 35.2



Node	A	B	C	D	E	F	G	H	I
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p_m	0.6666	0.6566	0.6666	0.6566	0.0266	0.6566	0.6666	0.6566	0.0266
p_d	0.1667	0.2217	0.1667	0.1217	0.0867	0.2217	0.1667	0.1217	0.8867

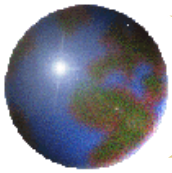
Jumps

- Some commodity prices such as gas and electricity exhibit jumps
- A process that can be assumed is then

$$d \ln S = [\theta(t) - a \ln S]dt + \sigma dz + dp$$

where dp is a Poisson process generating jumps

- Can be implemented with Monte Carlo simulation



Other Models

- Convenience yield follows a mean reverting process (Gibson and Schwartz)
- Volatility stochastic (Eydeland and Geman)
- Reversion level stochastic (Geman)

Weather Derivatives: Definitions

(page 782)

- Heating degree days (HDD): For each day this is max(0, 65 – A) where A is the average of the highest and lowest temperature in ºF.
- Cooling Degree Days (CDD): For each day this is max(0, A – 65)
- Contracts specify the weather station to be used

Weather Derivatives: Products

- A typical product is a forward contract or an option on the cumulative CDD or HDD during a month
- Weather derivatives are often used by energy companies to hedge the volume of energy required for heating or cooling during a particular month