Practical info

- After this lecture, course attendance certificates/diplomas will be available
- More practical info given after lecture...

Info to (Norwegian) PhD students

- This PhD Winter School is one of many courses available from:
- National Research School in Business Economics and Administration (NFB)
- www.nhh.no/nfb
- Specializations: Accounting, Economics, Finance, Management Science, Marketing and International business, Strategy and Management
- Register on the website to receive info!

Real options in electricity markets

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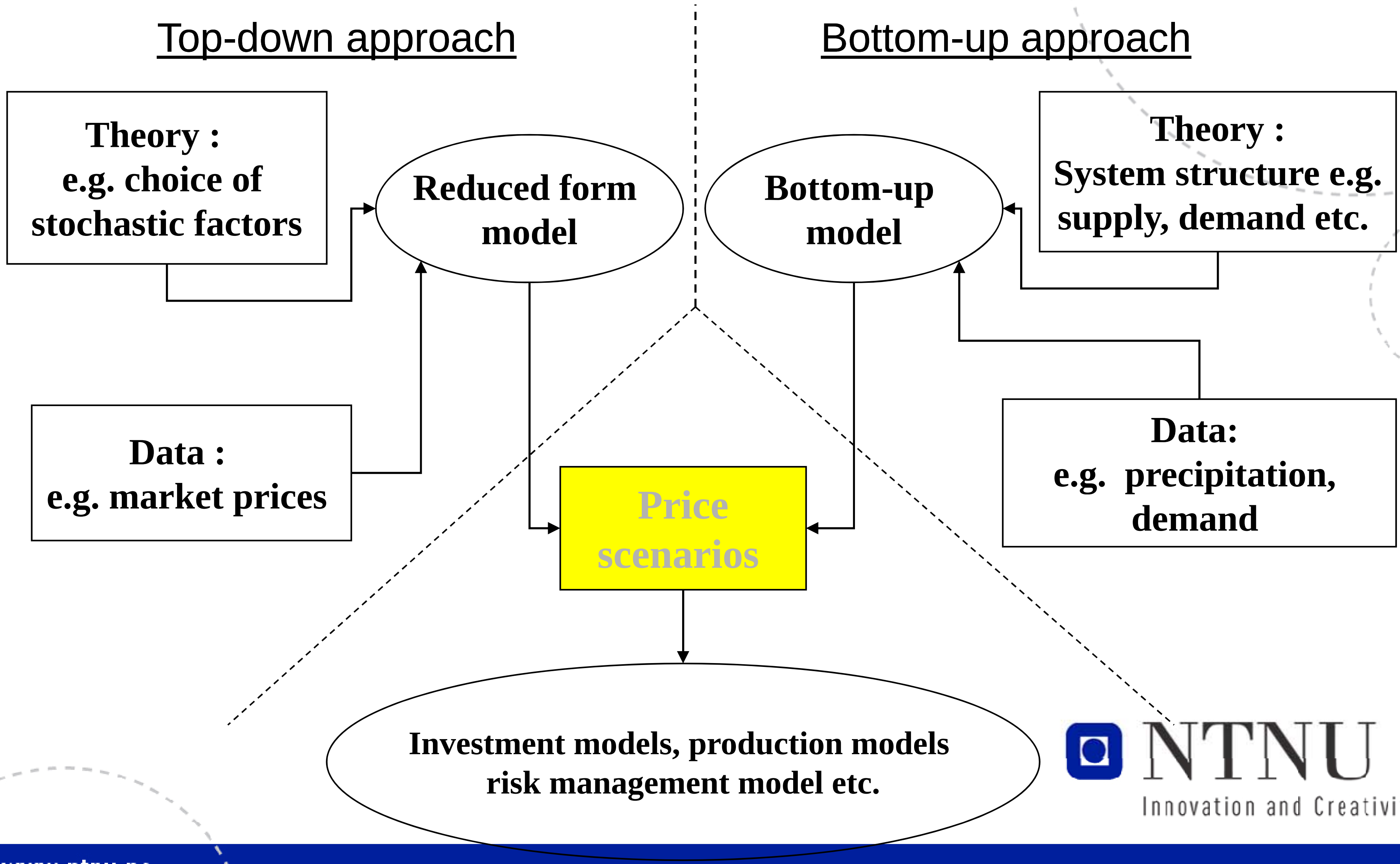
Outline

- Long-term electricity prices
- Choice of stochastic process for uncertainty
- Transmission expansion example

Existing approaches



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Market data

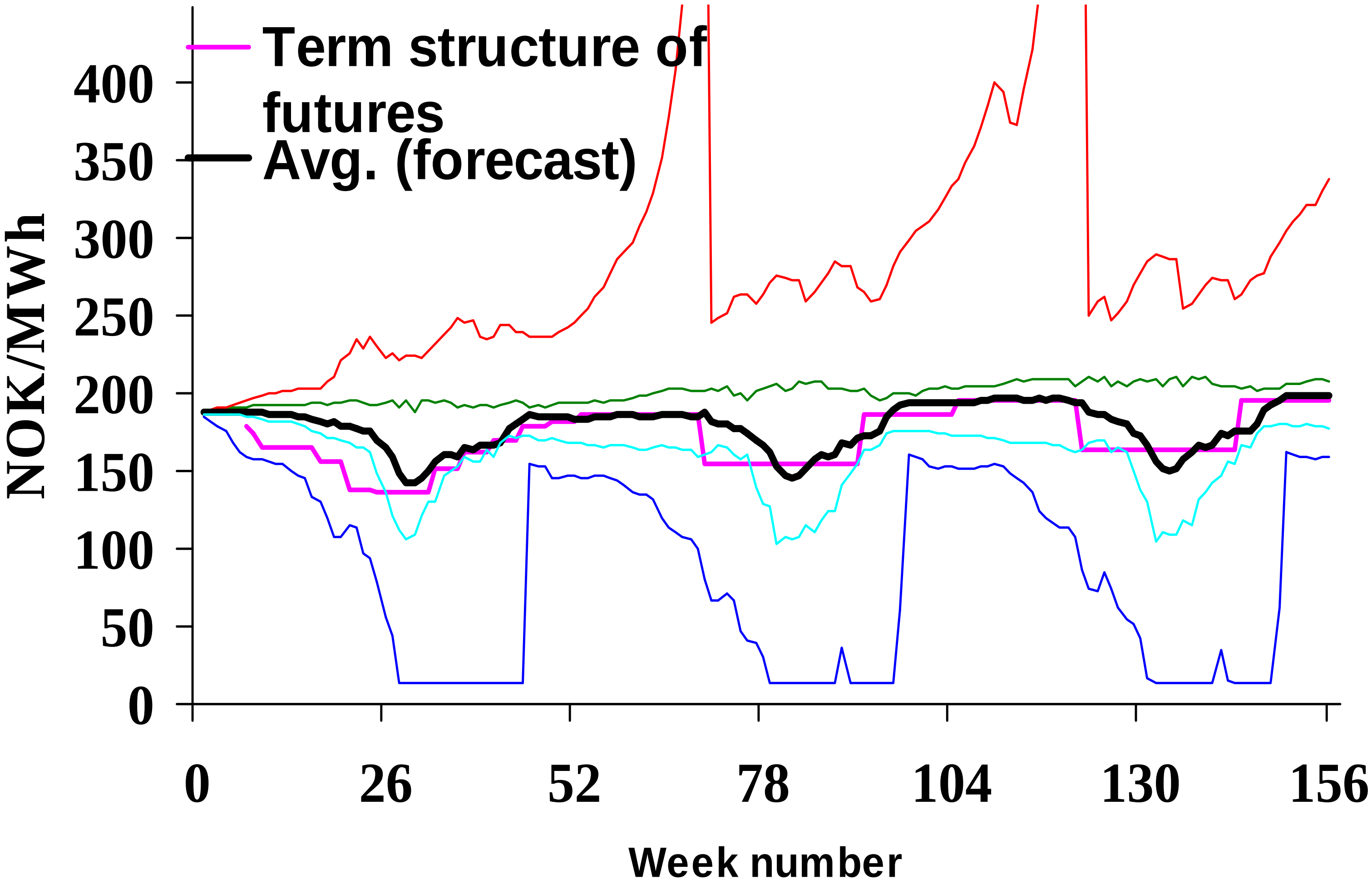
- Gives directly the current market value of future exchange of electricity
- Limited number of products (delivery/maturity dates) traded
- Low liquidity of some products
- Little long-term information

Bottom-up models

- Matching supply and demand to find prices
  - Wilmar, ELMOD, MPS, BALMOREL, MARKAL etc.
- Details of supply and demand, short and long term
- Expected spot prices <> value of future delivery

- Long horizons: Have to be able to forecast future investments, determinants of demand etc.

Example of bottom-up model output (MPS model)

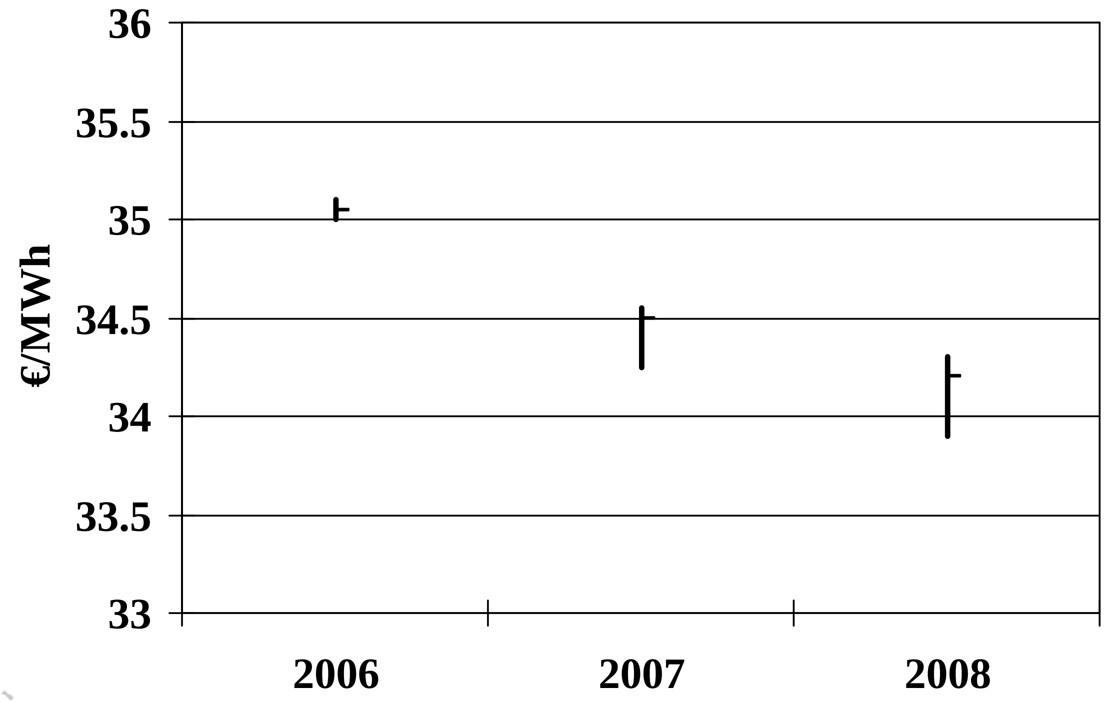


Electricity derivatives

- Forward: contract for delivery in a specified future time interval at an agreed price
- Futures: Same as forward, but changes in the contract price are settled daily
- Standardized
- Market’s informed consensus on future spot prices
  - adjusted for risk

Long term energy contracts

- Nord Pool: Year contracts for the next three years, after 1.1.2005 one listed ENOYR-08 (in €/MWh)
- Basesload prices 7 NOV 2005 (bid-ask and latest):



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What are the contracts use for?

- NB! A producer making investment decisions do not need to trade these contracts, only know the current price
  - Do not need perfect liquidity as long as one gets good price information, but good liquidity gives a smaller difference between buyer and seller price
- **The prices are the expected risk-adjusted value of future energy exchange**

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Power value = FWprice/$(1+r)^T$

- To have this power value locked in:
- Sell 1 MWh now f.ex. FWYR-12 to 49 €/MWh (disregards least contract size 1 MW)
  - No money change hands now!
- Loan 49/$(1+r)^T$ € to risk free interest rate r
- **This must be the power value**, since we in 2012 can deliver 1 MWh, receive the spot price, get payoff of 49 € minus spot price on the forward contract, use the 49 € we are left with to pay back the loan
  - Net cash flow Spot + (49 – Spot) – 49 = 0

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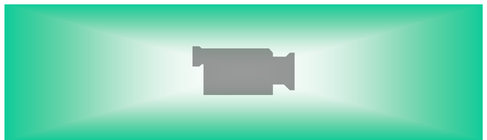
Uncertainty

- Long term price gives us exact value now, on future delivery
  - No uncertainty in value now
- Long term prices will change
  - Uncertainty about future values
- Spot prices, weather, external conditions etc. will still be uncertain
  - If the project can be altered/can react to development in such uncertain factors, this flexibility must be accounted for and valued
  - Deterministic analyses/tools (e.g. sensitivity analysis) will not do the job
- Long term prices are just as useful under uncertainty as when you know parts of the future



Forward curve estimate

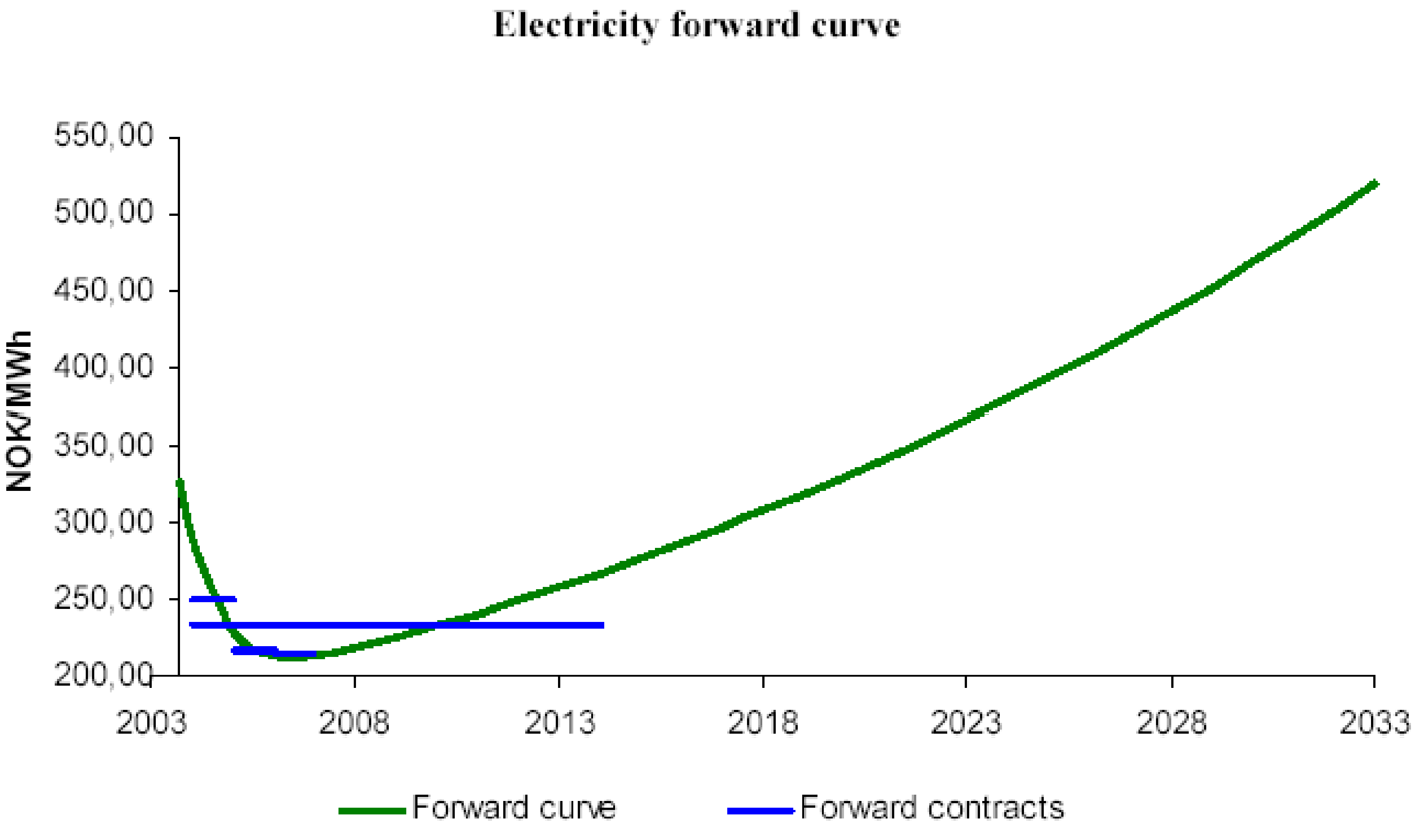


Figure 10: The figure shows the electricity forward curve on 12.09.2003. The forward curve prices all the contracts almost correctly.

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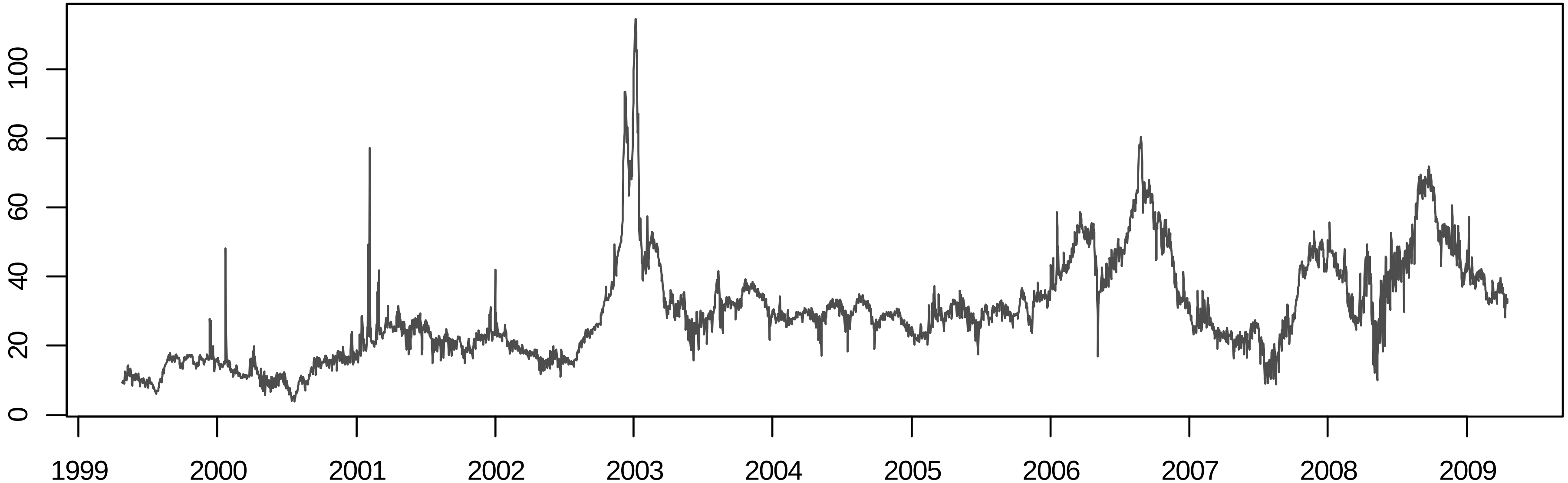
Choice of stochastic process

- Context: Real options modelling
- I.e. Irreversible investment under uncertainty
- Interested in the long-run dynamics of the underlying uncertain factors
- Good model: Simple, good fit with data and with theoretical properties

Daily spot price shows distinct characteristics



Seasonality

- Spot prices generally higher during winter

Spikes

- Both positive and negative
- Due to for example supply shortages or demand surplus

Mean reversion

- Mean reversion to long-run mean level
- Fast mean reversion of spikes

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Standard choice: GBM

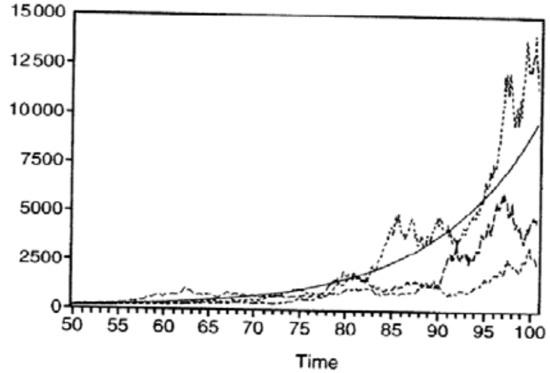

Figure 3.4. Sample Paths of Geometric Brownian Motion

- Geometric Brownian Motion: $dp = \alpha p dt + \sigma p dz$
- Price returns follow random walk
  - Any price change is persistent
- Assumes price nonstationary
- E.g. if prices are very high, it is equally likely they will continue up as going down
- Same with very low prices
- Not consistent with reasonable economic relationships

Standard alternative: Mean reverting process

- Simplest mean reverting process: Ornstein-Uhlenbeck Process: $dp = - \kappa p dt + \sigma dz$
- Prices are pulled toward the mean, here zero
  - Easy to generalize: e.g. reversion to a trend line
- No long-term uncertainty: there are no news that can bring this process onto a different expected level from here on
  - ”Long-term” must be seen in relation to the size of κ: A very slow mean reversion is close to a random walk, and in this case the effect of a piece of price-affecting news will only die slowly

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Lessons from oil/coal/natural gas

- Pindyck (1999), with data 1870-1996
- Energy prices follow trend reverting processes where the trends vary stochastically (trend line -> long-run marginal cost)
- A Geometric Brownian Motion ”is unlikely to lead to large errors in the optimal investment rule”

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Long-term-short-term model

- Pilipovic (1997), Schwartz & Smith (2000)
- (log of) spot prices is a sum of two factors:
- First factor is mean reverting
- Second factor is brownian motion

$$S(t) = \chi(t) + \xi(t)$$
$$d\chi(t) = -\kappa\chi(t)dt + \sigma_\chi dB_\chi(t)$$
$$d\xi(t) = \mu_\xi dt + \sigma_\xi dB_\xi(t)$$

- Has both mean reversion and long-term uncertainty
- But it is nonstationary, meaning the long-term factor can cause the price to become very high (or low)
- For real assets (long-lived) the dynamics of the long-term factor dominates
- This model is richer than a simple GBM, but still has limited richness
- Can add jumps, possibly spikes
  - Get increased richness, but many parameters

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Choice of process, conclusion

- Top-down vs bottom-up
- No model is ”right”
- Your model should be suitable in your application

An energy infrastructure investment under uncertainty

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References

- R S Pindyck (1999), The long-run evolution of energy prices, The Energy Journal 20(2),1-27