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Transmission Investment under Uncertainty: The Case of Germany-Norway

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Background

- Large price differences between Norway (Nord Pool) and Germany (EEX)
- Initiative by four producers in Germany and Norway
  - Merchant transmission investment (Joskow and Tirole 2005)
  - 570 km HVDC link
  - "NorGer"
  - Base case: 700 MW, alternative/upgrade option to 1400 MW

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Two fundamentally different power systems

Norway:

- dominated by hydropower
- almost 100 % of the entire production
- dry or wet years strongly influence the generation capacity

Germany:

- mix of different generations:
  - thermal power
  - nuclear power
- increasing share of wind power

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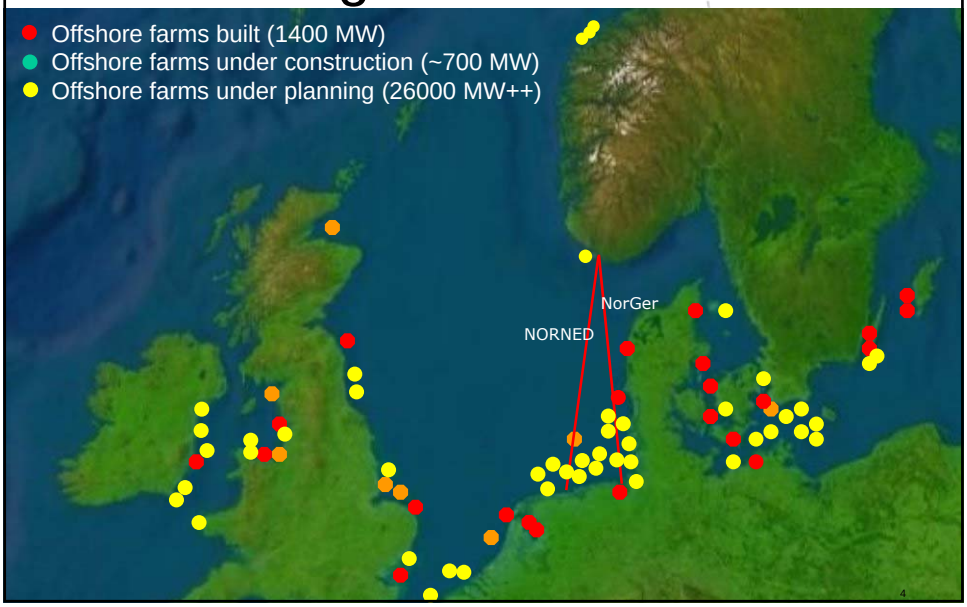
Connecting renewables



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Methodology

- Deng, Johnson and Sogomonian (2001)
- Copeland and Antikarov (2001)
  - Build MC simulators for 700 MW and 1400 MW static net present values
  - Estimate NPV volatility and invoke Samuelson's (1965) hypothesis, so PV can be assumed to have random walk properties
  - Estimate NPV(1400MW) as a constant times NPV(700MW)

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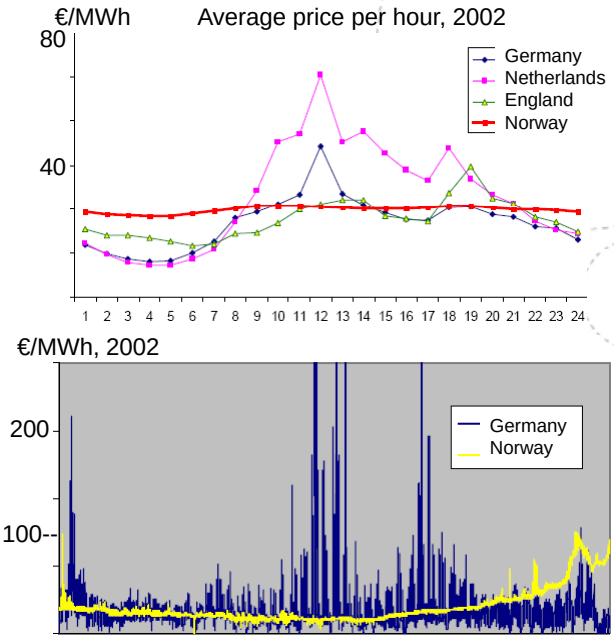
Data

- Spot price data from 2000
- Bottom-up-model analysis of what happens to price differences with new cable
  - Thanks to SINTEF/B. Grinden
  - Less than 9% smaller price difference (700 MW)



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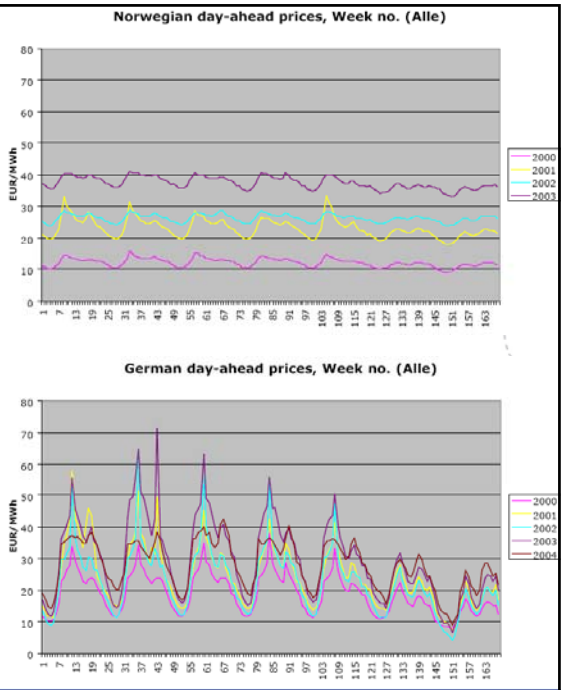
Over week

- Norway: Mainly a annual level effect
- Germany: Within-week effect



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Price/system effects of new cable

- A new cable will to some extent crowd out trade on the other cables to Sweden, Denmark, Netherlands
- Annual Norwegian price variations smaller
- Within-day/week price differences in Norway up
- Average prices in Norway up
  - Even though price reduction in dry years probably greater than price increase in wet years
- Lower volatility and higher prices in Norway
  - More investments
- Need a bottom-up model to realize and quantify this!

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Step 1:
Build Present Value model. Goal; find volatility and drift parameter for Real Options Valuation (ROV)

Step 2:
Build and solve Real Options model. (700 MW with compound option and 1400 MW)

Step 3:
Find optimal timing for building transmission capacity

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Assumptions
- Present Value

- Model Norway-Germany price difference directly
- Hourly time resolution
- No loss due to ramping
- Lifetime of cable: 40 years
- Stochastic parameters; electricity prices and exchange rate
- Goal: find volatility and drift parameters for ROV

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Technical parameters

Parameter	Parameter value
Capacity 1 (cap_{700})	700 MW
Capacity 2 (cap_{1400})	1400 MW
Investment cost 700 MW (k_1)	€ 819 mill
Investment cost 1400 MW (k_2)	€ 1.276 mill
Annual cost, 700 MW (ac_{700})	€ 4.3 mill [a]
Annual cost, 1400 MW (ac_{1400})	€ 8.7 mill [b]
Availability (av)	97.4 %
Loss	5%
Price reduction, 700 MW (red_{700})	8.4%
Price reduction, 1400 MW (red_{1400})	16.8%

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Electricity price process

- The parameters for the price processes are found using historical price data (OLS).
- The electricity price process consists of three parts
  1. Deterministic seasonality
     - Hour
     - Weekday
     - Month
  2. Stochastic annual price level
  3. Stochastic residuals

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Assumptions - Real Options Valuation

- Development of project value follows geometric Brownian motion (GBM) (Copeland & Antikarov 2001)
  - Hence annual revenue follows GBM
- The 700 MW cable can be upgraded to 1400 MW by paying the 700 MW investment cost
- The PV of the 1400 MW cable is a function of the PV of the 700 MW cable

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Results from present value simulator

- σ = 30%,
- α= 0%,
- ρ = 7%

- We assume present value/annual merchant revenues are GBM
- Discussion: Is GBM reasonable?
- It is a present value, so like an asset
- Samuelson (1965): Assets in efficient markets follow random walk
- Here, PV does not go negative
- On the other hand, Kanniainen (2009) shows that present values seldom have constant drift/volatility

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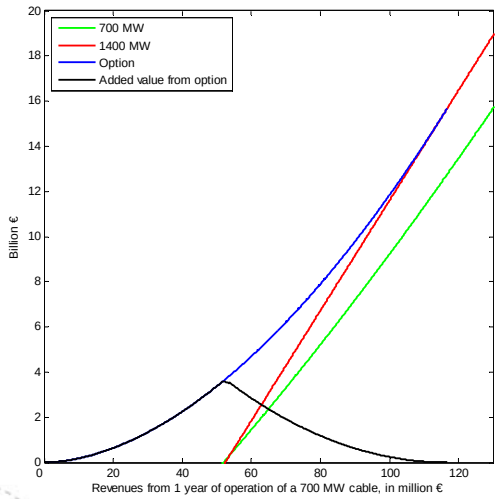
Switching option



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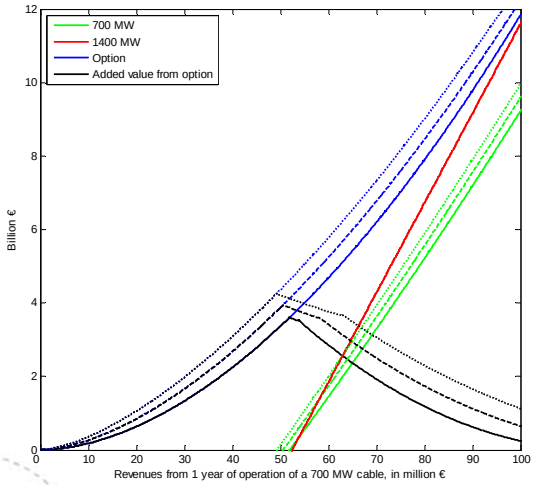
Effect of increased volatility



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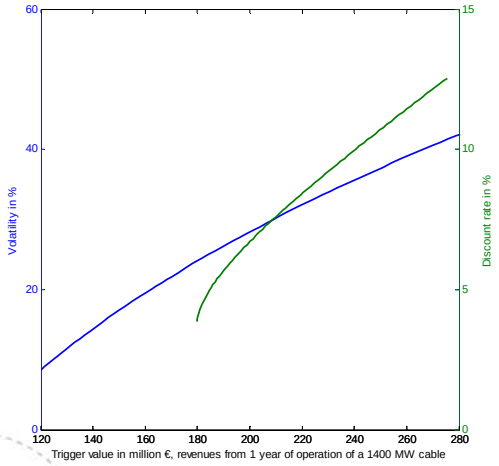
Investment trigger as function of discount rate and volatility



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Discussion

- Exclusive right to invest assumption
  - Statnett (National grid company and system operator!) with E.ON Netz has a competing project, almost identical
- Northern Germany is a surplus area – new internal German transmission needed?

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Conclusions

- Case of investment in transmission cable
- NorGer is profitable

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Questions?

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