Investments in natural gas networks under stochastic electricity and gas demand

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Introduction

- Often gas fields are at a distance to major gas demand hubs
- Building natural gas pipelines is very costly
- We analyze investments in gas fired power plants as an alternative to pipeline investments

Value of Flexibility

- Commodity prices are defined by supply and demand
  - There is high uncertainty regarding the future price levels
- Sensitivity analysis of deterministic models do not consider the stochastic nature of commodity prices
  - We use stochastic price processes
- For example, gas fired power plant investment in stages
  - Upgradeable base load plant
  - Peak load plant

Commodity prices

• We model electricity and gas demand with geometric Brownian motion

$$dX(t) = \mu X(t)dt + \sigma X(t)dB(t)$$

• The commodity prices are given with inverse demand function

$$P(Q,X) = X(t) \cdot a \cdot \left(Q(t)\right)^{-\frac{1}{\varepsilon}}$$

• $Q(t)$ is the total output to the market

• $\varepsilon > 1$ is the price elasticity

Optimal Production

- At time *t*, earnings from a gas plant are

$$C_P(t) = P_P(t)Q_P(t) = \frac{X_e(t)a_P\left(Q_P(t)\right)^{1-\frac{1}{\varepsilon_P}}}{K_S} - E(t)Q_P(t)$$

- The function is concave and thus optimal electricity production is given by the first order condition of optimality

$$Q_P(t) = \min\left(\left(\frac{\left(1-1/\varepsilon_e\right)X_e a_e}{E(t)K_S}\right)^{\varepsilon_e}, Q_P^{\max}\right)$$

- Similarly, the optimal output to a gas market

$$Q_T(t) = \min\left(\left(\frac{\left(1-1/\varepsilon_g\right)X_g a_g}{T(t)}\right)^{\varepsilon_g}, Q_T^{\max}\right)$$

The plant and pipeline values

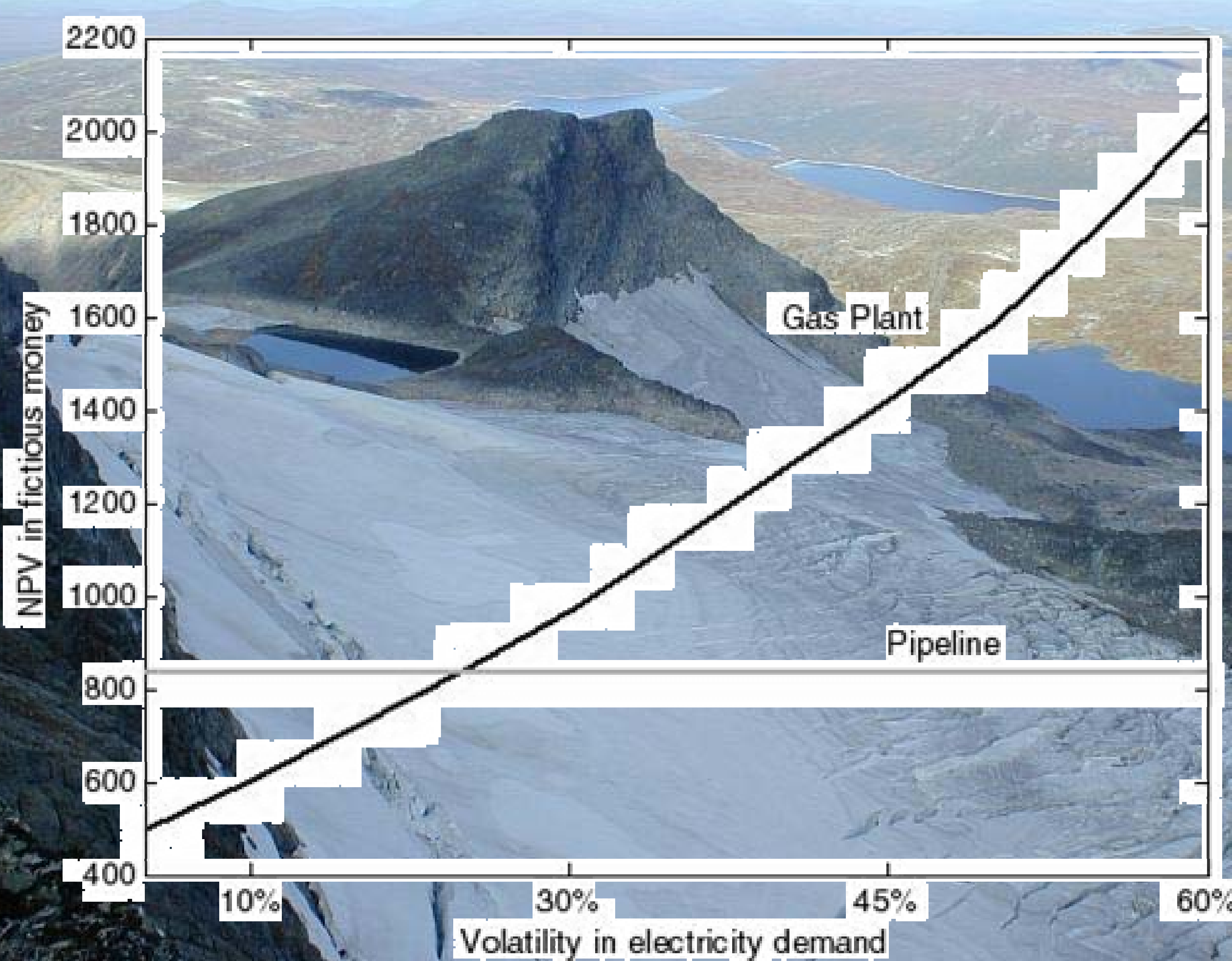
- NPV value of a gas fired power plant

$$V_P(0) = E\left[\int_{T_B^P}^{T_B^P + T_L^P} e^{-rs} P_P(s) Q_P(s) ds \mid F_0 \right] - I_P$$

- NPV value of a transmission line connecting a deposit to a gas market

$$V_T(0) = E\left[\int_{T_B^T}^{T_B^T + T_L^T} e^{-rs} P_T(s) Q_T(s) ds \mid F_0 \right] - I_T$$

Fictious example



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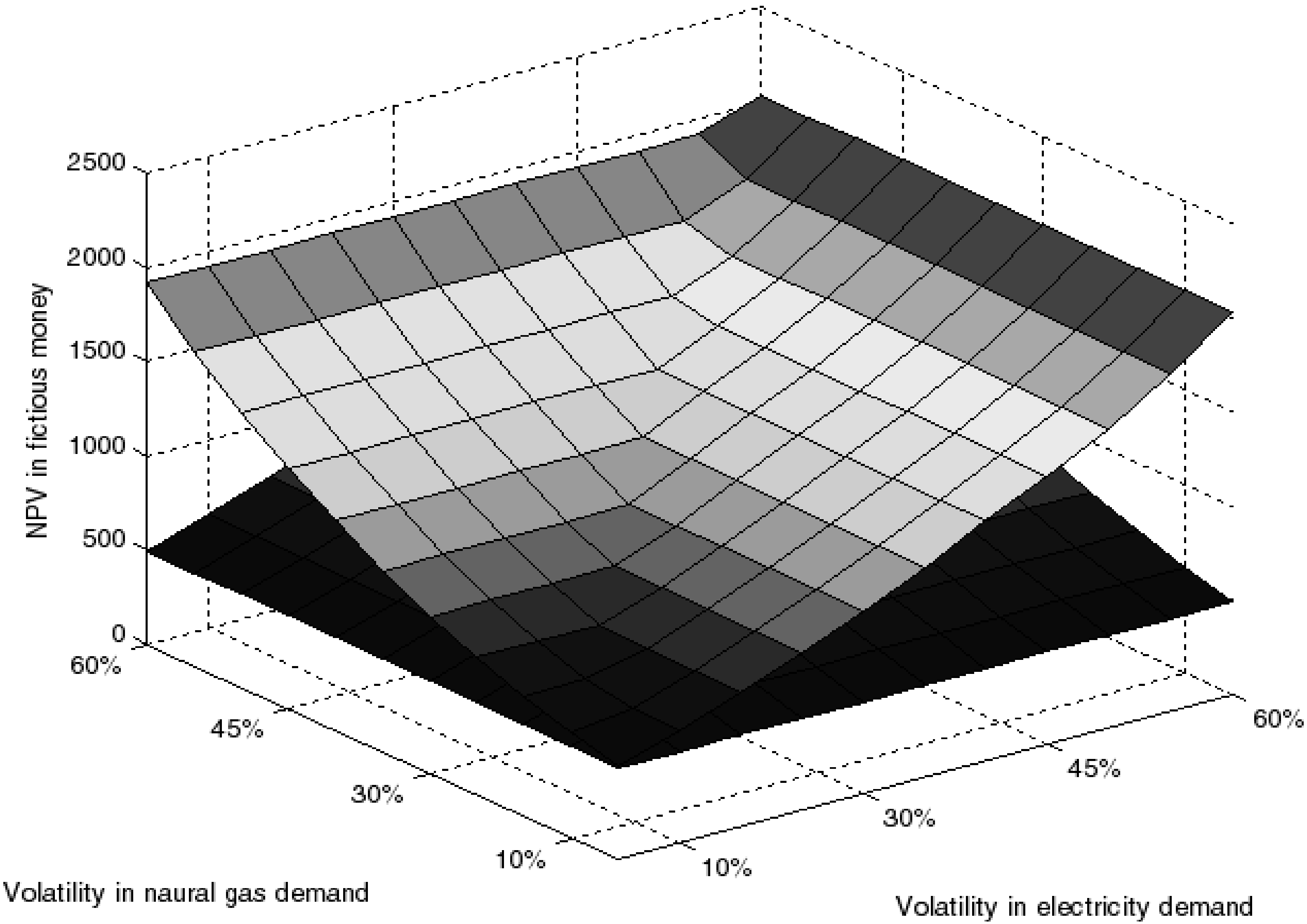

Extensions

- Taking competing gas providers into account
  - Complete information -> Deterministic excess supply function
  - Incomplete information -> Stochastic excess supply function