Adding flexibility in a natural gas transportation network using interruptible transportation services

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Outline

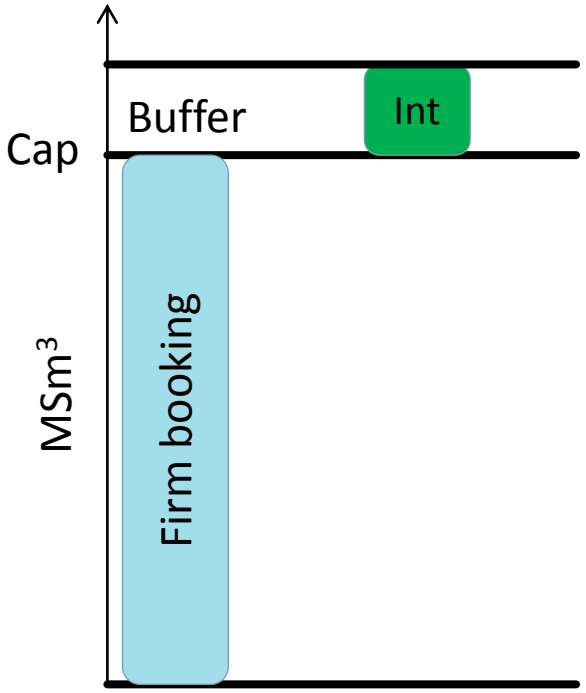
- Motivation
- Model description
- Data
- Results

Motivation

- Increase the total throughput in a natural gas transportation system while maintaining a high level of security of supply
- The TSO (Transportation System Operator) sells firm transportation capacity, but meets uncertainty when operating the system
  - Trade-off between capacity utilization and security-of-supply
- Uncertainties
  - Network capacities due to events (outages, etc)
  - Demand pattern
- Flexibility available to the TSO
  - Rerouting
  - Turn-up
  - Storage in pipelines

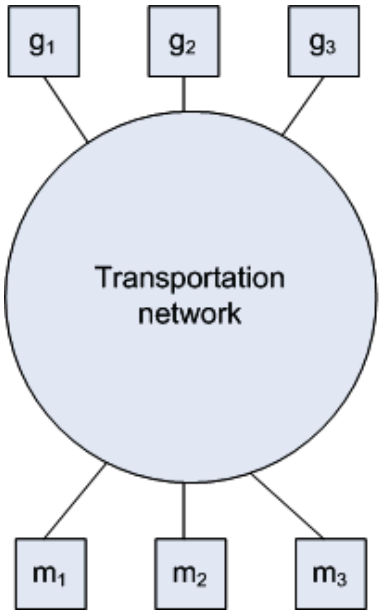
Definitions

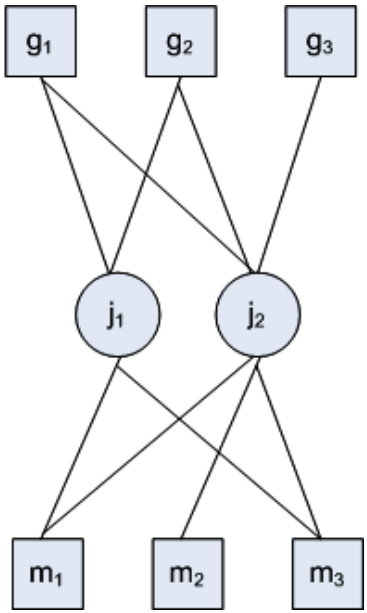
- **Booking points** are points in the network where producers (=shippers) need to buy transportation capacity to send gas through
- **Firm** contracts give transportation capacity with a certain level of security-of-supply
- **Interruptible** contracts give transportation capacity that the TSO can freely interrupt (not deliver)
  - Interruption is not compensated
  - Tariff is 50% of firm contract tariff
  - The TSO will prioritize the firm capacity
  - The TSO will minimize the required interruption in the system



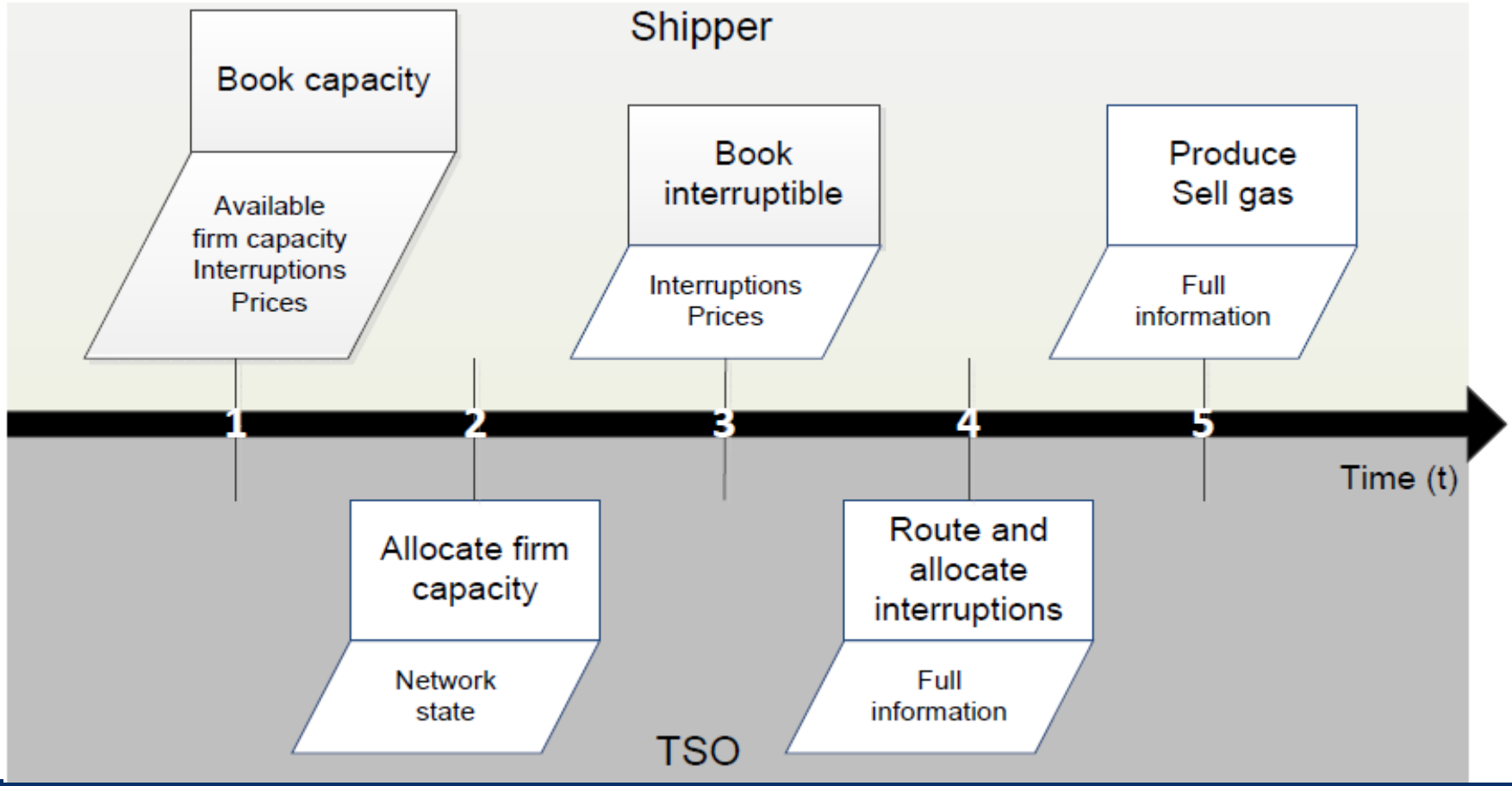
Model assumptions

- Both the shipper and the TSO has the same insight in the likelihood for events in the system
- The shipper does not have insight in the network topology except for the booking points
- The TSO does not have insight in production cost functions and gas market prices
- We aggregate all shippers to one decision maker
  - This avoids a game situation between the shippers
- Uncertain prices in the downstream gas markets
  - No price elasticity
  - No contracted sales

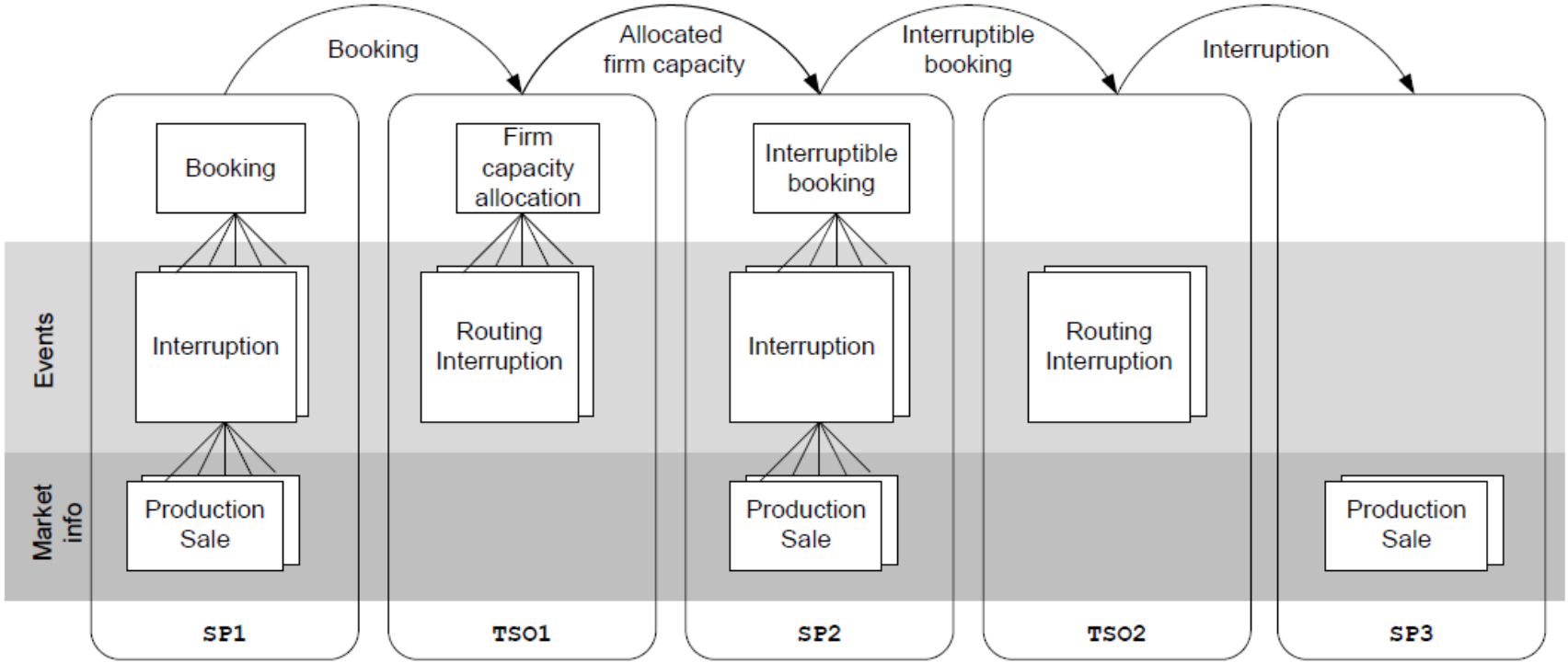




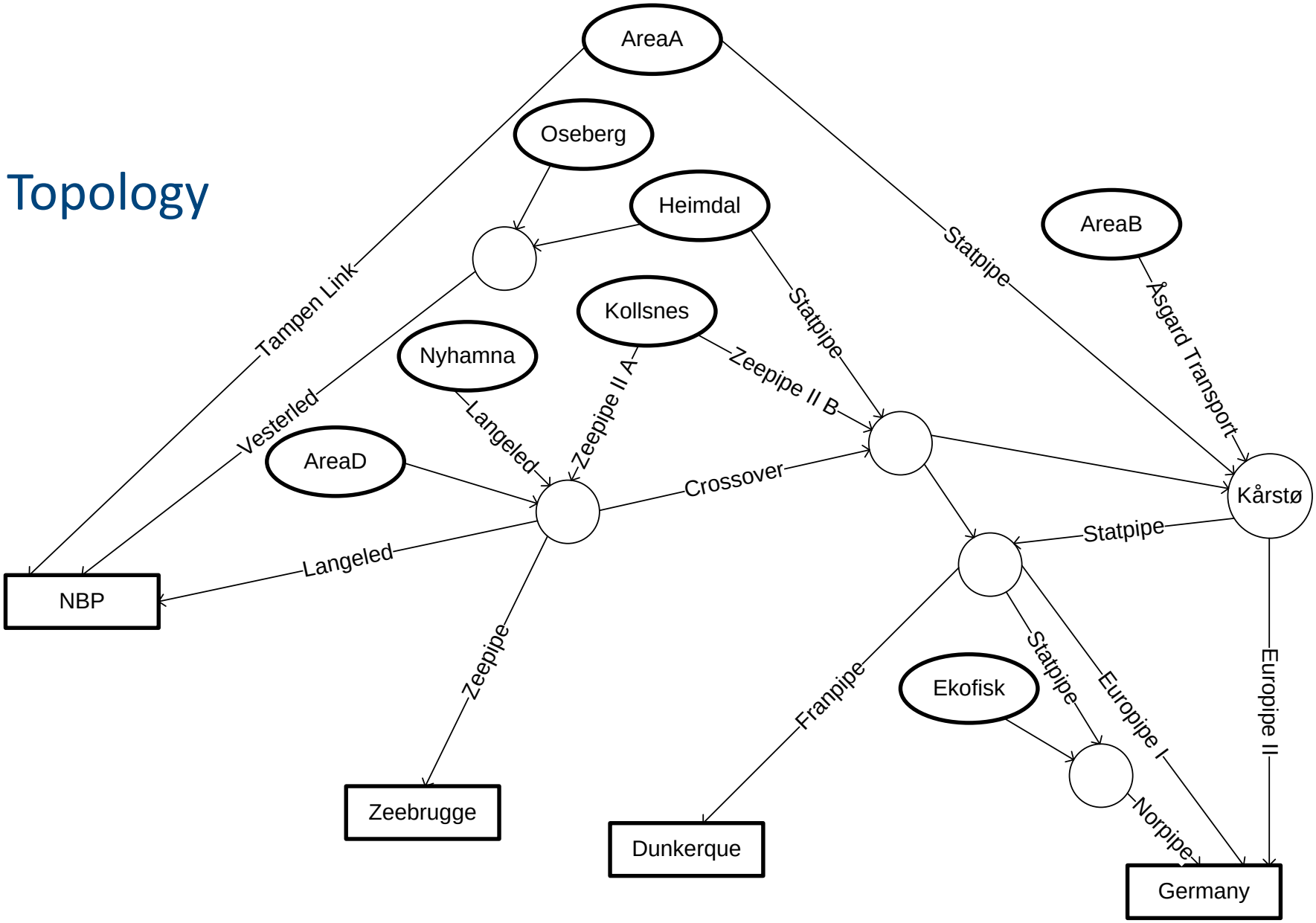
Decision sequence



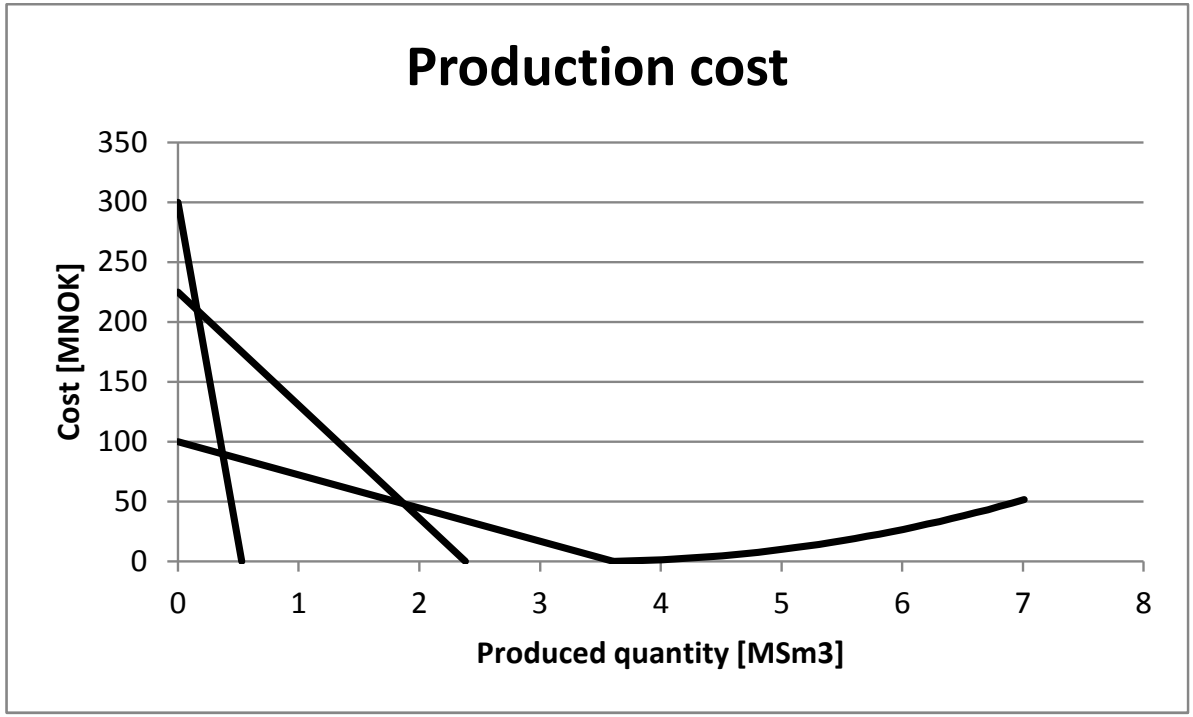
Connection between the models



Topology

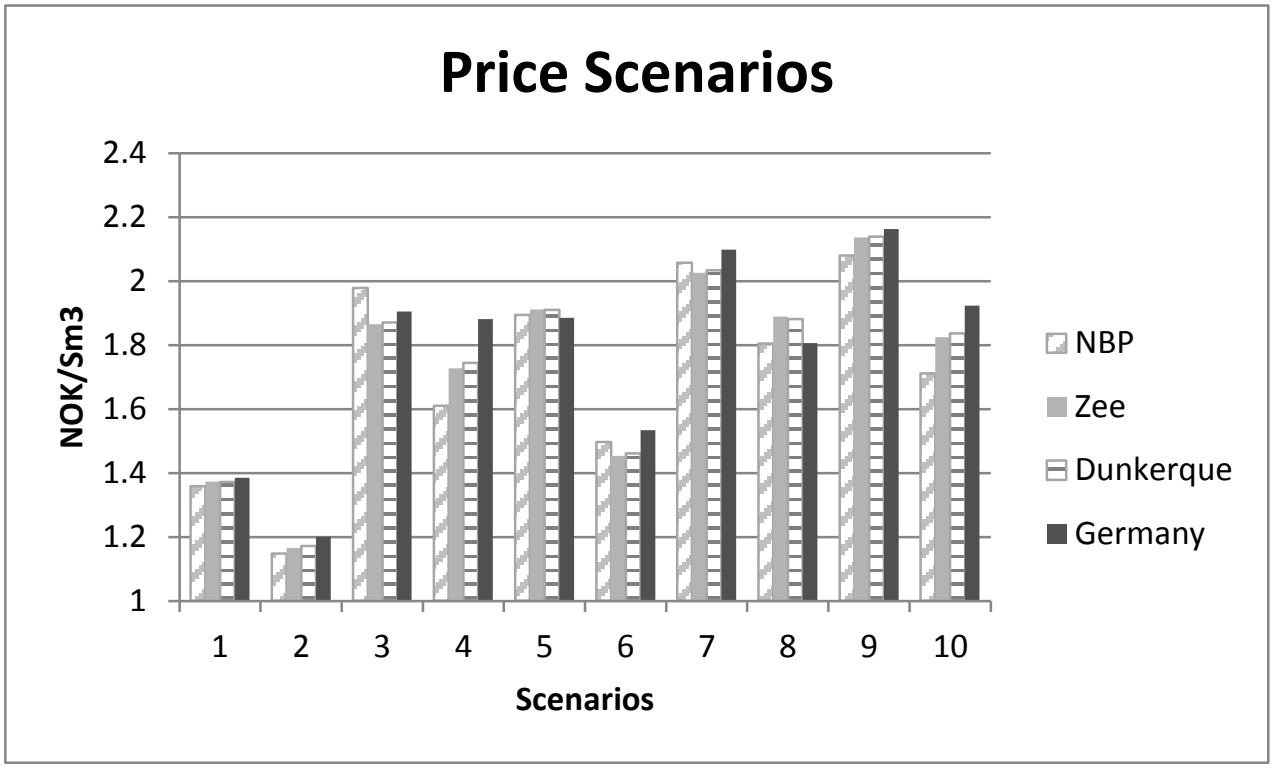

AreaA
Oseberg
Heimdal
AreaB
Statpipe
Tampen Link
Kollsnes
Nyhamna
Statpipe
Åsgard Transport
Vesterled
Zeepipe II A
Zeepipe II B
AreaD
Langeled
Crossover
Kårstø
Statpipe
Langeled
NBP
Zeepipe
Franpipe
Ekofisk
Statpipe
Europipe I
Europipe II
Norpipe
Zeebrugge
Dunkerque
Germany

Production cost



- Gas-to-oil ratios from Facts 2011
- Swing production cost from Kon-Kraft 2003 and Golombek et al. 1998

Gas price scenarios



- Mean, variance, skewness, kurtosis and corralations from 2010/2011 prices in NBP, Zeebrugge, GasPool and NetConnect
- Dunkerque price: 10% GasPool and 90% Zeebrugge

Events

- Synthetic data
- Individual events only
- An event causes capacity reduction
- Events in fields, landing points and the processing plants Kollsnes and Kårstø
- The probabilities are calibrated such that the availability corresponds to the average availability figures reported by Gassco (annual reports)

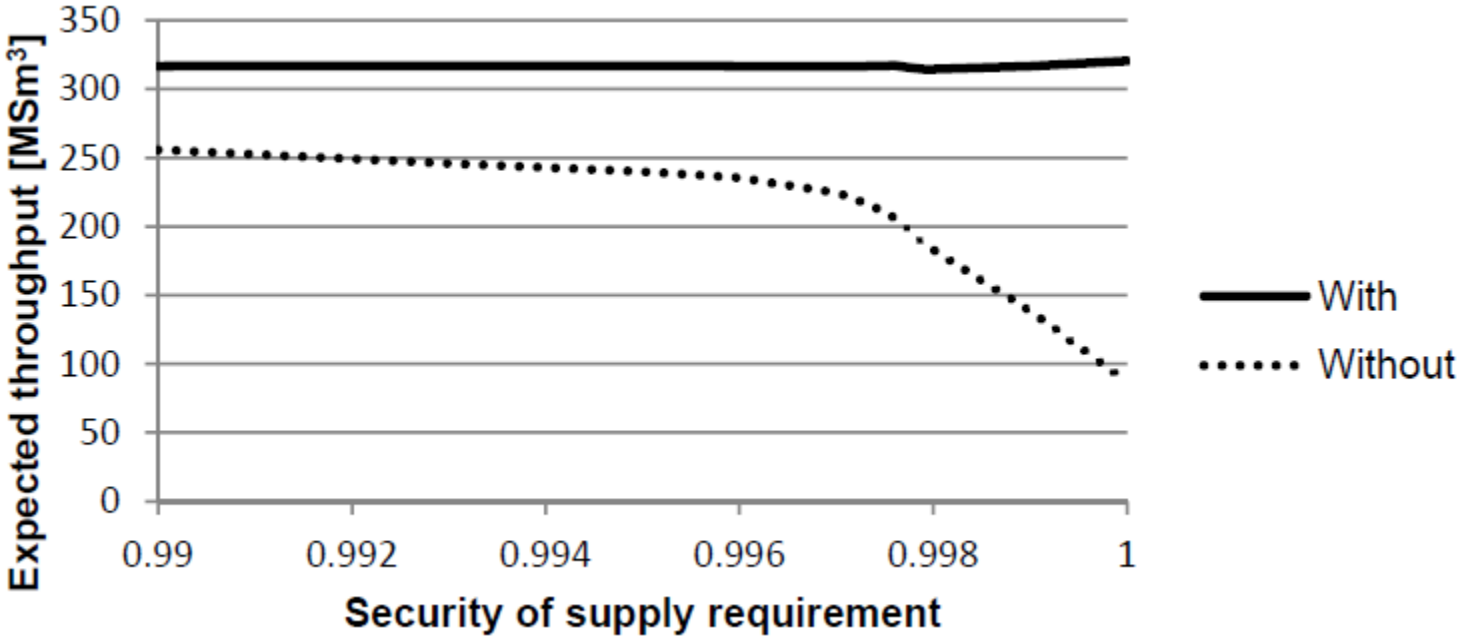
Scenario	Node	Prob	Cap reduction
0	No event	0.631	0 %
1	NBP	0.001	35 %
2	Zeebrugge	0.001	35 %
3	Dunkerque	0.001	35 %
4	Germany	0.001	35 %
5	AreaD	0.007	50 %
6	Nyhamna	0.004	75 %
7	Heimdal	0.007	50 %
8	Oseberg	0.005	70 %
9	AreaA	0.011	30 %
10	AreaB	0.013	25 %
11	Ekofisk	0.003	100 %
12	Kollsnes	0.069	25 %
13	Kollsnes	0.020	50 %
14	Kollsnes	0.010	75 %
15	Kollsnes	0.001	100 %
16	Kårstø	0.076	25 %
17	Kårstø	0.020	50 %
18	Kårstø	0.010	75 %
19	Kårstø	0.001	100 %

Tests

- Comparison with a benchmark
  - No interruptible booking

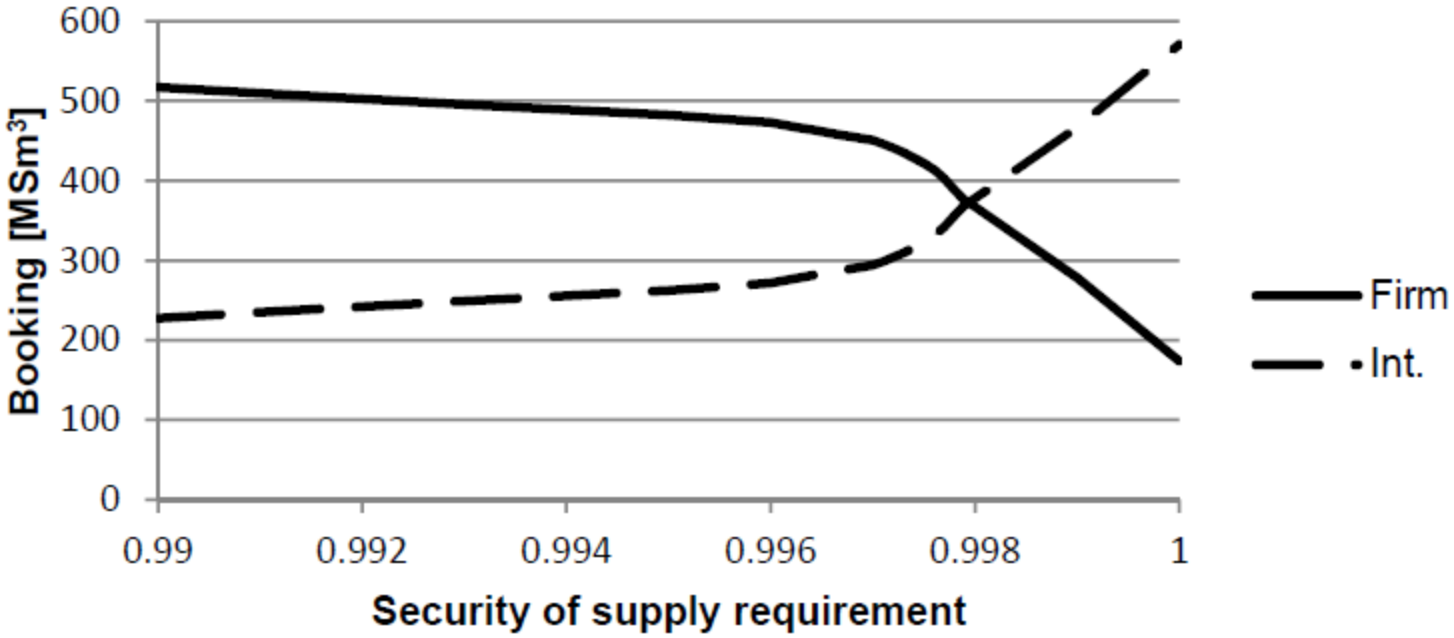
- Sensitivity:
  - Different requirements for the security-of-supply level for the firm capacity

Expected throughput



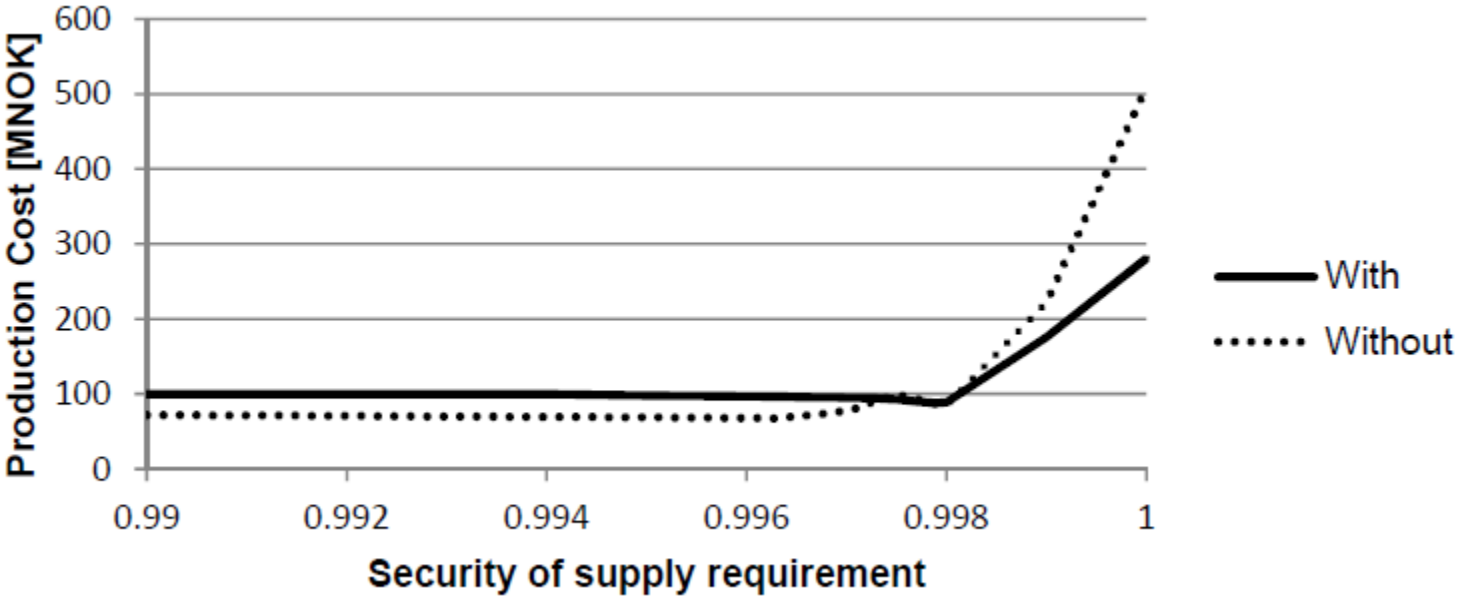
- 25-250% increased throughput compared to the benchmark
- Similar pattern for income, 13-274% increase

Total booking



- Unbalanced booking is valueable, books (and pays) for 90 MSm^3 additional entry capacity
- Reduced firm booking without interruptible is due to the balance requirement

Production cost



- The steep part of the realized production cost comes from lost oil income

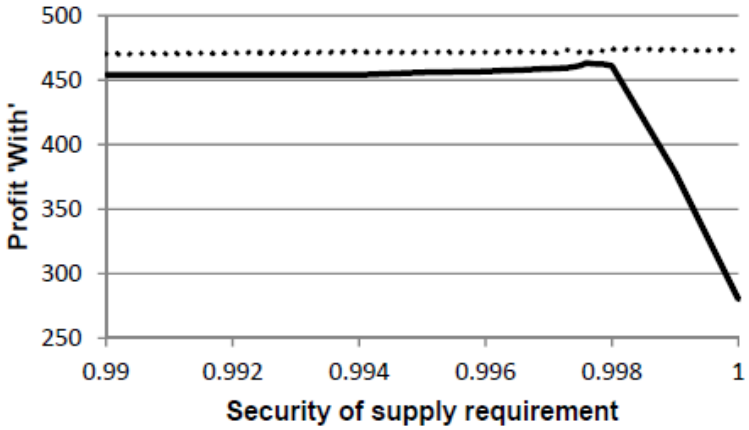
Different objectives

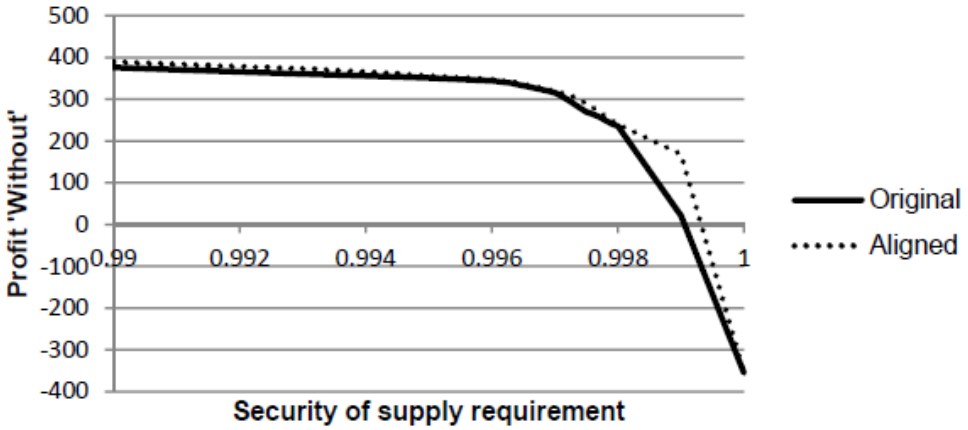
- TSO objective
  - Firm allocation: Min square deviation from firm nomination
  - Interruption and routing: Min tariff-weighted square interruption
- Producer objective: Max expected profit

- Lack mechanism to align the objectives
  - TSO might e.g. give priority to swing production rather than must-take production

- Tested alternative TSO models
  - Objective: Max social surplus (=producer surplus)
  - Allow interruption to exceed minimum interruptible level if that is most profitable

Profit increase with alternative TSO modelling





Conclusion

- The flexibility inherent in interruptible contracts can improve the utilization of a gas network with events
  - Security-of-supply requirements for firm contracts crucial for the size of this improvement
- The ability to book unbalanced (entry vs exit) can be valueable
- System "loss" can be experienced if producer and TSO have incoherent objectives
  - Design of TSO allocation principles and possibility for producers to send priority signals influences system performance