Insuring Unit Failures in Electricity Markets

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OUTLINE

- Introduction
- Model
- Case study
- Conclusions

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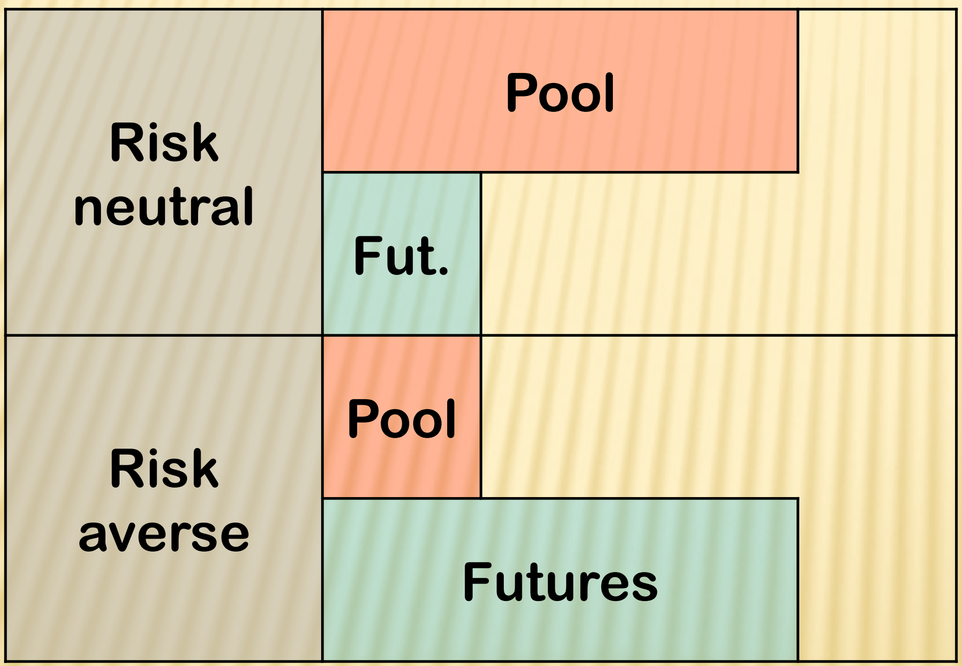
- Conclusions

INTRODUCTION

Pool market
(price volatility)

Futures market
(fixed price)

INTRODUCTION



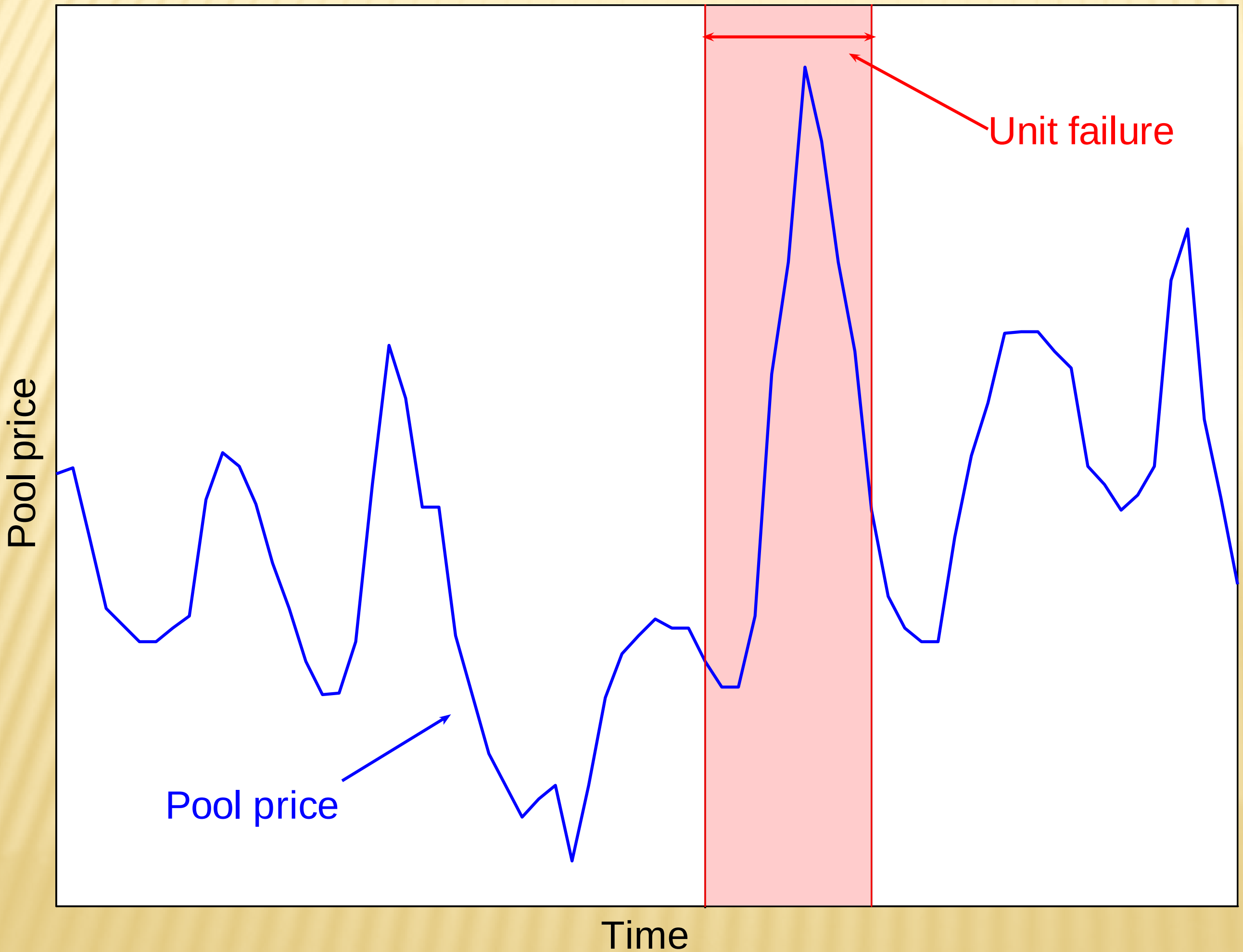
INTRODUCTION

Pool market
(price volatility)

Futures market
(fixed price)

Production unit

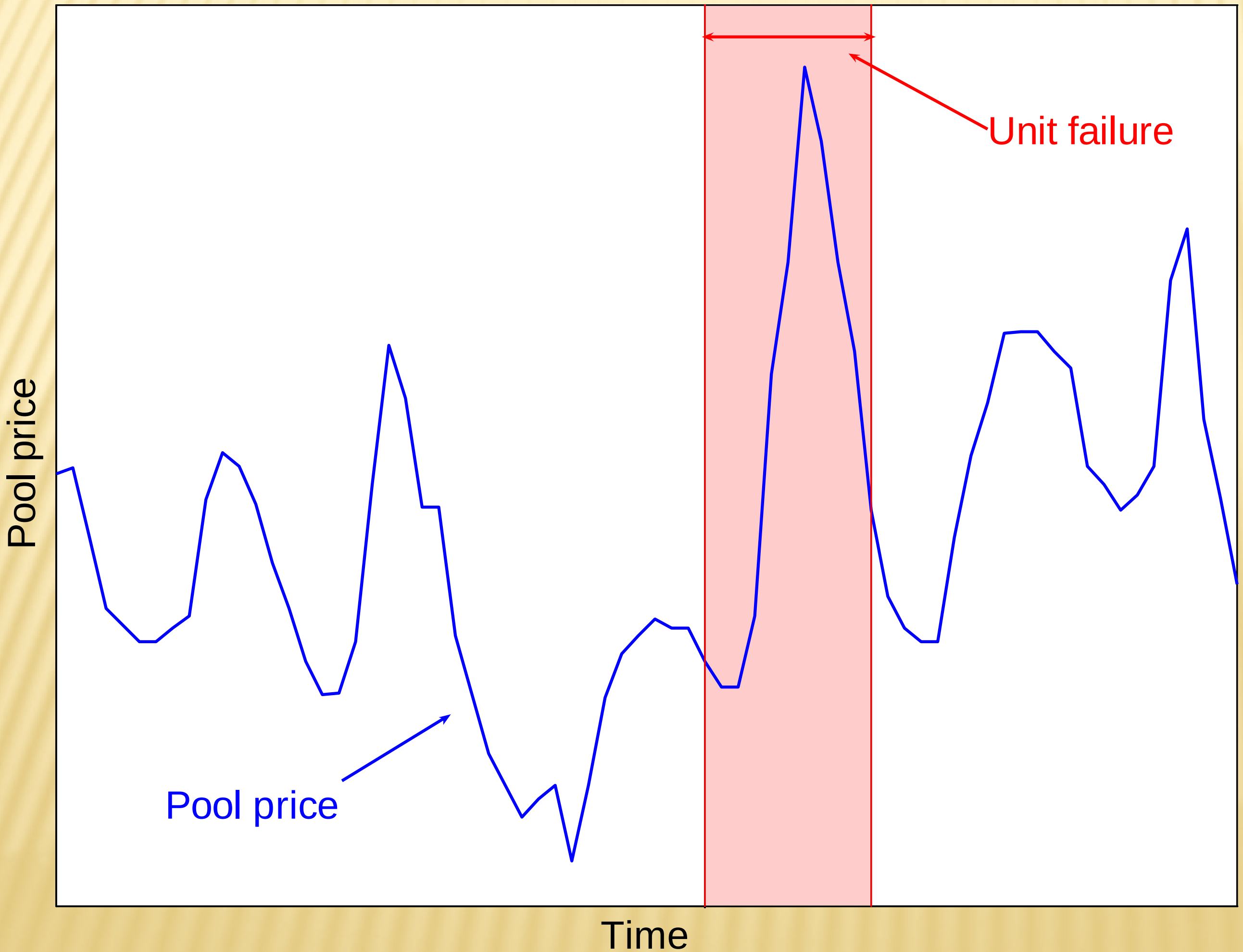
INTRODUCTION



INTRODUCTION

	Failures neglected	Failures considered
Risk neutral	Pool Fut.	Pool
Risk averse	Pool Futures	Pool Futures

INTRODUCTION



INTRODUCTION

Swiss Re New Markets and Mirant Offer Generator Forced Outage Insurance Product.

Swiss Re's Electricity Price and Outage Protection (ELPRO) is a dual-trigger solution which protects against volume and market price by financially firming up generation whenever:

- Generating units suffer unplanned outages, and
- Electricity price exceeds a pre-agreed strike price.

INTRODUCTION

Sources of uncertainty		Forward contracts	Insurance policy
Pool prices	Unit availability		

INTRODUCTION

Sources of uncertainty

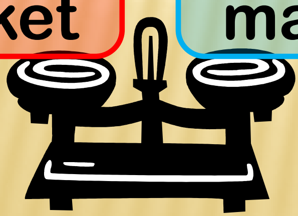
Pool prices | Unit availability

Forward contracts

Insurance policy

Pool market

Futures market



Insurance ?

INTRODUCTION

Sources of uncertainty

Pool prices

Unit availability

Forward contracts

Insurance policy

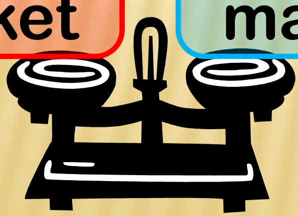
Scenario tree

Stochastic programming

Risk aversion

Pool market

Futures market



Insurance ?

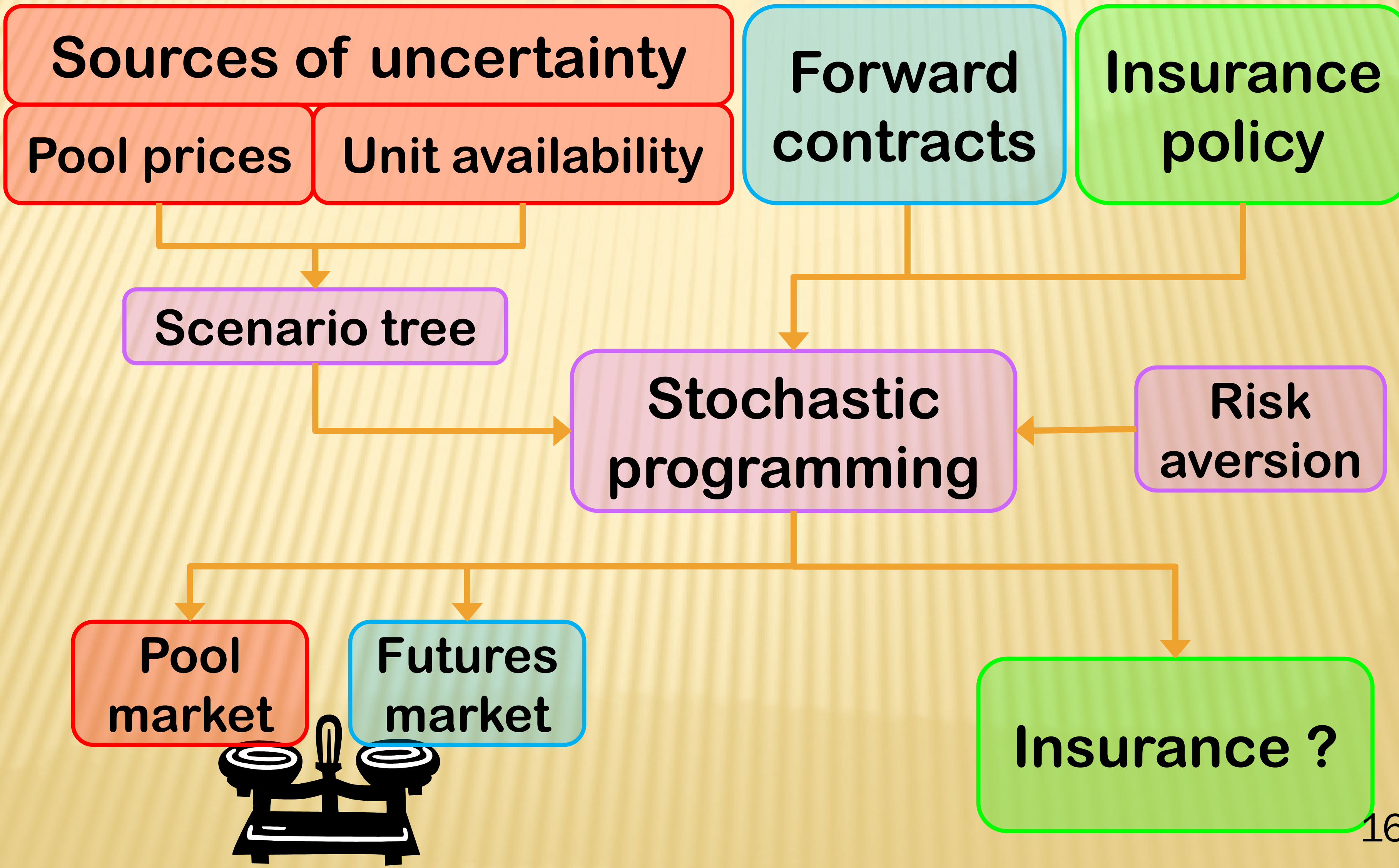
AIM

Analyze the effect of an insurance contract on the decisions of a power producer

OUTLINE

- Introduction
- **Model**
- Case study
- Conclusions

MODEL



Sources of uncertainty
Pool prices
Unit availability
Forward contracts
Insurance policy
Scenario tree
Stochastic programming
Risk aversion
Pool market
Futures market
Insurance ?

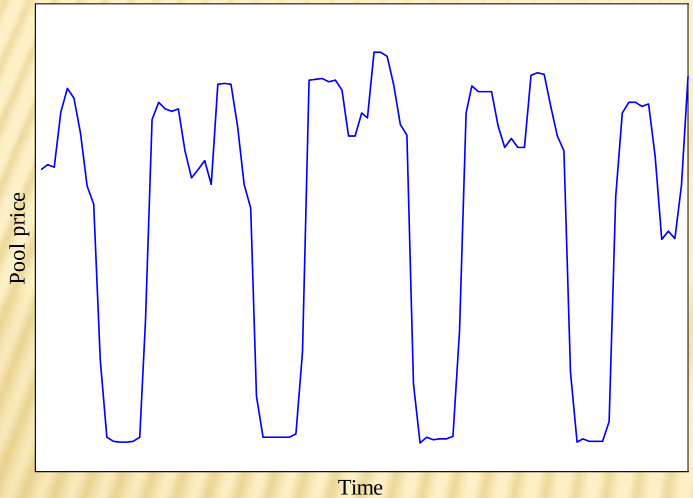
MODEL

Pool prices

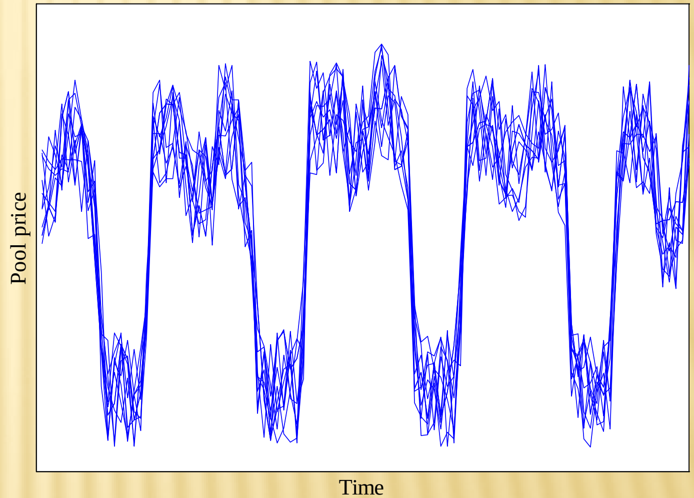
MODEL

Pool prices

Historical data



Pool price scenarios



ARIMA model

informs

MODEL

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Sources of uncertainty

Pool prices

Unit availability

Forward contracts

Insurance policy

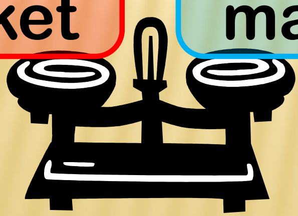
Scenario tree

Stochastic programming

Risk aversion

Pool market

Futures market



Insurance ?

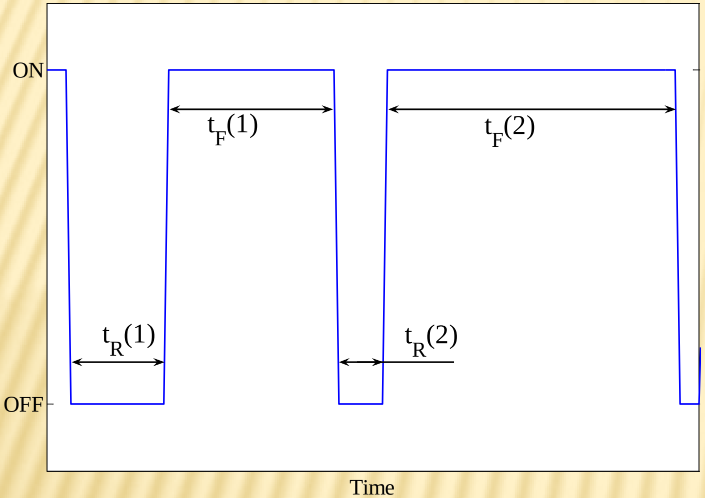
MODEL

Unit availability

MODEL

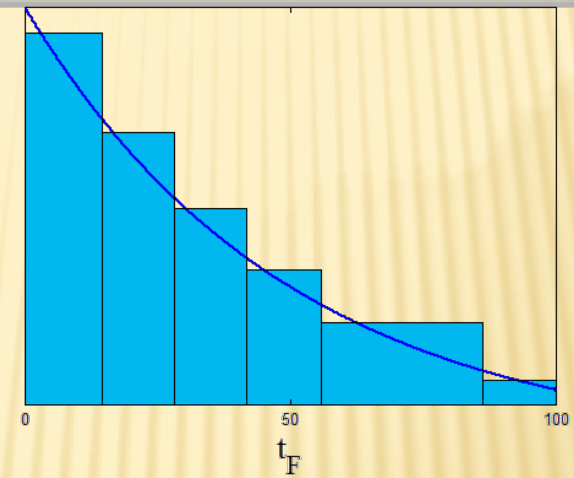
Unit availability

Historical data



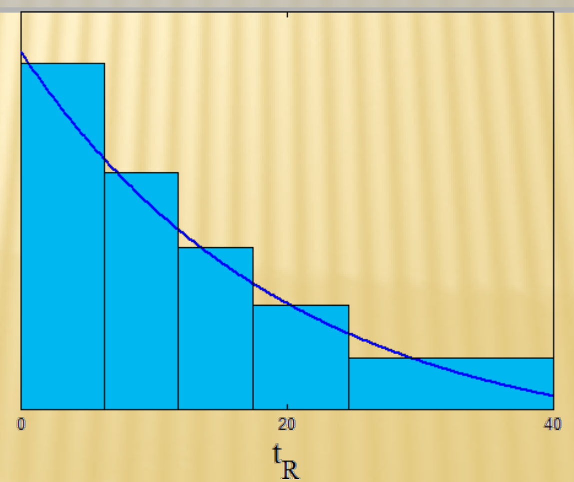
$$\text{FOR}(\%) = \frac{\text{MTTR}}{\text{MTTF} + \text{MTTF}}$$

Failure time series = 20, 35, ….



~ exp(MTTF)

Repair time series = 12, 8, ….

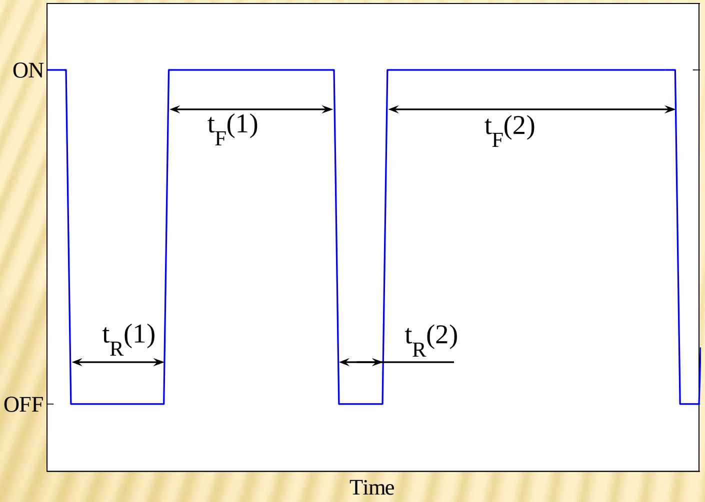


~ exp(MTTR)

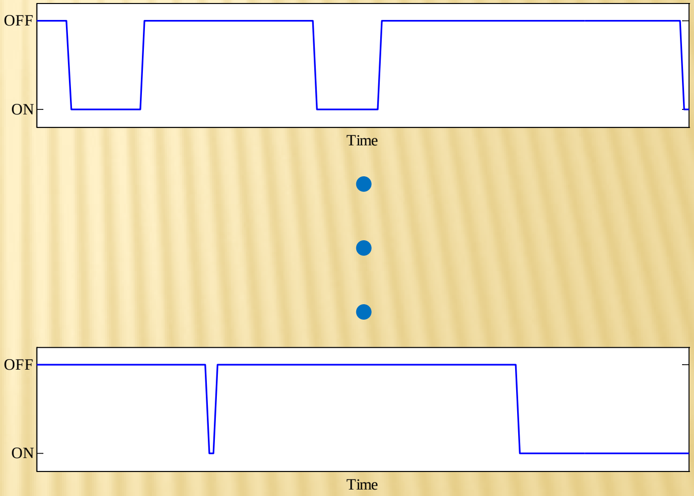
MODEL

Unit availability

Historical data



Availability scenarios



$t_F \sim \exp(MTTF)$
$t_R \sim \exp(MTTR)$

MODEL

Sources of uncertainty

Pool prices

Unit availability

Forward contracts

Insurance policy

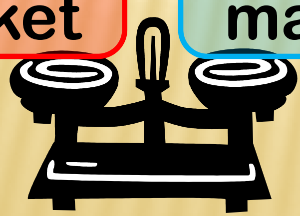
Scenario tree

Stochastic programming

Risk aversion

Pool market

Futures market



Insurance ?

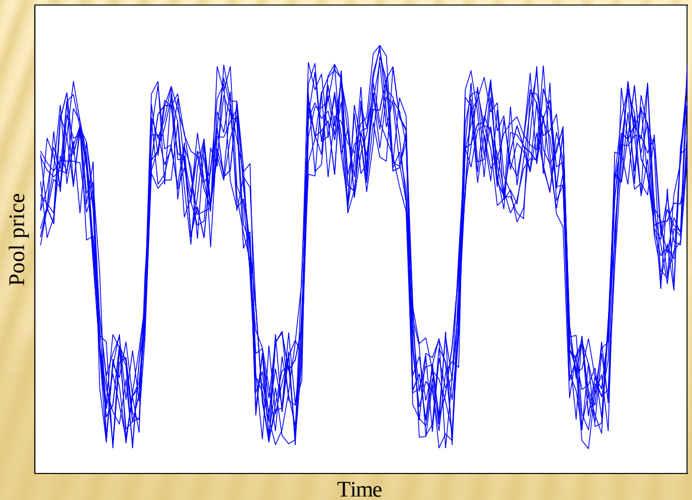
MODEL

Sources of uncertainty

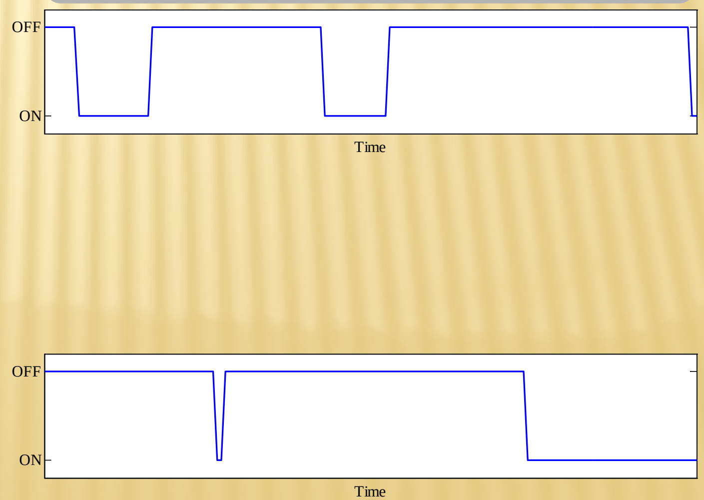
Pool prices | **Unit availability**

Scenario tree

Pool price scenarios



Availability scenarios



MODEL

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Pool prices

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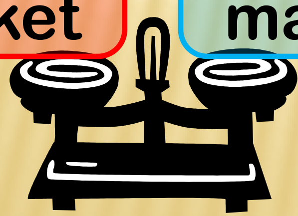
Insurance ?



MODEL

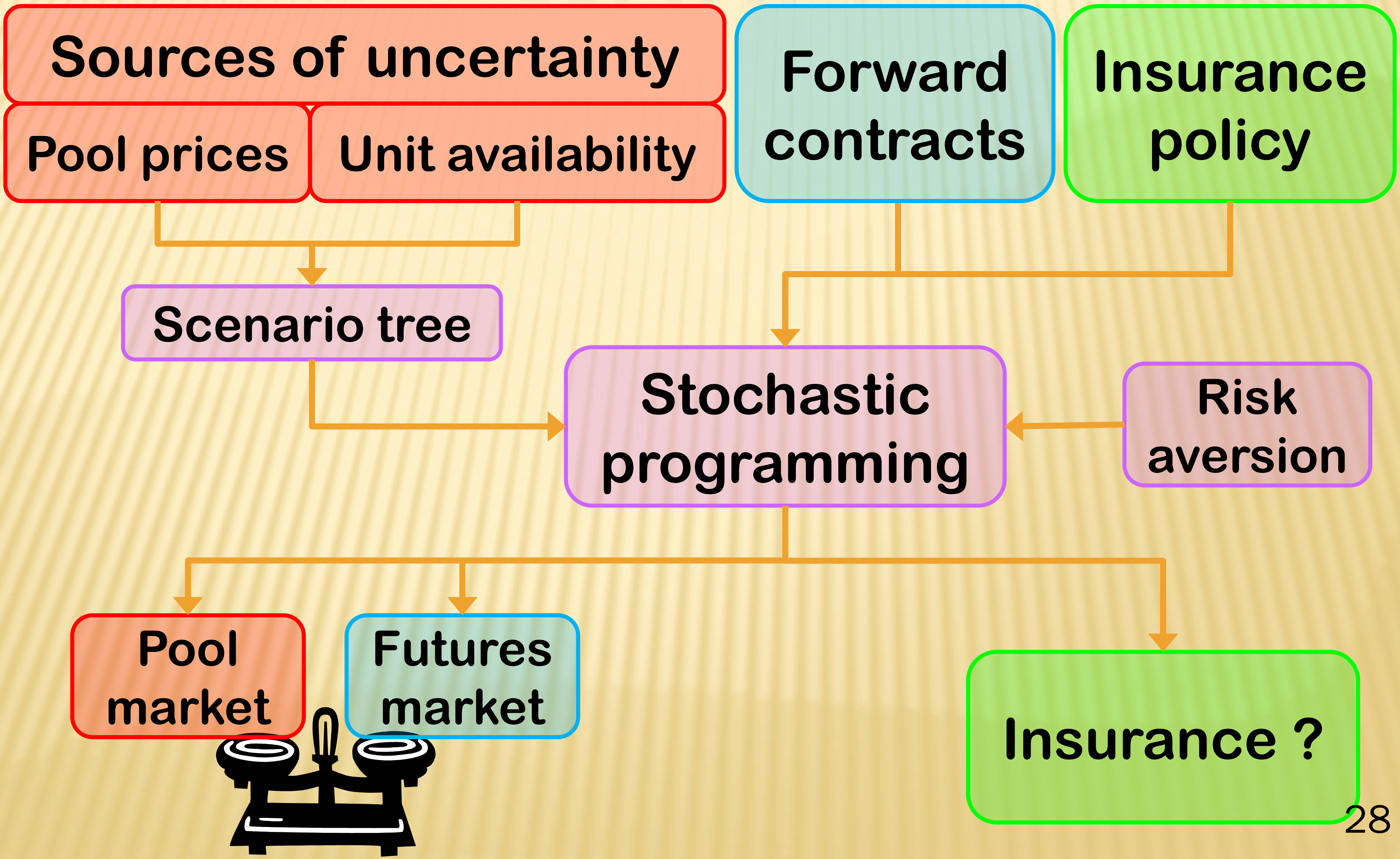
Forward contracts

MODEL

Forward contracts

- Specified quantity (MWh)
- Fixed price
- Future delivery period

MODEL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MODEL

Insurance policy

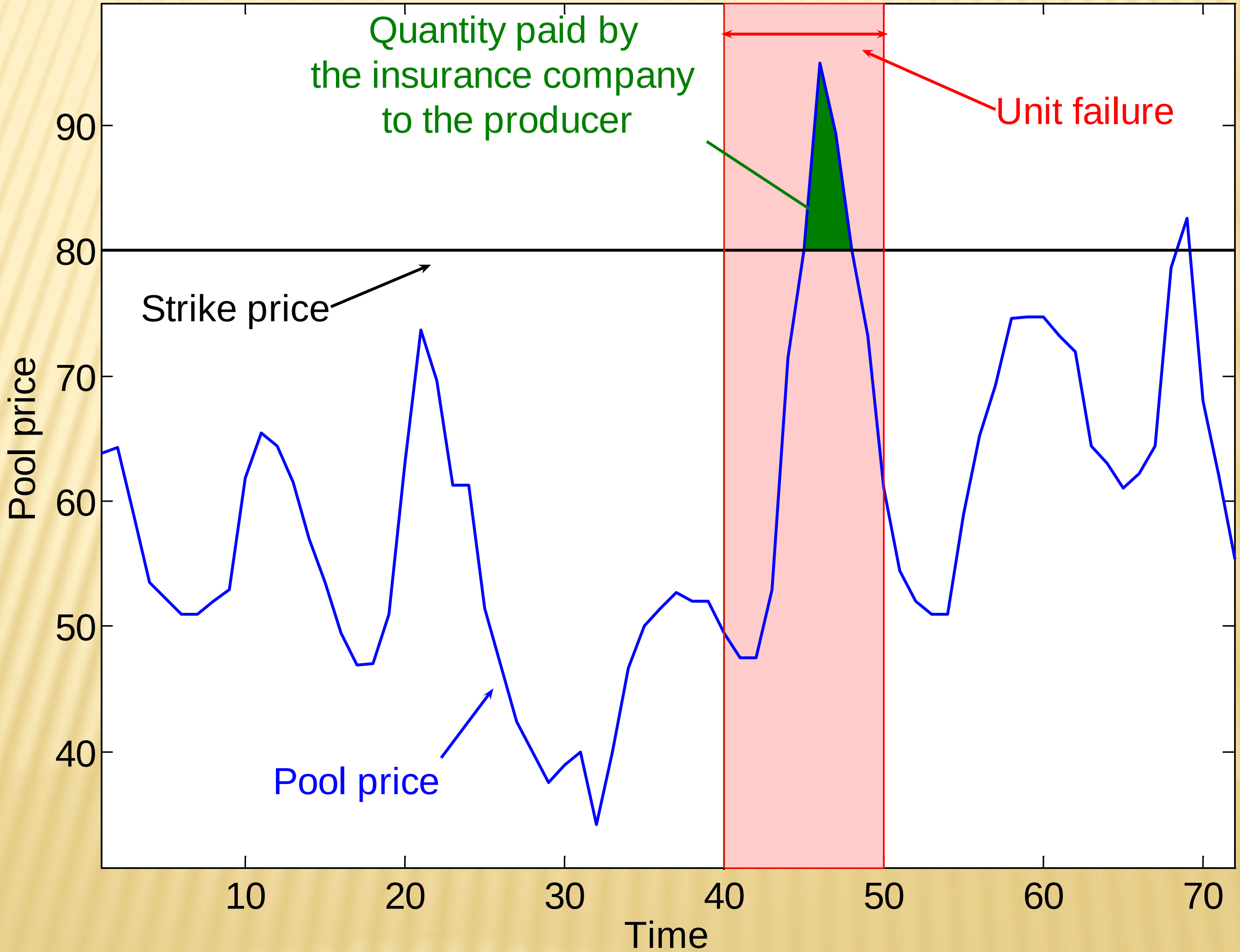
MODEL

Insurance policy

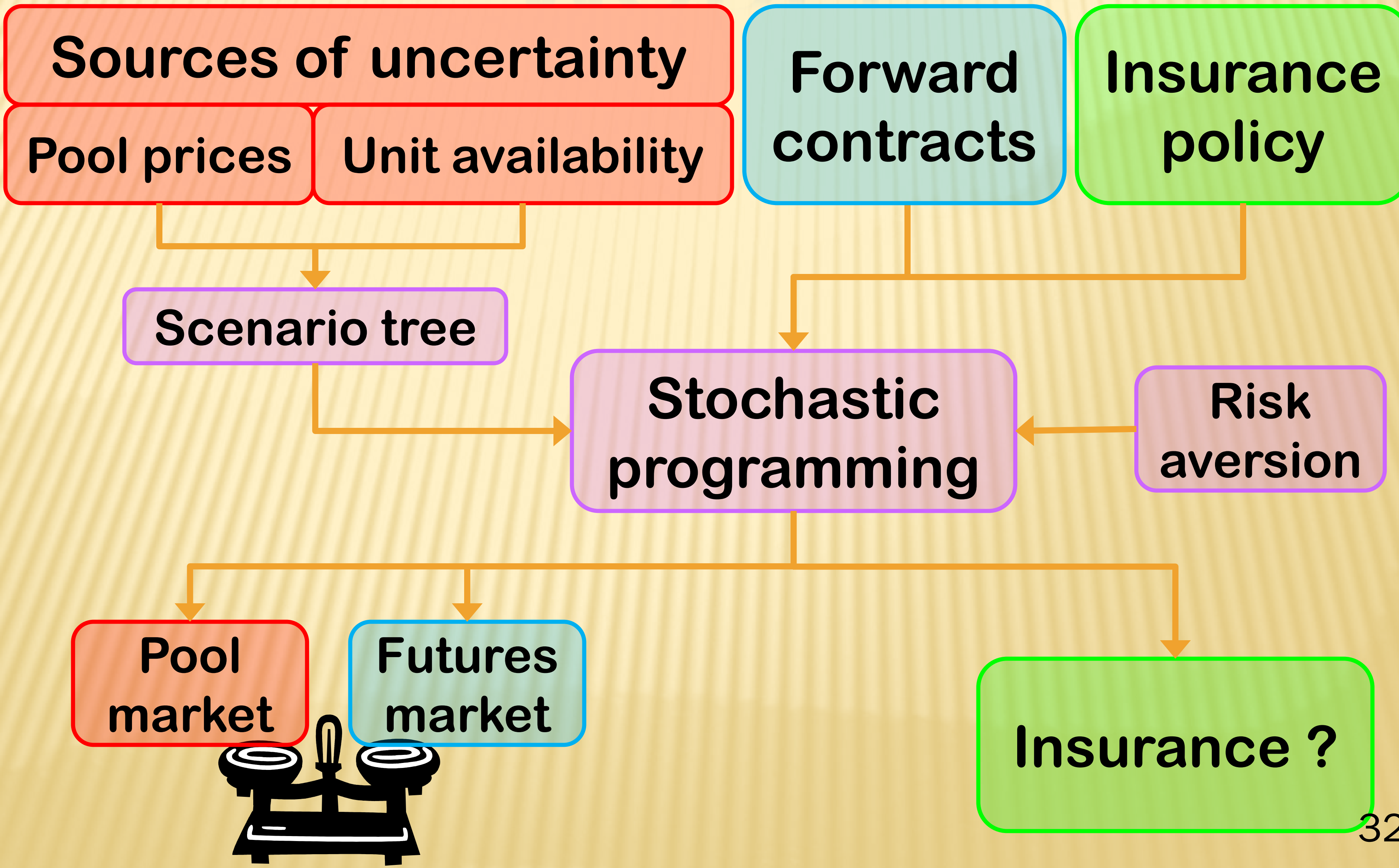
- Initial premium
- Insured power
- Time period covered
- Conditions:
  - Pool price > Strike price
  - Unit unavailable

INTRODUCTION

Insurance policy



MODEL



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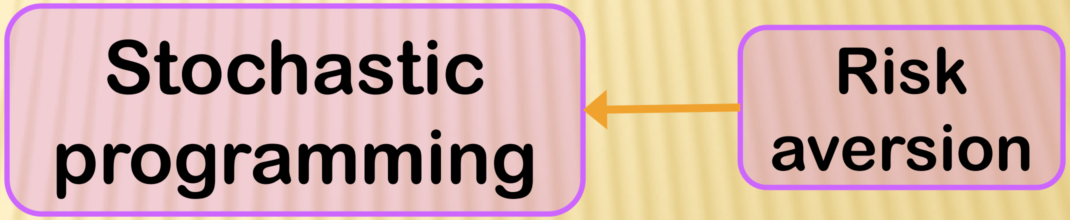


MODEL

Stochastic programming

Objective function

Maximize $CVaR_{\alpha}(\text{profit}_{\omega})$

Constraints

- Production unit limits
- Energy balance
- Forward characteristics

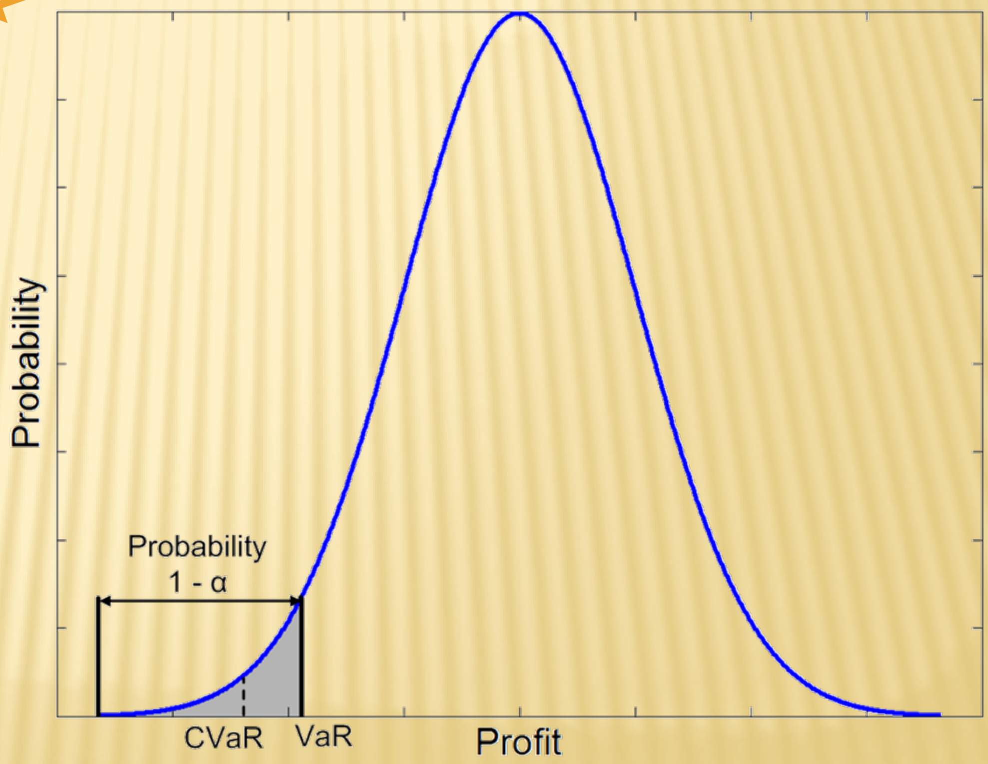
MODEL

Stochastic programming

Objective function

Maximize $CVaR_{\alpha}(\text{profit}_{\omega})$

Risk aversion



Constraints

Production unit limits

Energy balance

Forward characteristics

MODEL

Stochastic programming

Objective function

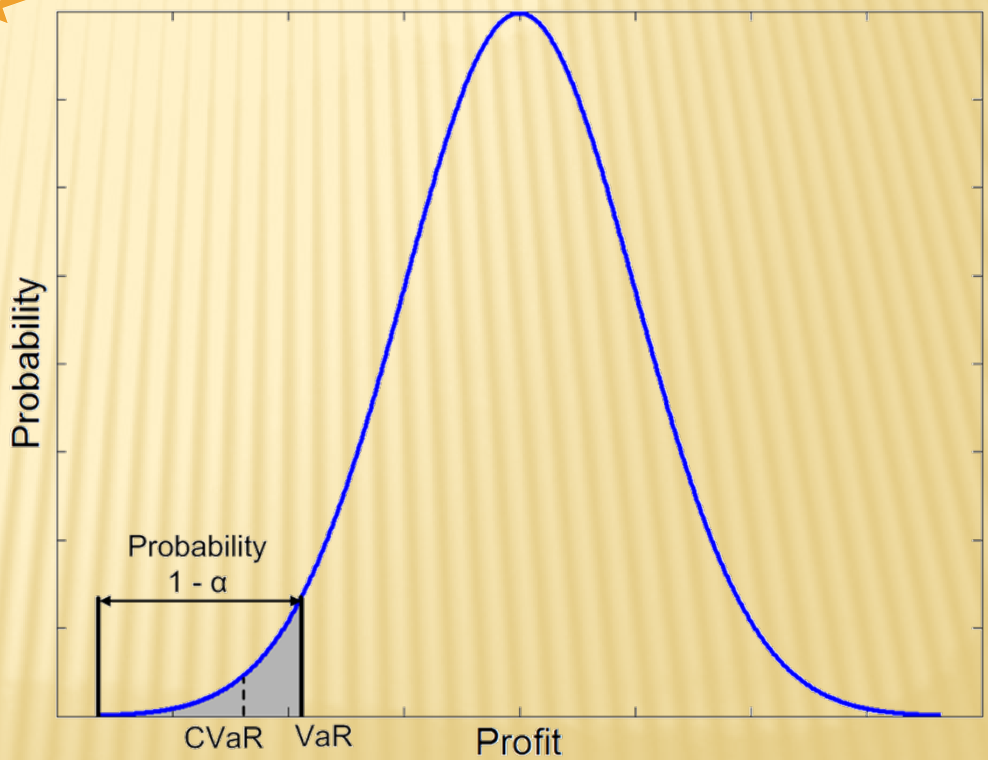
Maximize $CVaR_{\alpha}(\text{profit}_{\omega})$

Risk aversion

$$\text{CVaR}_{\alpha} = \zeta - \frac{1}{1-\alpha}\sum_{\omega=1}^{N_W}\pi_{\omega}\eta_{\omega}$$

$$-\,profit_{\omega} + \zeta - \eta_{\omega} \leq 0$$

$$\eta_{\omega} \geq 0$$



Constraints

Production unit limits

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Forward characteristics

MODEL

Stochastic programming

Objective function

Maximize $CVaR_{\alpha}(\text{profit}_{\omega})$

$$\text{profit}_{\omega} = \sum_{t=1}^{N_T} \pi_{\omega} \left(\boxed{\lambda_{t\omega}^{P} P_{t\omega}^{P} T_t} - C(P_{t\omega}^{G}) \right) + \sum_{c=1}^{N_C} \lambda_c P_c T_c + s_I \left(-M_I + P_I \sum_{t \in G_{\omega}} (\lambda_{t\omega}^{P} - \lambda_I) T_t \right)$$

Pool

$\lambda_{t\omega}^{P} \rightarrow$ Pool price

$P_{t\omega}^{P} \rightarrow$ Power sold in the pool

$T_t \rightarrow$ Duration of time period

Constraints

Production unit limits

Energy balance

Forward characteristics

MODEL

Stochastic programming

Objective function

Maximize $CVaR_{\alpha}(\text{profit}_{\omega})$

$$\text{profit}_{\omega} = \sum_{t=1}^{N_T} \pi_{\omega} \Big(\underbrace{\lambda_{t\omega}^{P} P_{t\omega}^{P} T_t}_{\text{Pool}} - \underbrace{C(P_{t\omega}^{G})}_{\text{Cost}} \Big) + \sum_{c=1}^{N_C} \lambda_c P_c T_c + s_I \left(-M_I + P_I \sum_{t \in G_{\omega}} (\lambda_{t\omega}^{P} - \lambda_I) T_t \right)$$

$C(\cdot) \rightarrow$ Cost function

$P_{t\omega}^{G} \rightarrow$ Generated power

Constraints

Production unit limits

Energy balance

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Stochastic programming

Objective function

Maximize $CVaR_{\alpha}(\text{profit}_{\omega})$

$$\text{profit}_{\omega} = \sum_{t=1}^{N_T} \pi_{\omega} \left(\underbrace{\lambda_{t\omega}^{P} P_{t\omega}^{P} T_t}_{\text{Pool}} - \underbrace{C(P_{t\omega}^{G})}_{\text{Cost}} \right) + \underbrace{\sum_{c=1}^{N_C} \lambda_c P_c T_c}_{\text{Forward}} + s_I \left(-M_I + P_I \sum_{t \in G_{\omega}} (\lambda_{t\omega}^{P} - \lambda_I) T_t \right)$$

$\lambda_c \rightarrow$ Forward price

$P_c \rightarrow$ Power sold through forward contract

$T_c \rightarrow$ Forward contract duration

Constraints

Production unit limits

Energy balance

Forward characteristics

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Stochastic programming

Objective function

Maximize $CVaR_{\alpha}(\text{profit}_{\omega})$

$$\text{profit}_{\omega} = \sum_{t=1}^{N_T} \pi_{\omega} \Big(\underbrace{\lambda_{t\omega}^{P} P_{t\omega}^{P} T_t}_{\text{Pool}} - \underbrace{C(P_{t\omega}^{G})}_{\text{Cost}} \Big) + \underbrace{\sum_{c=1}^{N_C} \lambda_c P_c T_c}_{\text{Forward}} + \underbrace{s_I \Big(-M_I + P_I \sum_{t \in G_{\omega}} (\lambda_{t\omega}^{P} - \lambda_I) T_t \Big)}_{\text{Insurance}}$$

$s_I \rightarrow$ Binary variable

$M_I \rightarrow$ Initial premium

$P_I \rightarrow$ Insured power

$t \in G_{\omega} \Leftrightarrow k_{t\omega} = \mathbf{0}$ and $\lambda_{t\omega}^{P} \geq \lambda_I$

$\lambda_I \rightarrow$ Strike price

Constraints

Production unit limits

Energy balance

Forward characteristics

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Stochastic programming

Objective function

Maximize $CVaR_{\alpha}(\text{profit}_{\omega})$

Constraints

Production unit limits

$$\mathrm{P}_{\max} \geq u_{t\omega} k_{t\omega} P^{G}_{t\omega} \geq P_{\min}$$

$k_{t\omega}$ → Input data (availability scenarios)

$u_{t\omega}$ → Binary variable (on/off)

Balance energy

Forward characteristics

MODEL

Stochastic programming

Objective function

Maximize $CVaR_{\alpha}(\text{profit}_{\omega})$

Constraints

Production unit limits

Energy balance

$$P_{t\omega}^{G} = \sum_{c \in F_t} P_c + P_{t\omega}^{P}$$

$$P_{t\omega}^{P} \geq (k_{tw} - \mathbf{1}) \sum_{c \in F_t} P_c$$

Forward characteristics

MODEL

Stochastic programming

Objective function

Maximize $CVaR_{\alpha}(\text{profit}_{\omega})$

Constraints

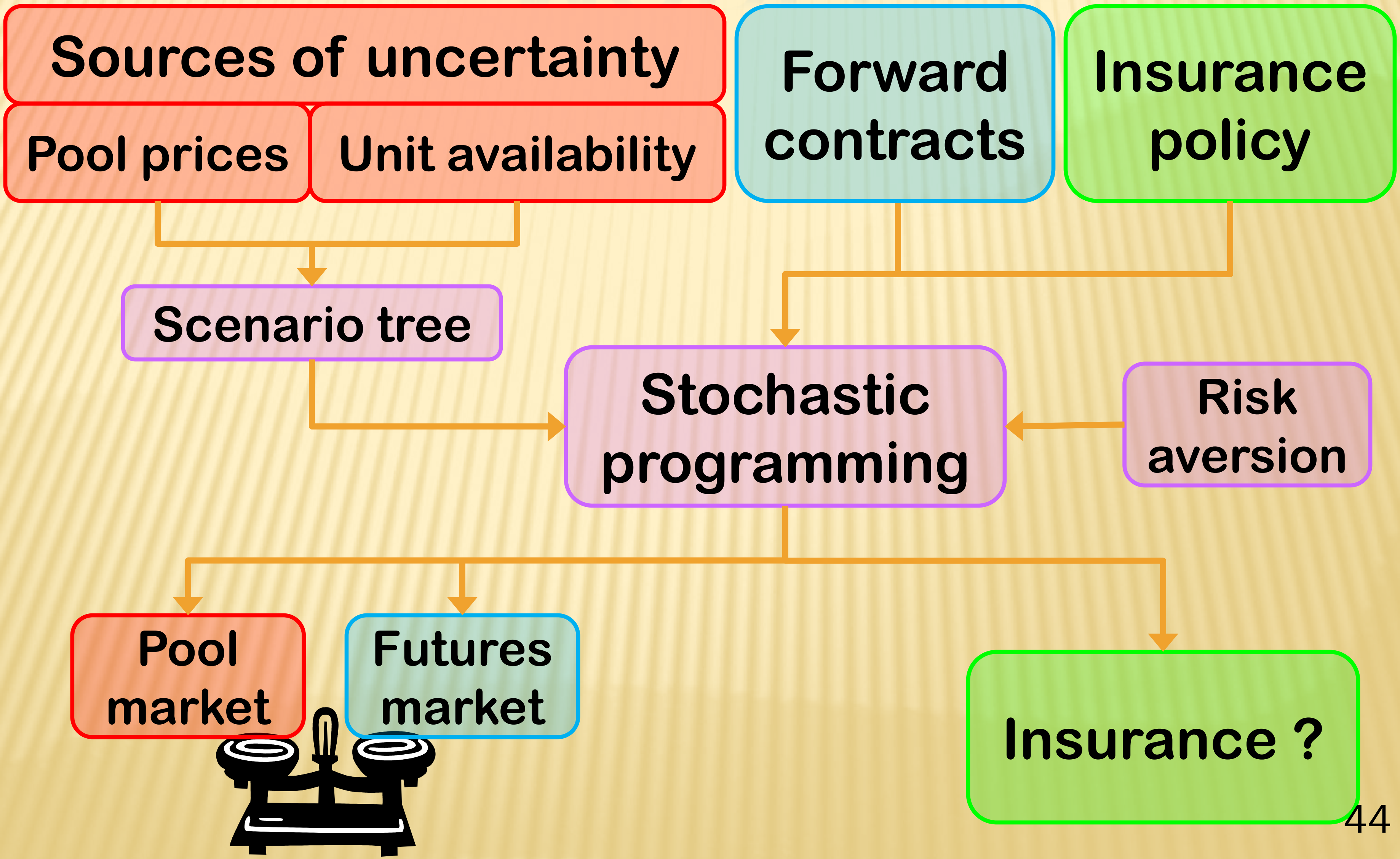
Production unit limits

Energy balance

Forward characteristics

$$P_c \leq P_c^{\max}$$

MODEL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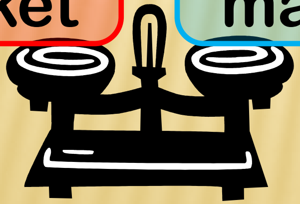
Insurance ?

MODEL

Pool market

Futures market



Insurance ?

OUTLINE

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CASE STUDY

- 3 months
- 4 forward contracts (3 monthly and 1 quarterly)
- 1 Insurance contract
  - Premium: 100,000 €
  - Insured power: 75 MW
  - Strike price: 10 €/MWh
- 300 pool price scenarios reduced to 50
- 10,000 availability scenarios reduced to 200
- Generating unit
  - Pmax = 500 MW & Pmin = 50 MW
  - Three FOR values: 0, 4 and 8%
  - Piecewise lineal cost function

CASE STUDY

Without insurance

FOR	α^P	Average P_c(MW)	CVaR (/10^6 €)
0%	0	0	11.7
	0.95	150	8.5
4%	0	0	11.2
	0.95	150	7.9
8%	0	0	10.7
	0.95	125	7.0

With insurance

FOR	α^P	Average P_c(MW)	CVaR (/10^6 €)	s_I
0%	0	0	11.7	0
	0.95	150	8.5	0
4%	0	0	11.2	0
	0.95	150	8.0	1
8%	0	0	10.7	1
	0.95	150	7.4	1

CASE STUDY

Without insurance

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CASE STUDY

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CASE STUDY

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	0.95	150	8.0	1
8%	0	0	10.7	1
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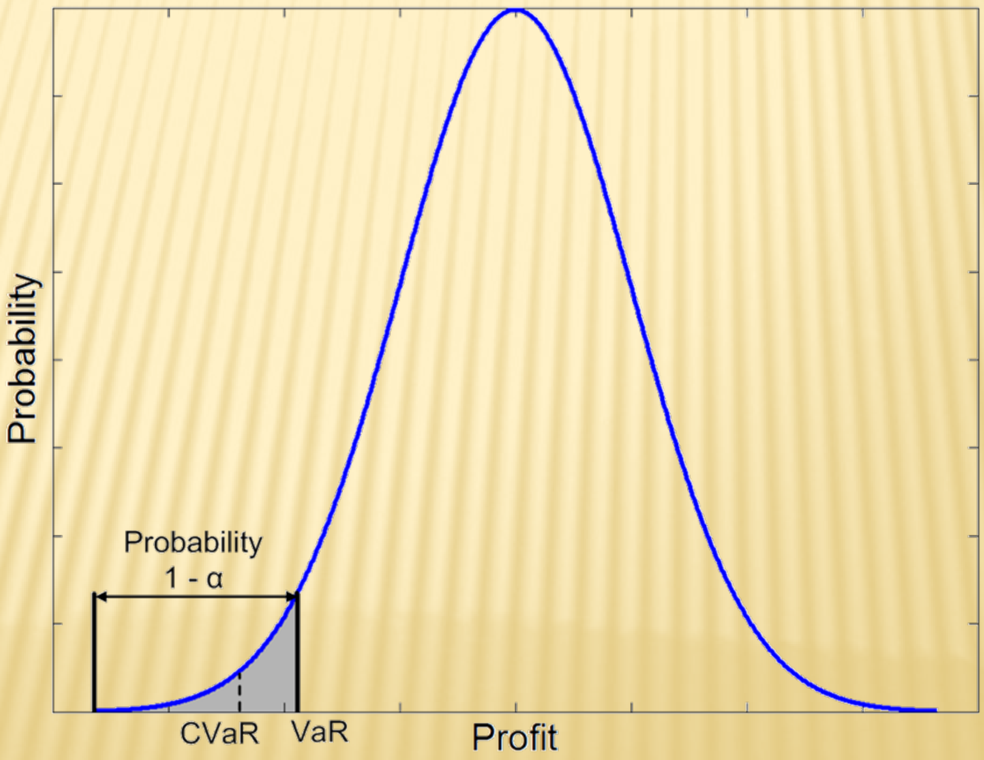
CASE STUDY

- **Critical premium:** the maximum amount that a producer is willing to pay in exchange for a given insurance contract.

CASE STUDY

- **Critical premium.**

CVaR is a coherent risk measure: $\mathbf{CVaR}_{\alpha}(Y+c)=\mathbf{CVaR}_{\alpha}(Y)+c$



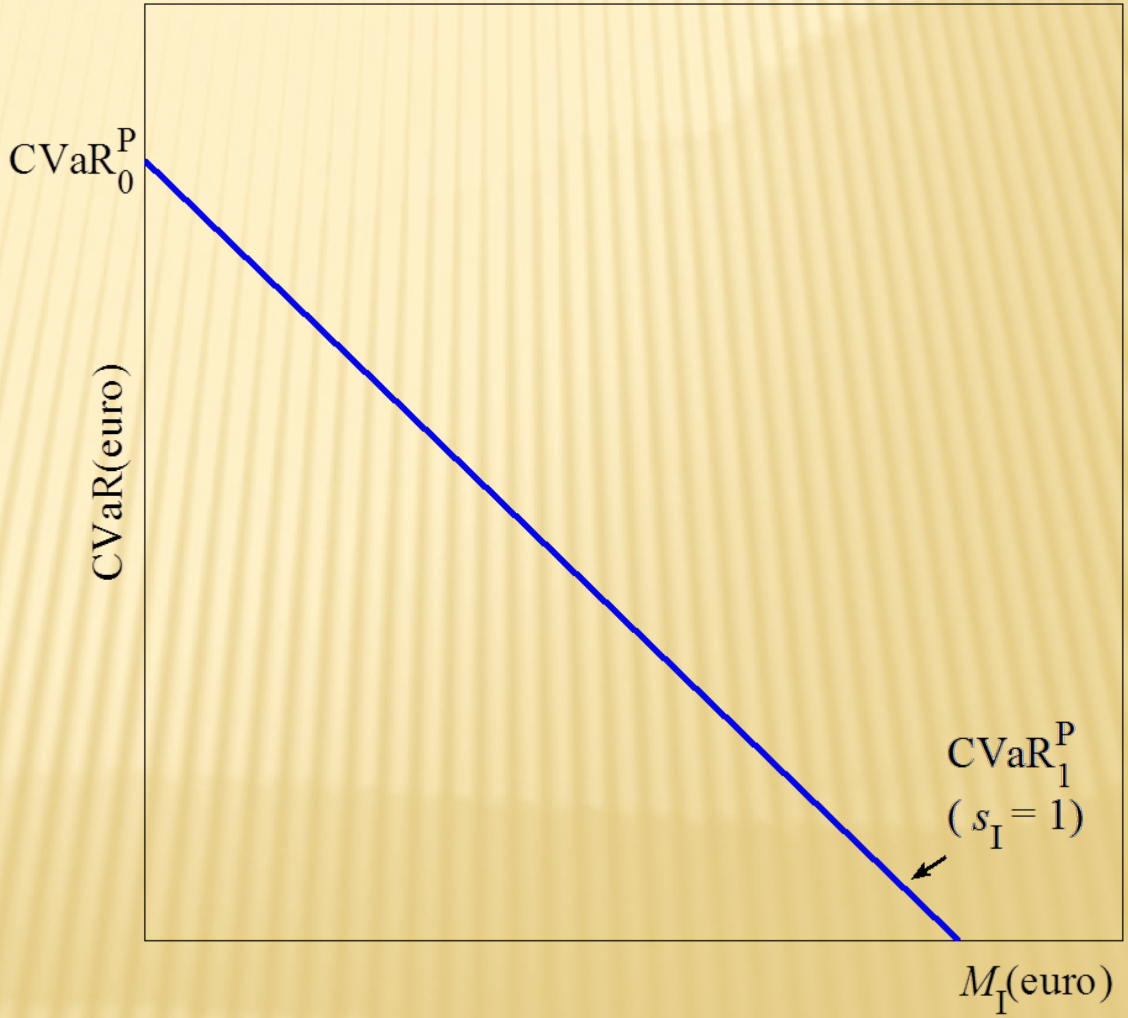
CASE STUDY

- **Critical premium.**

$$\mathbf{CVaR}_{\alpha}(Y+c)=\mathbf{CVaR}_{\alpha}(Y)+c$$

Case 1$(s_I=\mathbf{1})$:

$\mathbf{CVaR}_{\mathbf{1}}^{P}=\mathbf{CVaR}_{\mathbf{0}}^{P}-M_I$



CASE STUDY

$\text{CVaR}_{\alpha}(Y+c)=\text{CVaR}_{\alpha}(Y)+c$

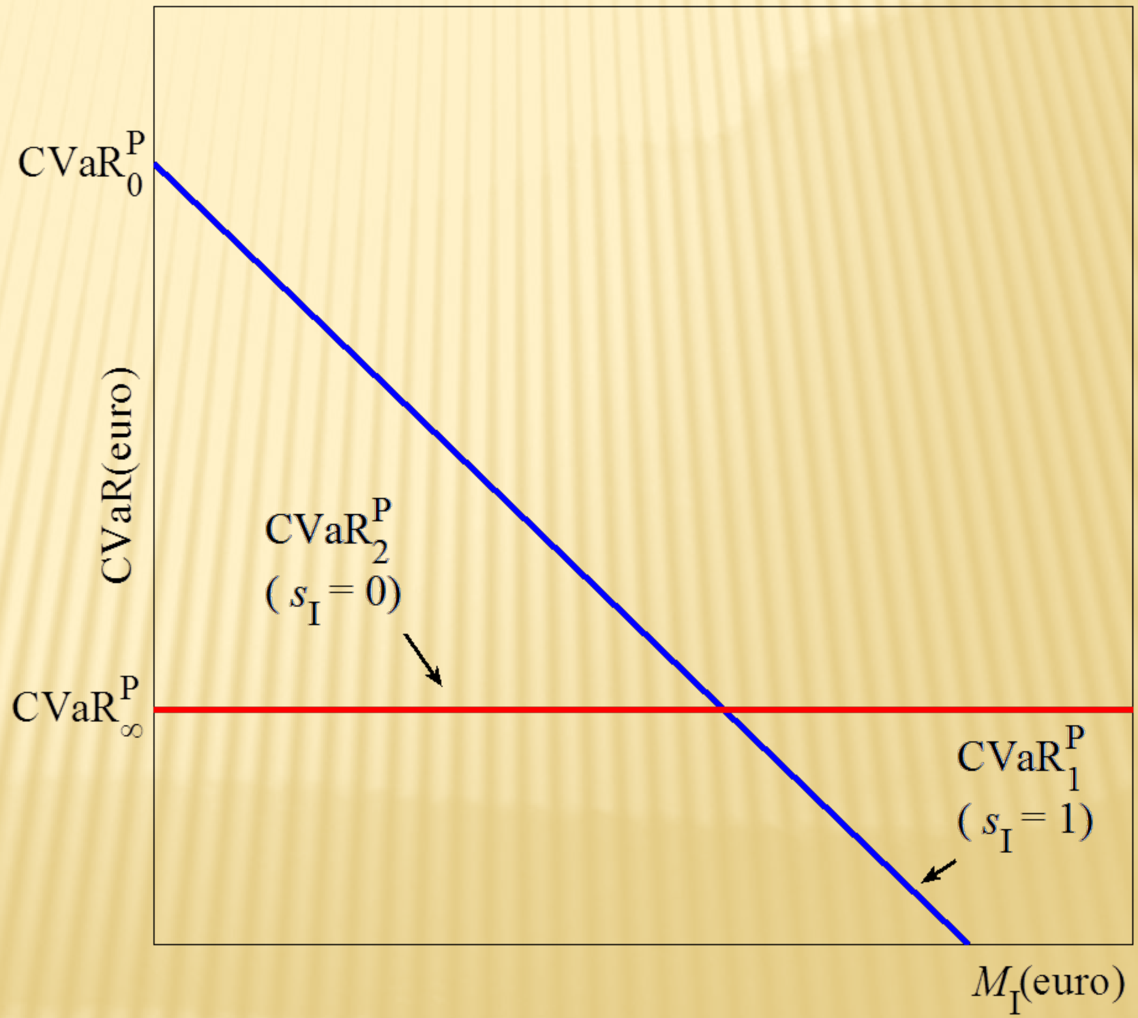
- **Critical premium.**

Case 1 ($s_I = 1$):

$\text{CVaR}_1^P = \text{CVaR}_0^P - M_I$

Case 2 ($s_I = 0$):

$\text{CVaR}_2^P = \text{CVaR}_\infty^P$



CASE STUDY

- **Critical premium.**

$$\text{CVaR}_\alpha(Y+c)=\text{CVaR}_\alpha(Y)+c$$

Case 1 ($s_I=1$):

$$\text{CVaR}_1^P=\text{CVaR}_0^P-M_I$$

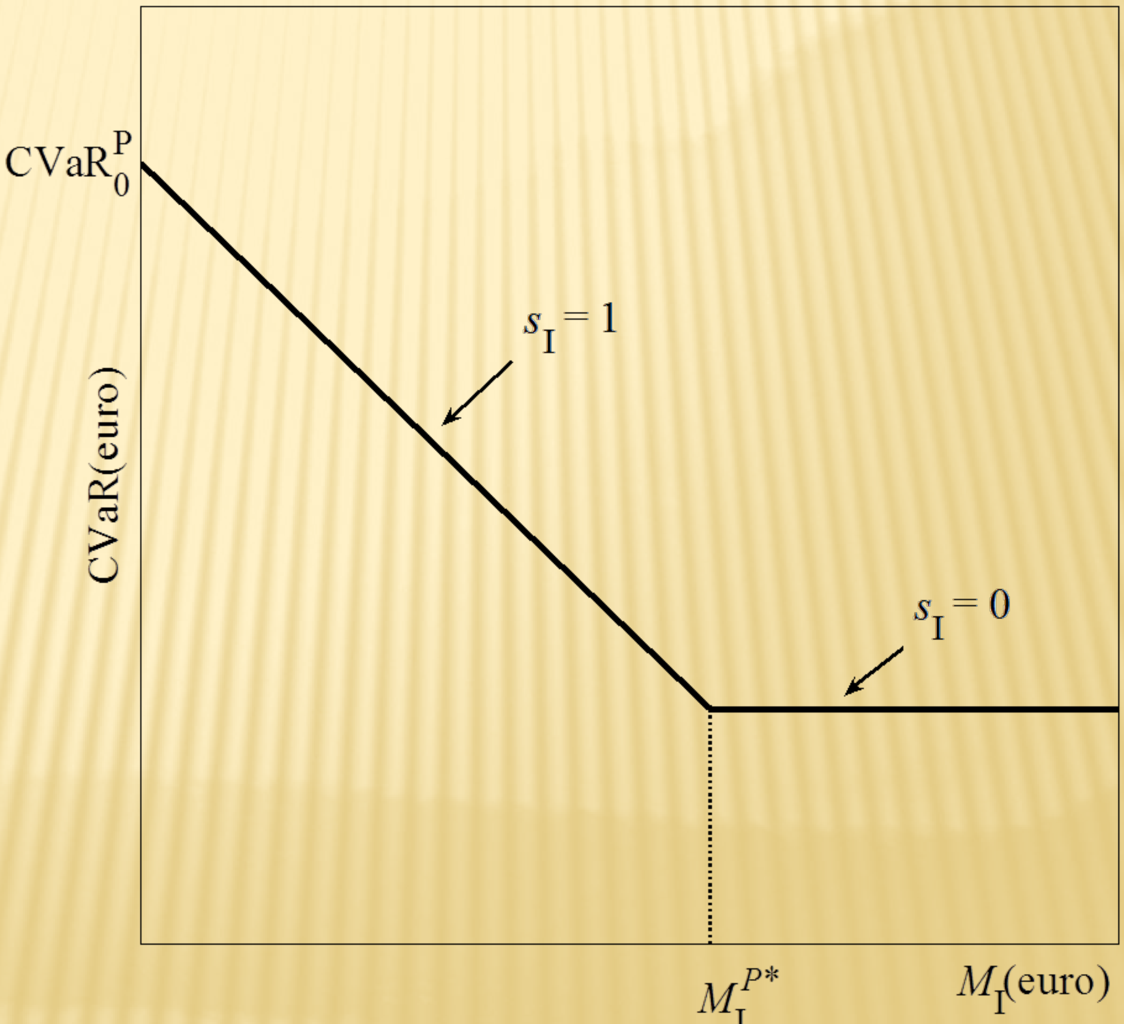
Case 2 ($s_I=0$):

$$\text{CVaR}_2^P=\text{CVaR}_\infty^P$$

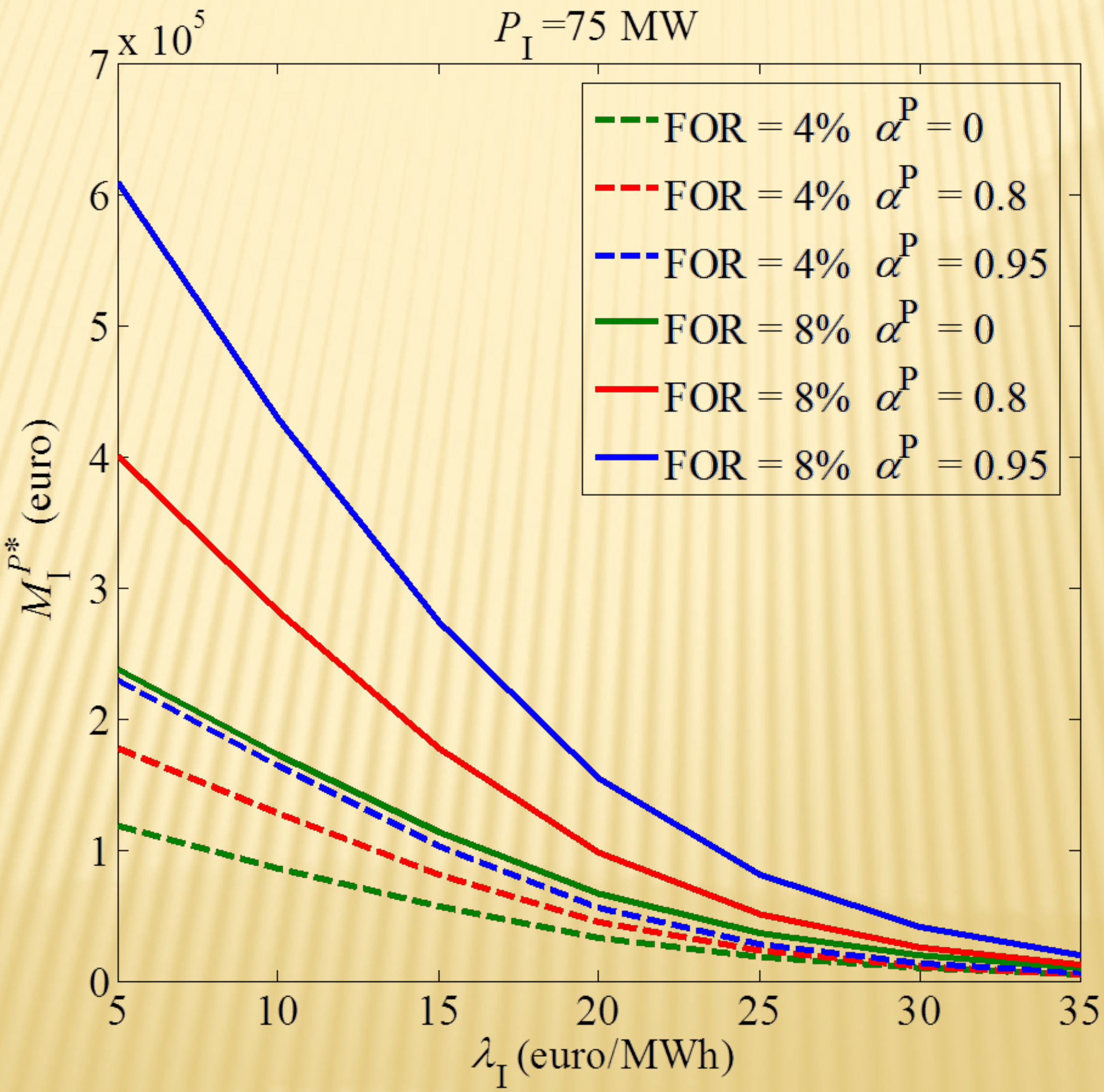
$$\text{CVaR}_1^P=\text{CVaR}_2^P$$

$$\text{CVaR}_0^P-M_I^{P*}=\text{CVaR}_\infty^P$$

$$M_I^{P*}=\text{CVaR}_0^P-\text{CVaR}_\infty^P$$



CASE STUDY



P_I =75 MW
x 10^5
M_I^{P*} (euro)
λ_I (euro/MWh)
FOR = 4% α^P = 0
FOR = 4% α^P = 0.8
FOR = 4% α^P = 0.95
FOR = 8% α^P = 0
FOR = 8% α^P = 0.8
FOR = 8% α^P = 0.95

CASE STUDY

Producer

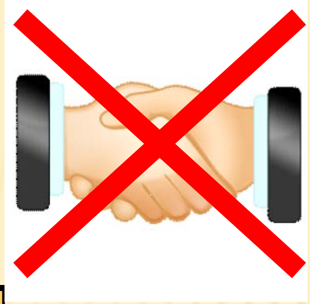
α^P	M_I^{P*}(€)
0	173.275
0.3	196.166
0.5	214.615
0.9	358.210

Insurance company

α^S	M_I^{S*}(€)
0	173.275
0.3	242.071
0.5	302.974
0.9	563.779

$$P_I = \mathbf{75}MW \quad \lambda_I = \mathbf{10}€/MWh \quad \mathrm{FOR} = \mathbf{8}\%$$

CASE STUDY



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0.3	196.166
0.5	214.615
0.9	358.210

Insurance company

α^S	M_I^{S*}(€)
0	173.275
0.3	242.071
0.5	302.974
0.9	563.779

$$P_I = \mathbf{75}MW \qquad \lambda_I = \mathbf{10}€ / MWh \qquad \text{FOR} = \mathbf{8}\%$$

CASE STUDY

Producer

α^P	M_I^{P*}(€)
0	173.275
0.3	196.166
0.5	214.615
0.9	358.210

Insurance company

α^S	M_I^{S*}(€)
0	173.275
0.3	242.071
0.5	302.974
0.9	563.779

$$P_I = \mathbf{75} MW \quad \lambda_I = \mathbf{10} € / MWh \quad \mathrm{FOR} = \mathbf{8}\%$$

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- Conclusions

CONCLUSIONS

Stochastic programming

CONCLUSIONS

Insurance

↑ Futures market

CONCLUSIONS

Insurance → ↑ Futures market

↑ FOR → ↑ Critical premium

↑ Risk aversion → ↑ Critical premium

CONCLUSIONS

Insurance

Producer **Risk** → Insurance company

CONCLUSIONS

Thank you!

Questions?

www.uclm.es/area/gsee