Financial Market for Restructured Power Systems

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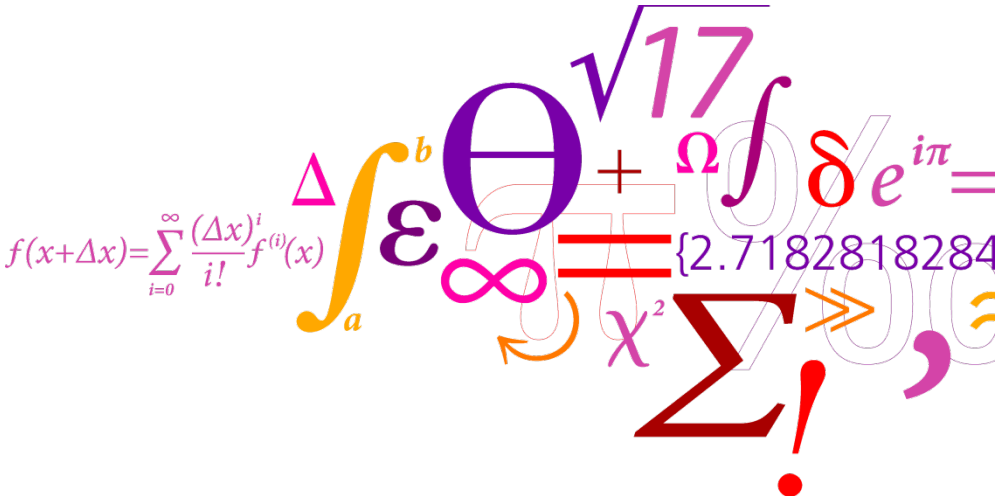
Centre for Electric Technology

16th September 2011



DTU Electrical Engineering
Department of Electrical Engineering

Outline

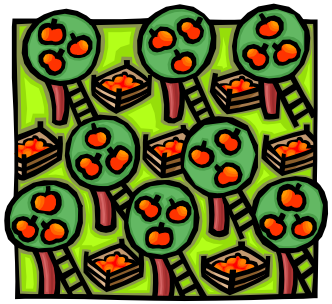
- Introduction
- Forward contracts
- Electricity options
- Conclusions
- Bibliography

Introduction

- What is a derivative?
  - financial instrument
  - its value is derived from the value of another underlying asset

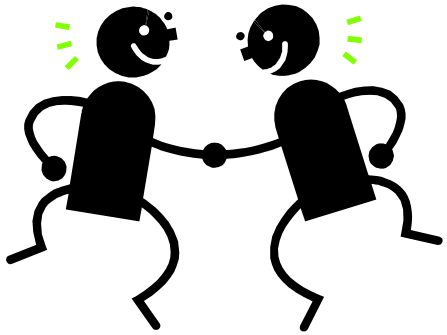
- What is a derivative for?
  - to facilitate the “buying” and “selling” of risk

Introduction



MARKET

CONTRACT



If price < 2 $/Kg

Receive 100(2-p)

If price > 2 $/Kg

Pay 100(p-2)

100 Kg. of apples

2 $/Kg

Introduction

- Derivatives as mechanisms to transfer risk
  - Farmer
    - Decrease the risk of having low prices
    - Increase the risk of having high prices (thereby losing additional income)
  - Fruit seller
    - Decrease the risk of having high prices
    - Increase the risk of having low prices (thereby paying more for the apples)

Introduction

- Wide variety of derivatives
  - rice derivatives traded since the eighteen century
  - pork bellies, live cattle, sugar, wool, lumber, copper, aluminum, gold, and tin
  - financial assets include stock indices, currencies, and Treasury bonds

- Since restructuration of electricity markets
  - electricity derivatives

Introduction

- Types of derivatives
  - Forward contracts
  - Futures contracts
  - Option contracts
  - Swaps
  - ...

Introduction

- Derivatives can be traded in two ways:
  - Ex-change market:
    - pre-defined and standardized contracts
    - traded through a central authority
    - free of the counterparty risk
    - Required to pay a margin fee
  - Over-the-counter (OTC):
    - contracts privately traded between 2 parties
    - flexibility to design products
    - significant counterparty risk

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Forward contracts

- Definition of forward/futures contract
  - The quantity and quality of the commodity
  - The date of delivery
  - The price to be paid
  - The date of payment following delivery

- Positions
  - Long position: party buying the commodity
  - Short position: party selling the commodity

Forward contracts

- Forward vs. Futures

Forward	*Futures*
Traded on over-the-counter market	Traded on an exchange
Not standardized	Standardized contract
Usually one specified delivery date	Range of delivery dates
Settled at end of contract	Settled daily
Delivery or final cash settlement usually takes place	Contract is usually closed out prior to maturity

Forward contracts

- How are they traded?
  - Initial auction
    - buy and sell offers are matched to obtain the settlement price
  - Continuous market
    - each agent can see other agents' orders
    - decide its own orders
    - executed following a price-time criteria

Forward contracts

- Trading

Pre-trading	Main trading		Post-trading
	Opening auction	Continuous trading	
8:30 – 08:55	08:55 – 09:00	09:00 – 16:00	16:00 – 17:00

Forward contracts

- Initial auction (EEX)

Bid		Ask	
Volume	Price	Price	Volume
17	15.25	15.20	11
15	15.23	15.23	12
16	15.16	15.25	15
		15.28	17

Forward contracts

- Initial auction (EEX)

Bid		Ask	
Volume	Price	Price	Volume
17	15.25	15.20	11
15	15.23	15.23	12
16	15.16	15.25	15
		15.28	17

Price	Bid volume	Ask volume	Volume matched	Surplus
15.16	48	0	0	48
15.20	32	11	11	21
15.23	32	23	23	9
15.25	17	38	17	21
15.28	0	55	0	55

Forward contracts

- Continuous trading (EEX)

Input: Ask
Price: 15.20 €/MWh
Qty.: 170

Bid		Ask	
BidQty	Bid	Ask	AskQty
160	15.20	**15.20**	**170**
140	15.14	15.22	175
100	15.12	15.28	180
		15.30	200

Execution: Ask
Price: 15.20 €/MWh
Qty.: 160

Bid		Ask	
BidQty	Bid	Ask	AskQty
140	15.14	**15.20**	**10**
100	15.12	15.22	175
		15.28	180
		15.30	200

Forward contracts

- Continuous trading (EEX)

Input: Ask
Price: 15.17 €/MWh
Qty.: 170

Bid		Ask	
BidQty	Bid	Ask	AskQty
100	15.20	**15.17**	**170**
60	15.19	15.22	175
100	15.12	15.28	180
		15.30	200

Execution: Ask
Price: 15.19625 €/MWh
Qty.: 160

Bid		Ask	
BidQty	Bid	Ask	AskQty
100	15.12	**15.17**	**10**
		15.22	175
		15.28	180
		15.30	200

Forward contracts

- Settlement price
  - Determination of the settlement prices at 16:00
  - Last traded price (on the exchange)
    - Trading volume of at least 5 contracts
  - Average of fair values (Chief trader procedure)
    - Needs to be between best bid and best ask at the end of trading
    - Free from arbitrage

Forward contracts

- Daily settlement example
  - Unit of 30 MW
  - Expected pool price of 53.3 €/MWh in Sep10
  - 30 contracts of the Base Month Sep10 for 53.3 €/MWh in July 1st
  - Expected revenue:

30MW x 24h/day x 30days x 53.3€/MWh=1155600€

  - Average spot price 47.53 (Profit 1026648 €)

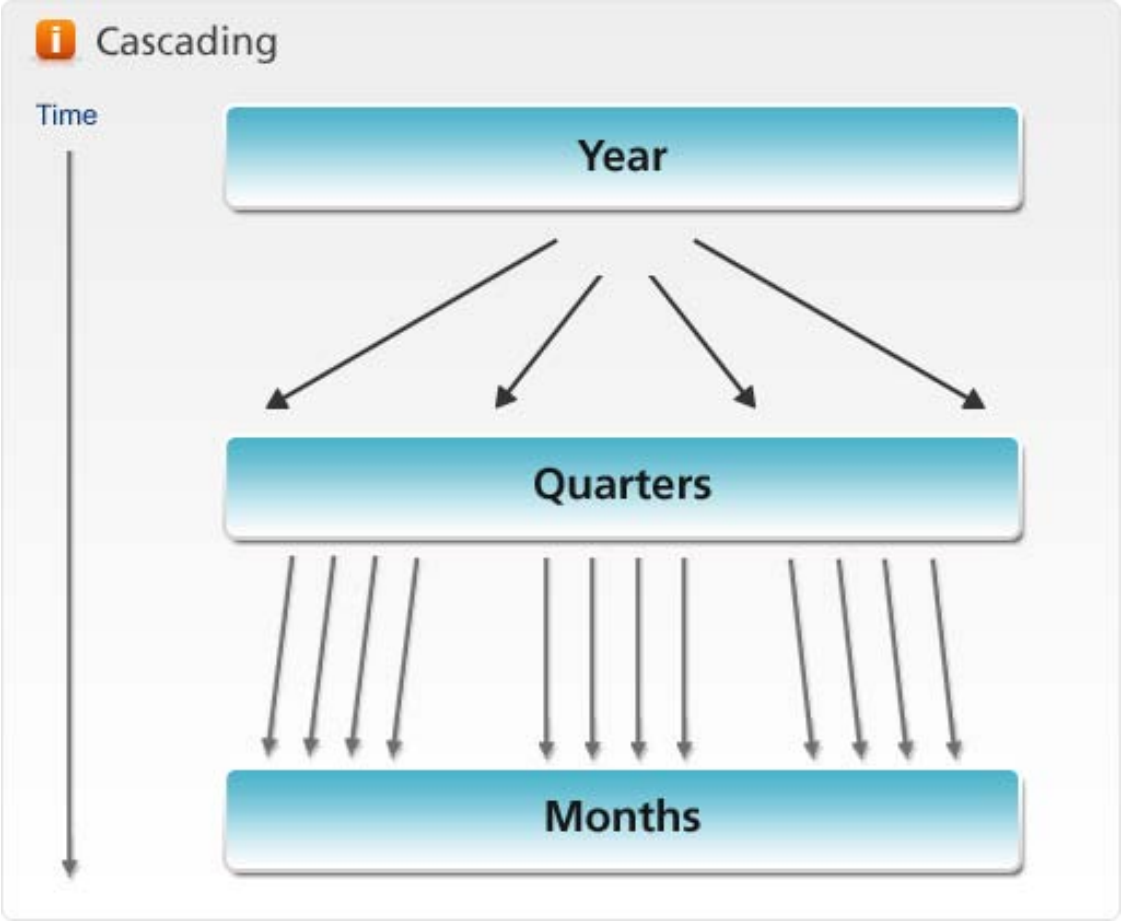
Forward contracts

- Daily settlement

Exchange trading day		Daily settlement price of the Future [€ per MWh]	Phelix Day Base [€ per MWh]	Average Phelix Day Base [€ per MWh]	Variation Margin [€] (-) Additional contribution (+) Credit
Derivatives trading	Thu, 01/07/10	53.50	-	-	0
	...	...	...	...	...
	Fri, 27/08/10	48.20	-	-	114,480
	Mo, 30/08/10	48.00	-	-	4,320
Derivatives and Spot trading	Tue, 31/08/10	47.00	48.00	48.00	21,600
	We, 01/09/10	47.50	48.20	48.10	-10,800
	Thu, 02/09/10	46.90	43.00	46.40	12,960
	...	...	...	...	...
	Fri, 24/09/10	47.80	38.00	44.30	-19,440
	Mo, 27/09/10	48.30	48.00	45.04	-10,800
	Tue, 28/09/10	48.00	53.00	46.37	6,480
	We, 29/09/10	Final settlement price: 47.53	54.50	47.53	10,152
Total:					128,952

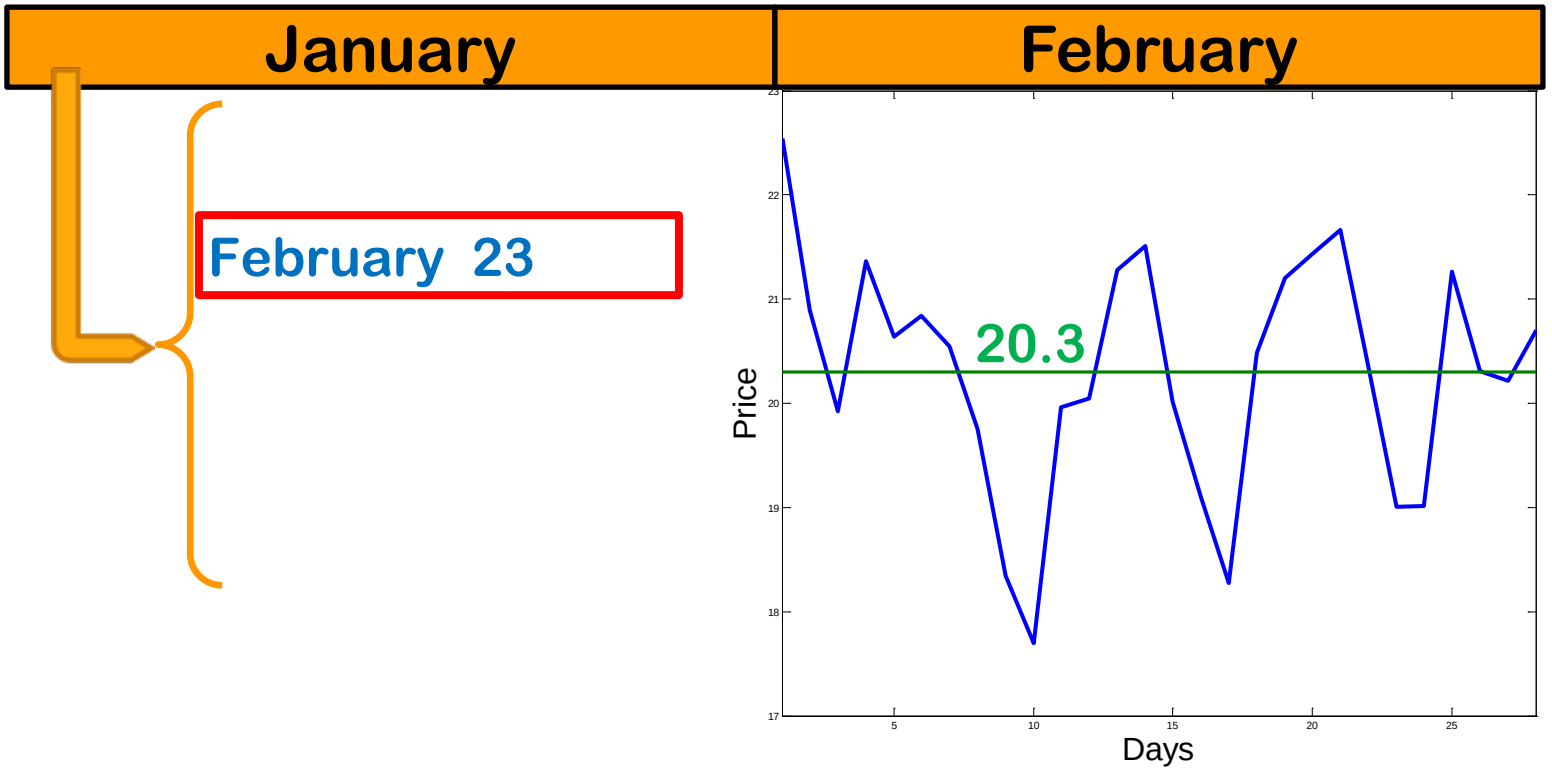
Forward contracts

- Cascading



Forward contracts

- Risk premium



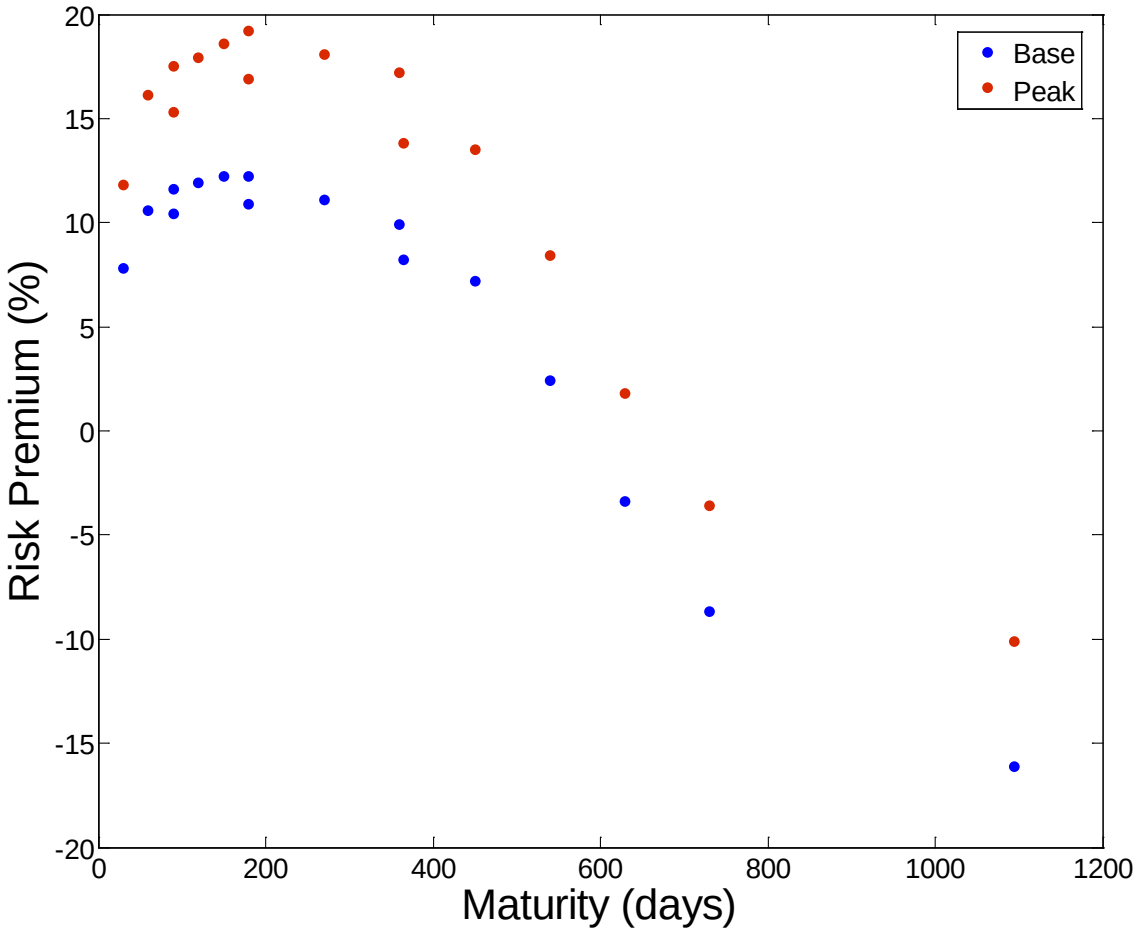
$$\text{Risk premium}_{t,T} = 100 \cdot \frac{F_{t,T} - S_T}{S_T} = 100 \cdot \frac{23 - 20.3}{20.3} = 13.3\%$$

Forward contracts

- Risk premium
  - –Retailers are more risk averse → RP ↑
  - –Producers are more risk averse → RP ↓

Forward contracts

- Risk premium (EEX)



Forward contracts

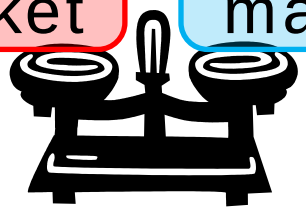
- GenCo model

Pool market
(price risk)

Futures market
(fixed price)

Pool market

Futures market

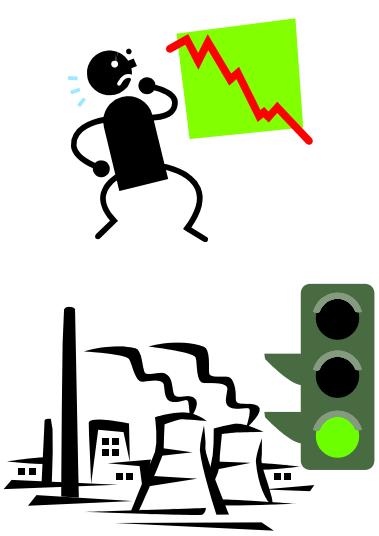


Forward contracts

- GenCo model
  - Risk neutral (maximize expected profit)
    - average spot > forward price → 100% spot
    - average spot < forward price → 100% forward
  - Risk averse (worried about getting low profits)
    - not so clear

Forward contracts

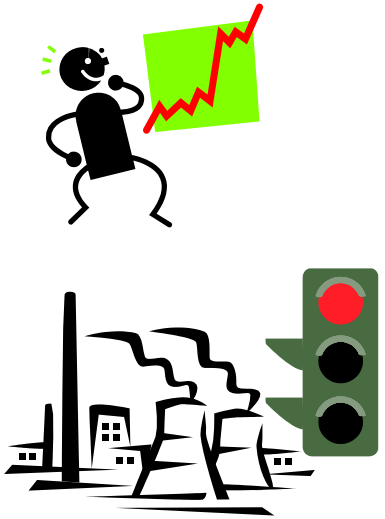
- GenCo model



Pool market
(price risk)

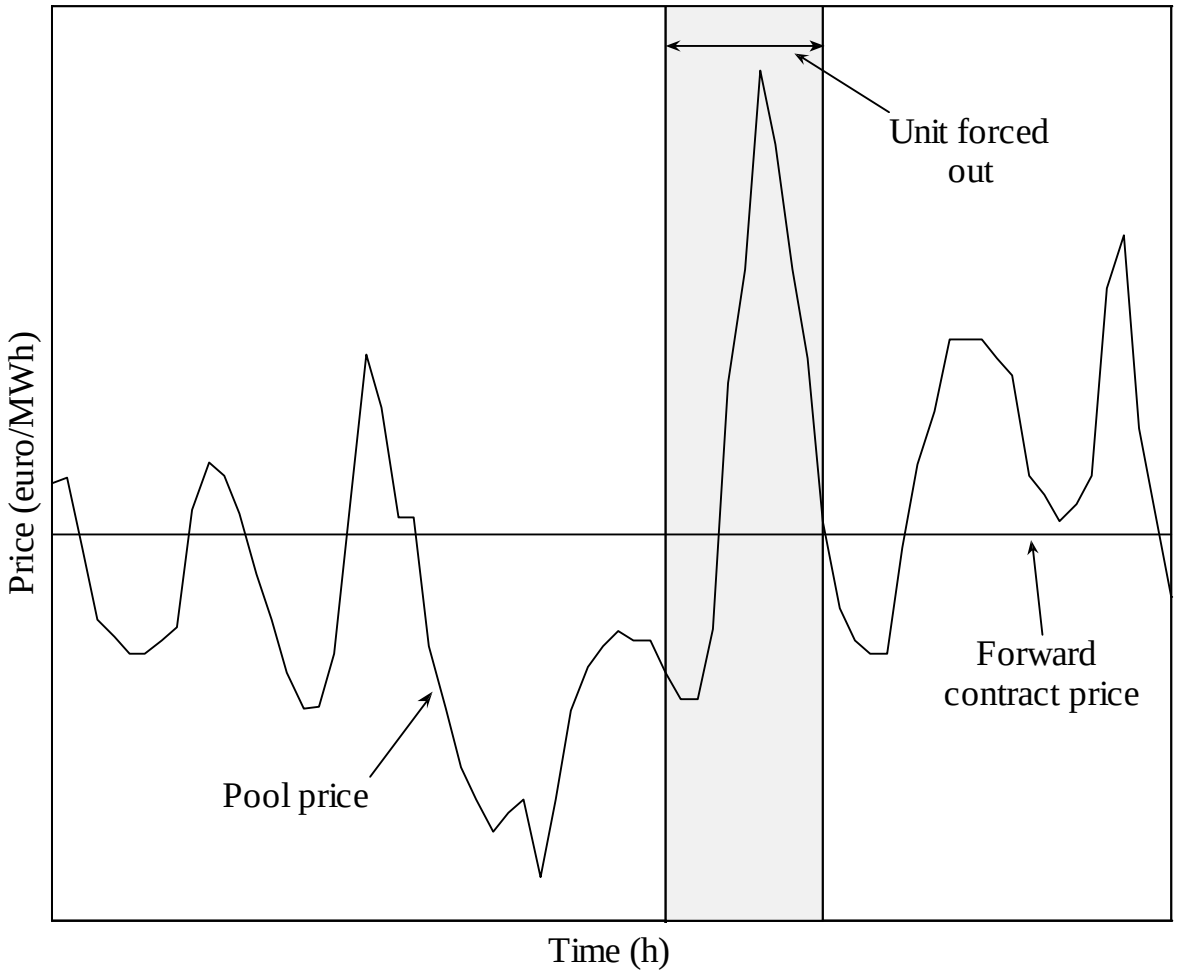
Production unit
(availability risk)

Futures market
(fixed price)



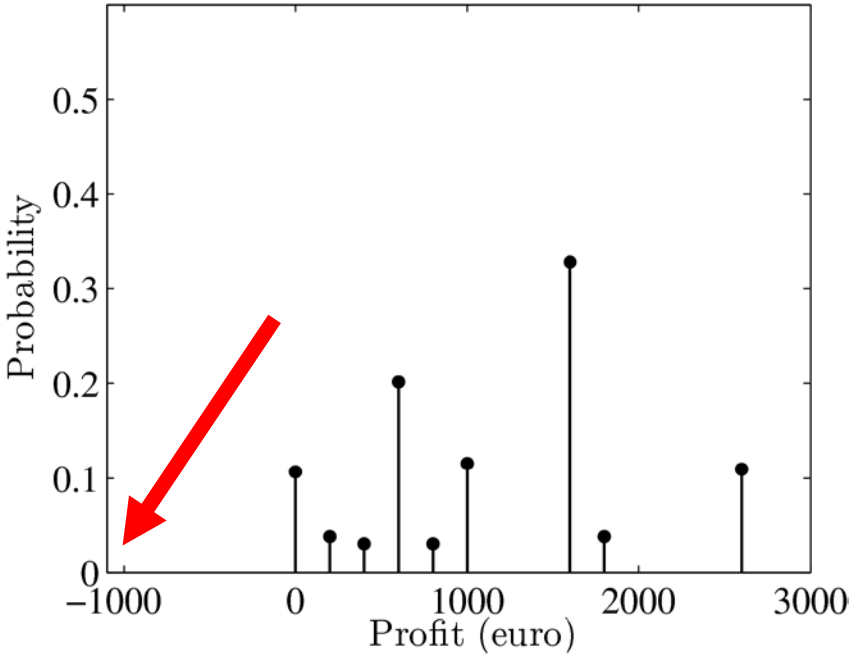
Forward contracts

- GenCo model

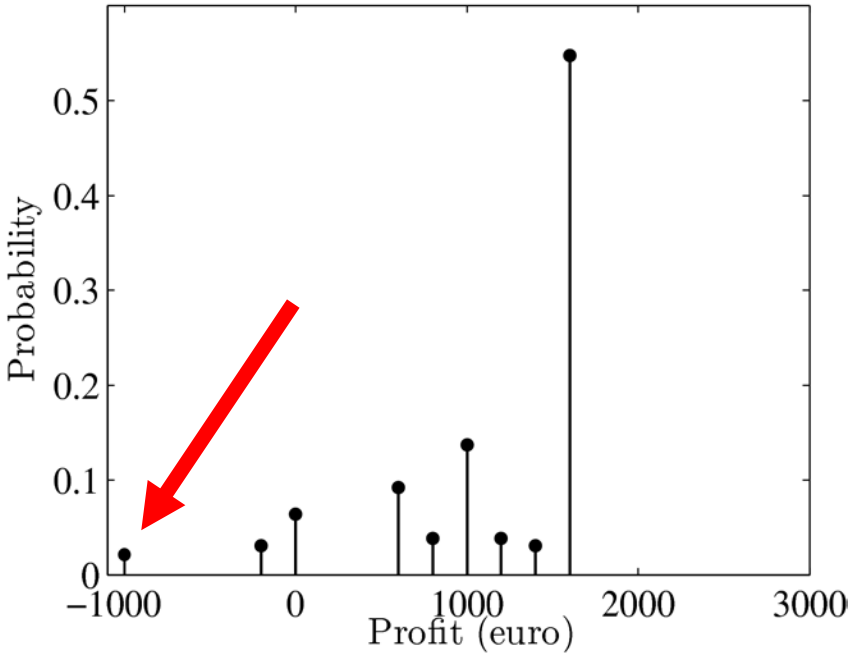


Forward contracts

- Example



Pool

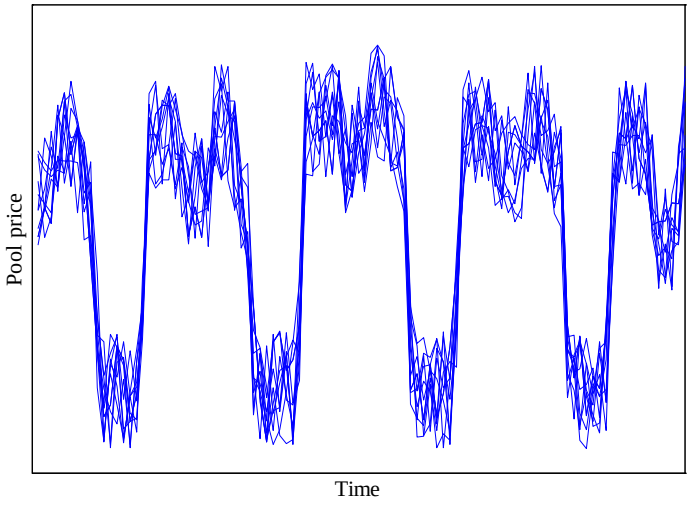


Forward contract

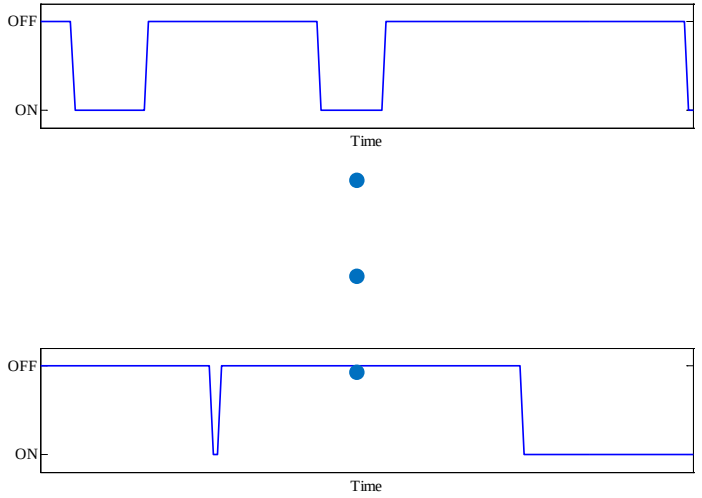
Forward contracts

- GenCo model
  - method: stochastic optimization
  - uncertainty characterization: scenario tree

Pool price scenarios



Availability scenarios



Forward contracts

- GenCo model

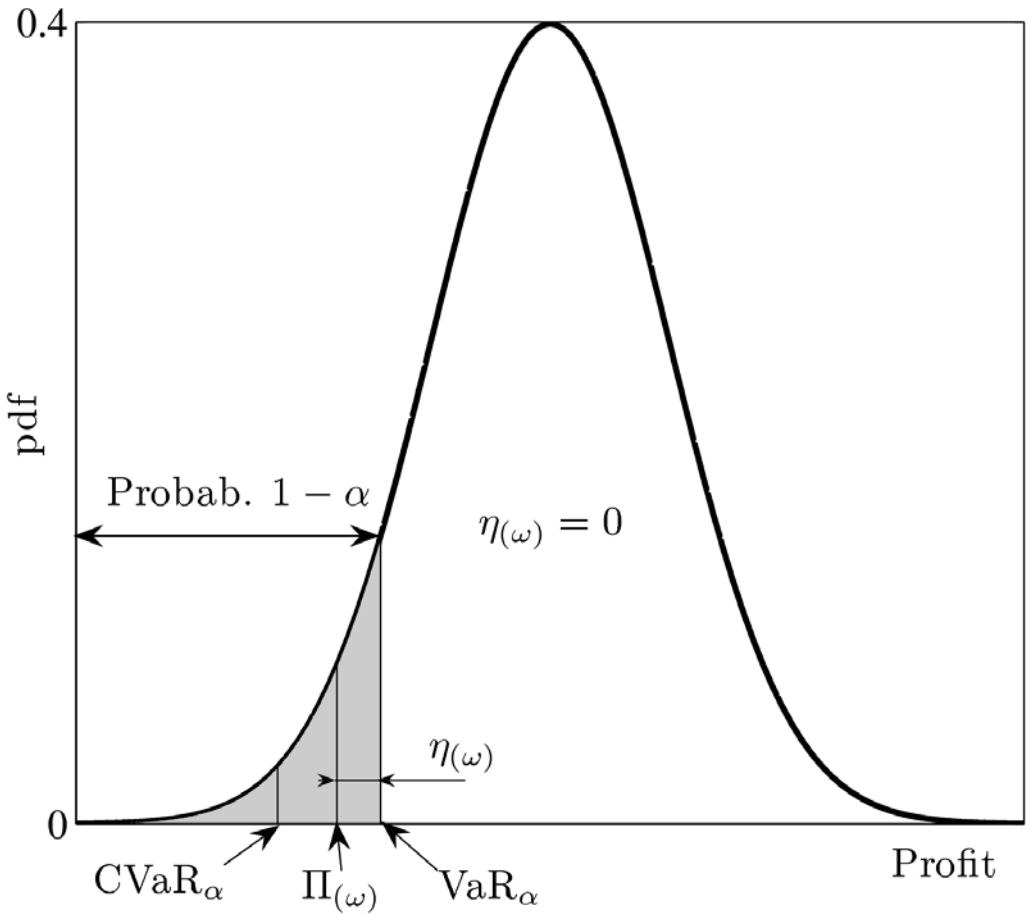
Maximize $CVaR_{\alpha}$(profit)

subject to

- Profit of the power producer
- Production cost of the units
- Technical limits of the units
- Energy balance
- Risk constraints
- Binary variable declarations

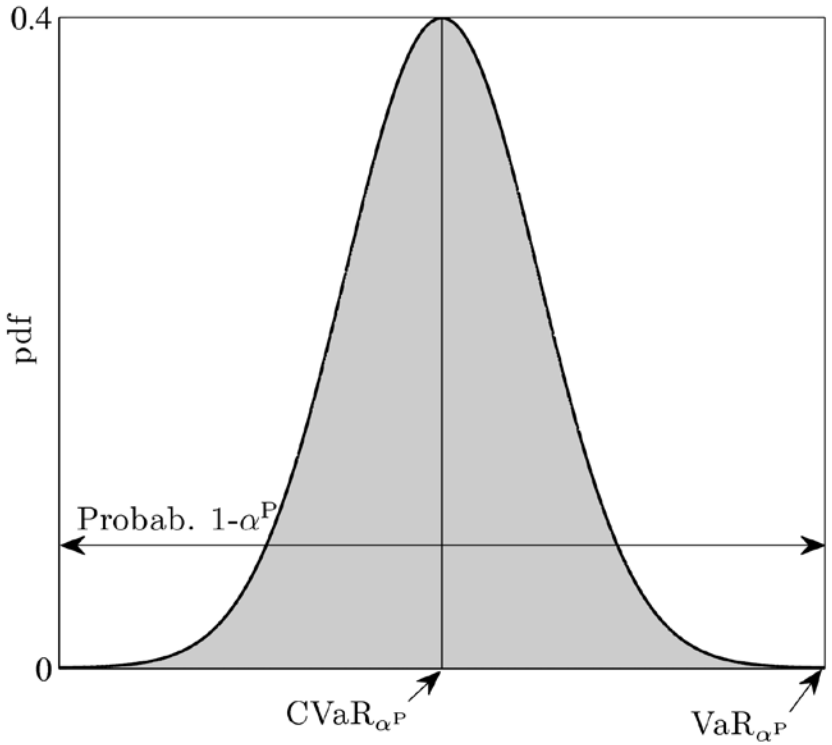
Forward contracts

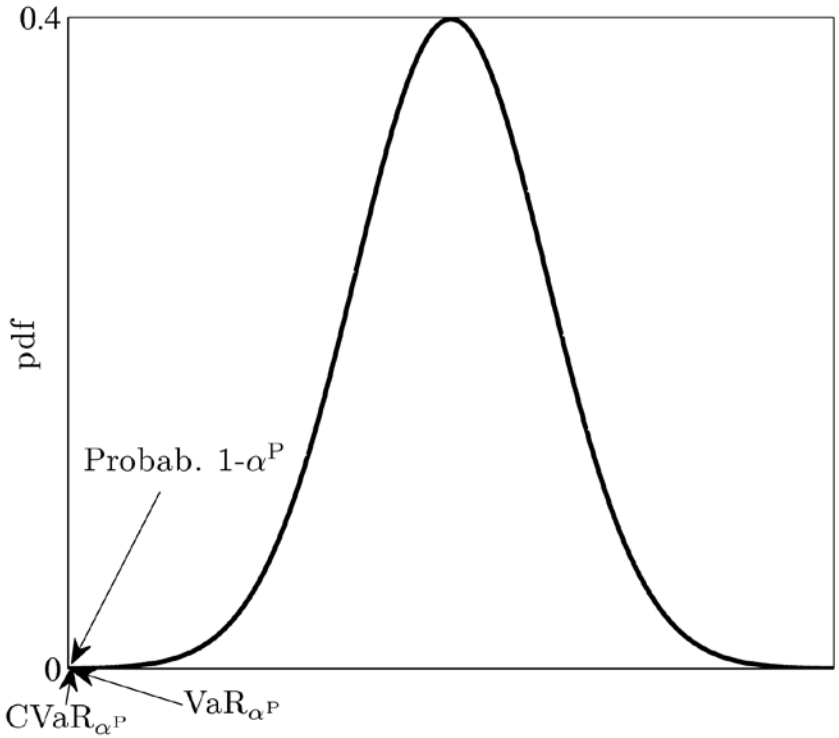
- CVaR



Forward contracts

- CVaR





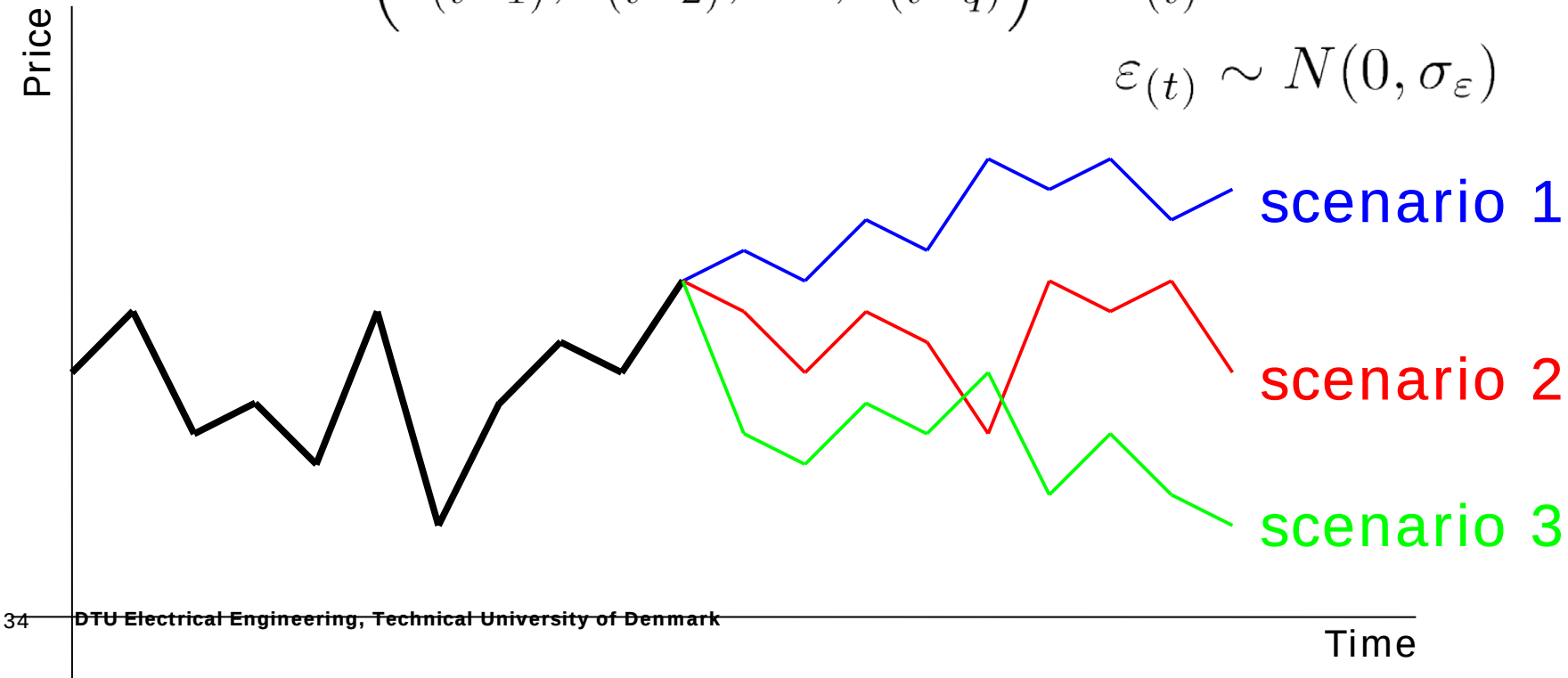
Scenario generation

- Pool price scenario generation: ARIMA

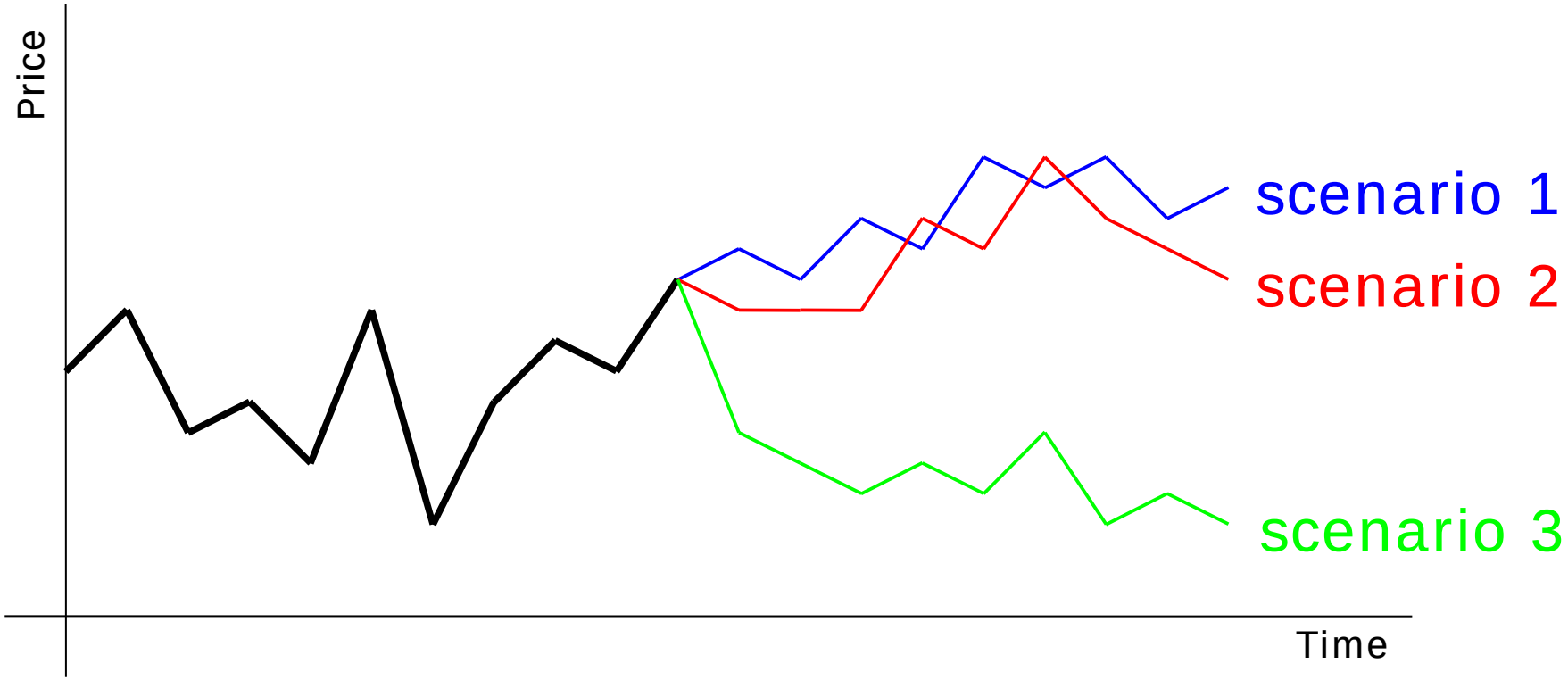
$$\widehat{\lambda^{\mathrm{P}}}_{(t)} = \Phi\left(\lambda^{\mathrm{P}}_{(t-1)}, \lambda^{\mathrm{P}}_{(t-2)}, \ldots, \lambda^{\mathrm{P}}_{(t-p)}\right) +$$

$$+\Theta\left(\varepsilon_{(t-1)}, \varepsilon_{(t-2)}, \ldots, \varepsilon_{(t-q)}\right) + \varepsilon_{(t)}$$

$$\varepsilon_{(t)} \sim N(0, \sigma_{\varepsilon})$$



Scenario Reduction



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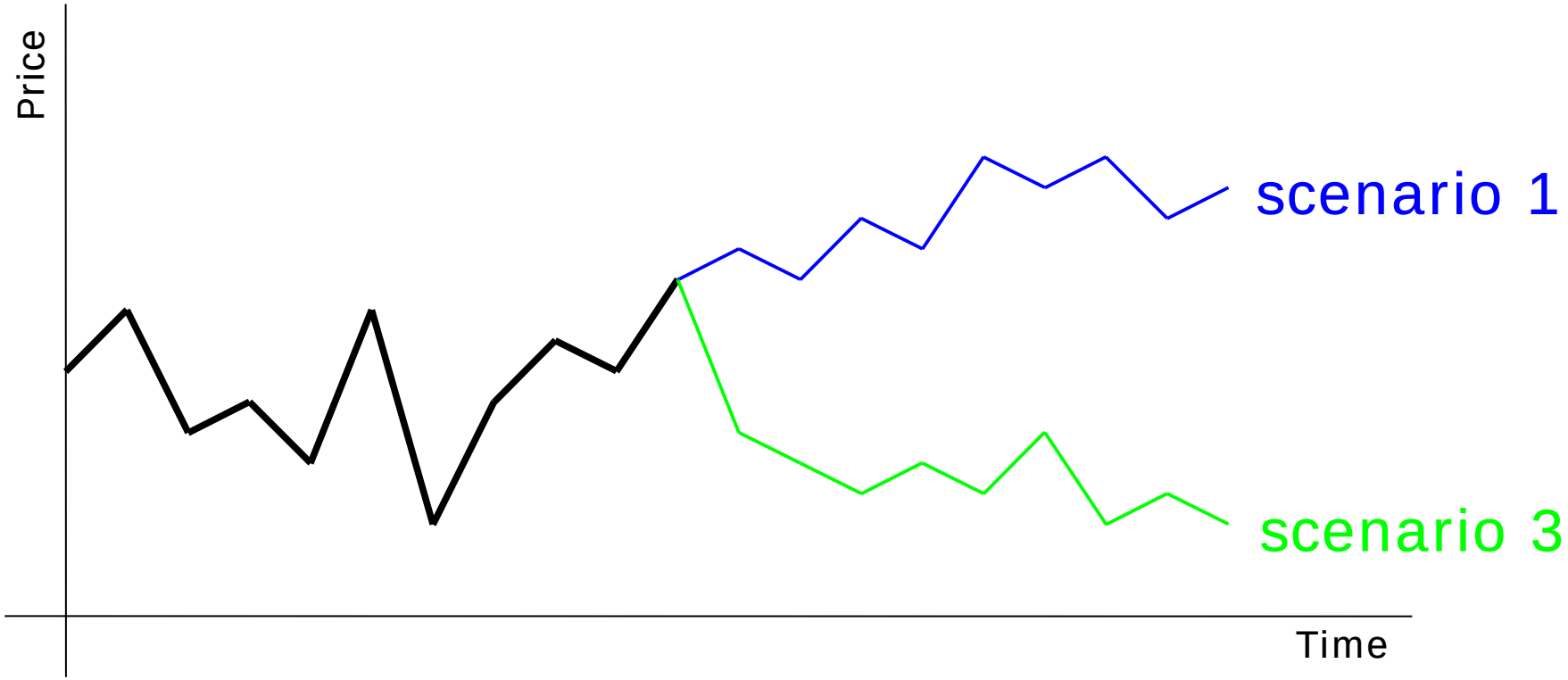

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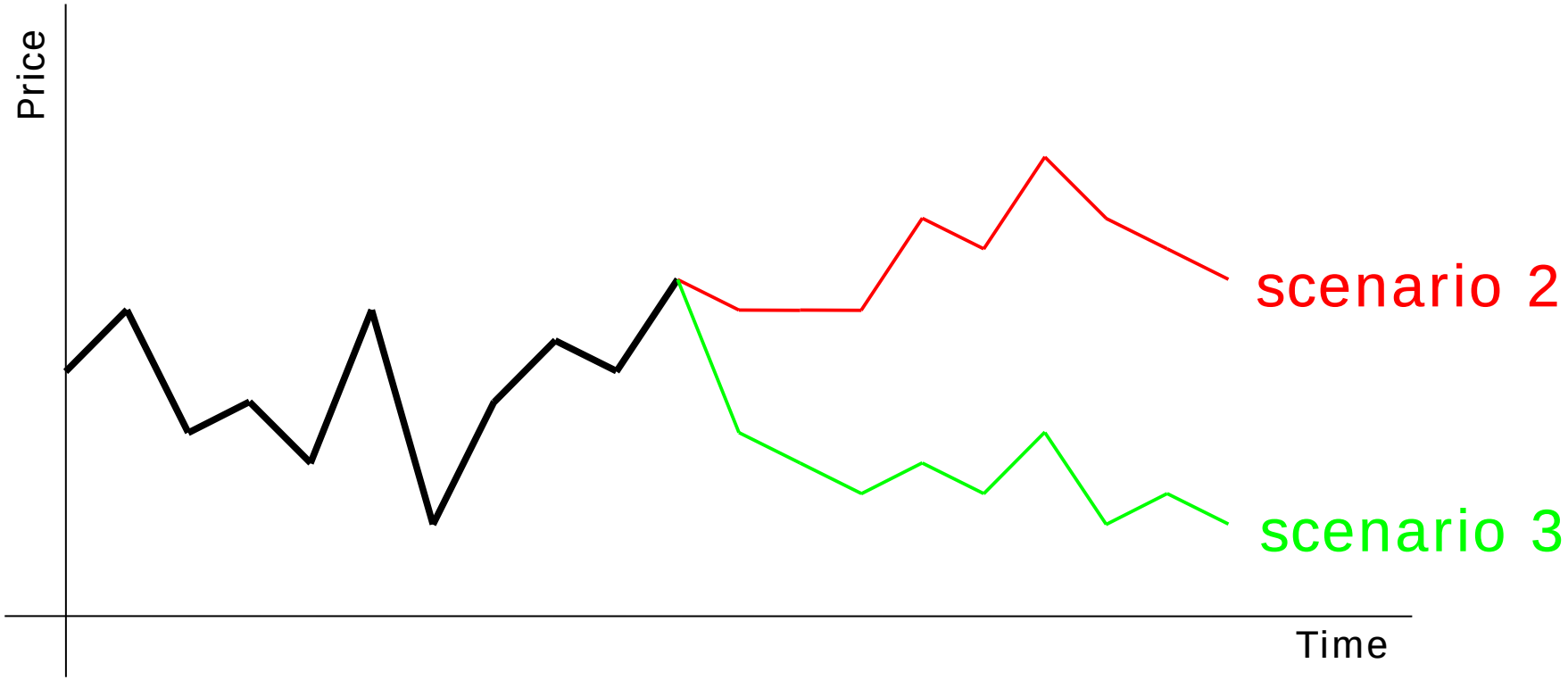

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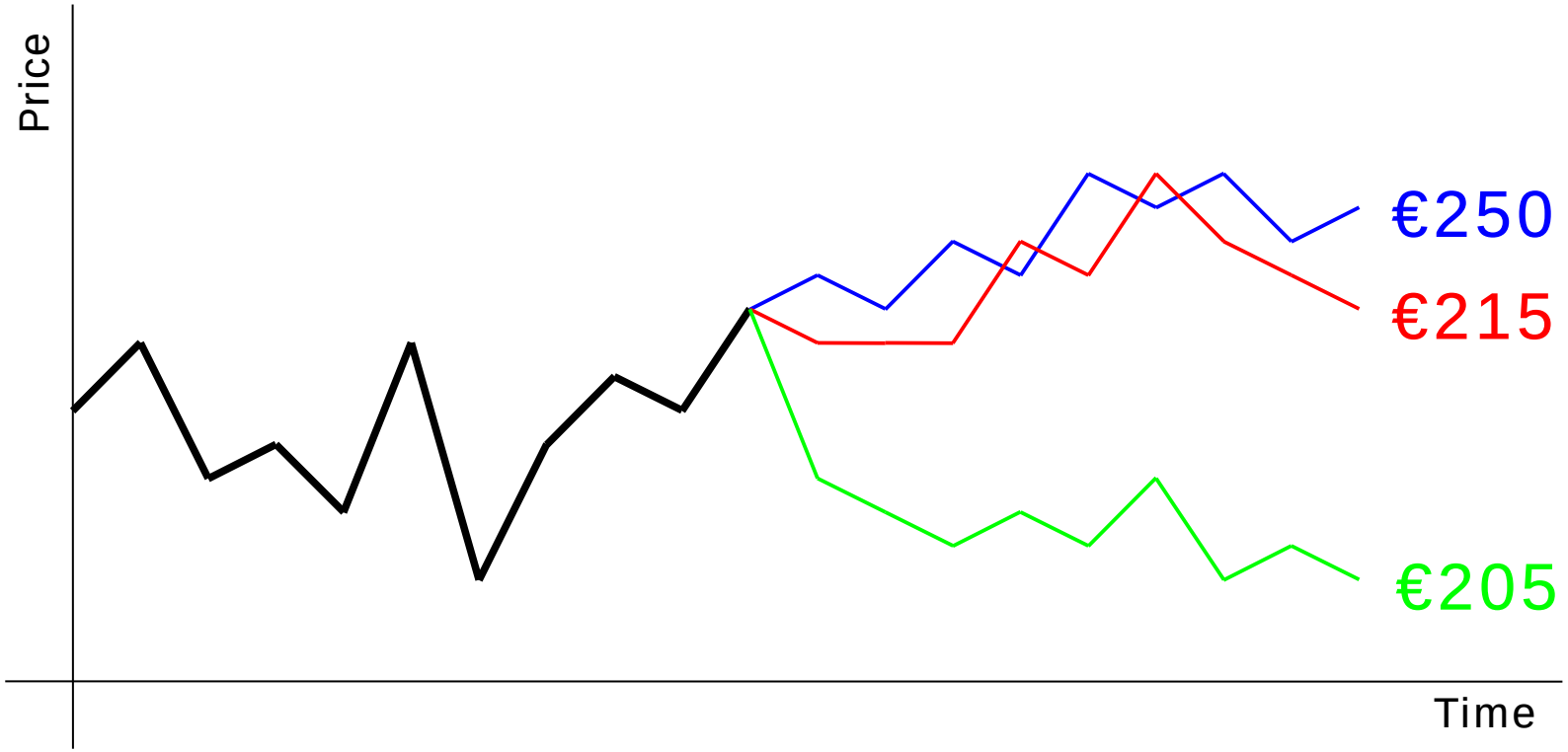

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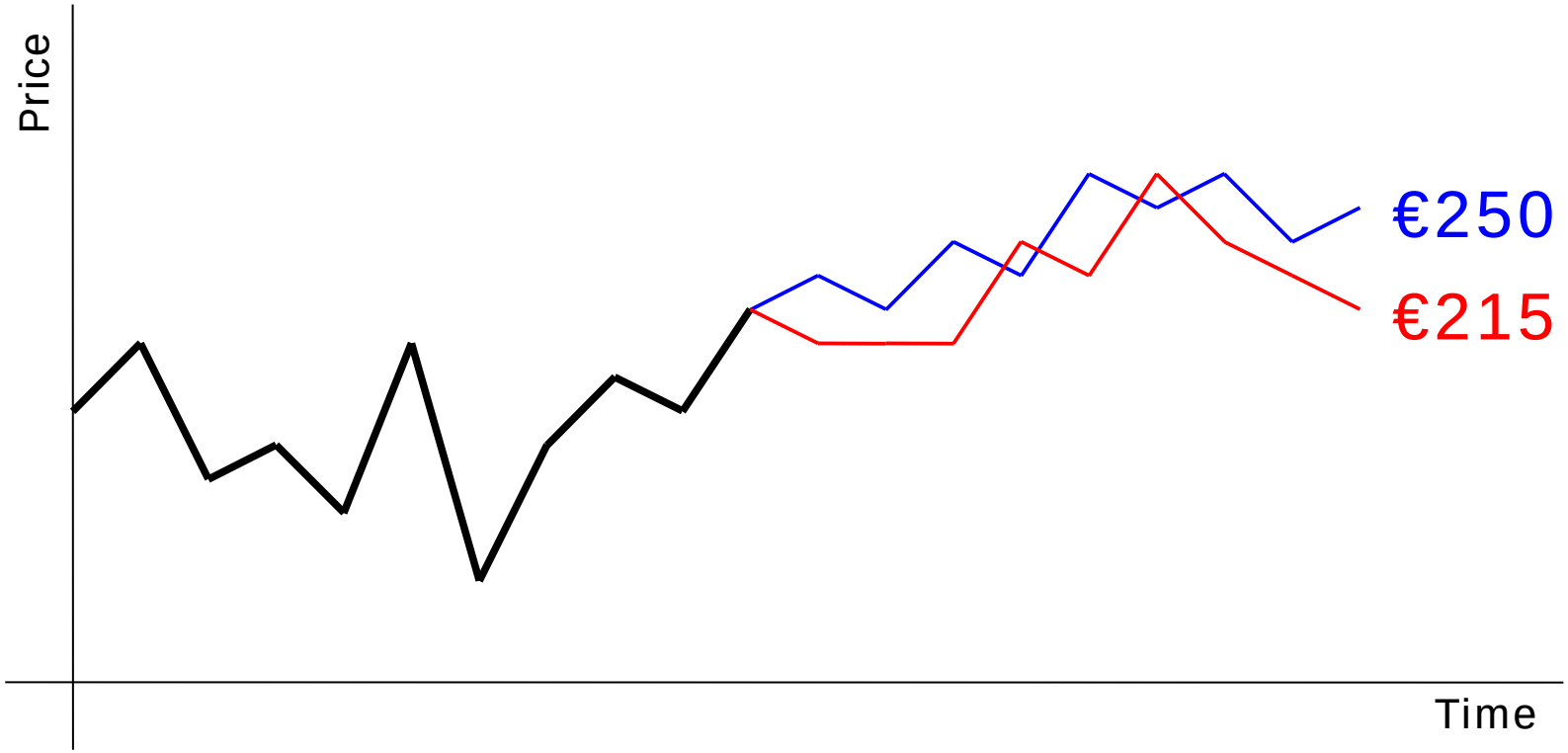

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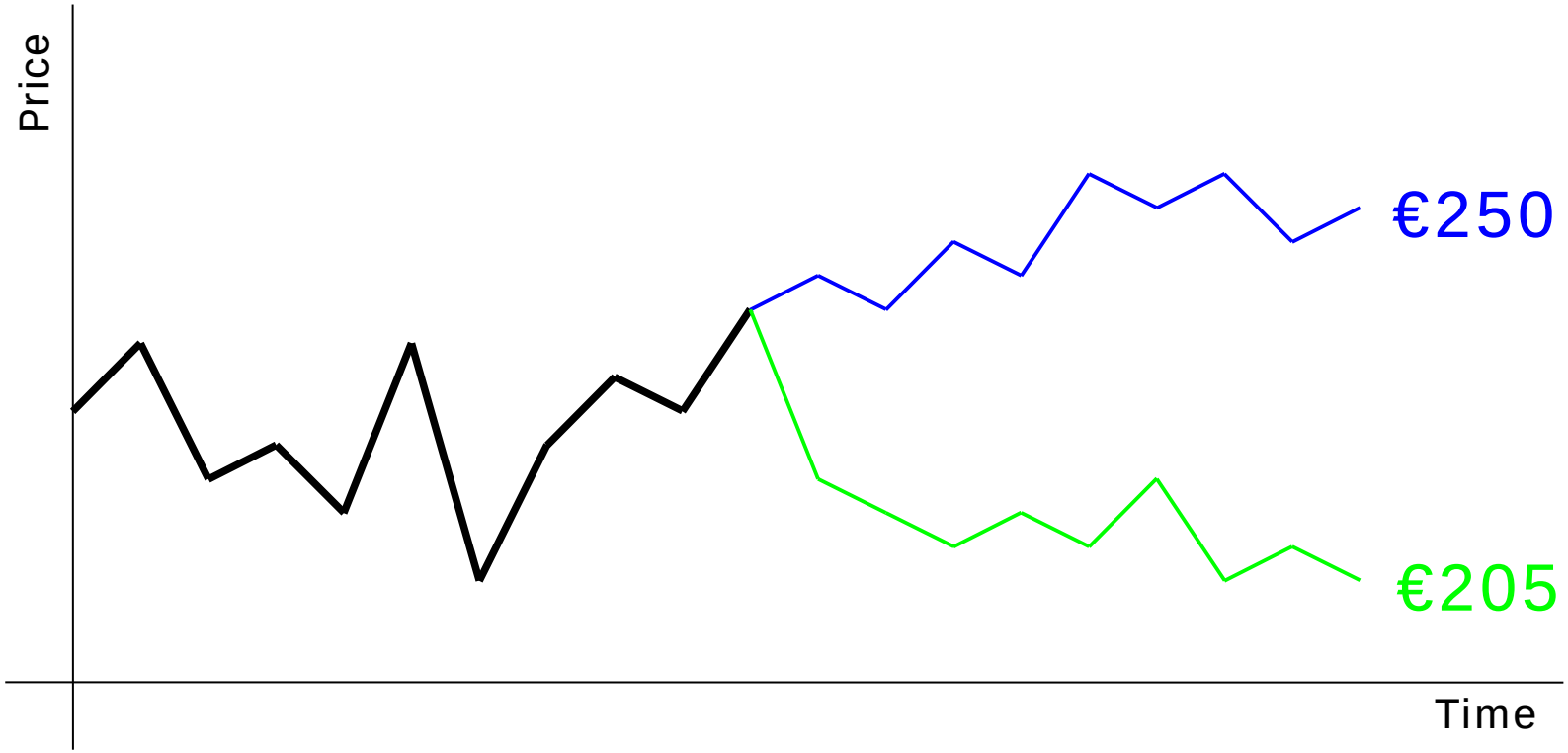

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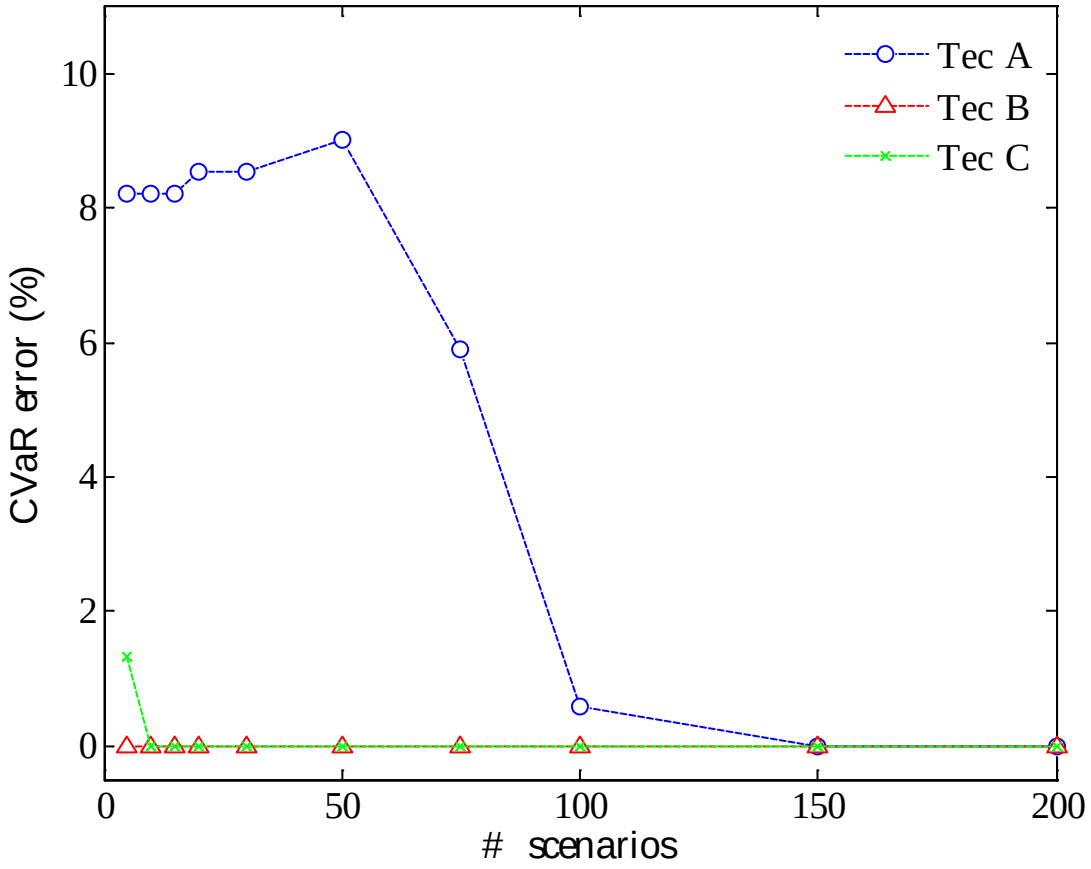

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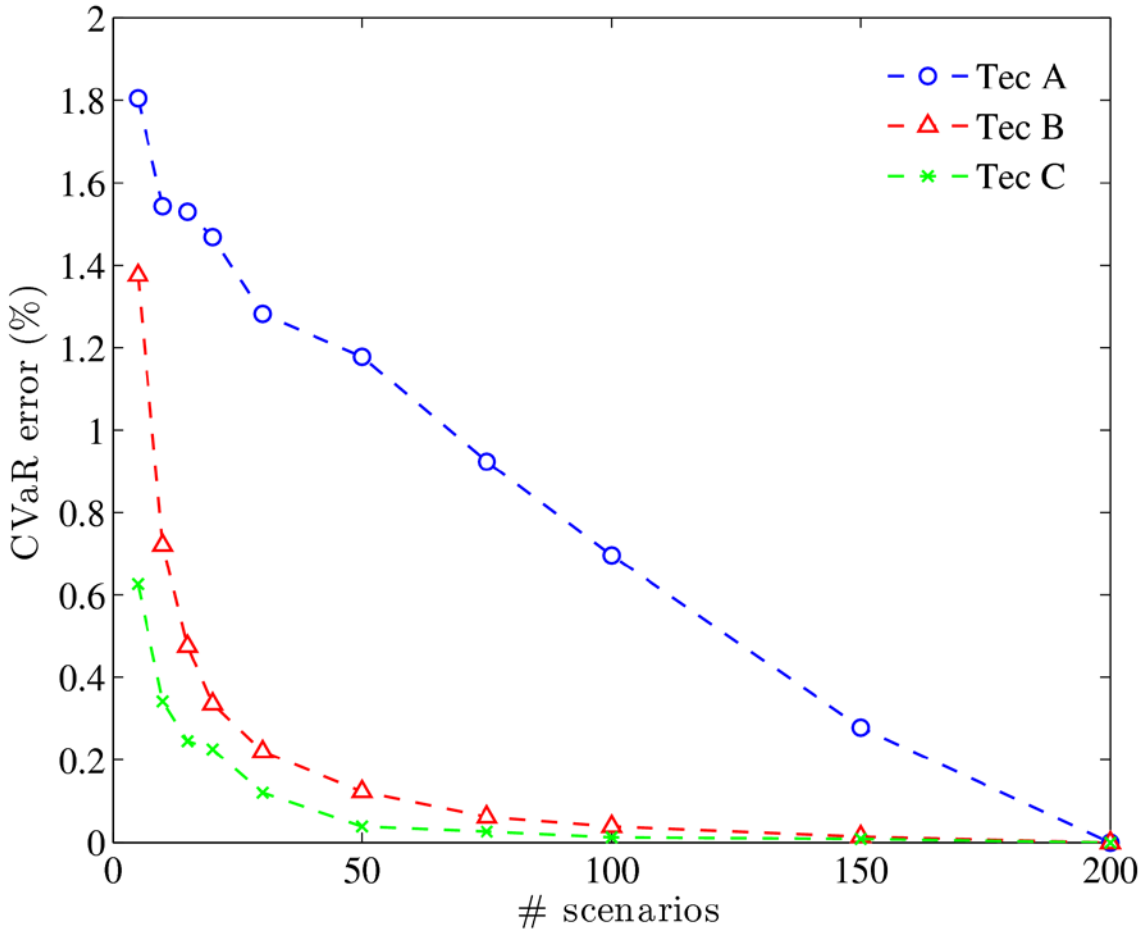
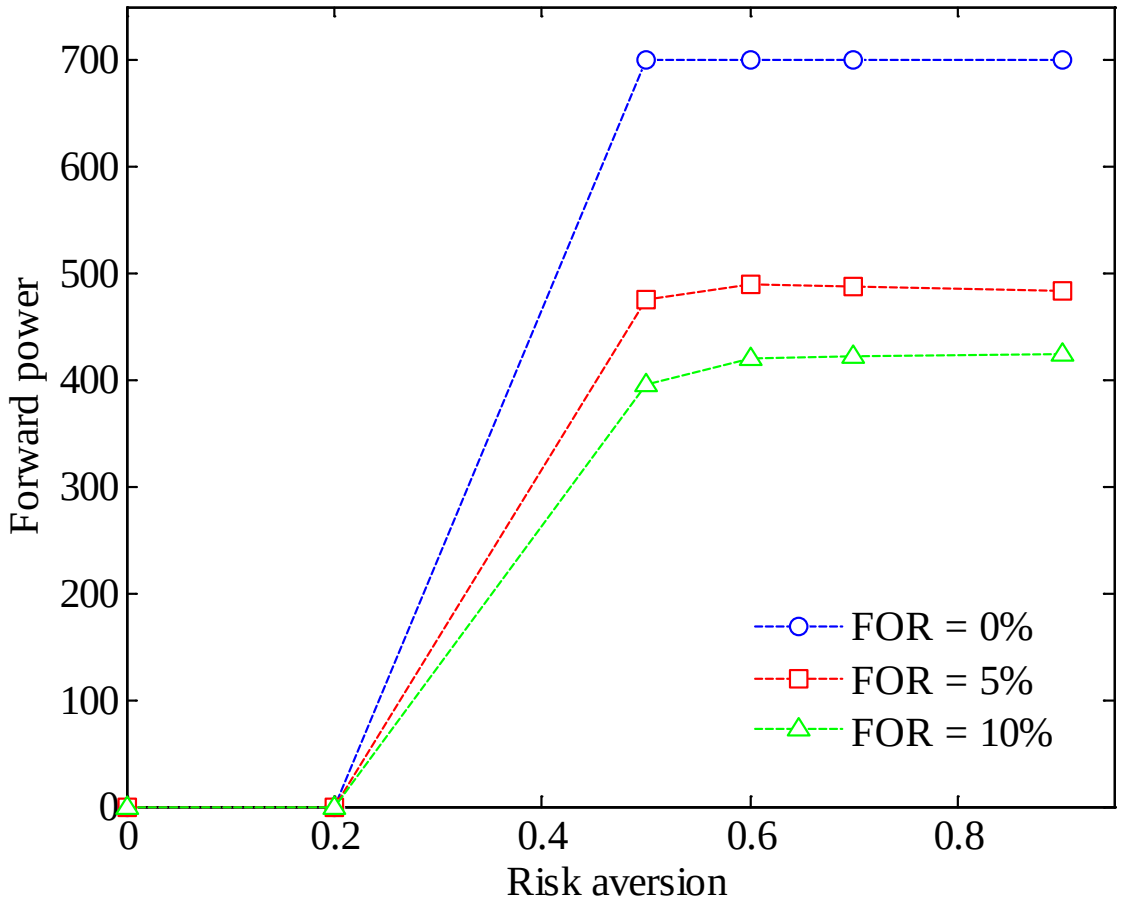


Forward contracts

- Case study: data
  - Study horizon of 8 weeks
  - One generating unit (50 scen.)
  - Pool price uncertainty (30 scen.)
  - Final tree of 1500 scenarios
  - Forward contracts
  - Risk aversion parameter
    - ✓ 6 values: 0, 0.2, 0.5, 0.6, 0.7, 0.9

Forward contracts



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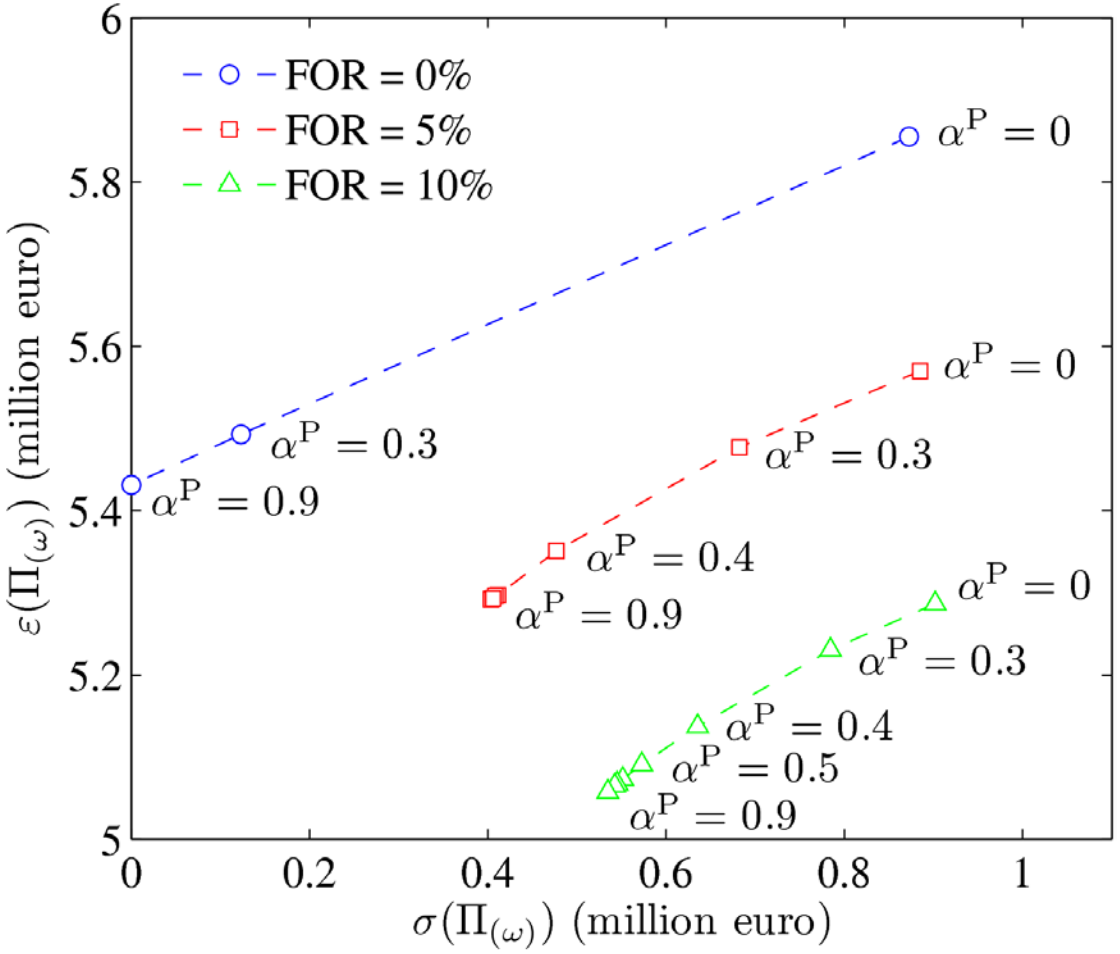

Forward contracts

- EEX (base/peak week/month/quarter/year) web

Continuous Trading | Phelix Baseload Week Futures

Name	Best Bid	Best Ask	No. of Contr.	Last Price	Abs. Change	Last Time	Last Vol.	Settl. Price
Week 36/11	-	-	-	-	-	-	-	48.91
Week 37/11	51.00	51.50	175	-	-	-	-	51.63
Week 38/11	56.00	56.75	-	-	-	-	-	56.25
Week 39/11	60.25	60.75	-	-	-	-	-	59.75
Week 40/11	60.25	62.00	-	-	-	-	-	60.63

Continuous Trading | Phelix Peakload Week Futures

Name	Best Bid	Best Ask	No. of Contr.	Last Price	Abs. Change	Last Time	Last Vol.	Settl. Price
Week 36/11	-	-	-	-	-	-	-	57.00
Week 37/11	60.00	60.50	-	-	-	-	-	60.88
Week 38/11	66.25	67.25	-	-	-	-	-	66.25
Week 39/11	71.50	73.50	-	-	-	-	-	71.75
Week 40/11	71.75	73.75	-	-	-	-	-	72.13

Forward contracts

- NordPool (base/peak week/month/quarter/year) web

PRODUCT SERIES	BID	ASK	LAST	+/-	%	HIGH	LOW	CLOSING
ENOW37-11	38,00	39,75	38,50	-1,25	-3,14	39,50	38,50	39,75
ENOW38-11	42,25	42,50		0,00	0,00			43,00
ENOW39-11	44,00	44,75		0,00	0,00			45,00
ENOW40-11	44,00	45,25		0,00	0,00			45,50
ENOW41-11	45,00	48,00		0,00	0,00			46,50
ENOW42-11	45,50	48,50		0,00	0,00			47,00
ENOPLW37-11	40,50	48,50		0,00	0,00			45,50
ENOPLW38-11	43,50	51,50		0,00	0,00			48,50
ENOPLW39-11	45,75	53,75		0,00	0,00			49,50
ENOPLW40-11	46,50	54,50		0,00	0,00			50,25
ENOPLW41-11	47,50	55,50		0,00	0,00			51,50

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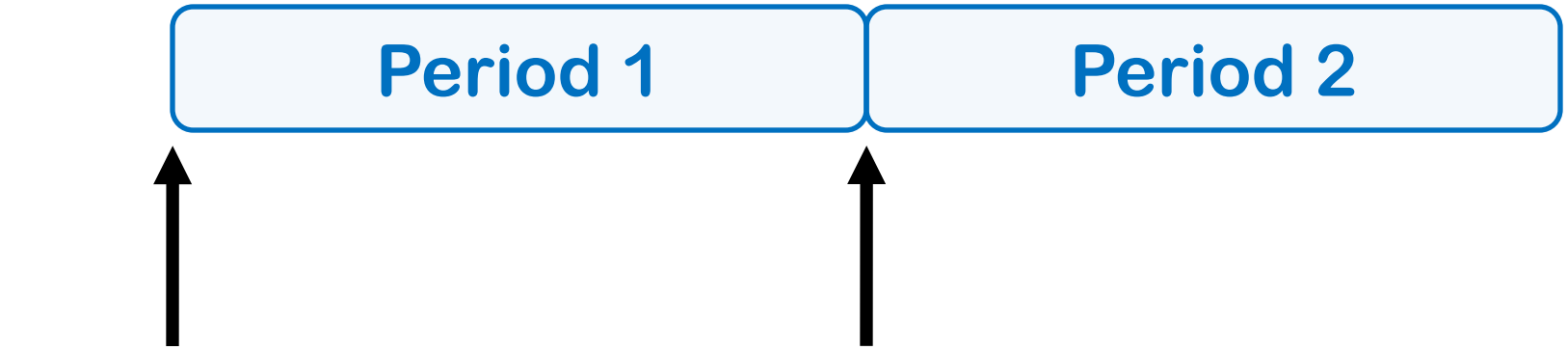
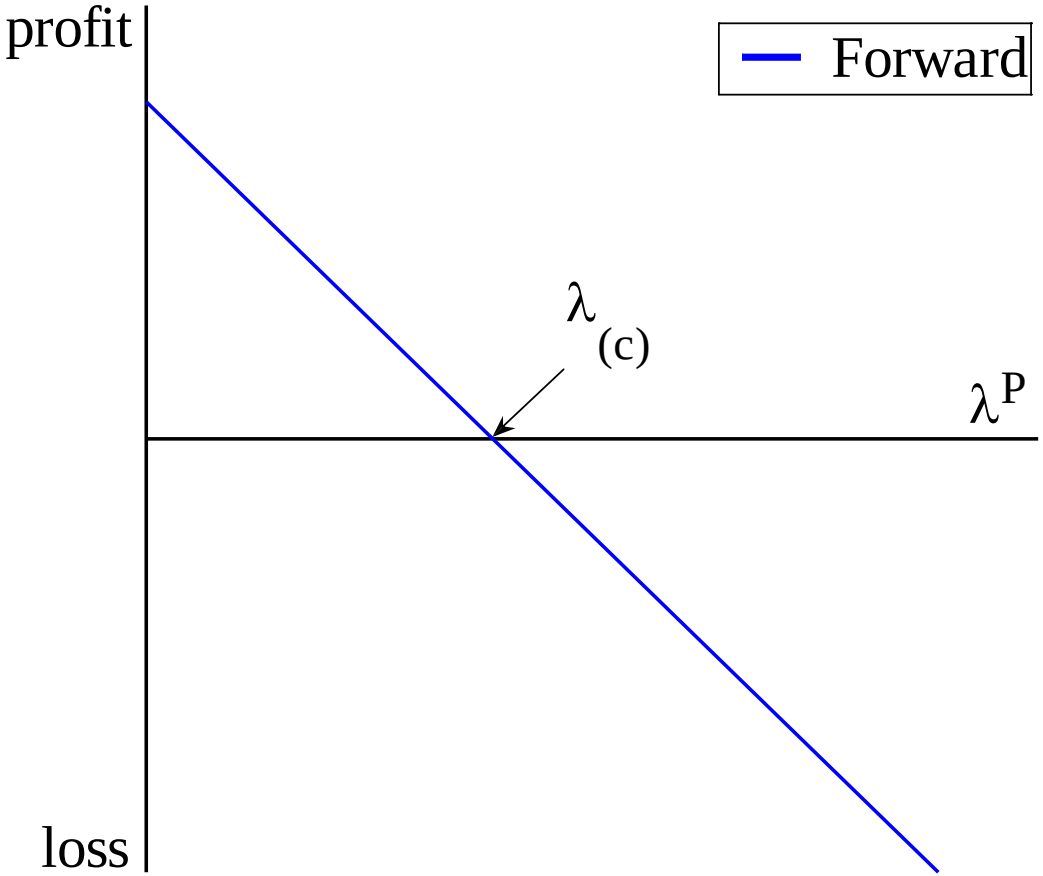
Electricity options

- Basic idea



Electricity options

- Basic idea



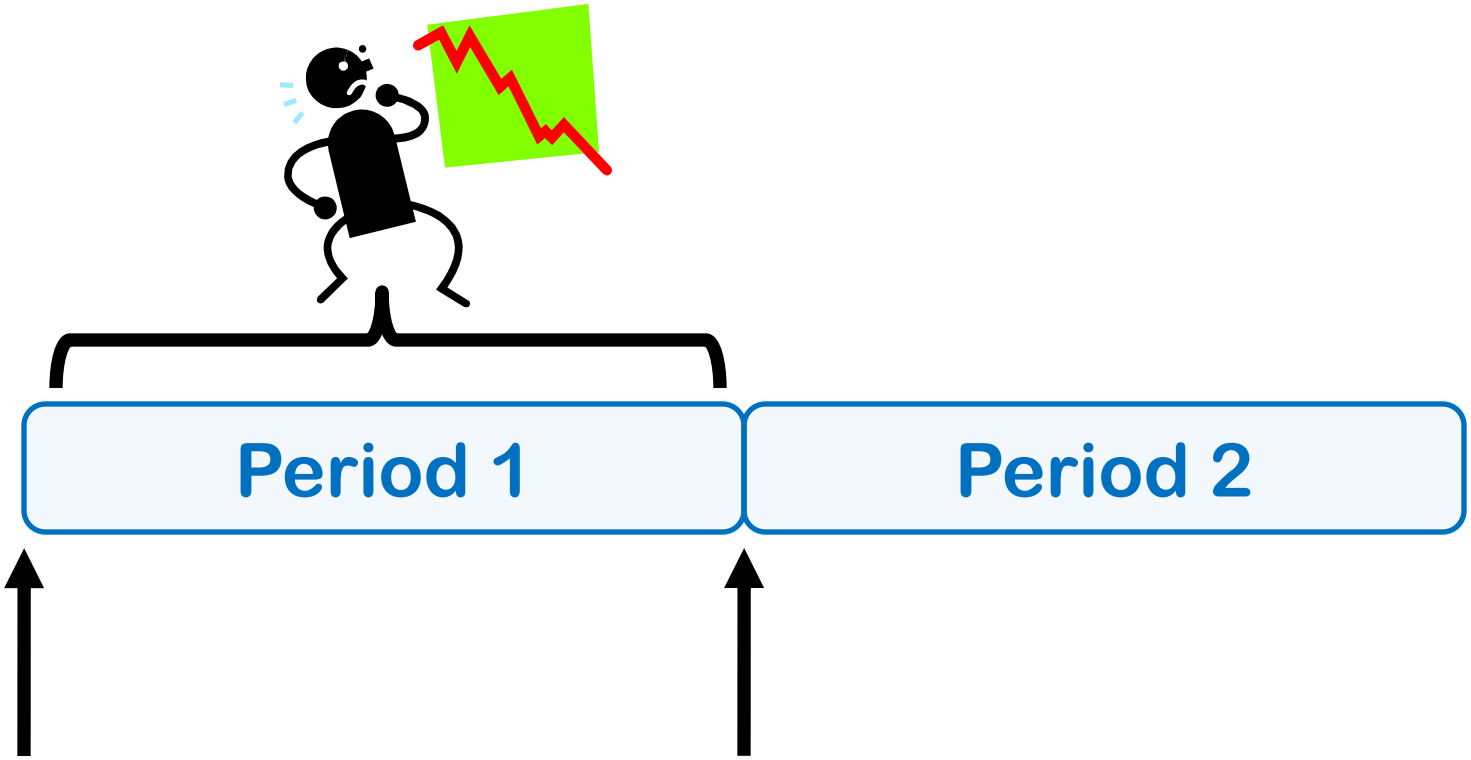
Electricity options

- Basic idea

Put option to sell electricity at
p €/MWh during period 2 (Δp)

Electricity options

- Basic idea

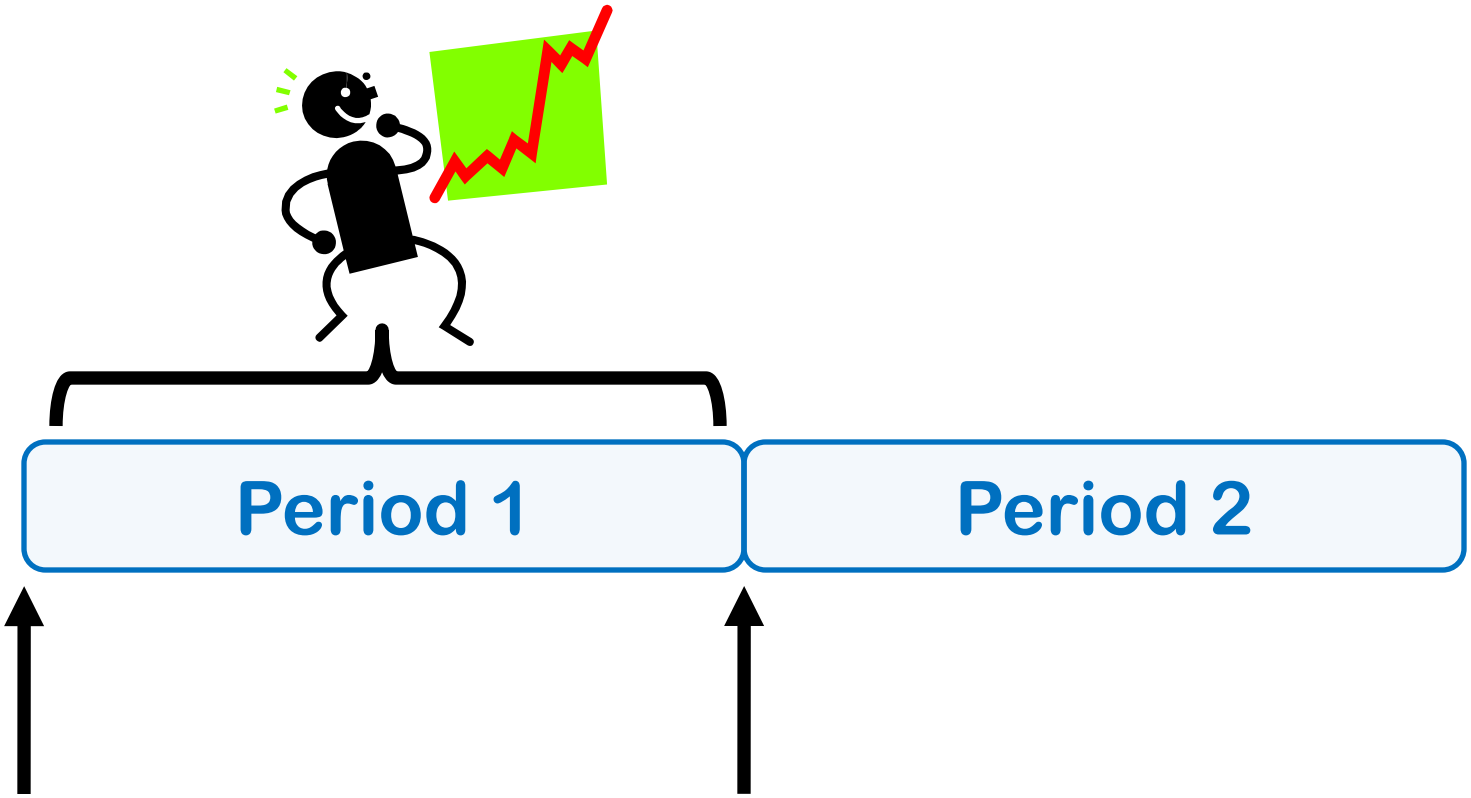


Put option to sell electricity at p €/MWh during period 2 (Δp)

Option is exercised to hedge against low prices

Electricity options

- Basic idea

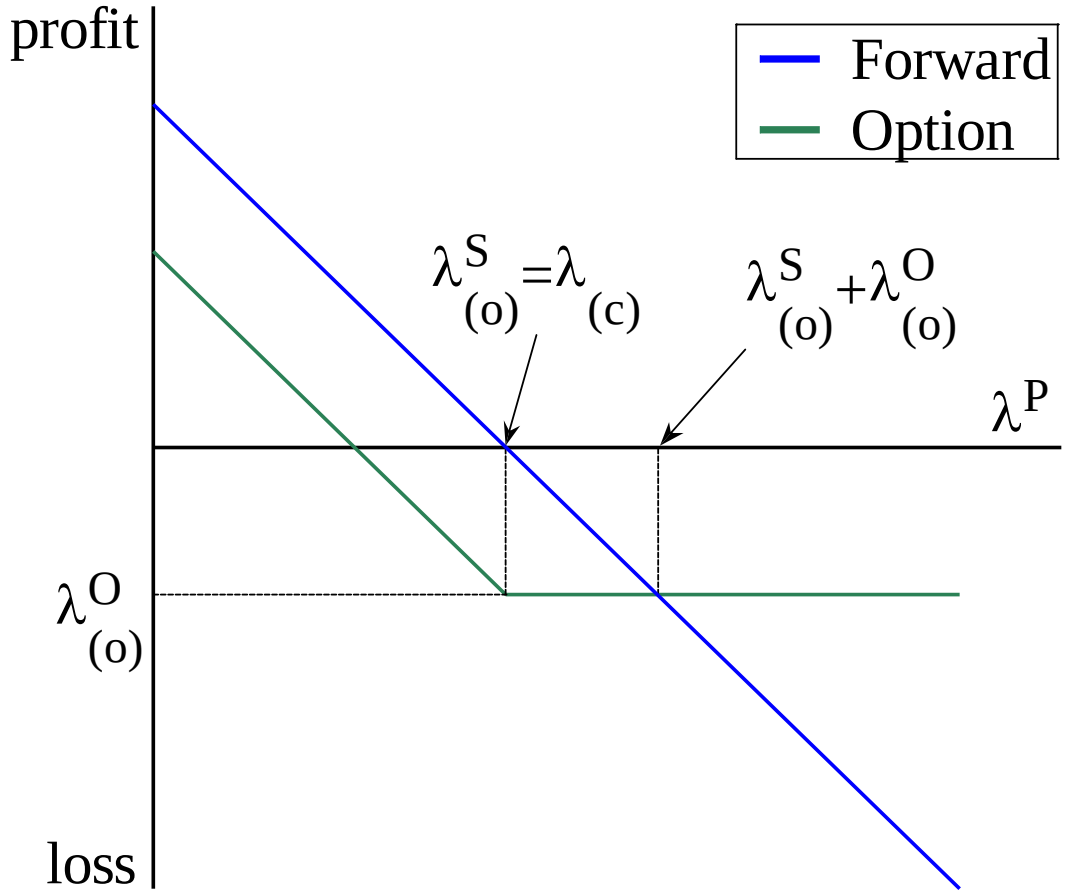


Put option to sell electricity at p €/MWh during period 2 (Δp)

Option is not exercised to obtain high profits

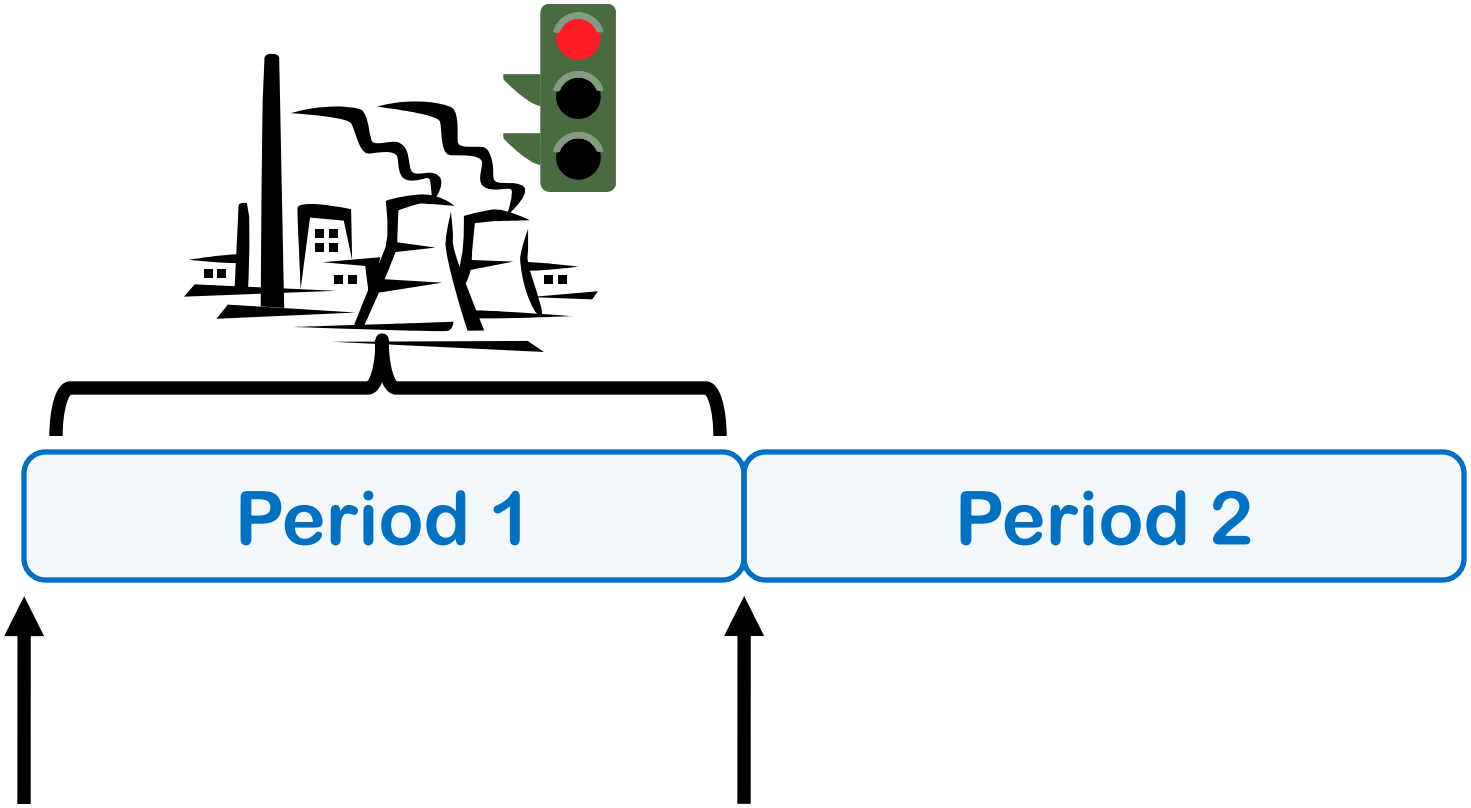
Electricity options

- Basic idea



Electricity options

- Basic idea

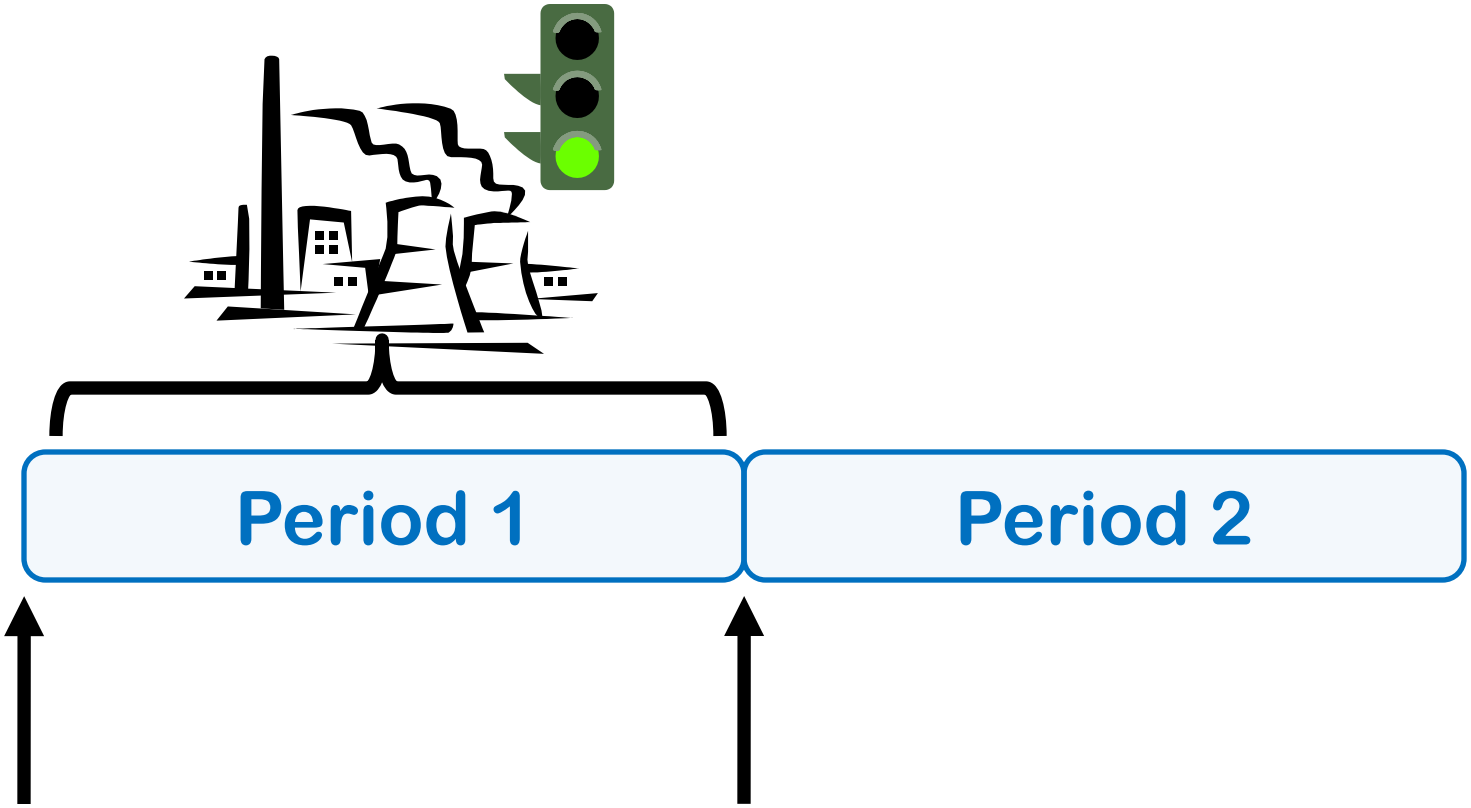


Put option to sell electricity at p €/MWh during period 2 (Δp)

Option is not exercised to hedge against unit failures

Electricity options

- Basic idea



Put option to sell electricity at p €/MWh during period 2 (Δp)

Option is exercised

Electricity options

- Definition

Right to buy	=> buy option	= call
... or to sell	=> sell option	= put
... a given futures contract	=> underlying asset	Phelix Base Year Future for the year 2011
... in a given quantity	=> number	1 MW
... at a price specified in advance	=> exercise price	EUR 52.00
... at or until a time specified	=> last trading day	09/12/2010

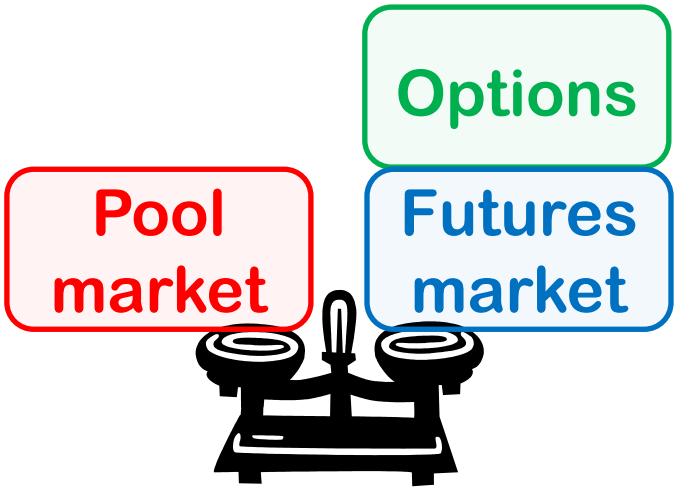
Electricity options

Sources of uncertainty

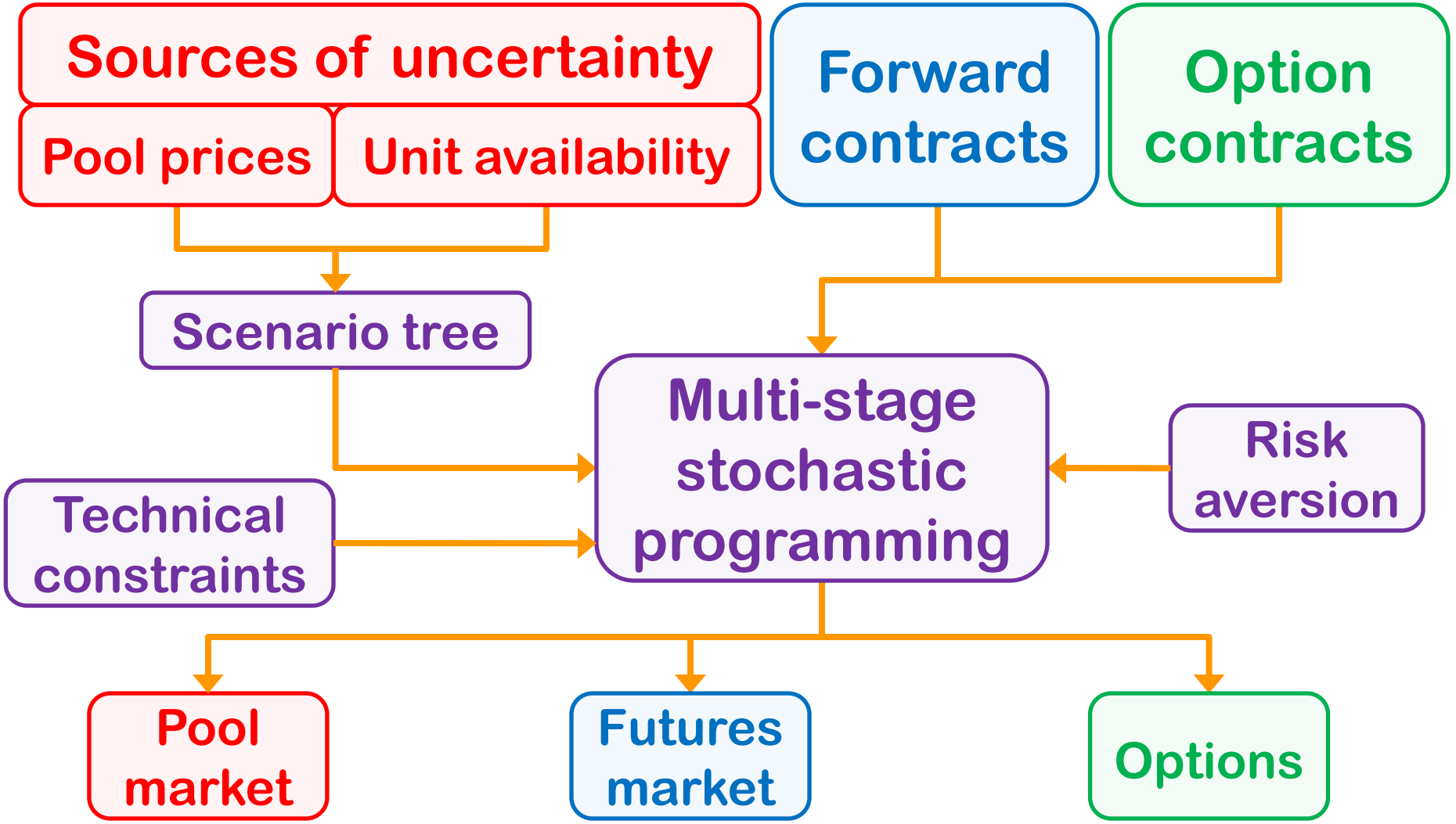
Pool prices | Unit availability

Forward contracts

Option contracts

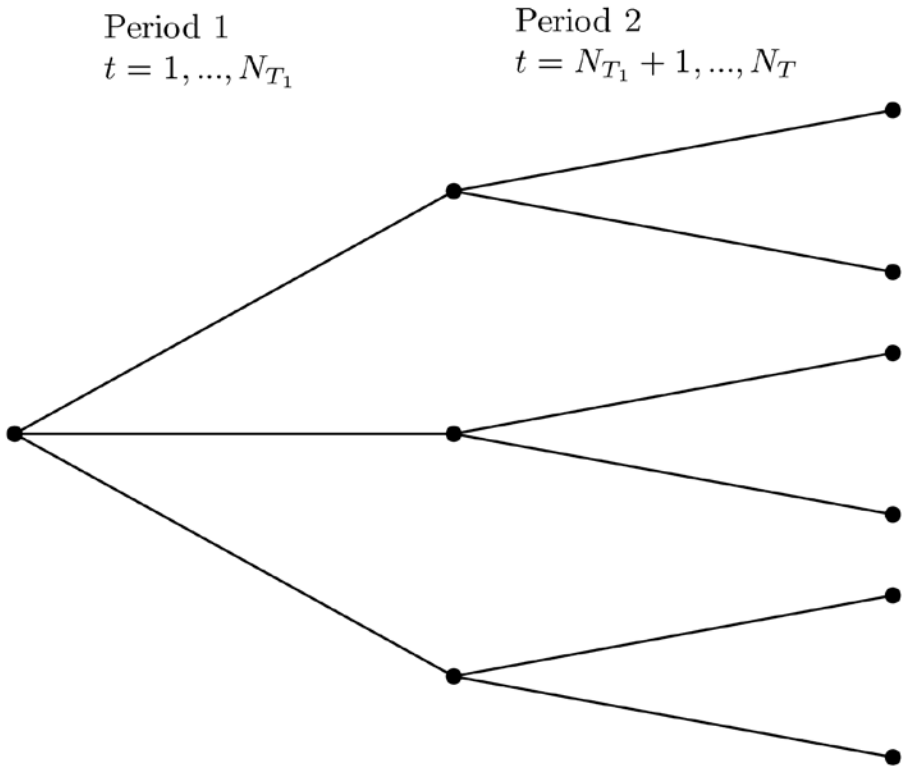


Electricity options



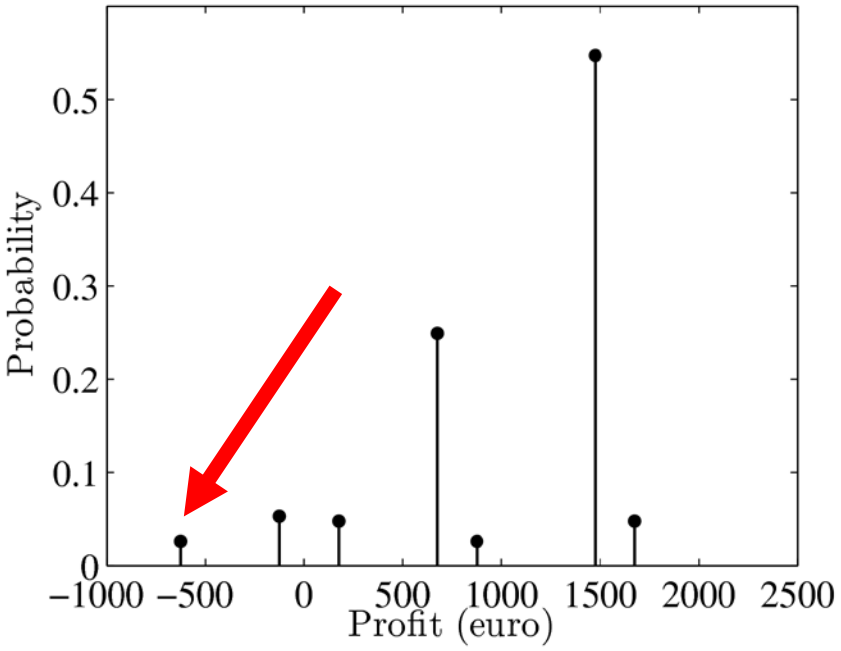
Electricity options

- Multi-stage stochastic programming

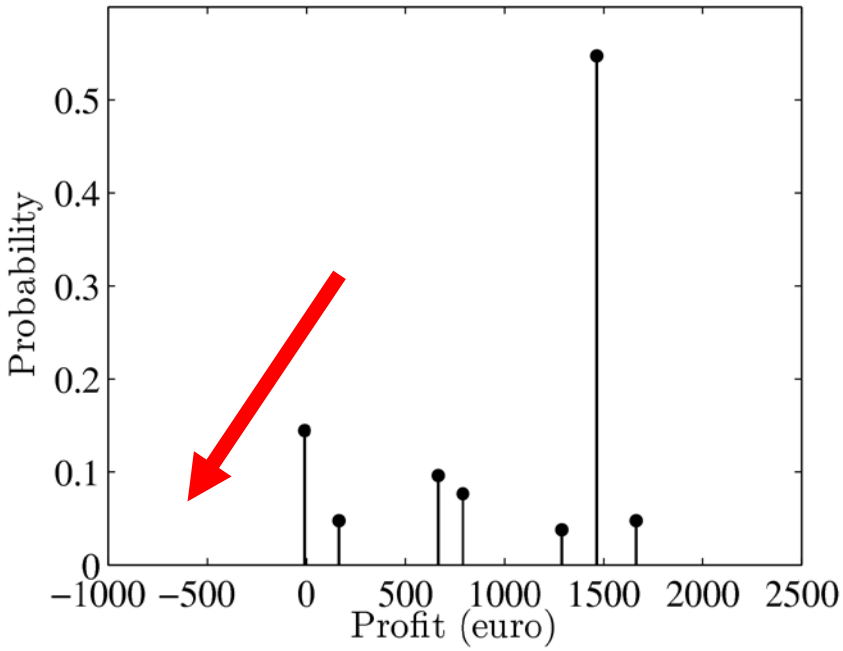


Electricity options

- Example



Forward contract



Option contract

Electricity options

- Case study: put option
  - Study horizon of 8 weeks
  - One generating unit (30 scen.)
  - Pool (30 scen.) / Forward contracts (3 scen.)
  - Final tree of 2700 scenarios
  - Put contract (last four weeks)
    - ✓ Strike price 21 €/MWh
    - ✓ Option price 0,1 €/Mwh
    - ✓ Power level 350 MW
  - Risk aversion parameter

Electricity options

- Case study: put option

α^{P}	FOR = 0%		FOR = 5%		FOR = 10%	
	Case (a)	Case (b)	Case (a)	Case (b)	Case (a)	Case (b)
0	5.087	5.418	4.984	5.314	4.878	5.209
0.5	5.078	5.117	4.872	4.970	4.664	4.860
0.9	5.078	5.055	4.549	4.649	4.374	4.499

Electricity options

- Case study: put option

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$E_2\{\lambda^{\mathrm{P}}_{(\omega,t)}\}$	22.41	22.58	22.64	20.97	24.39	21.85	22.35	20.28	26.01	22.04
$y_{(o,\omega)}$	0	0	0	1	0	0	0	1	0	0

Electricity options

- Case study: put option

α^{P}	FOR = 0%		FOR = 5%		FOR = 10%	
	Case (a)	Case (b)	Case (a)	Case (b)	Case (a)	Case (b)
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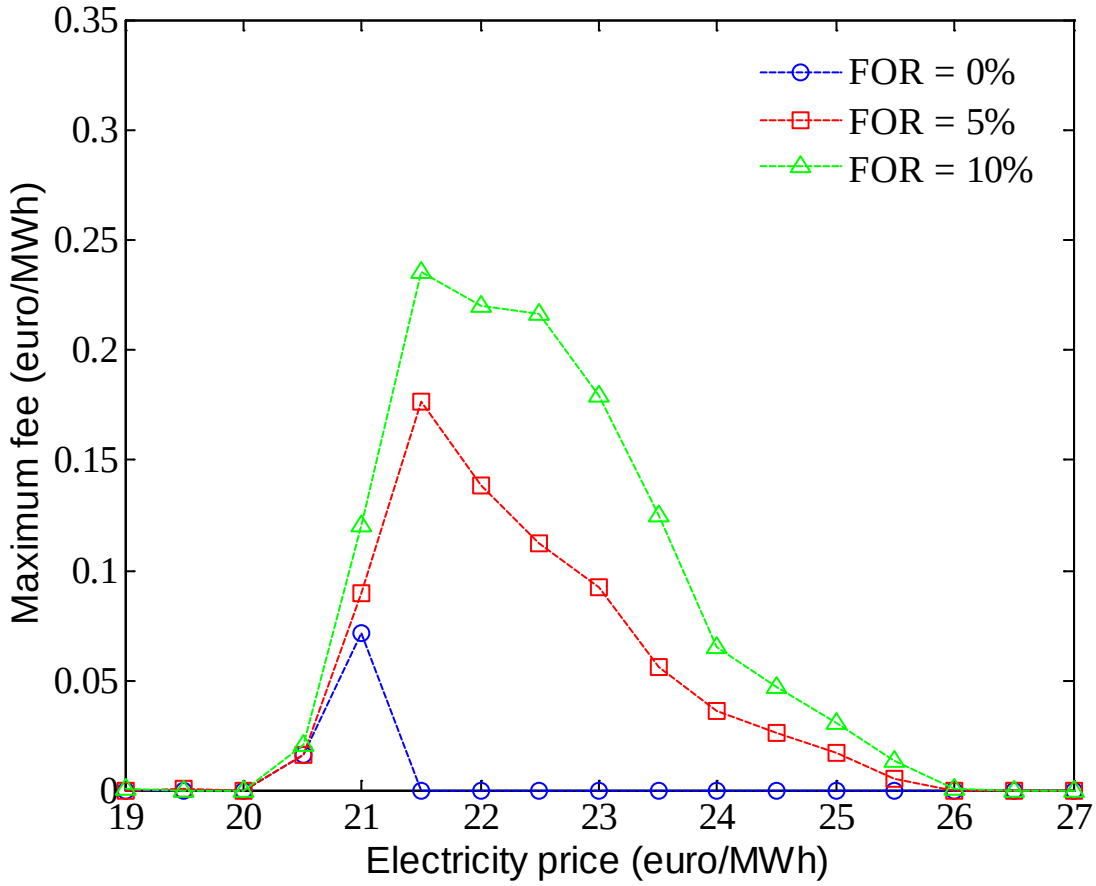
0.9	5.078	5.055	4.549	4.649	4.374	4.499

$E_2\{\lambda^{\mathrm{P}}_{(\omega,t)}\}$	$k_{(\omega,N_{T_1})}$									
	1	0	1	1	1	1	1	1	1	1
26.01	0	0	0	0	0	0	0	0	0	0
20.97	1	0	1	1	1	1	1	1	1	1
20.28	1	1	1	1	1	1	1	1	1	1

Electricity options

- Case study: put option



Electricity options

- EEX (web)

Continuous Trading | Phelix Baseload Month Futures

Name	Best Bid	Best Ask	No. of Contr.	Last Price	Abs. Change	Last Time	Last Vol.	Settl. Price
Sep-11	-	-	-	-	-	-	-	53.61
▼ Oct-11	62.75	63.75	-	-	-	-	-	62.60
C 5400	-	-	-	-	-	-	-	8.608
C 5500	-	-	-	-	-	-	-	7.624
C 5600	-	-	-	-	-	-	-	6.653
C 5700	-	-	-	-	-	-	-	5.704
C 5800	-	-	-	-	-	-	-	4.789
C 5900	-	-	-	-	-	-	-	3.924
C 6000	-	-	-	-	-	-	-	3.127
P 5400	-	-	-	-	-	-	-	0.015
P 5500	-	-	-	-	-	-	-	0.030
P 5600	-	-	-	-	-	-	-	0.058
P 5700	-	-	-	-	-	-	-	0.108
P 5800	-	-	-	-	-	-	-	0.193
P 5900	-	-	-	-	-	-	-	0.327
P 6000	-	-	-	-	-	-	-	0.529

Conclusions

- Derivatives are defined as financial contracts whose value depends on the value of another asset.

- Two main types of derivatives:
  - Future and forward contracts
  - Options

- Derivatives contracts are use to transfer risk in exchange for a given premium or fee.

Bibliography

[1] J.F. Marshall. *Dictionary of financial engineering. John Wiley & Sons* Inc, 2000.

[2] S.J. Deng and S.S. Oren. Electricity derivatives and risk management. *Energy, 31(6-7):940-953, 2006.*

[3] J. Hull. *Options, futures and other derivatives. Pearson Prentice Hall,* 2009.

Thanks

Questions?