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Wie wirken sich Information und Marktmacht auf Elektrizitätsmärkten mit hohem Anteil erneuerbarer Energien aus?

Building Competence. Crossing Borders.

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Motivation I

Todays Electricity market

- **Moderate share** of **renewables** in electricity market which are sheltered from real prices
- Higher share of **dispatchable production** units (gas, coal)
- High proportion of **day-ahead trading**
- Predictable demand and production follows consumption

Future Electricity Market

- **High share** of **renewables** in electricity markets with more volatile production which will participate in market.
- More **short-term trading** (intraday), since reliable forecast horizons are short
- **Aggregators** may develop

Motivation II

Todays Electricity market

- Inelastic demand, homogenous products, common knowledge of costs and technology, high entry costs, market manipulation, uncompetitive behavior.
- Thus, reducing asymmetric information would enhance efficiency.
- EU REMIT (2011)：requires to make information transparent relating to capacity and planned and unplanned unavailability.

Future Electricity Market

- Temporary market power may arise: asymmetric weather conditions
- Generators know better of their own generation possibility – the volatility of their supply capacities
- Less predictable demand- consumers act both as suppliers and demanders.
- A different level of information transparency.

Motivation III - Literature

In the context of multi-unit auctions, there is no consensus regarding the optimal level of transparency (information):

1. A higher level of **transparency is beneficial**: helps better predict market outcomes (Abbink et al. 2003, Holmberg and Wolak, 2015)
2. Too much **transparency undermines market performance**: facilitating collusion (Fehr 2013, Wolffram, 1998)

Motivation: Strategic behaviour

In a multi-unit auction, bidders might not be truth-telling:

Low cost/ Pivotal sellers might inflate the market price through bid-shading:

- Low cost sellers- monopoly power: **limit pricing strategy** (a partial bid shading)
- **Pivotal sellers-** his supply is pivotal to clear the market: bid shading strategy

- We design a sequence of integrated auction **experiments** to study the differential effects of **competition**, **market power** and **information**.
  - Vary degree of competitors and demand levels
  - Market power: Pivotality or monopolizing
  - Complete info – asymmetric info – incomplete symmetric info

Research Questions

To explore how **information transparency** influence market price under different levels of market power.

- Does variability of wind/PV generation across the market create additional opportunities to exercise **market power due to increasing asymmetry**?
- Does increasing uncertainty on the **supply side or the demand side** discourage strategic behaviour?

Methods

- **Method**: theoretical modeling (supply function competition- SFE) and laboratory experiments.
- A central problem with SFE is its multiplicity of equilibria. In our case, theoretical prediction is not clear.

Through constrained least square regressions

Theory

Possible SFE1, **SFE2**..

Experimental data

Experiments: Nobel Prize in Economics, 2002

Daniel Kahneman: “for the introduction of insights from psychological research into economics, in particular with regard to judgements and decisions under uncertainty”. Kahneman’s research is based on psychological experiments and questionnaires. **Founder of behavioral economics**.

Vernon Smith: “for the use of laboratory experiments as a tool in empirical economic analysis, in particular, for the study of different market mechanisms”. **Founder of experimental economics**.

Advantages of Experimental Economics

- **Controlled experiments** “most convincing method of creating the counterfactual”, that’s why increasing popularity
- **Causal relationships** can be inferred, because (in a perfect experiment world) everything can be kept equal while varying only one parameter
  - The level of transparency can be changed step by step to simulate different levels of uncertainty
- **Experiments complement** other methods of empirical investigation
  - specific advantages (control, causality) → **internal validity**
    An experiment is if the inferences about causal effects within the experiment are justified.
  - but potential disadvantages (artificiality,…?) → **external validity**
    An experiment is externally valid if its inferences and conclusions can be generalized from the population, treatment and setting being studied to other populations, policies and settings

Trade-off between internal and external validity:
The more control internally, the more “artificial” the situation.

Experimental procedure

- Subjects are **randomly assigned** to the treatment conditions – rules out selection bias.
- Processes are very **standardised** (e.g. video instructions)
- **Monetary incentives** are paid for economic decisions
- **Information conditions** and exogenous stochastic processes can be controlled (e.g. important for testing different levels of information).
- Enhanced control opportunities often imply that the **experimenter knows the predicted equilibrium exactly**.
  - Equilibrium and disequilibrium actions can be explicitly observed.
  - Quick or sticky adjustment can be explicitly observed.
- **Series of experiments** improves the reliability of conclusions
  - Allow to show the robustness of a phenomenon
  - But also its limits, the conditions under which it does not appear

Experiment on electricity markets

- Participants play electricity generators
- They sell electricity by offering supply quantities at various prices as in the spot market in Australia (there is no day-ahead market)
- The demand is randomly determined by the computer within a certain range
- Market price is determined according to specific rules
- Traders are paid according to the profit they make in a certain period
- Final profit in a period = revenue (price of electricity times quantity sold)

  \- costs of producing electricity
- They all recieve the same information, but may have different production costs

Main treatments

Information structure:

Benchmark: complete information, i.e. demand + the capacities and marginal costs of all market participants.

Supply uncertainty (asymmetric information), i.e. demand+ own type + probability of others type

Demand uncertainty (incomplete information), i.e. probability of demand+ all participants' type

Experimental design

Our experimental market consists of: **3 Electricity traders**, 2 Cost types, and 3 Demand levels {60 units, 100 units, 180 units}

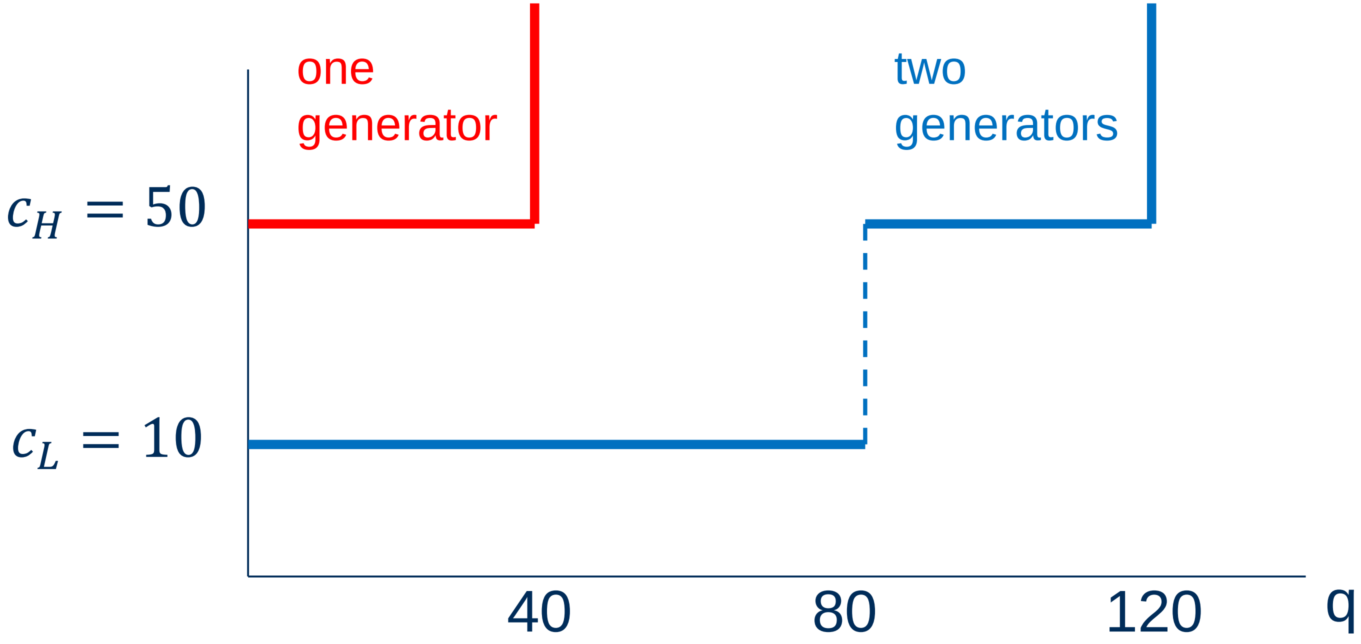
Technology type	Maximum capacity	Production costs
CHEAP (wind)	120 units	$10 /unit for the first 80 units $50 /unit for units 81 – 120
EXPENSIVE (biomass or gas)	40 units	$50 /unit

1. All have the CHEAP technology
2. All have the EXPENSIVE technology
3. Someone has the CHEAP and two have the EXPENSIVE technology
4. Two have the CHEAP and someone has the EXPENSIVE technology

In total, we have 12 scenarios

Design: Technology

- 3 bidders, each has either cheap or expensive technology (with uniform prob)



- Own costs always known.

Calculating the costs

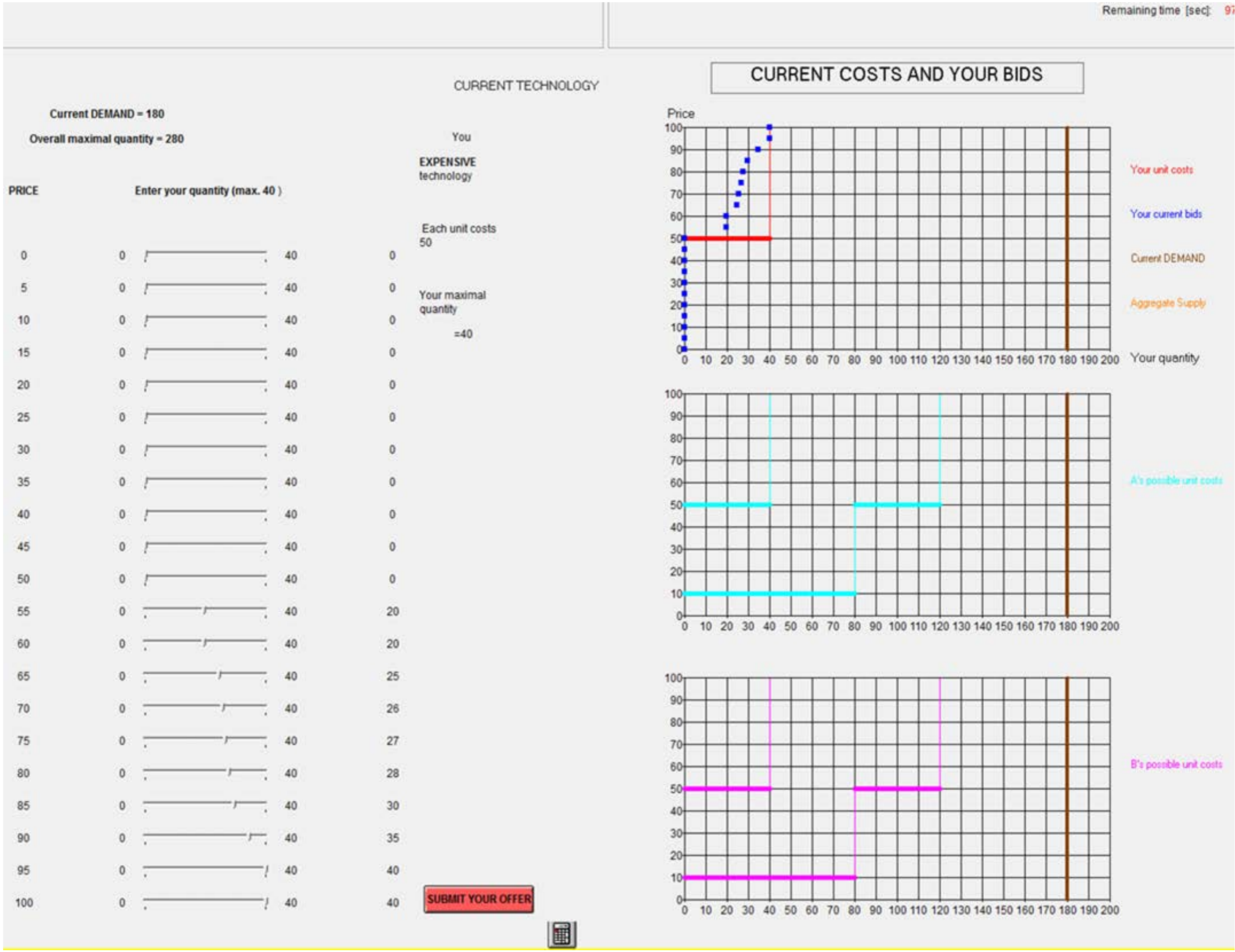
Technology type	Maximum capacity	Production costs
CHEAP	120 units	$10 /unit for the first 80 units $50 /unit for units 81 – 120
EXPENSIVE	40 units	$50 /unit

- Suppose you have the EXPENSIVE technology.
- Can supply a maximum of 40 units of electricity.
- Each unit of electricity costs $50.
- Supplying 10 units costs you:
  - 10 x $50 = $500
- Supplying 40 units costs you:
  - 40 x $50 = $2,000

Decisions in a screenshot (uncertain supply)

Each participant offers a quantity schedule for prices from 0 to 100.

The computer will determine a single market price and only the quantity you entered at that price is relevant to determine your market supply



Market price

- **A uniform-price auction: The market price is** the first price at which the aggregate supply at that price equals or exceeds the demand OR

- price cap at $100, when supply is below demand for any price.

Market price calculation

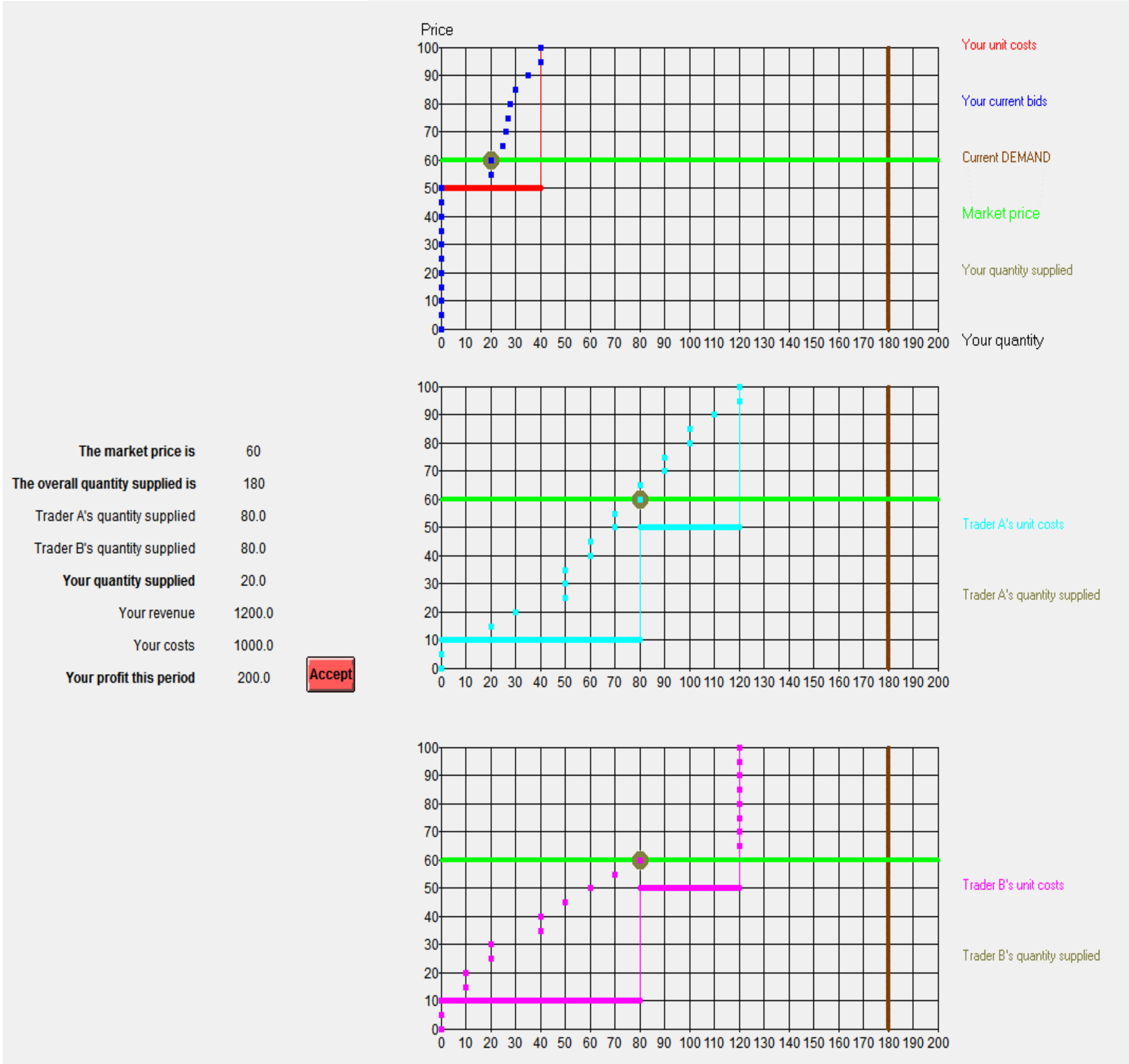
- **Example: ALL THREE EXPENSIVE TECHNOLOGY**

PRICE	Your offer	Trader A	Trader B	Aggregate Supply
30	0	0	0	0 + 0 + 0 = 0
50	10	20	20	10 + 20 + 20 = 50
70	10	30	30	10 + 30 + 30 = 70

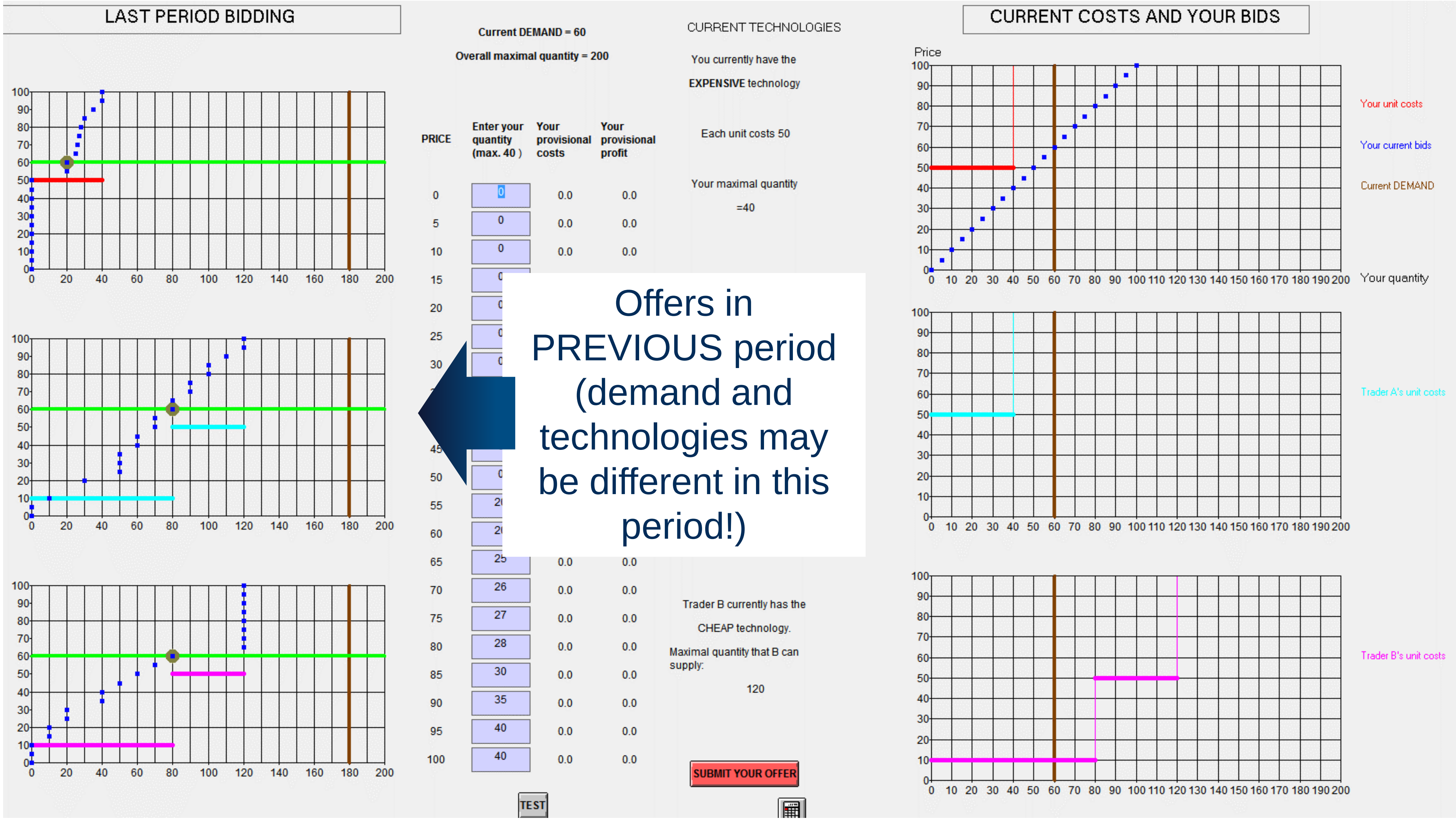
- If Demand = 60
  - If the price is $30, aggregate supply is 0 (insufficient to meet demand), price must be > $30
  - If the price is $50, aggregate supply is 50 (insufficient to meet demand), price must be > $50
  - If the price is $70, aggregate supply is 70, which exceeds demand.
- Therefore, the market price is $70.
- Allocation of units:
  - You will be allocated 10 units which equals your bid at a price of $50.
  - A and B will both be allocated 25 units since they are willing to supply 30 at a price of $70.
- Your revenue = 10 x $70 = $700
- Your costs = 10 x $50 = $500
- Your profit will be $200

Instructions – Results Screen

- Market price is $60
- Quantity supplied: 20
- Revenue: 20 x $60 = $1200
- Costs: 20 x $50 = $1000
  - EXPENSIVE technology
- Profit: $1200 – $1000 = $200

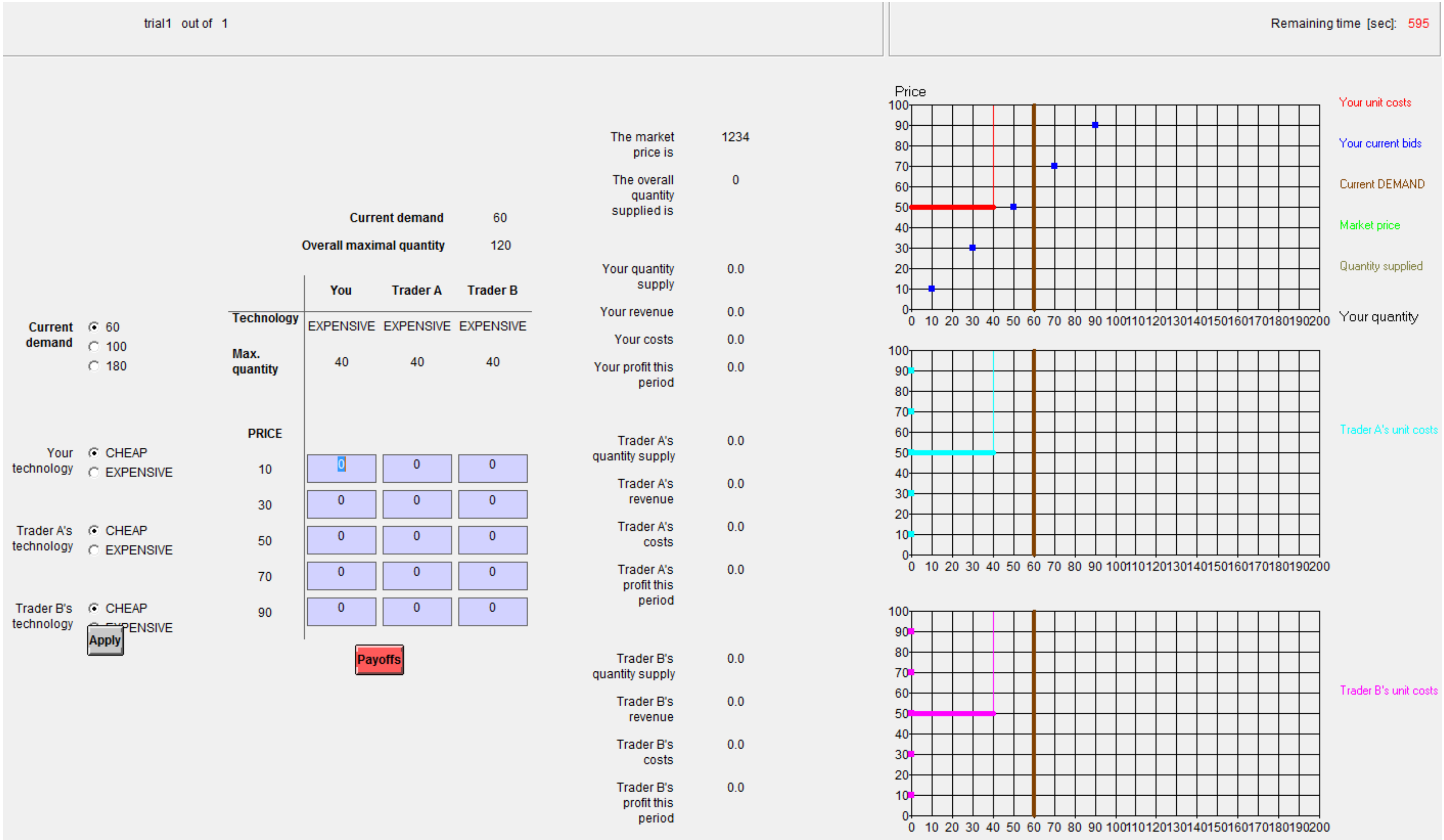


Available Information in transparent setting (baseline)



Offers in PREVIOUS period (demand and technologies may be different in this period!)

Instructions – Trial Phase



Design: Treatments

24 periods with random technology and random demand
(3 levels)

	competitive $3 \times c_L$	duopoly $2 \times c_L, 1 \times c_H$	monopoly $1 \times c_L, 2 \times c_H$	competitive $3 \times c_H$
Q_L	1/24	1/8	1/8	1/24
Q_M	1/24	1/8	1/8	1/24
Q_H	1/24	1/8	1/8	1/24

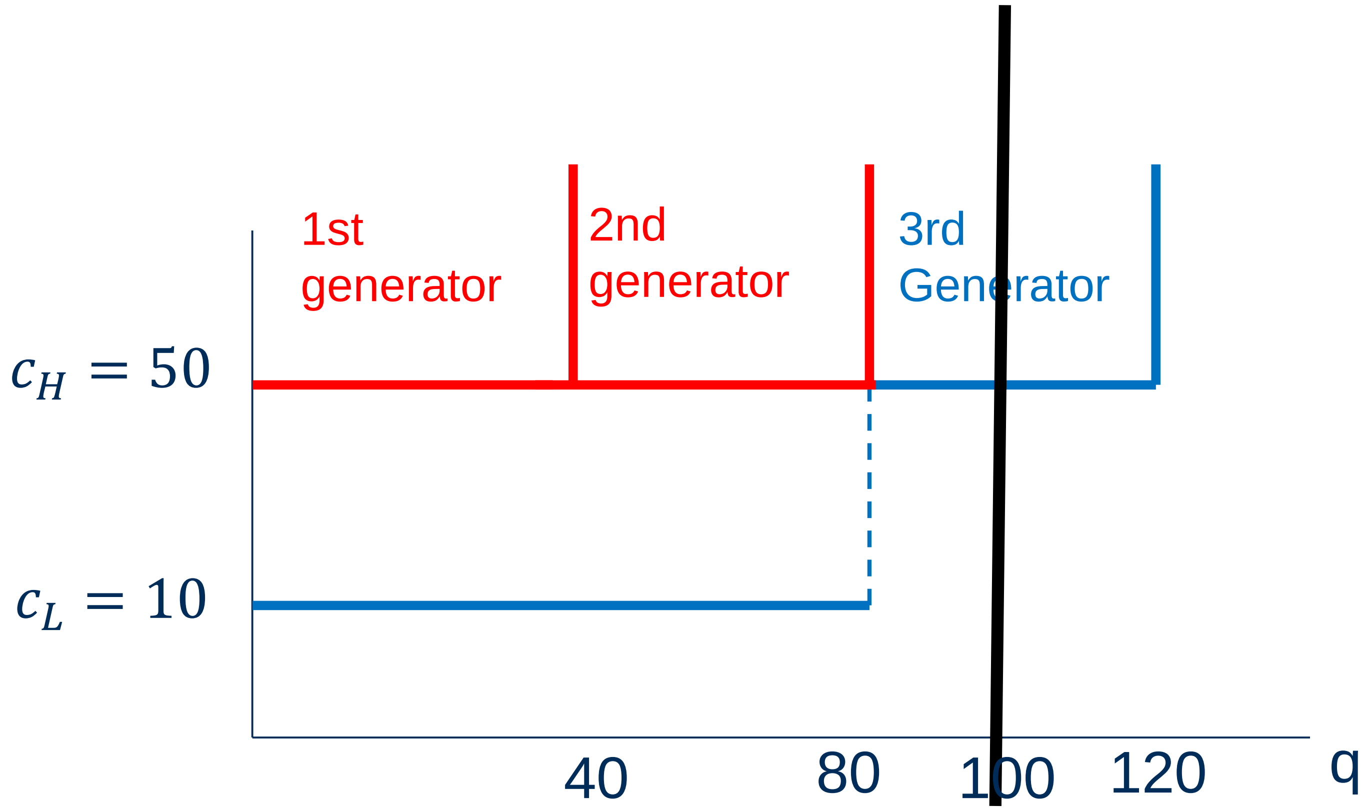
Number in cells 0 respective probability of occurrence. Experimental parameters: $(c_L, c_H) = (10, 50)$, $(Q_L, Q_M, Q_H) = (60, 100, 180)$.

Limit pricing

Pivotality

Situation: Pivotal and limit pricing

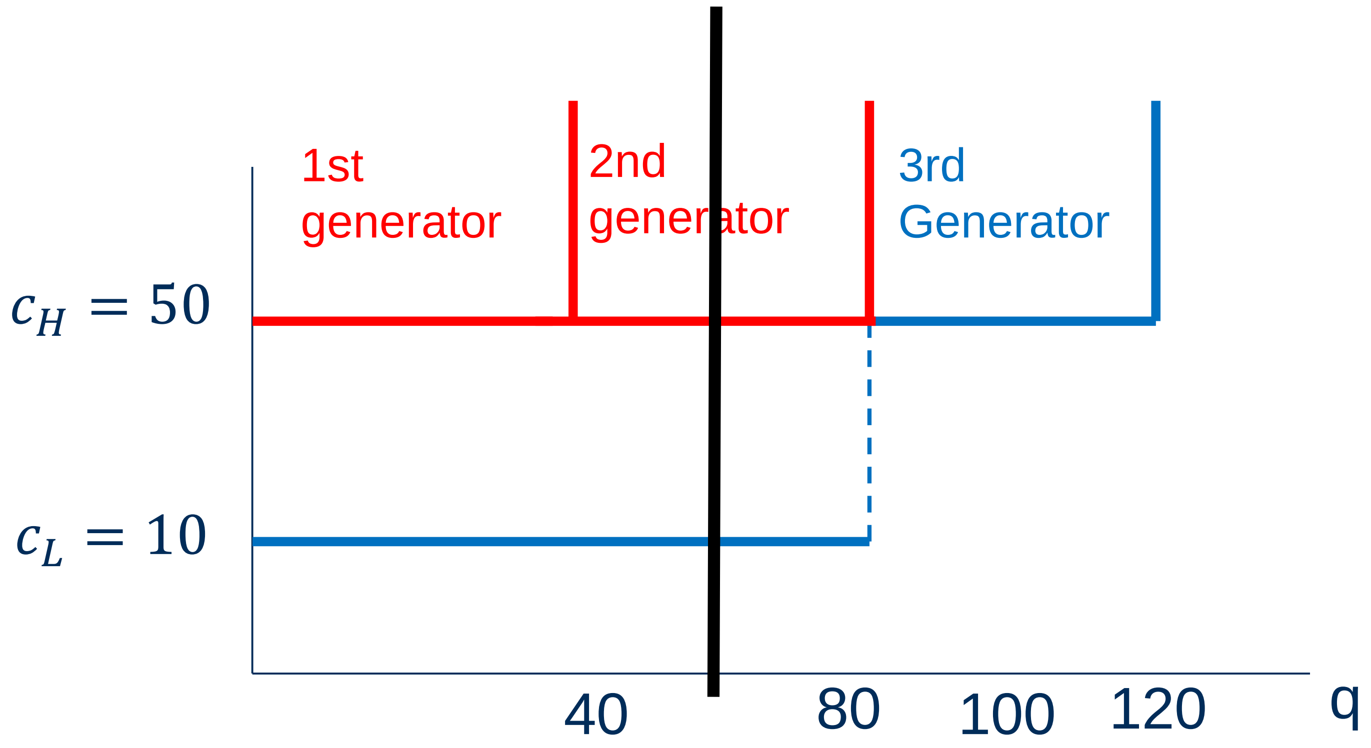
– One cheap and two expensive technologies, Demand = 100 (QM)



- Low cost bidder is pivotal
- Low cost bidder can apply limit pricing (can supply alone the demand)

Situation: Limit pricing

– One cheap and two expensive technologies, Demand = 60 (QM)



- Low cost bidder can apply limit pricing (can supply alone the demand)

Implementation details

Sessions were conducted at:

- UNSW Australia, Zurich University of Applied Sciences (ZHAW), The University of Zurich (UZH)
- In each session: 30 students divided into 10 matching groups
- Instructions on paper and video (Trial phase introduction) + Comprehension questions
- 24 rounds, 1 of the 24 rounds paid, randomly drawn

On average, 2 hours, students earned 26 AUD at UNSW, 45 CHF at ZHAW and UZH.

- We also conducted a limited session with practioners who were former electricity traders at Swissgrid – to see if any difference from students behavior.

Main results

Average prices by demand, state and treatment

		Competitive LLL	Duopoly LLH	Monopoly LHH	Competitive HHH
		s_1	s_2	s_3	s_4
$\bar{Q} = 60$	T_B	15.96	23.06	47.03	59.26
	T_D	17.37	24.5	43.21	61.05
	T_S	15.4	22.24	$36.34^{\Delta\Delta\Delta}$	56.25
$\bar{Q} = 100$	T_B	20	31.23	56.98	83.57
	T_D	24.74	33.73	56.19	79.25
	T_S	20.63	32.36	$51.74^{\Delta\Delta}$	$73.54^{\Delta\Delta}$
$\bar{Q} = 180$	T_B	34.82	60.65	83.33	100
	T_D	32.63	59.17	83.5	100
	T_S	41.25	60	$80.59^{\Delta\Delta\Delta}$	100

Result 1: Average price decrease in competition and increase in demand independent of the information structure for all states.

Result 2: In general, an increase in demand leads to a higher price if competition is weaker. The price increase between S3 and S2 is > than that between S2 and S1.

Uncertainty effect

Result 3:

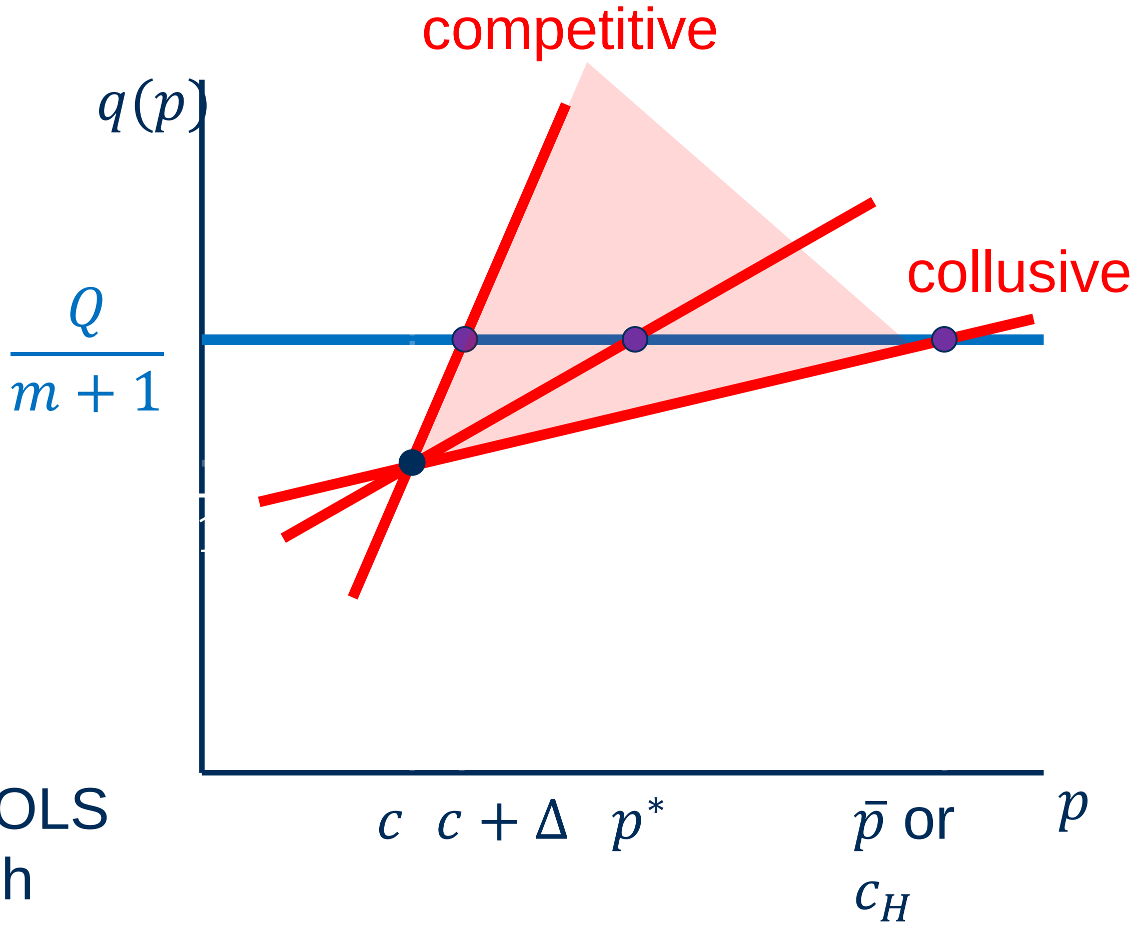
– Compare to complete information, **prices are significantly lower** in the **monopoly state for all demand level** as well as in the high-cost competitive state (S4).

– There is no robust statistical evidence that prices vary between complete information and demand uncertainty.

Competitive SSFE

- Each SSFE must verify

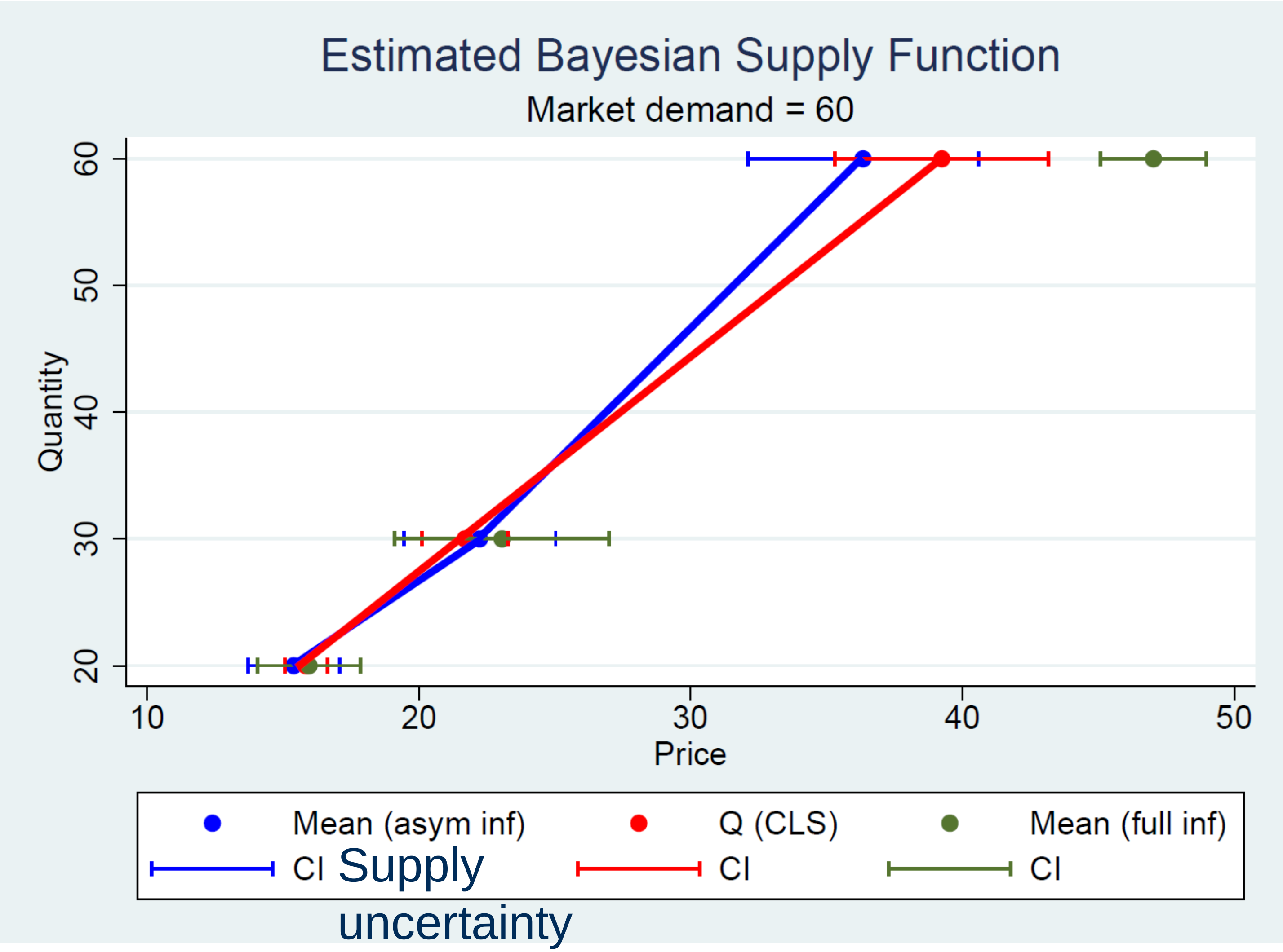
$$\alpha^* + \beta^* c = \frac{m-1}{m(m+1)} \bar{Q}$$



$\Longrightarrow$ SSFE's are ordered from **competitive** to **collusive** (coordination problem)

$\Longrightarrow$ Use linear restriction in OLS regression to «select» which empirical SSFE best matches the data

Estimated Bayesian Supply Function



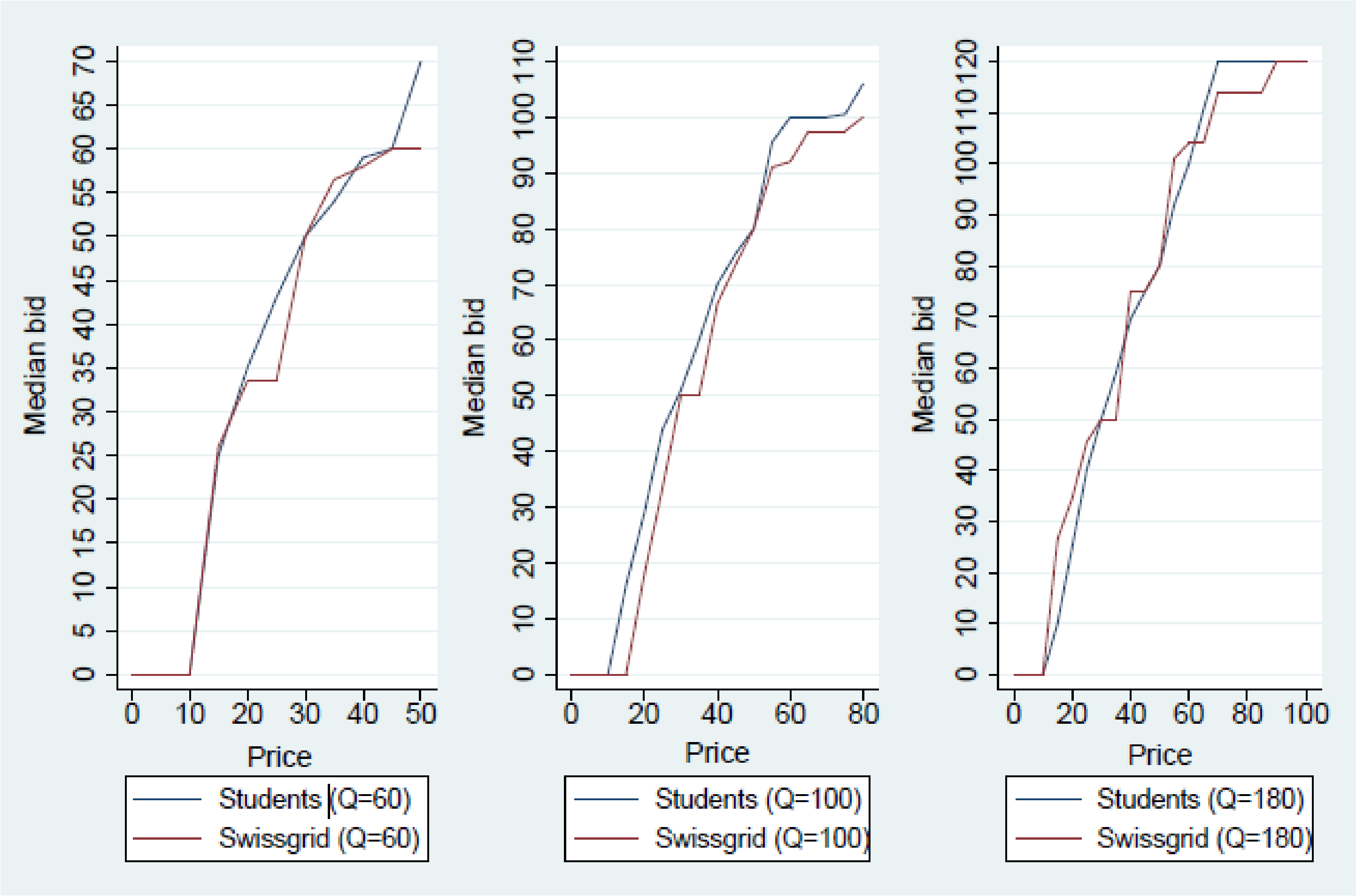
Supply uncertainty

Bayesian SFE tend to have a steeper bidding schedule.

Means: under supply uncertainty, traders bid more competitively

We use constrained OLS regressions to estimate the symmetric affine-line supply function.

Comparison between Swissgrid traders and students bidding



No significant difference in their bidding schedules.

Conclusions general

- Prices and strategic bidding responds to competition and demand in essentially the same way independent of the information structure

- Demand uncertainty has no meaningful effect on auction prices and strategic bidding. In particular, bid shading with market power occurs.

- Supply uncertainty reduces strategic bidding, particularly in cases of monopoly and/or pivotal market power.

– $\Longrightarrow$ **Less transparency** about demand or costs **not harmful** for market outcome (prices, efficiency)

- SFE identify equilibrium restrictions which can be used in OLS estimation as a tool of empirical equilibrium selection.

Conclusions electricity market

- The problem of **temporary market power** may arise in the future electricity market with a high share of renewables.

- **Less transparent** (supply side) wholesale electricity markets may lead to **more competitive bidding** (less strategic bidding) and lower average prices.

- Put differently: “Local” or “temporal” market power due to randomness associated with renewables may not be a problem with a sufficient degree of intransparency.

THANK YOU VERY MUCH FOR YOUR ATTENTION !