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Auctioning greenhouse gas emissions permits in Australia

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Overview

- Background on Australian Clean Energy Future
- Motivation
- Auction objectives
- Recommended auction design → AJARE Paper with Stefan Seifert, Peter Cramton and Suzi Kerr
- Experimental design
- Experimental results
- Conclusions

→ Joint work with Ben Greiner, Sascha Schweitzer, Stefan Seifert with valuable advice from Charles Holt, Axel Ockenfels, Andreas Ortmann, Bill Shobe

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Background

- The Australian government has been discussing the introduction of an Emissions Trading Scheme (ETS) for more than 10 years...
  - John Howard (1996-2007, Liberal-National Party Coalition)
    - Supported an ETS, changed position in 2002
    - In 2006 all Australian states (all with Labor Party state governments) developed a blueprint for an Australia-wide ETS
    - Supported again an ETS in 2007 (published a Green Paper)
  - Kevin Rudd (2007-2010, Labor Party)
    - Election promise: Kyoto ratification and Carbon Pollution Reduction Scheme (CPRS) to be introduced by 2012… but the CPRS was twice rejected creating a double dissolution election trigger...
  - Julia Gillard (2010-, Labor Party)
    - **8th of November 2011**, passes „Bill to encourage the use of clean energy, and for other purposes”.. includes a Carbon Pricing Mechanism

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Australia‘s Clean Energy Future (I)

- Emissions reduction targets to be agreed later based on advice from new Climate Change Authority.
- Copenhagen pledge: 5% by 2020 and 80% by 2050 on 2000 levels.
- Carbon Pricing Mechanism: AU$23/t$CO_2$e fixed price start (1 July 2012) rising by 5% (nominal) per annum before an emissions trading scheme starts on 1 July 2015.
- Coverage of Carbon Pricing Mechanism:
  - around 500 businesses will be liable emitting ≥25,000 tonnes of CO_2/a
  - stationary energy, industrial process, gas retailers, land fill facilities
  - 60% of Australian GHG emissions
  - Agriculture not covered instead credits from the Carbon Farming Initiative.
  - Transport more indirectly covered through changes in fuel tax credits or changes in excise.

How does carbon pricing work?

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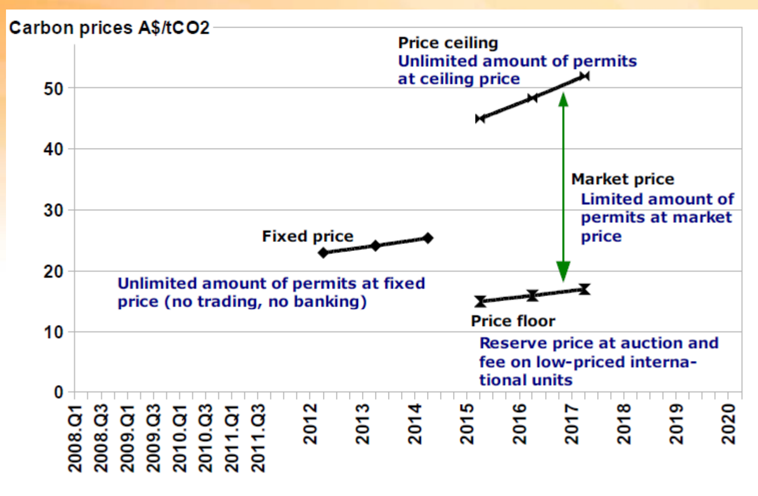
Australia's Clean Energy Future (II)

- **Auctioning will be the main method of allocation in flexible price period**
- Use of international carbon units
  - Eligible during the flexible charge period (from 1 July 2015)
  - Up to 50% of the total emissions liability for that entity for the year.
- Permits are date-stamped (vintages) and bankable
- Up to 5% borrowing (surrendering of permits with next vintages)
- Price ceiling and floor (see next slide)
- Compensation:
  - Households mainly compensated through taxation and welfare system.
  - Industry compensation in form of free permits worth ~AU$9.2 billion, mainly for emissions-intensive industries exposed to international trade (e.g. steel, coal, gas). To be reduced over time and subject to review.
- A Clean Energy Finance Corporation will invest AU$10 billion in 'clean' energy, with at least 50% of investment to go to renewable energy.

Australia's carbon price



Source: Frank Jotzo, http://www.crawford.anu.edu.au/pdf/events/2011/crawford_school_dialogue/September/fjotzo.pdf

Australian Government Auction Objectives

- Promote an efficient allocation of permits... with a minimum of risk and transaction costs = allocate permits to those who value them the most
  - Simple auction rules will attract more (smaller) bidders
- Promote efficient price discovery
  - Reveal market prices of permits particularly at early stages (advance auctions)
- Raise auction revenue (consistent with other objectives)
  - Not a primary goal
- Achievement of auction objectives depend on
  - choice of appropriate auction design (from auctioneer)
  - development of bidding strategy (from bidders)

Source: Australian Government's White Paper (2008)

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Motivation (I)

- Advice for Australian Government on auction design
- Australian carbon units will have a vintage year, showing when they become valid → mixture of multi-unit and multi-item auction
  - Carbon units are partial substitutes and become perfect substitutes over time (after validation date)
- No secondary carbon market exists in Australia yet, therefore the auction will need to support price discovery
  - EU Emissions trading auctions are mainly uniform price sealed bid auctions. Price discovery is no objective as a liquid secondary market exists. Multi-item auctions are unnecessary since no vintages, allowances are valid for a phase.
- Literature suggests with regard to clock vs. sealed bid:
  - Clock cognitively easier to understand, bidders specify their demand step by step
  - With clock better price discovery capabilities, important if there are no secondary markets (Kagel and Levin 2001; Holt et al. 2007; Mandell 2005; Ockenfels 2009)
  - But clock may ease collusion between bidders (Holt et al. 2008; Burtraw et al. 2010; Mougeot et al. 2009)
  - Do not reveal aggregate demand in clock? → Strategically equivalent to sealed bid Shobe et al. (2010) find no differences with and without demand revelation

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Motivation (II)

- Growing (experimental) market design literature on the design of multi-unit auctions
  - But in (experimental) literature almost exclusively tests of single-item multi-unit auctions → **Australian ETS design: multi-unit and multi-item**
  - Multiple items raise new questions:
    - Sequential or simultaneous
    - Order of sequence, switching rules, etc.
- Literature so far with regard to simultaneous vs. sequential
  - Simultaneous outperform sequential procedures when values of items are related, either as substitutes or as complements (e.g. McMillan 1994, McAfee & McMillan 1996, Cramton 1997, Milgrom 2000, 2004)
  - With multiple vintages which are partial substitutes, bidders may want to shift demand between vintages depending on price differences
  - Experiments with regard to Virginia NOx auction found higher revenues with simultaneous auctions (Porter et al. 2009). However, politicians were concerned by complexity of simultaneous auctions and chose to implement sequential auctions.

Recommendations for Auction Design

- Clock auction with intra-round bidding with aggregate demand revealed in each round,
- Simultaneous auctions of different vintages whenever applicable
- Allowing trade-exposed industries and other recipients of free permits to sell these permits in the auction (double auction extension)
- Proxy bids to accommodate small participants

To test experimentally:

- Sealed bid vs. Clock auction (no intra-round bidding)
- Sequential vs. Simultaneous
- Clock with information of aggregate demand vs. without info

Ascending Clock Auction with info (I)

- Auctioneer publishes total available quantity of permits (Supply), the initial reserve price, as well as the further schedule of price offers (bid increments)
- Auctioneer starts with collecting demand bids for the reserve price
  - Each bidder i responds by reporting his demand at this price
  - Auctioneer reveals total demand
- As long as total demand > total supply
  - Auctioneer announces next price and collects demand bids
  - Bidders report their demand for next price
  - Rule: Demand bids (quantity) cannot increase, they can only decrease
  - Auctioneer reveals total demand

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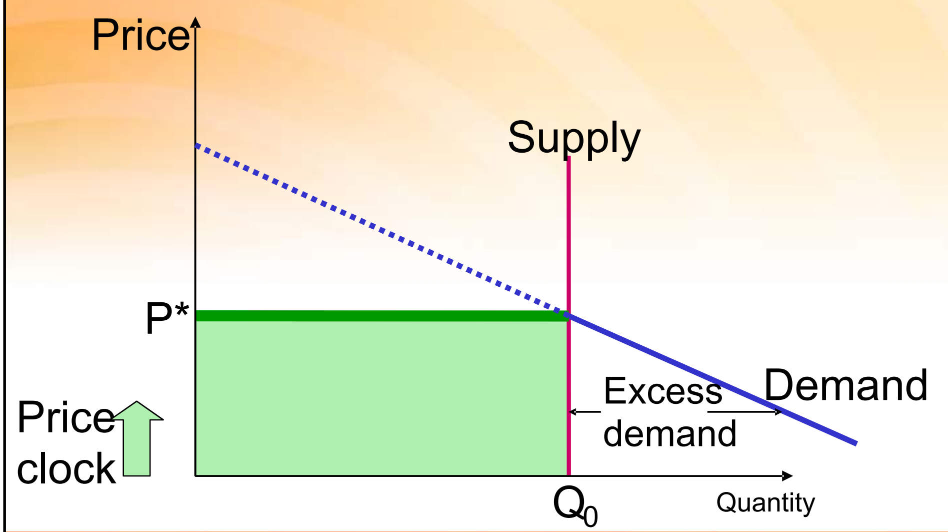
Ascending Clock Auction with Info (II)



Source: Cramton 2007

Ascending Clock Auction (III)

- If total demand ≤ total supply: auction ends
  uniform pricing
  - If total demand = total supply: price last round is clearing price
  - If total demand < total demand: clearing price is price of second last round
    All bidders *i* receive the quantity in this round
  - The remaining supply is allocated according to residual bids at *price of last round*:
    - Each bidder *i* receives in addition:
      $(d_i(p_{t-1}) – d_i(p_t)) * (s - \sum d_i(p_t)) / \sum (d_i(p_{t-1}) – d_i(p_t))$ units

EXAMPLE: 100 units and 2 bidders A and B

- second last round: A bids 70 units and B bids 40 units
- last round A bids 61 and B 34
- Total demand in last round 61+34=95 units
- Residual supply 100-95=5
- Residual demand (A: 70 – 61 = 9 units and B 40 – 34 = 6 units, total residual demand 15)
- A gets 61 + 9/3 = 64
- B gets 34 + 6/3 = 36

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Intra-round bidding (I)

- Bidders submit demand schedules for prices between price of this round (p_{t-1}) and next price (p_t)
- May increase efficiency since it makes discrete rounds continuous
- Smoothes closing of auction
- Allows for larger increments

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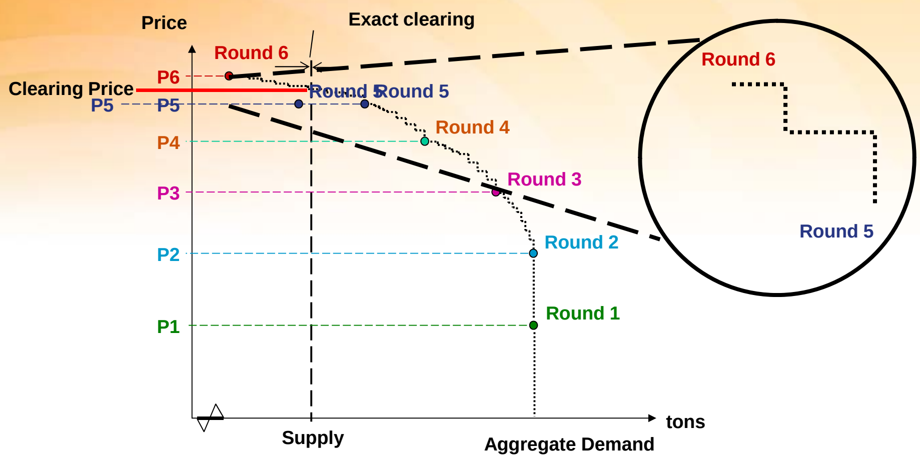
Intra-round bidding (II)



Source: Cramton 2007

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Auctioning multiple vintages

- In some auction events, several vintages of carbon units will be available
- All vintages are auctioned simultaneously
- For each vintage a separate clock is implemented
- Bidders may shift demand from one clock to another
- At the end of each round, a clock ticks forward if total demand for the respective vintage exceeds supply
- Auction continues as long as at least one clock ticks forward

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Hypotheses for the experiment

1) Higher social surplus with simultaneous auctions (allocative efficiency).
2) Better price discovery with open clock (information efficiency). Prices are closer to the Walrasian equilibrium and less volatile.
3) Lower prices with open clock (public revenue) since higher risk of collusion.

Experimental Design (I)

- 2 x 3 factorial design
- Each cell: 6 sessions, 2+4 auctions, 14 bidders
  → 504 participants

Two vintages	Sealed bid	Clock /wo info	Clock /w info
Sequential			
Simultaneous			

+ single-vintage auctions
+ sim. 2-vintage auctions with secondary market
+ 3 xxl sessions (42 bidders) for seq-clock /w info
→ 1134 participants

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Experimental design (II)

- 2 items (vintages), A and B
- 100 units of A, 80 units of B
- Induced individual demand functions based on random parameters in marginal abatement cost curve
- Technological progress / time discounting
  → B potentially less valuable than A (factors 0.8 & 1)
- Partial substitutes (A can be used as B, but B not as A)

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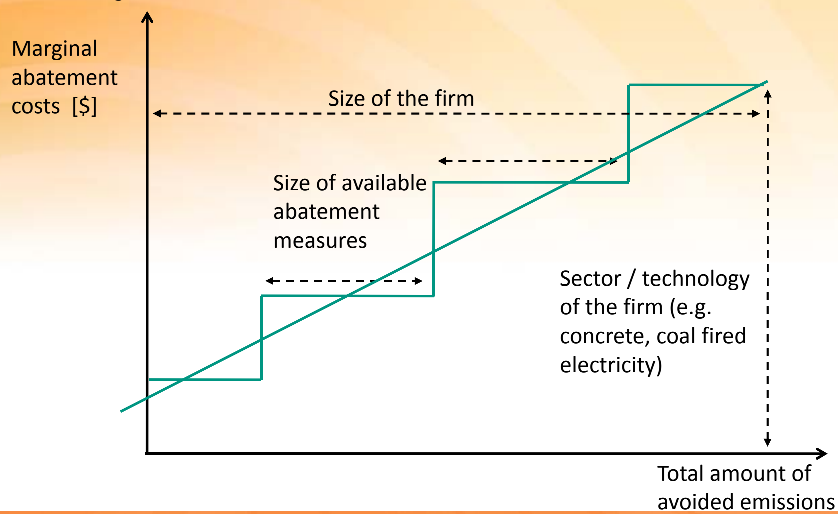
Valuation Design: Marginal Abatement Cost Curve



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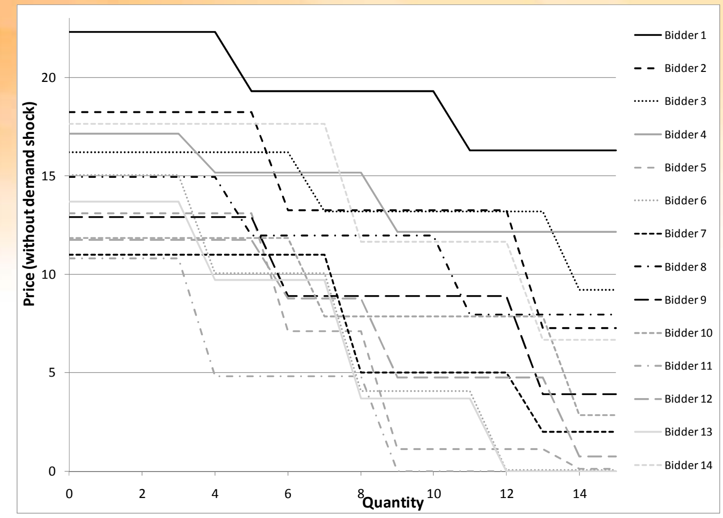
Demand schedule (example)



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Valuation Schedule (Example)

Seat No.	X	Bundle Values									Auction	X
Value (E$)		Quantity Item B										
		0	1	2	3	4	5	6	7	8	9	10
Quantity Item A	0	0	22	44	66	88	107	126	145	164	183	201
	1	27	49	71	93	115	134	153	172	191	210	228
	2	54	76	98	120	142	161	180	199	218	237	255
	3	81	103	125	147	169	188	207	226	245	264	282
	4	108	130	152	174	196	215	234	253	272	291	309
	5	132	154	176	198	220	239	258	277	296	315	333
	6	156	178	200	222	244	263	282	301	320	339	357
	7	180	202	224	246	268	287	306	325	344	363	381
	8	204	226	248	270	292	311	330	349	368	387	405
	9	228	250	272	294	316	335	354	373	392	411	429
	10	250	272	294	316	338	357	376	395	414	433	451
	11	272	294	316	338	360	379	398	417	436	455	473
	12	294	316	338	360	382	401	420	439	458	477	495
	13	316	338	360	382	401	420	439	458	477	495	513
	14	338	360	382	401	420	439	458	477	495	513	531
	15	360	382	401	420	439	458	477	495	513	531	548

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Experimental design (III)

Two vintages	Sealed bid	Clock with info	Clock w/o info
Sequential			
Simultaneous			

- 6 sessions per cell, 14 bidders per auction
- 2 training + 4 treatment auctions per session
- Each session with random demand structure, used for each treatment, and rotated and shifted within session
- All treatments:
  - Same interface and training auctions
  - Proxy bidding
  - No intra-round bidding in experiment

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Computer Interface

Experimental design (IV)

Two vintages	Sealed bid	Clock with info	Clock w/o info
Sequential			
Simultaneous			

- Auction details
  - Order of vintages when sequential: *higher value first*
  - Uniform pricing: *lowest accepted* vs. largest rejected bid
  - Activity: *bidding limit* enforces non-increasing demand
  - Bid rationing: proportional serving of excess demand
  - Demand switching with clock: *ex-post correction*
  - Price reversals with simultaneous sealed bid: *bid sorting*

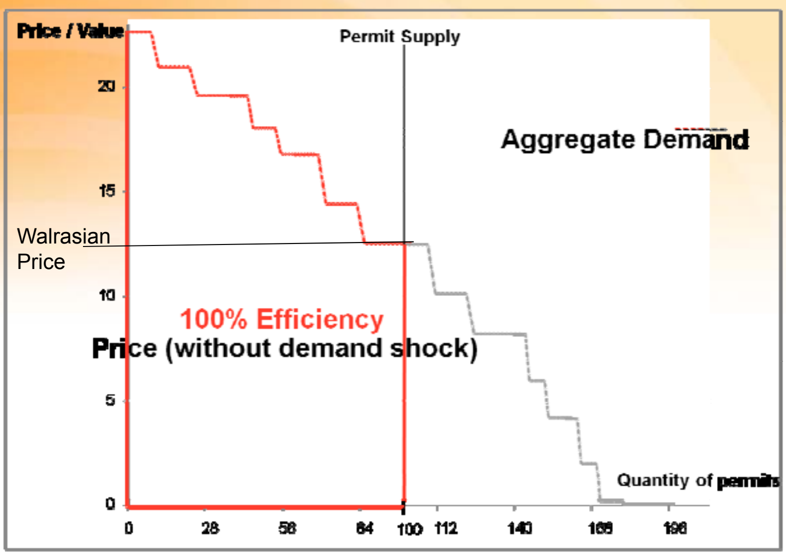
Experimental design (V)

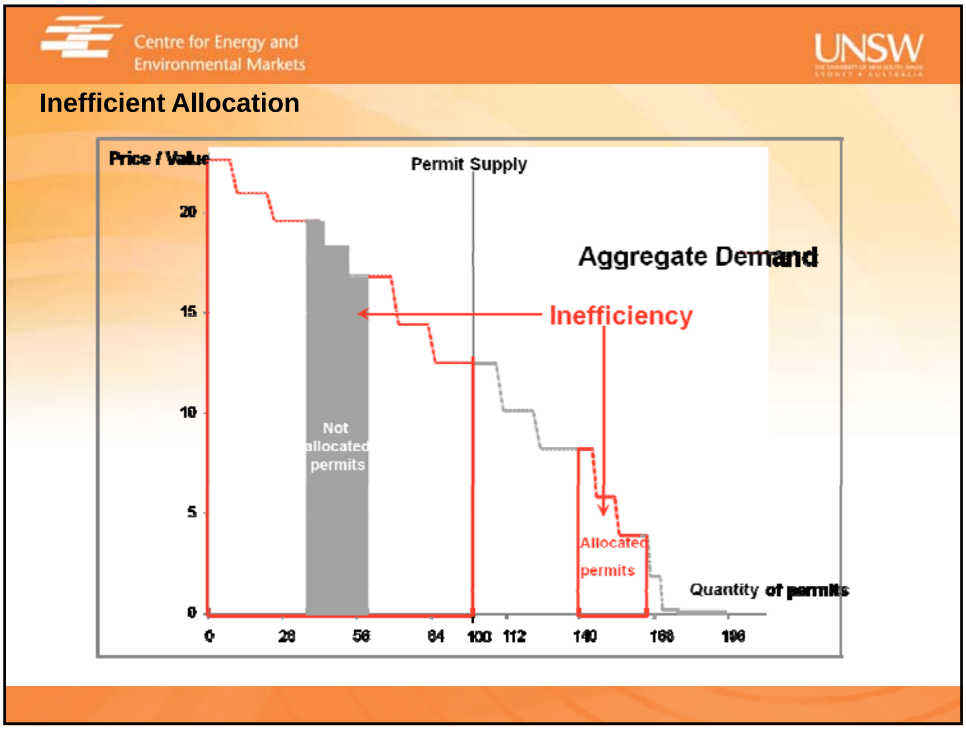
- **Procedures**
  - For each treatment, 2 sessions at UNSW, 4 at KIT
  - Instructions on paper and read aloud
  - Comprehension questions
  - Two training auctions (simple clock /wo proxy bidding)
  - After the training auctions:
    treatment specifics: video with rule changes
  - 1 of the 6 auctions paid, randomly drawn
  - UNSW: 1 E$ = AUS $0.15, KIT: 1 E$ = € 0.10
  - Avg. earnings: UNSW $32, KIT € 21 for ~2 hours

Experimental Results

- Benchmark: Walrasian Equilibrium (WE)
- Measures of interest:
  - Relative allocative efficiency
    - realized social surplus, max 1
  - Information efficiency: relative auction prices
    - the closer to 1, the more accurate
    - the lower the variance, the more reliable
  - Relative seller revenues (surplus) / bidder' profits (buyer surplus)
    - public revenues

Efficient Allocation

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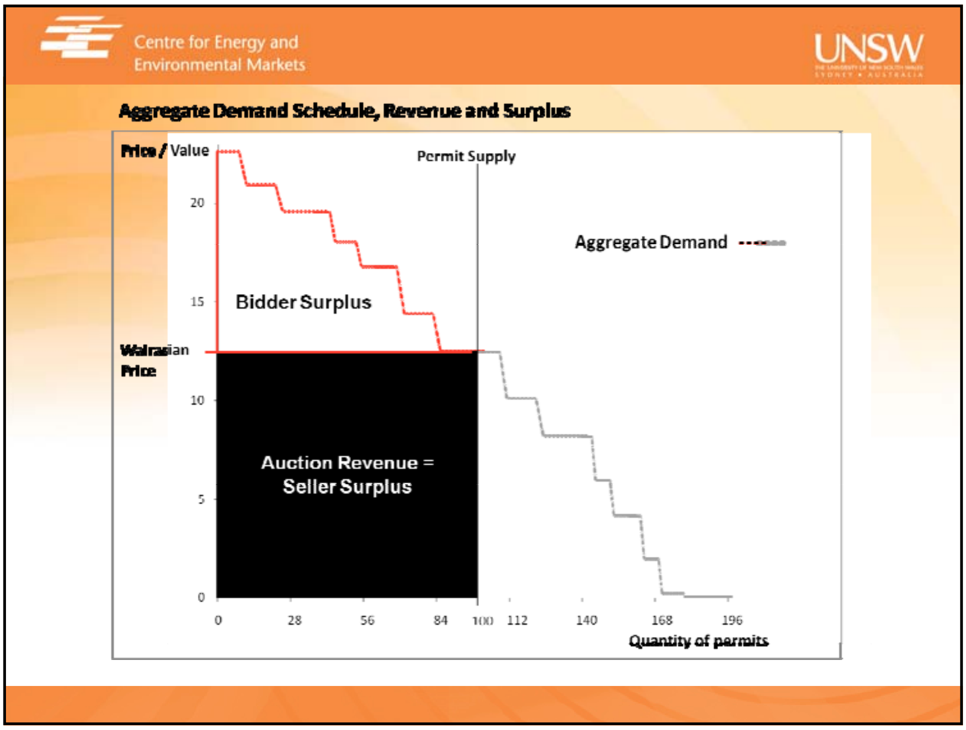
Inefficient Allocation
Price / Value
Permit Supply
Aggregate Demand
Inefficiency
Not
allocated
permits
Allocated
permits
Quantity of permits
20
15
10
5
0
0
28
56
84
100
112
140
168
196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Aggregate Demand Schedule, Revenue and Surplus
Price / Value
Permit Supply
Aggregate Demand
Bidder Surplus
Walrasian
Price
Auction Revenue =
Seller Surplus
20
15
10
5
0
0
28
56
84
100
112
140
168
196
Quantity of permits

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Results (I)

Efficiency	SB	CNoI	CI
SEQ	86.8%	88.3%	88.8%
SIM	85.9%	88.4%	88.7%

higher / lower
based on non-parametric tests

Prices A/B	SB	CNoI	CI
SEQ	0.973 / 0.846	0.976 / 0.743	0.981 / 0.807
SIM	0.860 / 0.715	0.900 / 0.828	0.879 / 0.763

+ slight evidence that open clock (CI) yields lower price variance across auctions

Revenues	SB	CNoI	CI
SEQ	92.2 %	88.7 %	90.7 %
SIM	79.8 %	87.0 %	82.9 %

B's profits	SB	CNoI	CI
SEQ	63.7 %	88.7 %	84.7 %
SIM	118.6 %	99.1 %	118.5 %

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Results (II)

Table 1: OLS regressions of auction outcomes on treatment parameters and controls

Independent	RelEfficiency	RelPriceA	RelPriceB	RelRevenue	RelBidderSurplus
Constant	0.7542***	0.9241***	0.8372***	0.8895***	0.1982
	[0.0096]	[0.0255]	[0.0385]	[0.0282]	[0.1176]
Auction rule					
isClock	0.0068	0.0248	0.0054	0.0165	-0.0335
	[0.0073]	[0.0267]	[0.0358]	[0.0281]	[0.1275]
isClock.isOpen	0.0038	-0.0171	-0.0007	-0.0103	0.0770
	[0.0061]	[0.0266]	[0.0303]	[0.0253]	[0.1135]
Market environment					
isSequential	0.0118**	0.1068***	0.0301	0.0741***	-0.2899***
	[0.0054]	[0.0209]	[0.0258]	[0.021]	[0.093]
Controls					
DemandShock	-0.0006	-0.0090***	-0.0075***	-0.0084***	0.0389***
	[0.0009]	[0.0027]	[0.0028]	[0.0024]	[0.0123]
RelVintValueScheme	0.0020	0.0160	-0.0113	-0.0014	0.0492
	[0.0056]	[0.0139]	[0.0173]	[0.0111]	[0.063]
Obs	144	144	144	144	144
R-squared	0.8514	0.3457	0.1018	0.2636	0.5895

Notes: *, **, and *** denote significance at the 10%, 5%, and 1%-level, respectively. Regressions are based on auctions 3 to 6 from all sessions. All regressions include fixed effects for demand structures. Robust standard errors are calculated at the independent session level and are given in brackets.

Baseline: Simultaneous Sealed Bid auction

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Results

- Hypotheses
  - Higher social surplus with simultaneous auctions (allocative efficiency).
  - Better price discovery with open clock (information efficiency). Prices are closer to the Walrasian equilibrium and less volatile.
  - Lower prices with open clock (public revenue).

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Conclusions

- No significant differences in multi-unit auction formats
  - Sealed bid and clock formats perform equally well
  - No evidence for increased collusion under clock
- But sequential auctioning of multiple (multi-unit) items yields higher efficiency and higher revenues than simultaneous auction
  - Bidders bid more aggressively on first item of sequential auction
- Recommendations for Australian ETS Auction
  - Use open clock auctions with proxy-bidding (reveal aggregate demand after each round)
  - Auction multiple vintages sequentially (with earliest vintage first)

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Outlook

- Bidding behavior analysis
  - Significant under-bidding in the simultaneous auctions
  - Balanced bidding behavior in the sequential auctions
- Include secondary market effect
  - Resale opportunity in a secondary market turns allocation auction from a private into a common value auction
  - Does this effect bidding strategy?

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Thank you.

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