Australian Carbon Pricing Mechanism: Experimental test of different auction designs

Dr. Regina Betz

S.CO.RE. Seminar, Loyola de Palacio Chair / Florence School of Regulation, Tuesday May 29th 2012
Key interdisciplinary perspectives & tools required to address challenges – CEEM’s unique strength

Drivers:
- Energy security
- Climate Change
- Societal Welfare

Requirements

Science & Engineering

Technological innovation

Economic transformation

Behavioral Change

Social sciences

Economics
CEEM’s core tasks

RESEARCH

Drivers:
- Energy security
- Climate Change
- Societal Welfare

Technological innovation

Economic transformation

Behavioral Change

Requirements

POLICY
IMPACT

EDUCATION
Overview

- Introduction to Australian Climate Policy
- Carbon Pricing Mechanism
- Auction objectives
- Recommended auction design
- Experimental design
- Experimental results
- Conclusions

AJARE Paper with Stefan Seifert, Peter Cramton and Suzi Kerr
Joint work with Ben Greiner, Sascha Schweitzer, Stefan Seifert with valuable advice from Charles Holt, Axel Ockenfels, Andreas Ortmann, Bill Shobe
Australia’s carbon pollution

- Highest carbon pollution per person
- One of the top 20 emitting countries

Source: Presentation by DCCEE at CEEM conference 2011
Australia’s mitigation challenge

108% of 1990 level

2000 level

emissions excluding deforestation and forestry

Kyoto period

106% of 1990 level

% change on 2000 level

+24%

-5%

-15%

-25%

Source: Presentation by DCCEE at CEEM conference 2011
It has been a long way....

- The Australian government has been discussing the introduction of an Emissions Trading Scheme (ETS) for more than 10 years...
    - 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...
08/11/2011
Australia passes the Clean Energy Future Package!

The end?
Australia’s Clean Energy Future Plan

Energy Efficiency

Renewable Energy

It is more than just a carbon price!!

Carbon Price

Land use

Source: Presentation by DCCEE at CEEM conference 2011
Carbon Pricing Mechanism (I)

- **Timing**:
  - Fixed price period: 1st July 2012 - 30th June 2015
  - Flexible period 1st July 2015

- **Target/cap**
  Fixed price period: no cap and no banking/borrowing
  Flexible price period: Default cap: 5% by 2020 on 2000 levels
  - Targets first 5 years agreed by May 2014 based on Climate Change Authority advice
  - Full banking and up to 5% borrowing

- **Coverage**
  - Australian wide, linking to international schemes to be considered
  - around 500 businesses will be liable emitting ≥25,000 t CO₂/a
  - 60% of Australian GHG emissions: CO₂, CH₄, N₂O, PFC
  - Mix of downstream & upstream: stationary energy, industrial process, gas retailers, land fill facilities
  - Agriculture & Land-use not covered instead Carbon Farming Initiative (CFI) credits
  - Some business transport emissions through changes in fuel tax credits or excise.
Carbon Pricing Mechanism (II)

- **Allocation**
  - Fixed price period: starting $23tCO₂e rising by 5% p.a.
  - Flexible price period:
    - Auctioning with compensation through free permits based on historic benchmarks
    - Price floor first 3 years starting at $15 rising at 4% real terms p.a.
    - Price ceiling for first 3 years 20$ above expected international price for 2015-16 rising at 5% real terms p.a.

- **Use of offsets**
  - Fixed price period: Use of CFI credits up to 5% of verified emissions
  - Flexible time period:
    - Unlimited use of CFI credits
    - International units up to 50% of the total emissions liability for that entity for the year.
    - Eligible units with provision to be extended: CERs, ERUs, RMUs
    - Qualitative restrictions to be defined
From fixed price to market price

Carbon prices A$/tCO2

- **Price ceiling**: Unlimited amount of permits at ceiling price
- **Fixed price**: Unlimited amount of permits at fixed price (no trading, no banking)
- **Price floor**: Reserve price at auction and fee on low-priced international units
- **Market price**: Limited amount of permits at market price

Source: Jotzo
Australia’s abatement challenge

**Chart 5.2: Australian emissions in the core policy scenario**

Actual demand for international credits will depend on how price floor is implemented.

It is all about compensation...
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)

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 and international linking is limited, 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? → Theoretical equivalent to sealed bid Shobe et al. (2010) find no differences with and without demand revelation
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
Ascending Clock Auction with Info (II)

Source: Cramton 2007
Ascending Clock Auction (III)

- If total demand \( \leq \) total supply: auction ends
  - If total demand = total supply: price last round is clearing price
  - If total demand < total supply: 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:
        \[
        (d_i(p_{t-1}) - d_i(p_t)) \times \left( s - \sum d_i(p_t) \right) / \sum (d_i(p_{t-1}) - d_i(p_t)) 
        \] 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
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
Intra-round bidding (II)

Source: Cramton 2007
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
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

<table>
<thead>
<tr>
<th>Two vintages</th>
<th>Sealed bid</th>
<th>Clock /wo info</th>
<th>Clock /w info</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequential</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simultaneous</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

+ single-vintage auctions
+ sim. 2-vintage auctions with secondary market
+ 3 xxl sessions (42 bidders) for seq-clock /w info
→ 1134 participants
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)
Valuation Design: Marginal Abatement Cost Curve

Marginal abatement costs [$]

Size of the firm

Size of available abatement measures

Sector / technology of the firm (e.g. concrete, coal fired electricity)

Total amount of avoided emissions
Demand schedule (example)
### Valuation Schedule (Example)

<table>
<thead>
<tr>
<th>Seat No.</th>
<th>X</th>
<th>Quantity Item B</th>
<th>Auction X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value (E$)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>22</td>
<td>44</td>
</tr>
<tr>
<td>1</td>
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<td>49</td>
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<td>2</td>
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<td>200</td>
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<td>7</td>
<td>180</td>
<td>202</td>
<td>224</td>
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<td>8</td>
<td>204</td>
<td>226</td>
<td>248</td>
</tr>
<tr>
<td>9</td>
<td>228</td>
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<td>272</td>
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<td>10</td>
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<td>272</td>
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<tr>
<td>15</td>
<td>360</td>
<td>382</td>
<td>401</td>
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</table>
Experimental design (III)

<table>
<thead>
<tr>
<th>Two vintages</th>
<th>Sealed bid</th>
<th>Clock with info</th>
<th>Clock w/o info</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequential</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simultaneous</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- 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
## Computer Interface

### Auction 1 of 1

<table>
<thead>
<tr>
<th>Item A</th>
<th>Quantity offered (in units)</th>
<th>My current bidding limit (in units)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
<td>20</td>
</tr>
</tbody>
</table>

#### My demand

- Item A: 13
- Item B: ?

### Auction History and Planning Table

**Price**

<table>
<thead>
<tr>
<th>Item A</th>
<th>My demand</th>
<th>Group demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>110</td>
</tr>
<tr>
<td>3</td>
<td>13</td>
<td>100</td>
</tr>
<tr>
<td>4</td>
<td>13</td>
<td>110</td>
</tr>
<tr>
<td>5</td>
<td>13</td>
<td>100</td>
</tr>
<tr>
<td>6</td>
<td>13</td>
<td>110</td>
</tr>
</tbody>
</table>

**Time left until next price level:**

- 0:23

---

**Price**

<table>
<thead>
<tr>
<th>Item A</th>
<th>My demand</th>
<th>Group demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>13</td>
<td>15</td>
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<td>15</td>
</tr>
<tr>
<td>30</td>
<td>11</td>
<td>15</td>
</tr>
</tbody>
</table>

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**Information about my current bid**

- 13 units of A at a price of $7
- 7 units of B at a price of $7

- My value of this bundle: $218
- Cost of this bundle at current prices: $140
# Experimental design (IV)

<table>
<thead>
<tr>
<th>Two vintages</th>
<th>Sealed bid</th>
<th>Clock with info</th>
<th>Clock w/o info</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Simultaneous</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **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

Walrasian Price

100% Efficiency Price (without demand shock)

Aggregate Demand

Permit Supply

Quantity of permits
Inefficient Allocation

The graph illustrates the inefficiency in permit allocation and demand. The x-axis represents the quantity of permits, while the y-axis shows the price/value.

- **Permit Supply**
- **Aggregate Demand**
- **Inefficiency**

The graph highlights the difference between allocated permits and not allocated permits, indicating where inefficiency occurs in the market.
Aggregate Demand Schedule, Revenue and Surplus

- Bidder Surplus
- Auction Revenue = Seller Surplus

Quantity of permits vs. Price / Value

Permit Supply

Auction Revenue = Seller Surplus

Walrasian Price
## Results (I)

### Efficiency

<table>
<thead>
<tr>
<th>Method</th>
<th>SB (%)</th>
<th>CNoI (%)</th>
<th>CI (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEQ</td>
<td>86.8%</td>
<td>88.3%</td>
<td>88.8%</td>
</tr>
<tr>
<td>SIM</td>
<td>85.9%</td>
<td>88.4%</td>
<td>88.7%</td>
</tr>
</tbody>
</table>

*Higher/lower based on non-parametric tests*

### Prices A/B

<table>
<thead>
<tr>
<th>Method</th>
<th>SB</th>
<th>CNoI</th>
<th>CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEQ</td>
<td>0.973 / 0.846</td>
<td>0.976 / 0.743</td>
<td>0.981 / 0.807</td>
</tr>
<tr>
<td>SIM</td>
<td>0.860 / 0.715</td>
<td>0.900 / 0.828</td>
<td>0.879 / 0.763</td>
</tr>
</tbody>
</table>

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

### Revenues

<table>
<thead>
<tr>
<th>Method</th>
<th>SB (%)</th>
<th>CNoI (%)</th>
<th>CI (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEQ</td>
<td>92.2 %</td>
<td>88.7 %</td>
<td>90.7 %</td>
</tr>
<tr>
<td>SIM</td>
<td>79.8 %</td>
<td>87.0 %</td>
<td>82.9 %</td>
</tr>
</tbody>
</table>

### B’s profits

<table>
<thead>
<tr>
<th>Method</th>
<th>SB (%)</th>
<th>CNoI (%)</th>
<th>CI (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEQ</td>
<td>63.7 %</td>
<td>88.7 %</td>
<td>84.7 %</td>
</tr>
<tr>
<td>SIM</td>
<td>118.6 %</td>
<td>99.1 %</td>
<td>118.5 %</td>
</tr>
</tbody>
</table>
## 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***         | -0.2893***        |
| **[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.
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).
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)
### Auction schedule

**Table 1 – Indicative Auction Schedule**

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</thead>
<tbody>
<tr>
<td>2015-16</td>
<td>15m*</td>
<td></td>
<td>1/8 + (2/8 - 15m)**</td>
<td>4/8</td>
<td>1/8</td>
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<tr>
<td>2016-17</td>
<td>15m*</td>
<td>1/8 + (1/8 - 15m)**</td>
<td>1/8</td>
<td>4/8</td>
<td>1/8</td>
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<td>2017-18</td>
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<td>1/8</td>
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<td>2018-19</td>
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<td>1/8</td>
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<td>2019-20</td>
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<td>2020-21</td>
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<td>2021-22</td>
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<td>1/8</td>
<td>4/8</td>
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</tbody>
</table>

* 15m refers to the 15 million unit limit, as discussed in 3.5 Auctions without a pollution cap in place.

** The number of 2015-16 vintage units available for auction in 2014-15 will be 1/8 of the total vintage allocation plus the excess units that were unable to be auctioned in 2013-14 due to the 15 million unit limit.

*** The number of 2010-17 vintage units available for auction in 2014-15 will be 1/8 of the total vintage allocation plus the excess of units that were unable to be auctioned in 2013-14 due to the 15 million unit limit.

Source: Australian Government 2012 - Auctions - Position paper on the legislative instrument for auctioning carbon units in Australia’s carbon pricing mechanism
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?
Thank you.

r.betz@unsw.edu.au

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