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Combinatorial Clock Auction Prices under Spiteful Bidding

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Market Economy

- Economic decisions (resource allocations) are
  - Price-based

- Price system in competitive world
  - Includes all the info necessary to make optimal (SW) decisions
  - (Imperfect markets → Distorted prices)

- Price → allocation

Prices

- Originate in markets
- Used by many price-taking economic agents
  - (Except for bilateral negotiations)

- Auctions result in
  - Allocation
  - Corresponding prices

This Presentation

- CCA prices
  - Relation to bidders' values
  - Through analyzing bidding behavior
    - In equilibrium
    - Through incentives
  - Based on joint work with
    - Maarten Janssen, University of Vienna
    - Bernhard Kasberger, University of Vienna

Content

- Auction prices in standard auctions
- In VCG mechanism
- In CCA
  - Overview
  - Preference to raise rivals cost
  - Real CCA example
  - Results

Standard Auctions

- IPV, risk neutrality, symmetry
  - Price = opportunity cost: value of other non-winning bidders
    - SP auction – exactly
    - FP auction – in expectation of the winner
- Risk aversion – higher prices
    - Price includes “insurance” against losing
- Value correlation and interdependence / asymmetry
    - Price includes informational / competitive rent (+/-)

VCG mechanism

- With multiple objects
  - Price = opportunity cost: value of other bidders
  - Discriminatory prices
    - Different bidders pay different prices for identical objects
- Yet, average price = average opportunity cost
- Opportunity cost
  - Can be seen as a 'fair' price, a market value

CCA Fair Pricing in Telecom

- Telecom regulators believe
  - In the absence of strategic behavior
    - CCA and SMRA lead to fair prices
  - Prices are fair
    - Good proxies for opportunity cost

- Thus
    - Auction prices must be related to users' values

New Life for Old CCA Prices

- Ofcom (UK) 2015
  - Annual license fees (ALFs) for mobile frequencies (2015+)
    - In 900 MHz and 1800 MHz bands
  - Using prices from recent Ireland and Austria CCA
  - Argument
    - These prices may provide a good reference point for determining the current market value
- Here: we check this argument

CCA - Origin

- Developed by Ausubel, Carmton, and Milgrom (2006)
  - Combinatorial auctions, combinatorial proxy auctions have been around before (Vernon Smith, Ausubel, others)
  - Computer science aspects
    - Direct solution to the WDP with 2000 bids of 5 bidders requires evaluating 32×10^{15} combinations (1000 years). Software tools
    - VCG and Core prices require some more
    - Indirect computations may tolerate up to 100’000 bids/ bidder

CCA - Details

- Consists of two phases
  - Clock phase (primary rounds) - SMRA (clock auction)
    - Nothing is yet allocated
  - Supplementary phase (supplementary round) - Proxy auction
- Binding restrictions:
  - Clock bids restrict supplementary bids

CCA - Applications

Ausubel and Baranov, 2015

Country and Auction	Year	Revenues, M
Trinidad and Tobago Spectrum Auction	2005	$25.1
UK 10 – 40 GHz Auction	2008	£1.43
UK L-Band Auction	2008	£8.33
Netherlands 2.6 GHz Spectrum Auction	2010	€2.63
Denmark 2.6 GHz Spectrum Auction	2010	DKK 1010
Austria 2.6 GHz Spectrum Auction	2010	€39.5
Switzerland Spectrum Auction	2012	CHF 996
Denmark 800 MHz Spectrum Auction	2012	DKK 739
Ireland Multi-Band Spectrum Auction	2012	€482
Netherlands Multi-Band Spectrum Auction	2012	€3800
UK 4G Spectrum Auction	2013	£2340
…		
Canada 700 MHz Spectrum Auction	2014	$5270

CCA - Applications

- Advertised as
  - Relatively complex tool
- But
  - If well understood, makes bidding very simple: bid your value
    - Truthful, or sincere bidding

CCA - Literature

- Issues with CCA
  - Goeree and Lin (2009, TE-2012)
    - If CCA prices are not in the core, truthful bidding is not EQ
  - Knapek and Wambach (2012)
    - Points out to strategic complexities
  - Beck and Ott (2011, draft)
    - Bidding above or below value can be optimal in CCA

CCA - Literature

- Amendments
  - New rules, fine-tuning, etc.
  - Ausubel Baranov (2015): CCA is extremely flexible
    - Different sorts of
      - Reserve prices
      - Activity rules (in clock) and Caps (in supplementary phases)
      - Quantity caps and floors, set-aside
      - Pricing rules (VCG, core-adjustments)

CCA - Literature

- Comparisons of CCA with VCG and other auctions (CCA)
  - Pr[efficient outcome], E[revenue, surplus, *etc*.]
  - Reasonably good performance
- This presentation
  - Those are marginal improvements: CCA fine-tunings
  - CCA seems wrong at a more fundamental level
    - We want auction outcome be robust to all we do not know
    - Not only values are private, but also preferences ($\max(v - p)$?)

Robustness check – Spite motive

- “Industry argument”
  - Future revenues depend on market competition
  - Investments into infrastructure are necessary
  - If others pay (much) more for their licenses
    - They are more restraint in their investments (less budget)
    - You have a competitive advantage
  - Business strategy:
    - Get licenses, and make others harder to get them

Spite motive – Raising Rivals' Payment

- Other (economic) argument:
  - "Look good/ bad" argument, or principal-agent aspect
  - Auction outcome can only be evaluated by comparing
    - What the winners get, and for how much

- Have won a better package at a lower price
    - Good
    - Otherwise – career problems for members of the bidding team

Real CCA Outcome

Swiss 2012 CCA	ORANGE 160 MHZ	SUNRISE 160 MHZ	SWISSCOM 255 MHZ
OVERALL LICENCES COST	128 M	400 M	299 M
800 MHz	20	20	20
900 MHZ	10	30	30
1800 MHz	50	40	60
2.1 GHz	40	20	60
2.6 GHz (paired)	40	50	40
2.6 GHz (unpaired)	_	_	45

Spite Motive as Lexicographic Preference

- Assumed preferences: lexicographic
  - Maximize own profit
  - For equal profits
    - Choose bids that result in higher rivals' prices
- In standard auctions (FP, SP, VCG, *etc*.)
  - No effect
  - Same EQ, same outcomes

Result 1 – Supplementary Round

- From “Spiteful Bidding and Gaming in CCA” (2014)
  - Under some conditions (on the clock phase, later)
    - Bidding own value is a weakly **dominated** strategy
      - Compare with VCG – weakly **dominant** strategy
    - Bidding maximal feasible (allowed) bids on packages is optimal (best response)
      - Even with no (zero) value
    - Bids and values are not anymore related

To result 2

Example 1 - Basic Ingredients

- Three identical bidders
- Two bands, 1 and 2, with three blocks each
- Bidders are interested in three packages (x,y)

Package Nr.	Package (x,y)	Eligibility (5,8)	Value
1	(1,2)	21	50
2	(2,1)	18	46.5
3	(1,1)	13	40

Example 1 – Clock Phase

- Assume: truthful bidding

Round	Clock Prices		Bid	EP	Value	Cost	Surplus
1	1	4	(1,2)	21	50	9	41
2	1	5	(2,1)	18	46.5	7	39.5
3	2	5	(2,1)	18	46.5	9	37.5
4	3	5	(2,1)	18	46.5	11	35.5
5	4	5	(2,1)	18	46.5	13	33.5
6	5	5	(2,1)	18	46.5	15	31.5
7	6	5	(2,1)	18	46.5	17	29.5
8	7	5	(1,1)	13	40	12	28

Example 1 – Relative Cap Implications

- Let a bidder bid $b(1,1) = b$ ($b \geq 12$) in the supplementary round
- His other bids are restricted by:
  - $b(2,1) \leq b + 7$
  - $b(1,2) \leq b(2,1) + 4 \leq b + 11$
  - $b(3,0) \leq b + 9$
  - $b(0,3) \leq b(1,2) + 3 \leq b + 14$

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Example 1 –Supplementary Round

- Assume: truthful bidding

Packages →	(1,1)	(2,1)	(1,2)	(3,0)	(0,3)	Price for (1,1)
Supplementary bids	40	46.5	50	0	0	16.5

  - Prices: $p(1{,}1) = (46.5 + 50) - (40 + 40) = \mathbf{16.5}$ – Opportunity cost

- Equilibrium bidding (undominated) – unique outcome

Packages →	(1,1)	(2,1)	(1,2)	(3,0)	(0,3)	Price for (1,1)
EQ 1 bids	24	31	35	33	38	23
EQ 2 bids	40	47	51	49	54	23

  - Prices: $p(1{,}1) = (49 + 54) - (40 + 40) = \mathbf{23}$ – 40% higher!
    - No bids on (3,0) and (0,3): $p(1{,}1) = (47 + 51) - (40 + 40) = \mathbf{18}$

Example 1 –Supplementary Round

- Another (dominated) EQ

Bidder	(1,1)	(2,1)	(1,2)	(3,0)	(0,3)	Price for (1,1)
1	17	24	28	23	31	17
2	18	25	28	23	31	18
3	19	26	29	23	31	19

  - Lower (riskier) bid → lower price
  - Resembles FP auction – pay-your-bid
  - Continuum of such equilibria

Result 2 – Supplementary Round

- From “Budget Constraints in CCA” (2015)
- Under budget constraint B
    - Conservative: no bids above B (the only way in VCG)
    - Neutral: Bids above B but payment is always below B
    - Risky: Bids above B, payment can be above B, but is below B in EQ
- Result:
    - Continuum of Hawk-Dove type of Equilibria
        - 3 bidders’ case: 1 Hawk + 2 Dove bidders

Result 2 – Supplementary Round

- Hawk bidder
  - Bids low on what he wins, and high (>B) on the other packages
  - Pays low price (<B) in EQ, but if others deviate / miscoordinate
    - Either wins nothing
    - Or wins a different package at high (>B) price
- Dove bidders
  - Bid B on what they win, and high (>B) on the other packages
  - Pay B in EQ

Result 2 – Supplementary Round Prices

- In the supplementary round
  - CCA price is determined not by values of others
  - But by which equilibrium is played
    - How much risk bidders are willing to accept

Example 2 – CCA Equilibrium Analysis

- Two bidders, one band, two objects, continuous time
- Values
  - Private information (as well as bids)
  - $v_i(1)$ follows distribution $F(x)$ over $[11, \infty)$
  - $v_i(2) = v_i(1) + \varepsilon_i$, where ε_i follows distribution $G(x)$ over $[0,10]$
- Clock prices increase continuously until there is no excess demand
- Tie-breaking rule
  - (1) Clock allocation or (2) both winners is chosen

Example 2 – CCA Equilibrium

- Equilibrium (undominated)
  - Clock phase demand of a bidder i (as a function of $v_i(1)$, $v_i(2)$)
    - $d_i = \begin{cases} 2, & if\ p < 10 \\ 1, & if\ p = 10 \\ 0, & if\ p > 10 \end{cases}$
  - Supplementary phase bids:
    - In EQ: $b_i(1) = 10$, $b_i(2) = 20$, auction price $p_i(1) = 10$
    - VCG prices would be $p_i(1) = \varepsilon_{-i} \in [0,10]$

Example 2 – CCA Equilibrium

- Why is it an EQ?
  - Bidding for 2 longer (price>10):
    - Win 2 at price 20, worse than win 1 at price 10
  - Bidding for 1 earlier:
    - Lower competitor's price
  - Dropping to 0 before price >10
    - Winning nothing

Result 3

- CCA Equilibrium prices are uncorrelated with values
  - $p_i(1) = 10$ is the upper-bound of the support of $G(x)$
- Clock phase does not provide any info about values
- Activity/cap rule does not play any role here, efficient outcome
- Demand expansion
  - Bids are above demand in the clock (needed for Result 1) →
  - So that bids are above values in the supplementary round

Example 3 – CCA Price Distortions

- Two bidders, two band, two objects in each band, continuous time
- Additive values, private information (as well as bids)
  - Band 1: $v_i^1(1) > 10$, $v_i^1(2) = v_i^1(1) + \varepsilon_i^1$, $\varepsilon_i^1 \in [0,10]$
  - Band 2: $v_i^2(1) \in [0,20]$, $v_i^2(2) = v_i^2(1) + \varepsilon_i^2$, $\varepsilon_i^2 \in \left[0, v_i^2(1)\right]$
- CCA EQ outcome:
  - Package (1,1), prices: $p_i(1,1) = 10 + {\varepsilon^2}_{-i}$
    - Components 10 and ${\varepsilon^2}_{-i}$ in $p_i(1,1)$ are distorted

Result 4

- Not only CCA prices are biased from opportunity cost
  - But also distorted
    - Price ratios do not reflect relative opportunity costs
- Thus
  - Comparing what winners have won and what they have payed
    - In multi-band CCA
    - Can be misleading

Result 5 – Excess Supply in Clock

- Excess supply in the clock phase
  - Complicate the analysis of the supplementary phase
  - No dominant EQ anymore (Result 1 fails)
- Yet, demand expansion remains an EQ outcome
  - Example 2 modified
    - 3 bidders, 4 units, values
      - $v_i(1) > 20$, $\varepsilon_i(2) \in [0,10]$, $\varepsilon_i(3) = \varepsilon_i(4) = 0$

Result 5 – Excess Supply in Clock

- EQ:
  - Clock
    - Bid for 3 up to $p = 10$, then switch to 1
  - Supplementary round
    - $b_i(1) = v_i(1)$, $b_i(2) = v_i(1) + \varepsilon_i(2)$, $b_i(3) = v_i(1) + \varepsilon_i(2) + 10$,
  - Outcome: max $\varepsilon_i(2)$ bidder ($j = 3$) wins 2, others win 1
    - $p_{1,2}(1) = 10$, $p_3(2) = 10 + \max \varepsilon_{1,2}(2)$
    - VCG prices: $p_1(1) = \varepsilon_2(2)$, $p_2(1) = \varepsilon_1(2)$, $p_3(2) = \varepsilon_1(2)+\varepsilon_2(2)$

Summary

- Apart from issues within CCA, there are problems with CCA outcomes
  - CCA prices might be uninformative to the economy
    - As well as the clock phase development
    - Relative prices as well
  - Using them for ALFs can be problematic
    - These prices may have no / little relation to market values
      - Even relative prices