Identifying Dependencies in the Demand for Government Securities

Jason Allen, Jakub Kastl and Milena Wittwer

Bank of Canada, Princeton University, Stanford University

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Introduction

Supply for T-securities

- Governments issue T-securities to fund fiscal expenditures

→ Primary objective: achieve lowest cost of financing over time

Demand for T-securities

- Existing work focuses on the aggregate demand → substitutes
- Demand of an individual institution?
  - Shaped by portfolio, demand of different clients etc. → ???

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- Governments issue T-securities to fund fiscal expenditures

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- Demand of a dealer?
  - Shaped by portfolio, demand of different clients etc. → ???

This Paper

1. Proposes a method for identifying the dependencies in the demands of primary dealers (PDs) across different T-securities
   - Focus on the primary market, use an institutional feature: **simultaneous T-Bill auctions** where banks submit demand schedules

   → Allows us to control for unobserved heterogeneity:
   - same market rules, participants, time period, economic situation. . .

2. To help governments decide how to split securities across maturities

Related Literature

Macroeconomic perspective

- Shleifer (1985), Krishnamurthy and Vissing-Jørgensen (2012)

→ We: primary market, demand of an individual institution

Multi-unit auctions

- empiric.: Guerre et al. (2000), Hortaçsu (2002),Hortaçsu and Kastl (2012)
- theoret.: Kastl (2011), Wittwer (2019)

→ We: extend methodology & focus on split between maturities

IO demand estimation

- Berry et al. (1995), Koijen and Yogo (2019)

→ We: institutional feature to work around unobserved heterogeneities

Institutional Environment

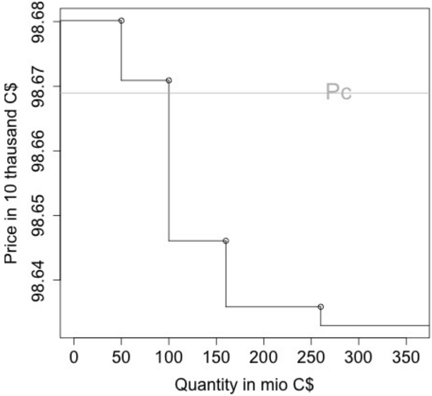
- There are three types of T-bills in Canada: m= 3, 6, 12 months
- Sold every other Thursday by the Bank of Canada (BoC)

→ In 3 separate auctions run in parallel

- 2 groups of bidders:
  - dealers (d) and
  - customers (c) who can only submit bids through a dealer
- From auction opening until closure, bidders may update their 'bids'

Pay-As-Bid Auction

A 'bid' in an auction is a bid step function: $\{b_k, q_k\}_{k=1}^{K_i}$



- Given a supply Q_m market clears at p_m^c such that $\sum_i y_m^i(p_m^c) = Q_m$. Every bidder pays their bid for all allocated units.

Data Set

- All 366 Canadian T-bill auctions of 3,6,12M btw. 2002, 2015
- All bidderIDs
  - Avg: 10.6 bidders participate in one auction
  - Avg: 95 % of active dealers go to all 3 auctions
- All individual bids (including updates)
  - Avg: # of steps in bid-function: about 4.5

Goal

- All 366 Canadian T-bill auctions of 3,6,12M btw. 2002, 2015
- All bidderIDs
  - Avg: 10.6 bidders participate in one auction
  - Avg: 95 % of active dealers go to all 3 auctions
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⇒ Measure whether/how closely securities are substitutable/complementary

Micro-Foundation of Demand

At time τ, dealer i wants maturity m

1. **to fulfill standing orders or for own balance sheets**
2. **to sell them in the secondary market (SM)**, where
   - different clients demand different maturities
     - the amounts that clients demand of each maturity can be correlated
     - clients may view bills as substitutes (!)
   - it is costly for the dealer to turn down clients, in particular, if several clients arrive but not all can be served (relationship/reputation loss)

more

Micro-Foundation of Demand

At time τ, dealer i wants maturity m

1. **to fulfill standing orders or for own balance sheets** $\rightarrow t_{m,i,\tau}$
2. **to sell them in the secondary market (SM)**, where $\rightarrow \lambda_{m,i}, \delta_{m,i}$

- different clients demand different maturities
  - the amounts that clients demand of each maturity can be correlated
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more

Equation to Estimate

Consider bidder i at time τ. His true MWTP for amount q_m of maturity m is

$$v_m(q_m, \vec{q}_{-m}, s_{m,i,\tau}) = f(t_{m,i,\tau}) + \lambda_{m,i} q_m + \vec{\delta}_{m,i} \cdot \vec{q}_{-m}$$

if he wins amounts $\vec{q}_{-m}$ of the other maturities $-m$.

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Challenges

1. Bidder has private information $s_{m,i,\tau}$

→ Generates incentives to misrepresent the true demands (strategic bid shading)

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2. Disconnected market design: In auction m the bidder is not allowed to submit bids that depend on the amount of assets offered in $-m$

→ We observe $b_m(q_m, s_{m,i,\tau})$ not $v_m(q_m, \vec{q}_{-m}, s_{m,i,\tau})$ w/o knowing $s_{m,i,\tau}$

Estimation Strategy

Estimation Strategy

1. Estimate $\mathbb{E}[v_m(q_m, \vec{Q}^c_{-m}, s_{m,i,\tau})|\text{win } q_m]$ and $\mathbb{E}[\vec{Q}^c_{-m}|\text{win } q_m]$
   - Identifying assumption: conditional on observed auction/date characteristics, the information of each bidder at time τ is private and iid across bidders
2. Use variation in $\mathbb{E}[\vec{Q}^c_{-m}|\text{win } q_m]$ across q_m for bidder i at time τ:

$$\hat{\mathbb{E}}[v_m(q_m, \vec{Q}^c_{-m}, s_{m,i,\tau})|\text{win } q_m] = fe_{m,i,\tau} + \lambda_{i,m} q_m + \vec{\delta}_{-m} \cdot \hat{\mathbb{E}}[\vec{Q}^c_{-m}|\text{win } q_m]$$

Estimation Strategy and Specifications

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Specifications

- Benchmark model: all dealers are ex-ante symmetric
- 2 groups: main dealers with large fixed-income trading desks vs. others

Findings

3M Bill auction of a main dealer

$$\hat{v}_{3M,i,\tau} = fe_{3M,i,\tau} + \lambda_{3M} * q_{3M} + \delta_{3M,6M} * \hat{\mathbb{E}}[Q^C_{6M}|\text{win } q_{3M}] + \delta_{3M,12M} * \hat{\mathbb{E}}[Q^C_{12M}|\text{win } q_{3M}] + \epsilon$$

λ_{3M}	-6.213^{***} (0.0487)	≈ -0.229 bps
$\delta_{3M,6M}$	$+1.054^{***}$ (0.111)	≈ 0.039 bps
$\delta_{3M,1Y}$	$+0.363^{**}$ (0.123)	≈ 0.013 bps
Constant	995670.9^{***} (0.543)	≈ 159.1 bps
Observations	28592	

Quantities in % of total supply in the auction

SE in parentheses, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

benchmark 6M,12M

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3M Bill auction of a main dealer

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benchmark 6M,12M

3M auction

- Dealer's WTP ↓ by 1.67 bps if (0,0,0) → (500mil, 0,0) of (3M,6M,12M)
- Dealer's WTP ↑ by 0.29 bps if (0,0,0) → (0, 250mil,250mil) of (3M,6M,12M)

Estimation Results: Summary

- **3,6,12M bills are weak complements (not substitutes!)**

→ Individual cross-market elasticities in the primary market seem to differ from aggregate elasticities in the secondary markets

→ Dealers have heterogeneous preferences

Policy Recommendations

How to split supply across maturities to achieve max. revenue on a day?

= Short-term perspective which ignores roll-over costs

Opposing effects

1. $p_{3M} > p_{6M} > p_{12M}$ given yield curve $\rightarrow$ issue only 3M bills
2. bills are complements $\rightarrow$ issue a maturity mix

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2. bills are complements $\rightarrow$ issue a maturity mix

Findings

- Issuing only 3M bills is optimal

$\rightarrow$ "yield-curve effect" dominates the effect from complementarities

details

Conclusion

1. We estimate demand interdependencies of primary dealers leveraging an institutional feature of Treasury Bill auctions
   - Bills of maturities behave as weak complements
   - Micro-foundation:
     - Bills can be substitutes in the macro economy but compl. for a PD
     - It depend on PD's role in the secondary market

   → Findings confirm heterogeneities across dealers

2. We analyze whether reshuffling supply across the maturities can increase auction revenues
   - Issuing only 3M bills is optimal when taking a short-term perspective

→ Open question
   - maximize long-term objective function that includes roll-over risk

Thank you!

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Micro-Foundation

- Let there be only 2 auctions, each offering one maturity ($M = 2$)
- Each bidder i is either a dealer ($g = d$) or a customer ($g = c$)
- He draws a private signal before each time τ he places a bid

$$s^g_{i,\tau} \equiv \left(\boldsymbol{s^g_{1,i,\tau}} \quad \boldsymbol{s^g_{2,i,\tau}} \right) \sim F^g \text{ iid across } i \text{ and } \tau$$

- He will use the amount q_m he wins in auction m in two ways

$$\begin{cases} (1 - \kappa_{m,i})\% \text{ of } q_m & \text{to fulfill existing customers orders or for personal usage} \\ \kappa_{m,i}\% \text{ of } q_m & \text{for future resale in the secondary market} \end{cases}$$

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- He will use the amount q_m he wins in auction m in two ways

$$\begin{cases} (1-\kappa_{m,i})\% \text{ of } q_m & \Rightarrow U(q_1, q_2, s^g_{i,\tau}) \\ \kappa_{m,i}\% \text{ of } q_m & \Rightarrow \text{Expected resale profit} \end{cases}$$

Micro-Foundation

- After the auction, clients will demand amounts $\{\boldsymbol{x_1}, \boldsymbol{x_2}\} \sim G$
- Depending on how much the bidder won at auction $\{q_1, q_2\}$ he

$$\begin{cases} \text{sells } \{x_1, x_2\} \text{ at } \{p_1, p_2\} & \text{if } x_1 \leq \kappa_{1,i} q_1 \ \& \ x_2 \leq \kappa_{2,i} q_2 \\ \text{sells only } x_1 \text{ at } p_1 & \text{if } x_1 \leq \kappa_{1,i} q_1 \ \& \ x_2 > \kappa_{2,i} q_2 \\ \text{sells only } x_2 \text{ at } p_2 & \text{if } x_1 > \kappa_{1,i} q_1 \ \& \ x_2 \leq \kappa_{2,i} q_2 \\ \text{sell nothing} & \text{otherwise} \end{cases}$$

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→ Revenue from resale:

$$revenue(x_1, x_2 | q_1, q_2) = p_1 x_1 + p_2 x_2$$

where p_1, p_2 are pinned down by the inverse demand of this bidder's clients given $\{x_1, x_2\}$

Micro-Foundation

- Turning clients down is costly
- $cost(x_1, x_2|q_1, q_2)$ increases in x_1 and x_2 & is supermodular

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  - $cost(x_1, x_2|q_1, q_2)$ increases in x_1 and x_2 & is supermodular

→ Expected benefit from winning $\{q_1, q_2\}$ in the auction

$$V(q_1, q_2, s^g_{i,\tau}) = U(q_1, q_2, s^g_{i,\tau}) + \mathbb{E}\left[revenue(\boldsymbol{x_1}, \boldsymbol{x_2}|q_1, q_2) - cost(\boldsymbol{x_1}, \boldsymbol{x_2}|q_1, q_2)\right]$$

→ True MWTP is $\frac{\partial V(q_1, q_2, s^g_{i,\tau})}{\partial q_1}$ which we approximate by a linear function (Taylor expansion)

back

Simplified Resampling Procedure

Assume

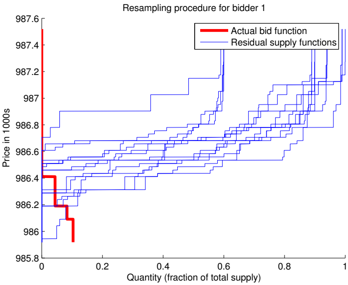
- N potential bidders are ex-ante sym and play the sym BNE
- Private information is independent across bidders, no updates
- All $T \times M$ auctions have identical covariates

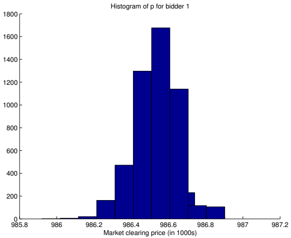
Procedure

1. Fix bidder i and the bidding schedules he submitted in all auctions he participated in. If he did not bid in an auction, replace his bid by 0.
2. Draw a random subsample of $N - 1$ bid vector triplets with replacement from the sample of $N(T \times M)$ bids in the data set.
3. Construct bidder i's realized residual supply $\forall m$ were others to submit these bids to determine
   - realized clearing prices $\vec{p} = \{p_{3M}, p_{6M}, p_{12M}\}$
   - if i would have won $\vec{q}_i = \{q_{i,3M}, q_{i,6M}, q_{i,12M}\}$ for all $(\vec{q}, \vec{p})$.

$\rightarrow$ Repeat many times $\Rightarrow$ Consistent estimate of the joint distr. of $\vec{P}$ and $\vec{Q}_i$

Resampling method





Actual Resampling Procedure

Is more complicated:

- We observe all updates of a bidder

→ Enough data that we do not have to pool auctions across dates (private info is only conditionally independent)

- We account for differences btw. dealers and customers (ex-ante symmetry required only within the same group)
- and for info asymmetries btw bidders who observe customer bids and those who do not

back

Findings

The average dealer - 3M Bill auction

	estimated MWTP v_k in C$		submitted bid b_k in C$	
λ_{3M}	$-6.123^{***} \approx$ -0.25 bsp	(0.0487)	$-\ ^{***} \approx$ -0.19 bsp	(0.0256)
$\delta_{3M,6M}$	$+0.178^{**} \approx$ 0.007 bsp	(0.0625)	$+0.384^{***} \approx$ 0.015 bsp	(0.0599)
$\delta_{3M,1Y}$	$+0.241^{***} \approx$ 0.010 bsp	(0.0669)	$+0.367^{***} \approx$ 0.015 bsp	(0.0642)
Constant	995661.0^{***}	(0.367)	995651.4^{***}	(0.351)
Observations	58542		58542	

Quantities in % of total amount issued in the auction
Standard errors in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The average dealer - 6M Bill auction

	estimated MWTP v_k in C$		submitted bid b_k in C$	
λ_{6M}	$-8.450^{***} \approx$ 0.17 bsp	(0.0485)	$-7.789^{***} \approx$ 0.15 bsp	(0.0465)
$\delta_{6M,3M}$	$+0.626^{***} \approx$ 0.01 bsp	(0.106)	$+1.034^{***} \approx$ 0.02 bsp	(0.102)
$\delta_{6M,1Y}$	$+0.437^{***} \approx$ 0.01 bsp	(0.114)	$+0.642^{***} \approx$ 0.01 bsp	(0.109)
Constant	991656.7^{***}	(0.721)	991639.0^{***}	(0.692)
Observations	42282		42282	

Quantities in % of total amount issued in the auction
Standard errors in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

back

Findings

The average dealer - 12M Bill auction

	estimated MWTP v_k in C$		submitted bid b_k in C$	
λ_{6M}	$-8.450^{***} \approx 0.17$ bsp	(0.0485)	$-7.789^{***} \approx 0.15$ bsp	(0.0465)
$\delta_{6M,3M}$	$+0.626^{***} \approx 0.01$ bsp	(0.106)	$+1.034^{***} \approx 0.02$ bsp	(0.102)
$\delta_{6M,1Y}$	$+0.437^{***} \approx 0.01$ bsp	(0.114)	$+0.642^{***} \approx 0.01$ bsp	(0.109)
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Quantities in % of total amount issued in the auction
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back

Findings

6M Bill auction of a main dealer

	estimated MWTP v_k in C$/bsp		submitted bid b_k in C$	
λ_{6M}	-9.499^{***} (0.0848)	≈ -0.199 bsp	-8.738^{***} (0.0826)	≈ -0.183 bsp
$\delta_{6M,3M}$	$+1.217^{***}$ (0.177)	≈ 0.0261 bsp	$+1.541^{***}$ (0.172)	≈ 0.0330 bsp
$\delta_{6M,1Y}$	$+0.940^{**}$ (0.200)	≈ 0.0193 bsp	$+1.131^{***}$ (0.195)	≈ 0.0233 bsp
Constant	991419.6^{***} (1.058)	≈ 179.4 bsp	991402.2^{***} (1.031))	≈ 179.8 bsp
Observations	21406		21406	

Quantities in % of total amount issued in the auction
Standard errors in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

- Dealer's WTP ↓ by 1.52 bps if (0,0,0) → (0,200mil,0) of (3M,6M,12M)
- Dealer's WTP ↑ by 0.11 bps if (0,0,0) → (100mil,0,100mil) of (3M,6M,12M)

back

Findings

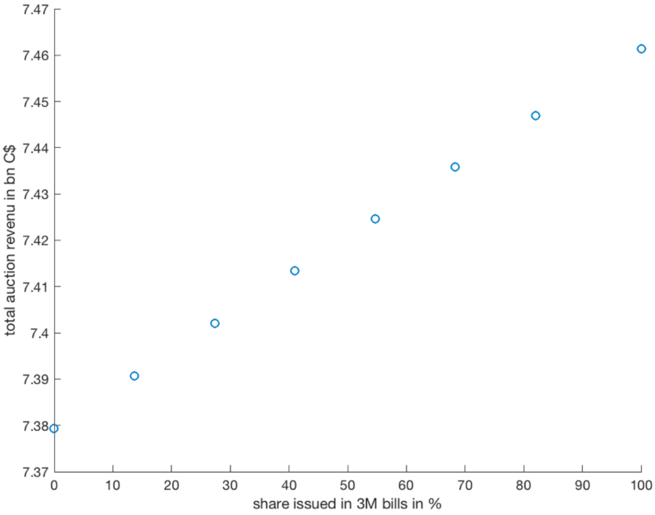
12M Bill auction of a main dealer

	estimated MWTP v_k in C$/bsp		submitted bid b_k in C$	
λ_{12M}	-19.82^{***} (0.152)	≈ -0.209 bsp	-18.23^{***} (0.146)	≈ -0.193 bsp
$\delta_{12M,3M}$	$+0.887^{***}$ (0.342)	≈ 0.0100 bsp	$+0.957^{***}$ (0.327)	≈ 0.0107 bsp
$\delta_{12M,6M}$	$+1.412^{**}$ (0.388)	≈ 0.0133 bsp	$+2.403^{***}$ (0.372)	≈ 0.0238 bsp
Constant	981251.4^{***} (1.863)	≈ 195.9 bsp	981210.3^{***} (1.782)	≈ 196.4 bsp
Observations	25134		25134	

Quantities in % of total amount issued in the auction
Standard errors in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

- Dealer's WTP $\downarrow$ by 1.61 bps if (0,0,0) $\rightarrow$ (0,0,200mil) of (3M,6M,12M)
- Dealer's WTP $\uparrow$ by 0.04 bps if (0,0,0) $\rightarrow$ (100mil,100mil,0) of (3M,6M,12M)

back


total auction revenu in bn C$
7.47
7.46
7.45
7.44
7.43
7.42
7.41
7.4
7.39
7.38
7.37
0
10
20
30
40
50
60
70
80
90
100
share issued in 3M bills in %

Counterfactual

How does revenue change if we reshuffle supple?

Challenge: approximate counterfactual bids (lack of theory)
Approach: approximate

$$b^{cf}_{m,i}(q_{m,k}) = \hat{v}alue_{i,m}(q_{m,k}) - \hat{s}hading_{i,m,k} \; \forall i, m$$

with

$$\hat{s}hading_{i,m,k} = \text{estimated value for } q_{m,k} - \text{submitted bid}$$

$$\hat{v}alue_{i,m}(q_{m,k}) = \hat{\epsilon}_{m,i,k} + \hat{\lambda}_m q_{m,k} + \hat{\delta}_m \cdot \hat{\mathbb{E}}[\boldsymbol{q^*_{-m,i}} | q_{m,k}]$$

→ By construction bids change only due to changes in $\hat{\mathbb{E}}[\boldsymbol{q^*_{-m,i}} | q_{m,k}]$

Counterfactual

How does revenue change if we reshuffle supple?

Challenge: For each $\vec{Q}$, find fixed point of $\hat{\mathbb{E}}[\boldsymbol{q^*_{-m,i}}|q_{m,k}]$ for all i, m, k

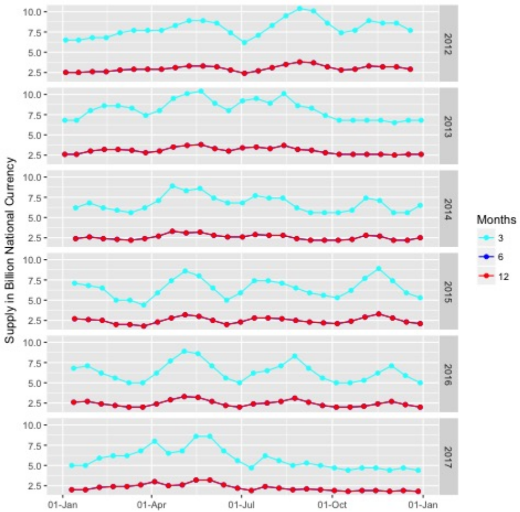
→ Focus on 5 main dealers with complementary preferences

- Let all other bidders respond only passively (scale up their demand in proportion to supply, keeping same prices)

$$\max_{\vec{Q}} Rev(\vec{Q}) = \max_{\vec{Q}} \left\{ \sum_{m=1}^{M} \sum_{i=1}^{N_m} \int_0^{q^*_{m,i}} b^{cf}_{m,i}(x)dx \right\} \text{ s.t. } \sum_m Q_m = \text{total debt}$$

back

Policy Recommendations: Canada's Issuance Strategy



Estimation Strategy: Stage 1

Estimate $v_m(q_m, \vec{q}_{-m}, s_{m,i,\tau})$ & distribution of winning quantities

- Assume all play BNE & back out which valuations rationalize the bids we observe
- Identifying assumption: private info of i at time τ about maturities is iid across bidders i conditional on observed auctions/date characteristics

$\rightarrow$ Solves problem 1 [strategic bid shading]

Estimation Strategy: Stage 2

Problem 2 [disconnected market design]

- Bidder's true MWTP for q_m is $v_m(q_m, \vec{q}^c_{-m}, s_{m,i,\tau})$
  where $\vec{q}^c_{-m}$ is the amount he will win of the other two assets
- He does not know $\vec{q}^c_{-m}$ at the time he bids (auctions run in parallel)

→ Integrate out the uncertainty:

$$\mathbb{E}[v_m(q_m, \vec{Q}^c_{-m}, s_{m,i,\tau})| \text{ win } q_m]$$

Estimation Strategy: Stage 2

Problem 2 [disconnected market design]

- Bidder's true MWTP for q_m is $v_m(q_m, \vec{q}^c_{-m}, s_{m,i,\tau})$ where $\vec{q}^c_{-m}$ is the amount he will win of the other two assets
- He does not know $\vec{q}^c_{-m}$ at the time he bids (auctions run in parallel)

→ Regressions with bidder-auction-time fixed effect using bid funs. with > 1 step k

$$\hat{v}_{m,i,\tau,k} = fe_{m,i,\tau} + \lambda_{m,i} * q_{m,i,\tau,k} + \vec{\delta}_{m,i} \cdot \hat{\mathbb{E}}[\vec{Q}^c_{-m} | \ldots] + \epsilon_{m,i,\tau,k}$$

- Notation: maturity m, bidder i, time τ, step k