Participation Screen for Collusion in Auctions

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1 What is economics?

Wikipedia:

1. "Economics is the social science that studies the production, distribution, and consumption of goods and services."

2. "the science which studies human behaviour as a relationship between ends and scarce means which have alternative uses."

3. "Economics aims to explain how economies work and how economic agents interact. Economic analysis is applied throughout society, in business, finance and government, but also in crime, education, the family, health, law, politics, religion, social institutions, war and science."

2 My niche

Economics is typically divided into micro (behavior of individuals, firms and other agents) and macro (aggregate stuff, monetary and fiscal policy...).

Research can be theoretical or empirical (econometrics) or both. Both theory and econometrics can be applied or pure theory.

My broad field: Applied microeconometrics.

My niche: Empirical industrial organization (study of firms and industries).

3 Microeconometrics and causal inference

Some tools of causal inference:

1. Lab experiments, Field experiments. (internal validity quaranteed, external debatable)

With observational data:

2. Structural models: Theoretical model maps one-to-one to empirical model. (external validity quaranteed, internal debatable)

3. Program evaluation/causal inference literature. (internal validity ok if done properly, external debatable)

Search for exogenous variation like natural/quasi/pseudo experiments, structural breaks and discontinuities, regime/policy ghanges.

Apply: IV, matching, RD, panel, SE... techniques. Huge progress in the last 25 y, econometrics at the frontier.

4. Simultaneous equations methods (part of 2. and 3. too). This paper!

4 Why to test for collusion

Collusion often induces welfare losses. (Normally market power. In procurement through taxes).

Incentives to collude in auctions can be reduced in at least two ways:

1. Design the auction in such a way that collusion is hard to agree upon or sustain.

2. Use methods to detect collusion and prosecute the guilty bidders.

5 Summary

I propose a new test to detect collusion that 1. is robust to unobserved heterogeneity; 2. Requires data only on entry decisions.

Gap: PZ 1999 (RAND) has property 2, but not 1. PZ 1993 (JPE) has property 1, but not 2.

TRICK: Take a duopoly entry model with complete information.

Apply it in an incomplete info setting.

Interpretation of the parameters changes from the competition to collusion effect.

6 Motivation

A robust test that uses only entry decision data is important because:

1. Price data not always available or very costly.

2. Sometimes not enough variation in prices (my application, franchising...).

3. Lang&Rosenthal (1991, RAND): Pricing outcomes that seem collusive emerge noncooperatively in simultaneous FPSB auctions with decreasing returns to scale and entry costs. My test ok.

7 Plan of the talk

Part 1: Methodological contribution

Intuition behind the PZ 1999 and the new test

Testing methodology and identification

Monte Carlo

Part 2: Application

Market and the results

8 Idea

Both tests can detect *collusion* in auctions (generally in static simultaneous discrete games of incomplete information with binary strategic space).

Require data on entry and bidder identities, but not on bids. Works both on territorial allocation and phony bidding schemes.

The problem: How to tell collusion from competition as similar participation patterns can be observed under both regimes?

Method: Does the identity of the competitors affect participation after all the heterogeneity is controlled for?

9 Contributions

The main C: New test to detect collusion that is better/complementary to an existing test (PZ).

Improvement: Robust to unobserved heterogeneity. This comes with costs.

The minor C: First territorial allocation application, typically phony bidding studied.

Tiny C: Application results interesting to competition authority.

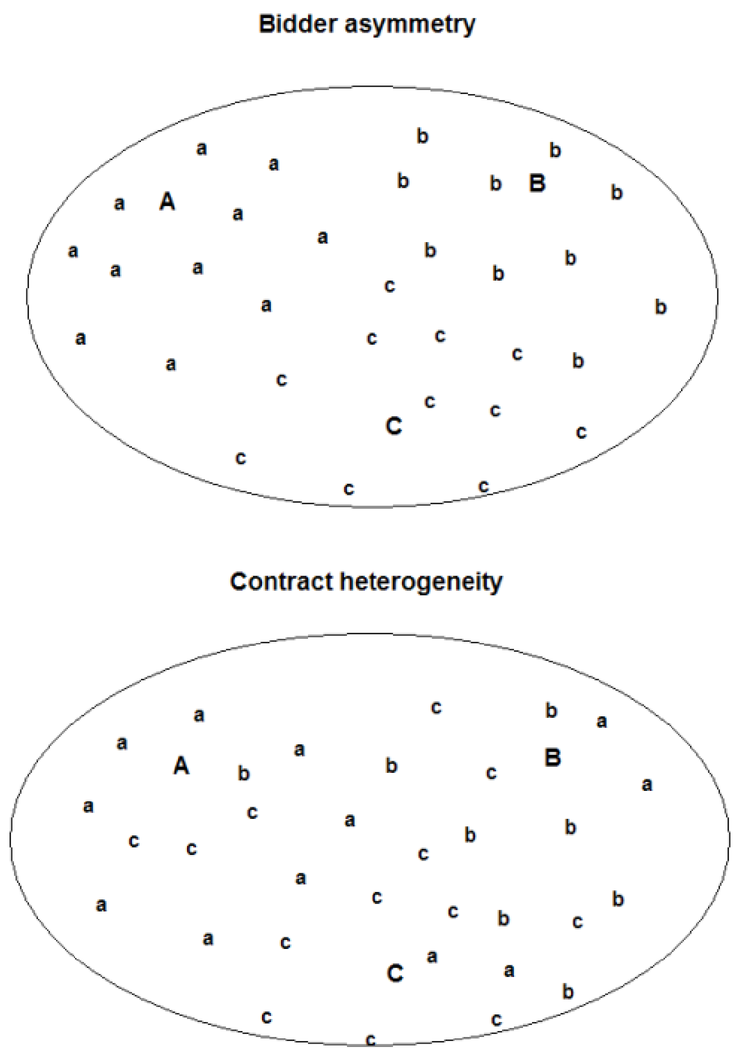

Figure 1:

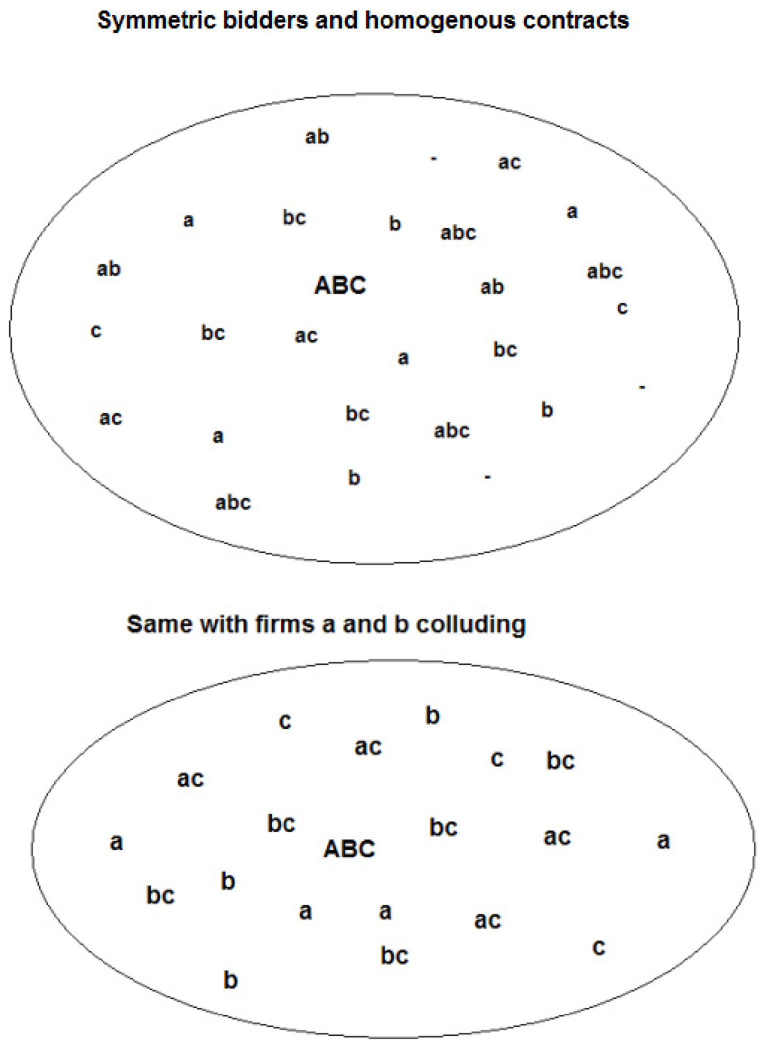
Symmetric bidders and homogenous contracts
ab
-
ac
a
bc
b
abc
a
ab
ABC
ab
abc
c
c
bc
ac
a
bc
-
ac
bc
abc
b
a
b
-
abc
Same with firms a and b colluding
c
b
ac
ac
c
bc
bc
bc
a
ABC
ac
a
b
bc
a
a
ac
bc
c
b

Figure 2:

10 Testing

A standard CI simultaneous duopoly entry game nests both the tests:

$y_1^* = x_1\beta_1 + y_2\delta_1 + u_1,$

$y_2^* = x_2\beta_2 + y_1\delta_2 + u_2,$

$y_i = 1$ if $y_i^* \geq 0$, otherwise $y_i = 0$, $i = 1, 2$.

Given some assumptions, the δ_i's are a measure of collusion.

PZ test: single equation probits of participation (without $y_j\delta_i$'s).

H_0: $Corr(\epsilon_{1t}, \epsilon_{2t}) = 0$

H_1: $Corr(\epsilon_{1t}, \epsilon_{2t}) \neq 0$ (< 0 territorial allocation; > 0 phony bidding)

Analogous to any test based on H_0:$\rho_\epsilon = 0$ in bivariate probit

$y_1^* = x_1\beta_1 + \epsilon_1$

$y_2^* = x_2\beta_2 + \epsilon_2$,

$\binom{\epsilon_1}{\epsilon_2}$~$IIDN\left(\begin{bmatrix}0\\0\end{bmatrix}, \begin{bmatrix}1 & \rho_\epsilon\\ \rho_\epsilon & 1\end{bmatrix}\right)$. $y_i = 1$ if $y_i^* \geq 0$, otherwise $y_i = 0$.

My test: estimate the endogenous simultaneous equations system as in Tamer (2003, RES). Use the BR (1990,1991) logic of treating (1,0) and (0,1) outcomes as the same outcome. In pure strategies (1,1) and (0,0) outcomes unique eq. (when δ's neg.)

H_0: $\delta_i = 0$ for all $i = 1, 2$

H_1: $\delta_i \neq 0$ for some $i = 1, 2$.

11 Some identification assumptions

IA1 (both tests): x_1 and x_2 (and ρ_u in the new test) capture entirely the competitive behavior. This seems plausible if the shocks are private.

IA2 (only PZ): $\binom{\epsilon_1}{\epsilon_2}$~$IIDN\left(\begin{bmatrix}0\\0\end{bmatrix}, \begin{bmatrix}1 & \rho_\epsilon\\ \rho_\epsilon & 1\end{bmatrix}\right)$, where $\epsilon_i = y_j\delta_i + u_i$, $i = 1, 2$.

IA3 (only PZ): $Cov(u_1, u_2) = \rho_u = 0$. Relaxing this is the contribution!

IA4 (only new): Let $U = (u_1, u_2)$ be a random vector independent of x with a known joint conditional distribution F_u that is absolutely continuous with mean 0 and unknown covariance matric Ω.

$\Rightarrow \rho_u \neq 0$ is allowed even though then the y's are correlated with the u's.

IA5 (only new): $\delta_1 \times \delta_2 > 0$.

In territorial allocation case, both δ's are negative and in the phony bidding case both δ's are positive. Likelihood fct looks different for neg. and pos. δ's.

IA6 (only new): There is one *unique* continuous regressor in either the x_1 or x_2.

PZ is not robust to unobserved heterogeneity. BUT: Requires less observations. Is computationally very fast and easy to implement. Likelihood fct is easy to optimize. Does not require an exclusion restriction. Extensions to richer strategy space and more players are easier (MN/MV-probit vs. CT2009).

Both tests can be applied to cases with more that two bidders by conducting the analysis pairwise.

12 Monte Carlo

DGP:

$$y_1^* = \beta_{10} + x\beta_{11} + z_1\beta_{12} + \min(z_2, z_3)\beta_{13} + y_2\delta_1 + u_1$$

$$y_2^* = \beta_{20} + x\beta_{21} + z_2\beta_{22} + \min(z_1, z_3)\beta_{23} + y_1\delta_2 + u_2$$

$$\binom{u_1}{u_2} \sim IIDN\left(\begin{bmatrix}0\\0\end{bmatrix}, \begin{bmatrix}1 & \rho\\ \rho & 1\end{bmatrix}\right).$$

PZ: probit: $y_1^* = \beta_{10} + x\beta_{11} + z_1\beta_{12} + \text{min}(z_2, z_3)\beta_{13} + \epsilon_1$ (same for 2, then test corr(ϵ_1, ϵ_2)).

New test: max L

$$L_{ML}(b) = \sum_{t=1}^{T} \left[\begin{array}{c} y_{t1}y_{t2} \log(P_1(x_t, b)) + (1 - y_{t1})(1 - y_{t2}) \log(P_2(x_t, b)) \\ +((1 - y_{t1})y_{t2} + y_{t1}(1 - y_{t2})) \log(1 - P_1(x_t, b) - P_2(x_t, b)) \end{array} \right],$$

where $P_1(x_t, b) = \Pr[(y_{t1} = 1, y_{t2} = 1)|x] = \Pr(u_{t1} \geq -x_{t1}\beta_1 - \delta_1; u_{t2} \geq -x_{t2}\beta_2 - \delta_2)$ and

$P_2(x_t, b) = \Pr[(y_{t1} = 0, y_{t2} = 0)|x] = \Pr(u_{t1} < -x_{t1}\beta_1; u_2 < -x_{t2}\beta_2)$

Different model specifications used in the Monte Carlo analysis

Model	β_{10},β_{20}	β_{11},β_{21}	β_{12},β_{22}	β_{13},β_{23}	δ_1,δ_2	ρ
1.	0	0.3	-0.3	0.2	0	0
2.	0	0.3	-0.3	0	-0.3	0
3.	0	0.3	-0.3	0	-0.45	0
4.	0	0.3	-0.3	0	-0.6	0
5.	0	0.3	-0.3	0.2	0	-0.5
6.	0	0.3	-0.3	0	-0.45	-0.5
7.	0	0.3	-0.3	0.2	0	0.5
8.	0	0.3	-0.3	0	-0.45	0.5

Results:

1. PZ tests works very well for models with $\rho = 0$ even in small samples (250 obs) but fails when $\rho \neq 0$.

2. Solving the simultaneous equations model as in Tamer (2003) is a very tricky numerical optimization problem. At small or moderate (1000 obs) samples all the tried standard optimization algorithms fail: 1. Multiple local maxima. 2. Very slow if any convergence. 3. Problems in identifying the δ's and the ρ separately.

Fortunately, these problems can be solved.

For 1: Use an evolutionary algorithm (in R, the rgenoud package). Randomized starting population. Good at finding global max in difficult problems. Slow.

For 2: Run EA long enough, then finish with Nelder-Mead.

For 3: Impose IA3 ($\delta_1 \times \delta_2 > 0$) on the likelihood with a distance based ($constant \times \delta_1 \times \delta_2$) penalty fct (good with EA). With 250 obs, need to impose $\delta_1 = \delta_2$.

Then the new test works even when $\rho \neq 0$.

13 Application

Helsinki school yard snow removal auctions in autumns 2003 (#153), 2004 (#37) and 2005 (#65). Total 258.

Simultaneous FPSB auctions with secret reservation price.

Contract controls: Yard size, shape (3 variables from the maps of the yards), region, time, distance from the city garage.

Bidder controls: Bidder's own cost proxy (# of bids to the 6 nearest schools), the cost proxy of the most dangerous competitor for a given school.

14 Results

The PZ test shows that collusion seems likely in 2003. (Sig. at 1 % for 2003-2005. 2003 sig. alone but 2004-2005 not.)

Strategic behavior not important (= competitors' characteristics are not important), which also supports collusion.

The new test suggests collusion also, but not significant.

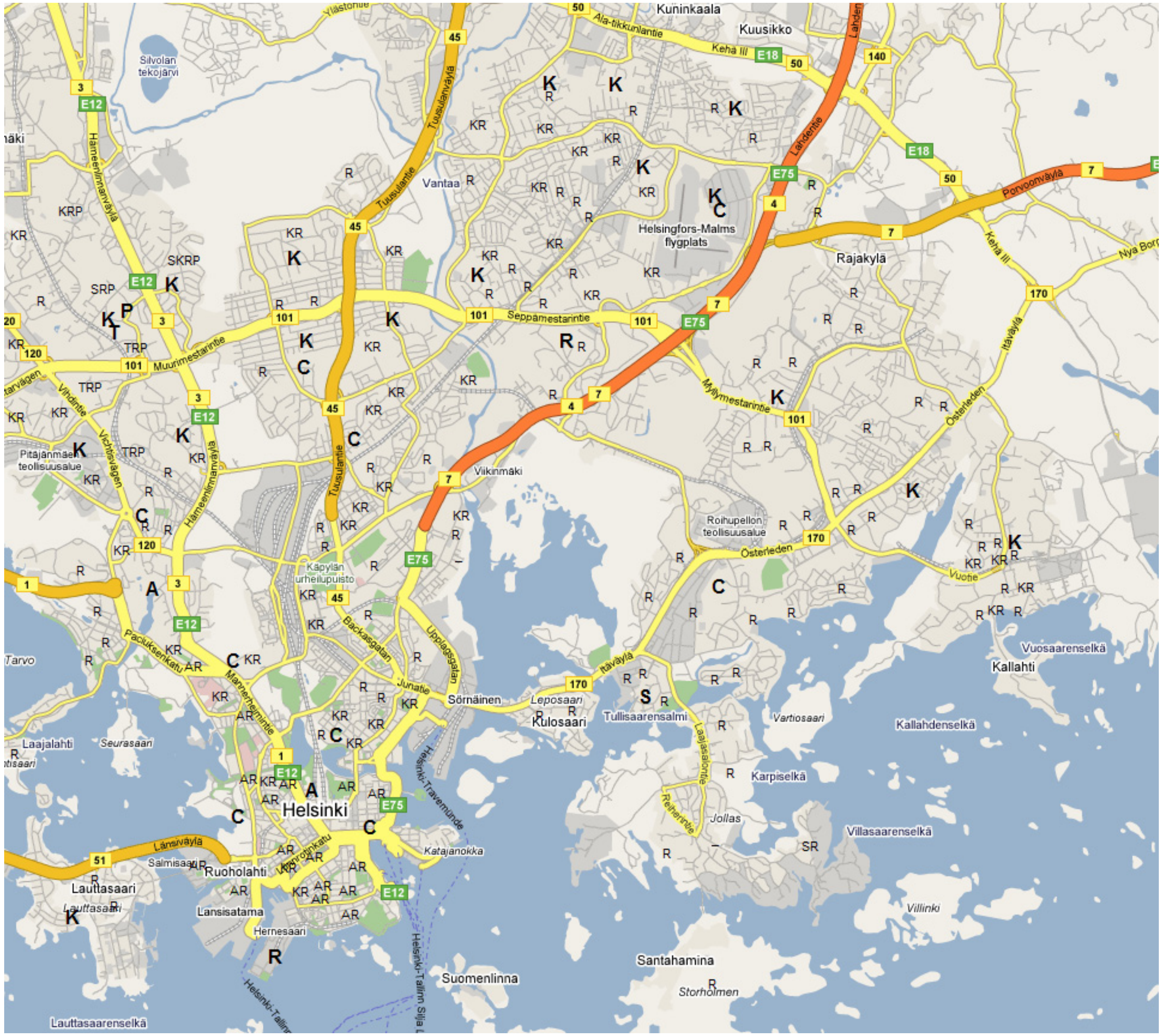

Figure 3:


Pitäjänmäen
teollisuusalue
TRP
Hämeenlinnanväylä
Tuusulantie
Käpylän
urheilupuisto
Backasgatan
Junatie
Sörnäinen
Paciuksenkatu
Mannerheimintie
Laajalahti
Seurasaari
Helsinki
Länsiväylä
Salmisaari
Ruoholahti
Lauttasaari
Länsisatama
Hernesaari
Katajanokka
Suomenlinna
Helsinki-Travemünde
E12
E75
120
51
45
7

Figure 4:

15 Discussion

A test for territorial allocation can easily be fooled by submitting phony bids.

However, both the tests discussed here and many other tests as well should be able to detect phony bidding.

Unfortunately, by calculating phony bids in a sophisticated way, a cartel member can fool all the existing tests.

However, this may be costly. Moreover, these tests can be used to detect past misbehavior.