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Trading in Networks: a Classroom Experiment

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Abstract

This paper describes a classroom experiment that demonstrates coordination and competition between traders in a network. Students test theoretical predictions concerning the emergence of equilibrium and the division of surplus between buyers and sellers. The experiment is appropriate for use in teaching intermediate microeconomics, industrial organization, transportation economics and game theory.

JEL codes: A22; B21; C92

Introduction

Networks permeate economic life – consider for example transportation networks, communication networks and financial networks. Networks generate a host of interesting and important questions. How does a network's structure affect its aggregate efficiency and stability? Is there a single equilibrium for a network? How is a network's total surplus distributed between agents?

This paper describes a classroom experiment that introduces students to the economics of networks by demonstrating coordination and competition between traders in a network. Students test theoretical predictions concerning the emergence of equilibrium and the division of surplus between agents. The experiment is appropriate for use in teaching intermediate microeconomics, industrial organization, transportation economics and game theory.

A paper by Choi, Galeotti, and Goyal (2014) describes a research experiment that confirms theoretical predictions of equilibrium for a stochastic choice model under uncertainty for a complex network structure. Our classroom experiment is a special case of this experiment. Another reference is Kosfeld (2015) who provides a general background survey of recent experimental work in economics focusing on social and economic networks, issues of coordination and cooperation, buyer-seller networks, and network formation.

Design

Students act as part of a team. Teams in the network are arranged in a circle. Each team is a "node" of the circle. There must be an even number of teams.

Each round of the experiment two randomly chosen teams ("traders") are tasked with moving a virtual good from one end of the circle to the other. The two trader teams are chosen to be at opposite ends of the circle. If they can successfully move the good they will profit by sharing equally one dollar of surplus minus the cost of transport.

There is a transport cost because the good must follow a trade route through the other nodes by following one of the two available paths. Teams along a trade path ("transporters") can require payment to allow transport through their node. The cost of transport is determined by having potential intermediaries submit bids. [1]

Each potential intermediary submits a bid, and that bid is added to the total bid for all teams along the same potential trade path. There are two possible paths and the lower of the two transport costs determines the path chosen. Every team from that path is paid its own bid amount. Whatever surplus is left over gets divided equally between the two transporter teams. If both potential trade paths bid a total of one dollar (or more) no trade occurs and the profit that round is zero for everybody. If there is a tie for total bid amount the winning path is chosen by a coin flip.

Implementation

The experiment is run in a classroom with a projector connected to a laptop running an Excel spreadsheet.[2]

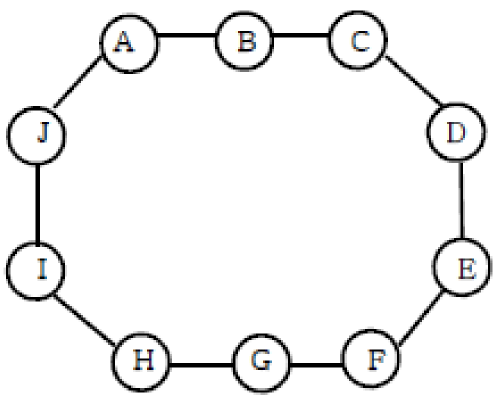
[1] Since teams are offering a service at a price, proper auction terminology would call this an "ask", however for maximum student comprehension we are using the everyday analogy of a firm "bidding" on a job. An alternative analogy is that intermediary teams are charging a transportation toll at each node.

[2] The spreadsheet template is available from the authors.

Students are divided into teams of between two and four. Each team is a node in the network. There is an even number of nodes, each node labeled alphabetically. The experiment consists of timed rounds, with teams competing to accumulate money over the total number of rounds. The team with the maximum virtual money by the end of the experiment is rewarded with cash by the instructor.

The network is a ring structure. Diagram 1 shows the example of a ring with ten nodes.

Diagram 1



Ring 10

Each round a randomly chosen pair of nodes/teams is chosen to comprise the trader teams. For example, in diagram 1 nodes the pair A and F could be chosen to be traders. The other possible pairs are BG, CH, DI and EJ.

If team A and team F can transport the good from A to F they will divide the net profit equally.

If the sum of bids from the path BCDE is lower than the sum of bids from JIHG (and lower than one dollar) then the traders' joint profit will be one dollar minus the sum of the individual bids from teams B,C,D and E. Each team B, C D and E will be awarded whatever they individually bid.

This setup introduces students in the simplest possible way to the fundamental problem any agent in a network faces – trying to achieve a balance between competing needs: bidding high as an individual team to maximize individual profit vs. cooperating with other path members to keep their joint bid lower than the competing path.[3]

To summarize how teams play the game:

- Each round two teams at opposite ends of the ring are chosen to be the “trader” teams. Let’s suppose teams A and F are chosen this round with A wanting to transport a good to F. If this could be done at zero cost team A and team B would each make 50 cents profit.
- However for A and F to transport the good they have to pay a price to either the “transporter” teams in group/path BCDE or in group/path GHIJ.
- Each of the teams B,C,D,E,G,H,I,J submits an individual bid to help transport the good. They cannot discuss or coordinate their bid with other teams. Whichever group (or path) of teams, (B, C, D, E) or (G, H, I, J) submits the lowest collective bid gets the contract. The collective winning bid cannot exceed $1 or else there will be no transporting/profit for any team in the game. Each team in the winning path group receives what it bid, and A and F divide whatever is left over.

An Excel spreadsheet template has been created to facilitate running and using the experiments. By entering the bids each round Excel immediately calculates the winning bids, updates charts showing the pattern of bids, and tracks total profits per team. At the conclusion of

[3] An application to the real world is the tension between a bank taking on excessive liquidity risk figuring that their financial partners can bail them out with cash if they get in trouble vs. the general risk of a financial network collapsing and setting off a chain of banking failures if too many individual banks are imprudent.

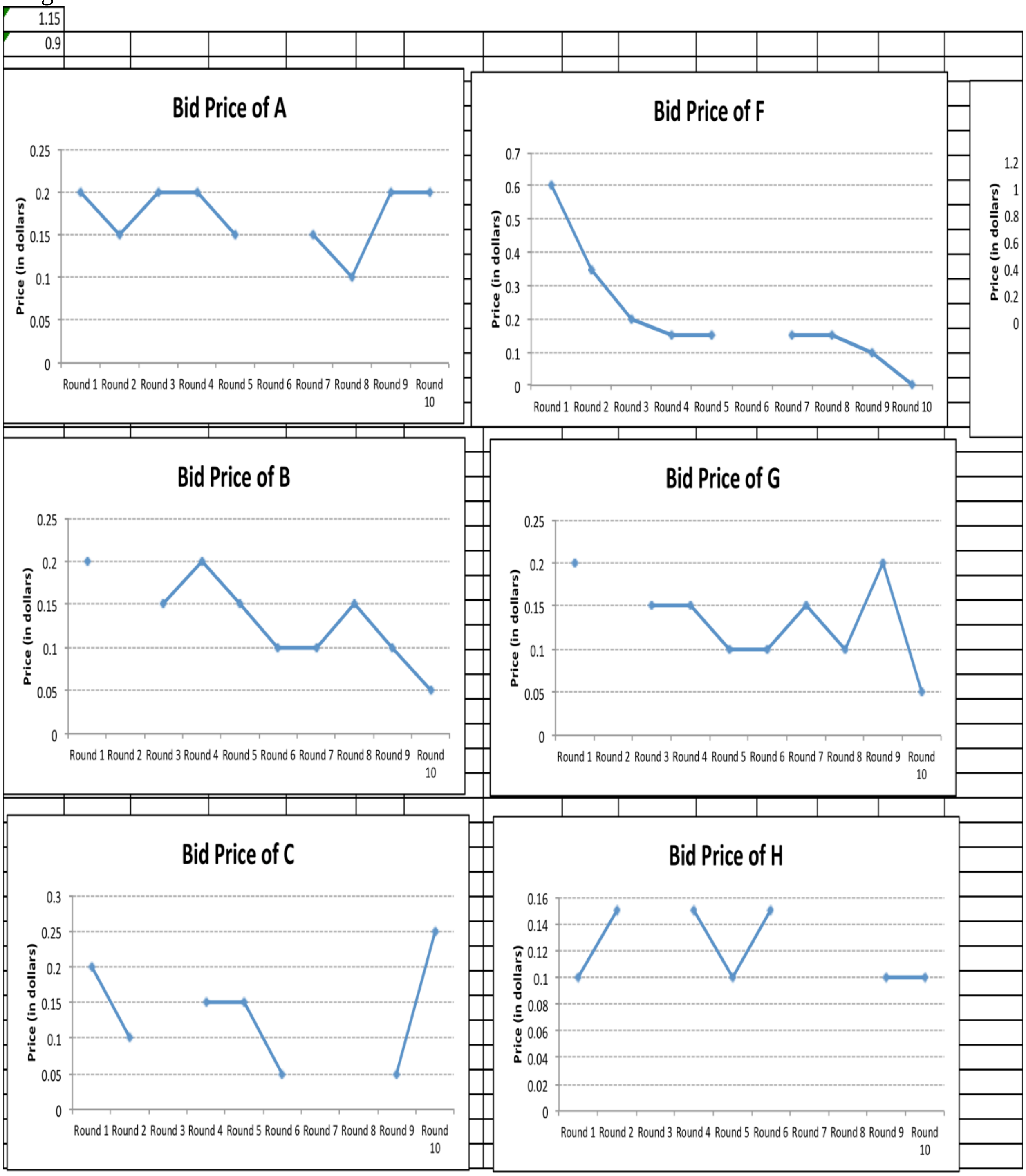
the last round the results can be projected and the students debriefed immediately on the summary results and also the behavior of individual teams.

Diagrams 2 and 3 show examples of screenshots from parts of the spreadsheet main page from an experiment. For a ten round experiment with ten teams the spreadsheet is 100 columns by 130 rows.

Diagram 2

Round 2		AA3								
Group	**Random #**	**Role**	**Set**	**Bid Price**	**Set Total**	**Trade Happened?**	**Trade Happened? Adjustment**	**Trading Profit Total**	**Trading Cost Total**	**Earnings**
A	0.50737	Transportor	2	0.15	0.6	YES	YES	0	0.6	0.15
B	0.100742	Trader	0		0	YES	YES	1	0	0.2
C	0.96234	Transportor	1	0.1	0.85	NO	NO	0	0	0
D	0.719657	Transportor	1	0.25	0.85	NO	NO	0	0	0
E	0.120273	Transportor	1	0.15	0.85	NO	NO	0	0	0
F	0.50737	Transportor	1	0.35	0.85	NO	NO	0	0	0
G	0.100742	Trader	0		0	YES	YES	1	0	0.2
H	0.96234	Transportor	2	0.15	0.6	YES	YES	0	0.6	0.15
I	0.719657	Transportor	2	0.15	0.6	YES	YES	0	0.6	0.15
J	0.120273	Transportor	2	0.15	0.6	YES	YES	0	0.6	0.15
	Manual			**Manual**						0.2
										0.4
						Count "Yes"				
						6				
		Random # Generator if bid prices of two sets are tie								
		Role	**Set**	**Random #**		**Trade Happened? New**				
		Transportor	1			#NUM!				
		Transportor	2			#NUM!				
				Manual						
				Round 2 Result						
				A				0.6		
			J		B					
		I				C				
		H				D				
			G		E					
				F						
		Path Price								
Total		**Group**	**Round 1**	**Round 2**	**Round 3**	**Round 4**	**Round 5**	**Round 6**	**Round 7**	**Round 8**
1.55		**Transportors Win**	0.85	0.6	0.65	0.6	0.45	0.4	0.45	0.45
1.2		**Transportors Not Win**	1.1	0.85	0.65	0.7	0.6	0.55	0.6	0.5
0.95		**Traders**	0.15	0.4	0.35	0.4	0.55	0.6	0.55	0.55
1.3										

Diagram 3


1.15
0.9
Bid Price of A
Bid Price of F
Bid Price of B
Bid Price of G
Bid Price of C
Bid Price of H
Price (in dollars)
Round 1 Round 2 Round 3 Round 4 Round 5 Round 6 Round 7 Round 8 Round 9 Round 10

Concepts

The experiment is aimed at introducing economics students to the study and analysis of economic networks. Networks are not a purely microeconomic phenomenon. Consider, for example, international trade networks and banking networks.

In discussing results of the classroom experiment the details of network structure have critical implications for equilibrium (Choi el al. discuss 'critical' nodes though we don't have them in our simple ring structure.)

Topics that can be discussed include:

- Competition vs. cooperation.
- Betrand equilibrium.
- Emergence of equilibrium without explicit communication.
- Efficient (where trade occurs) and inefficient equilibria.
- Strategic interaction, pricing and division of surplus.
- Experiments can make predictions about equilibria.
- Introduction to hypothesis testing with experiments.
- Banking networks.
- International trading networks.

This experiment does not deal with the topic of network formation.

Results

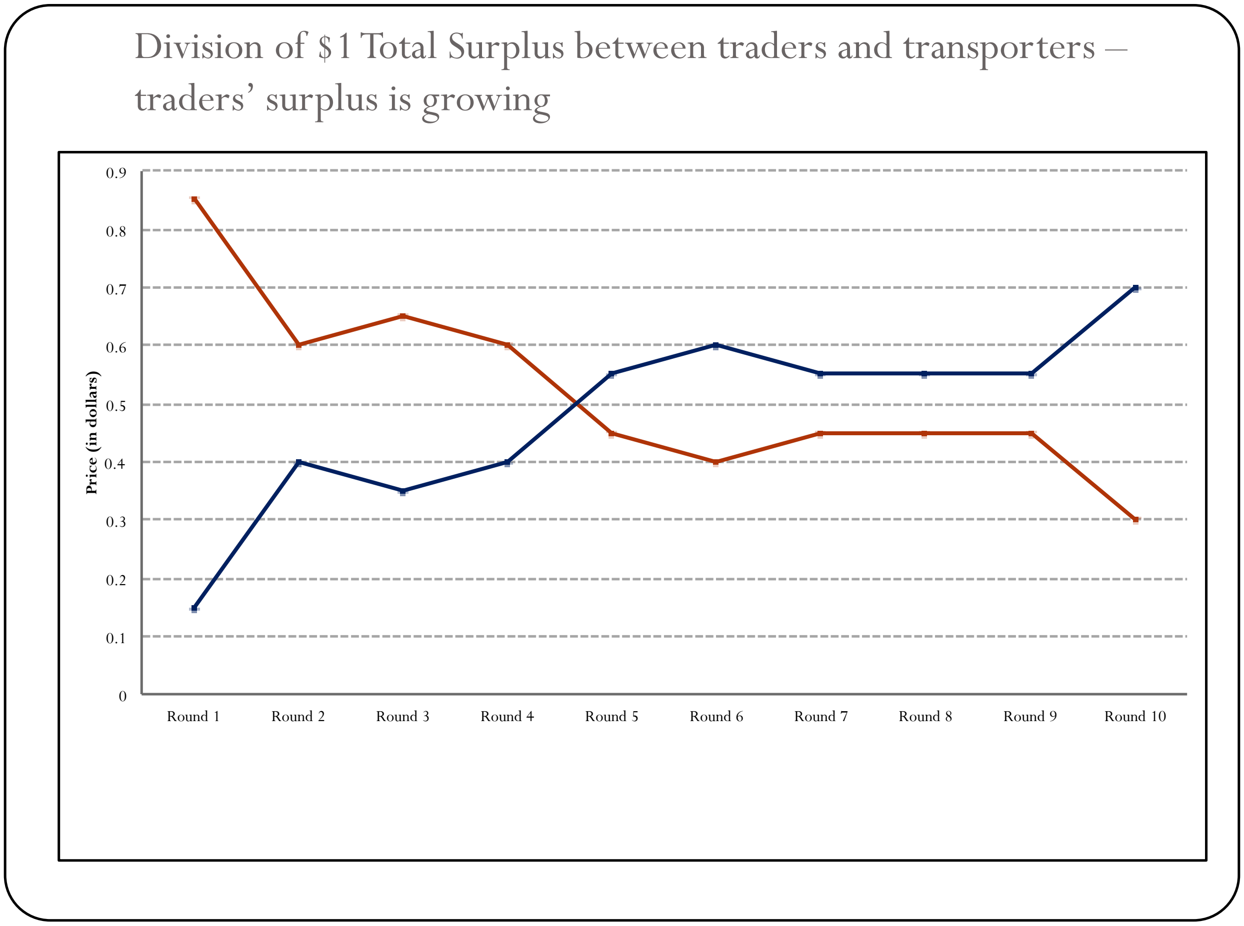
Two runs have been made with the new spreadsheet tool. The second experiment was run in a principles of economics class with 60 students, in a 10 node ring, with 10 rounds of two minutes each. We deviated from the Choi et al. design by allowing communication within each path starting at round seven.

The summary results are:

- An equilibrium value for the division of the surplus emerged at round 7 at around 40 cents (combined) for transporters.
- This result is broadly consistent with Choi et al., where an equilibrium emerges, except that the Choi experiment equilibrium profit for transporters combined is around 20 cents, but with no communication in a 60 round game.
- Why doesn't the transporter surplus get bid down to zero? Students said they realized they should implicitly cooperate with the other competing transporter path group at 40 cents total for a path (each individual bids 10 cents) even though that only gave their group of four teams a 50% chance of making 40 cents.
- Allowing intra-path communication seems to have stabilized the downward drift in average rewards to transporters.

Diagram 4 shows the path of the division of the total available $1 surplus. When communication within a path/group was allowed the surplus allocated to transporters stabilized at 40 cents per group (ten cents per team.) As expected in the last round transporter teams defected from their promise to bid only 10 cents each and transporter surplus fell.

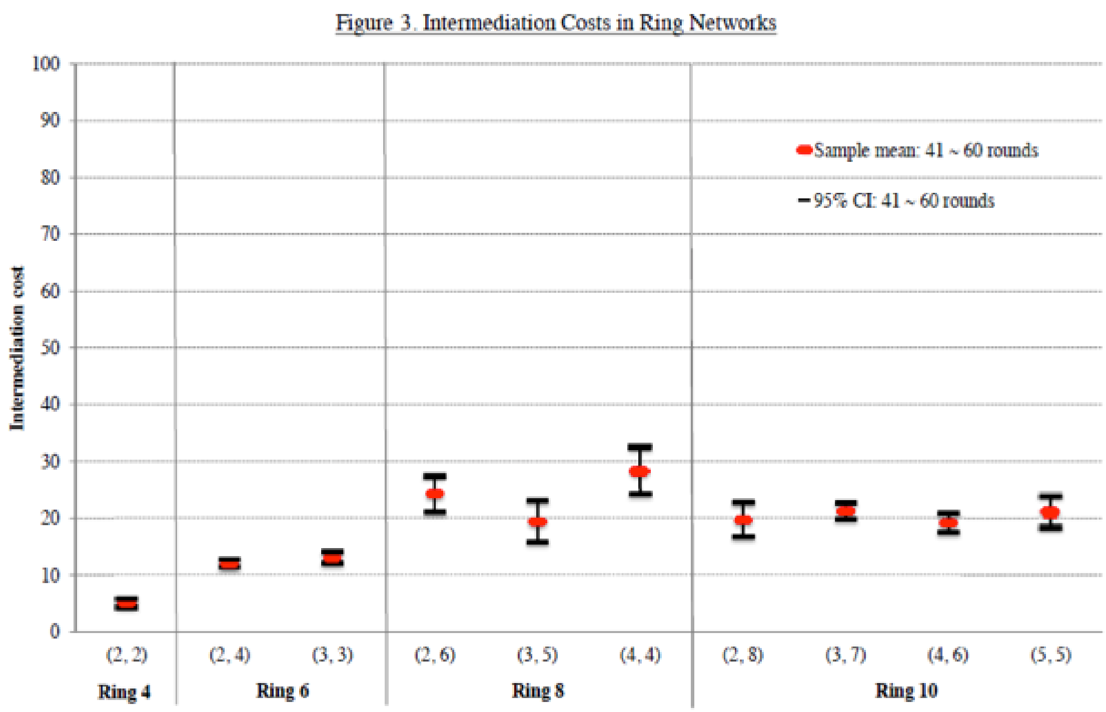
Diagram 4



Traders are the blue line, transporters the red line.

For comparison and classroom discussion Diagram 5 presents the result of the Choi et al. paper. The last point on the right for a 5,5 (10 node balanced) ring is the relevant result with a 60 round research experiment. This comparison allowed the instructors to make the point to the students (many of whom had never participated in an economics experiment) that the research experiment predicted the general pattern of their own behavior surprisingly well. This opened the door to a broader discussion of experimental economics, what it is and how it complements the standard economics they are familiar with.

Diagram 5



Trading in networks: theory and experiments S. Choi, A. Galeotti, S. Goyal - Cambridge-INET Working Paper, 2010.

Conclusion

This paper describes a classroom experiment that demonstrates coordination and competition between traders in a network. Students test theoretical predictions concerning the emergence of equilibrium and the division of surplus between buyers and sellers. The experiment is a simple version of a ring network research experiment by Choi et al. (2014.) An Excel spreadsheet template allows instructors to automate most of the calculation, presentation and debriefing involved in running the experiment.

Results in a principles of economics class are surprisingly consistent with the research experiment results. The economics of networks have been studied for some time, but the use of experiments to study the properties of alternative networks structures is relatively recent. This classroom experiment introduces students to an area of economics that has acquired new significance and interest. In future we plan to run the experiment in more classes and a broader range of classes.

References

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M. Kosfeld. Economic Networks in the Laboratory: A Survey, Institute for Empirical Research in Economics, University of Zurich, 2015.