Using Trading Simulations to Teach Market Microstructure Concepts

Asli Ascioglu, Bryant College
Lynn Phillips Kugele, Christian Brothers University

This paper describes an equity trading simulation case designed to demonstrate fundamental microstructure concepts such as the price discovery process, the difference between quote-driven and order-driven markets, and the role of the specialist and market maker. In addition, the case provides a simplified framework for clarifying the importance of liquidity (or, conversely, the effects of illiquidity), and illustrating currently newsworthy topics such as "front-running." Survey results from students participating in the Trading Simulation Case average above 4 (on a 5-point Likert scale) with regard to their enjoyment of the exercise as well as in response to questions regarding their understanding of the trading process, the function and operation of the limit order book, market making activity and how front-running can occur.

INTRODUCTION

This paper introduces a simulation case (Financial Trading System's Interactive Markets (FTS) component) and discusses the use of FTS to explain important market microstructure concepts such as the differences between market orders and limit orders, the way the limit order book works, trading characteristics between a thinly traded security and a frequently traded security, and the process of making a market in a security. Since the case provides a full view of the limit order book students build during the simulation, we demonstrate currently controversial topics such as front-running by using the live limit order book.

The structure of financial markets – how buyers and sellers interact, the role and function of other market participants and the trading rules and regulations governing trading interaction – is a fundamental concern in market microstructure research which focuses on the impact of organization and regulation on market efficiency, price discovery, trading costs and liquidity.

While hardly a household phrase itself, interest in the concepts underlying market microstructure – both from academics and from the general public – has been fueled by recent news coverage concerning the role market makers and specialists play in price setting and trade execution, debates over the current structure and regulatory oversight of U.S. financial markets and allegations of collusion, front-running and penny-jumping.

Trading simulations offer the opportunity to demonstrate the fundamental concepts of market microstructure in an interactive, instructor-controlled, participatory setting designed to enhance the students understanding of somewhat difficult, fuzzy, or illusive concepts. Taking the role of a primary market participant provides the setting for students to learn the concepts of market microstructure experientially. Trading games which do involve interaction among students, allowing the students' actions to drive the

price discovery process, typically utilize minimal technology. For example Angel's (1997) Broker Game[1], Shrader and Helgeson's (1993) Experimental Financial Assets Markets[2], Cooper and Grinder's (1997) Option Pricing Theory Classroom game[3] and Maxam and Maxam's (2003) One Hour Classroom Trading Simulation[4].

With the availability of more sophisticated, technology-driven tools, however, comes the challenge of incorporating them effectively into the classroom - whether it be one or two modules on market structure and the trading process or an entire class devoted to market microstructure.

This paper and the underlying simulation case differ from extant work in three significant ways. First, the simulation case is based on Financial Trading System's Interactive Markets component which is a readily available product requiring only a computer lab, Internet access and Excel. FTS' commercially available and widely-used simulation product provides a common foundation as compared with less well-known and proven options. Second, the simulation case provides a controlled environment where students have the opportunity to experience and more fully understand the basic mechanics of trading typically provided by most in-class exercises and games, such as, market orders and limit orders, the limit order book and the process of making a market in a security. In addition, our case offers a setting designed to illustrate more illusive concepts such as price discovery and "learning" as information is impounded via the trading process itself. Further, the case provides the opportunity to demonstrate currently controversial topics such as front-running. Third, as will be described below, the class makes the market and develops all prices, a process which incorporates the basic dividend discount model along with probability into the equity valuation process, thus re-enforcing basic concepts in finance.

The remainder of the paper is organized as follows: Section 2 provides a brief overview of the Financial Trading System component utilized in this simulation case. Section 3 describes the case in terms of prior knowledge required of students, instructions to students, instructions for running the case as well as suggestions for follow-up classroom discussion and debriefing. Section 4 concludes with the results of student surveys and conclusions regarding the use of simulations to enhance the teaching of microstructure concepts.

FINANCIAL TRADING SYSTEM - INTERACTIVE MARKETS COMPONENT

FTS (Financial Trading Systems) offers an entirely web-based software package which "creates a trading room that runs in real-time and can be used by students sitting either across the room from each other or across the world."[5] FTS Interactive Markets allows the simulation of both order-driven and quote-driven markets with the students acting as the trading crowd whose objective is to discover prices based on information in a trading problem. FTS allows different types of auctions to be conducted: call markets, opening price auctions, Treasury auctions, closing market auctions (without price discovery), and continuous double auctions. Real-world features such as margins and short selling may be incorporated at the instructor's discretion.

FTS' software-based solution offers several distinct operational and instructional advantages over other offerings. The software is commercially available and widely used in both U.S. and foreign universities, both in classroom/labs and in dedicated trading

room settings. The modules are scalable, offering several additional components for more sophisticated installations. All components may be accessed entirely via the web, requiring only Internet Explorer 5.5 or above, Microsoft's Excel and Internet access, or, alternately, in larger installations, they may be run via a local intranet installation.

From an instructional standpoint, FTS Interactive Markets requires no third-party data feed though outside data may be integrated if desired. The system itself generates no quotes or orders; the students form the trading crowd and generate their own prices, allowing them to fully participate and thus understand where prices originate and what drives the price discovery process. Additionally, the instructor has substantial flexibility in controlling the trading parameters as well as the ability to halt trading for discussion or to illustrate points brought out through the trading process.

For a more complete description of FTS' software offerings, see their website at www.ftsweb.com.

FTS EQUITY TRADING SIMULATION CASE

In our FTS simulation case, students are provided prior lessons about the operation of the limit order book, illustrated by Electronic Communication Networks (ECNs), floor-based trading systems such as NYSE, AMEX and dealer markets such as Nasdaq. Before the trading simulation begins, a one-hour class period is reserved to fully explain the simulation game. The moderator of the simulation game (instructor) can alter various default settings such as interest rate, the number of trading periods, or information types. She also starts the game and can pause the game at any time for discussion. We run the game using the default settings for simplicity.

In the default setting, students/teams trade two securities, ABC and CRA. There are two types of traders differentiated by their level of initial cash and the number of securities in their beginning portfolio. Each trading session includes two periods with each period lasting 390 seconds.[6] At the end of the each period, there is a dividend distribution determined by the economic condition in that period. As a default, there are three possible economic conditions for ABC and four possible economic conditions for CRA. For illustration purposes, the economic conditions and the associated dividends for ABC are provided in Table 2.

Table 2. FTS Simulation Economic Conditions and the Dividends

Firm ABC	Economic Conditions	Dividend Amount
Event X	**Poor economic conditions with labor strike**	**$ 0**
Event Y	**Poor economic conditions without labor strike**	**$ 12**
Event Z	**Fair economic conditions with good labor relations**	**$ 24**

At the beginning of the first trading period, each student receives incomplete, private information about the economic condition for both period 1 and period 2. This information is delivered by the FTS program to each student's screen at the beginning of period 1 and at the beginning of period 2. For example, at the beginning of period 1, one

student/team might receive information such as "Period 1: NOT X; Period 2: NOT Y", while another student might be told "Period 1: NOT Y; Period 2: NOT Z." Students never receive incorrect information (for example: if the economic condition in period 1 is Z and period 2 is X, none of the students receive "Period 1: NOT Z" or "Period 2: NOT X"). All students have private partial information about the economic conditions for both periods at the beginning of period 1. At the beginning of period 2, they have information on the realized economic condition in period 1 along with private partial information about period 2.

The Bidding Process and The Transactions of a Complete Game

Students post their bid and ask prices at the beginning of period 1 based on the expected price they calculate by using the information they receive about the economic condition for both period 1 and period 2. After receiving the information for both periods at period 1, each student calculates the expected value for each security based on the dividend discount model, incorporating the probabilities of each economic condition and their private information.[7] When the moderator begins the game, there are no prices/no orders sent by the software; students must make the market. They post their initial bid and ask quotes based on their calculated expected values and, since each student/team receives incomplete information, their expected values and their posted quotes differ, often substantially. For a more complete description and illustration of the probabilistic equity valuation method, see Appendix A.

A student who has a lower (higher) expected value than the expected values of other students, will buy (sell) from (to) the market. As students trade based on their expected price, they also observe where the market moves. If price decreases (increases) as trading continues, students who had high (low) expected prices lower (increase) their expectations about the value of a security. As trading continues, students continue submitting limit orders and/or market orders, with the limit orders making the market. A limit order to buy (sell) makes the bid (offer) side of the limit order book. There is no restriction on the number of orders they can submit. Each student's number of transactions depends on her (his) use of market orders versus limit orders, and how often she was behind the best bid (offer) side of the market. Bidding continues until the period ends.

The transactions of a complete game include individual transactions of students at period 1 and period 2. On their screen, they can see their average transaction price. Their profit is also calculated based on their transactions in period 1 and period 2. Students can have different bidding motives. Some students try to be behind the best bid and best offer quotes just to profit from the spread, and do not use their expected value of a security as much as others. Those students' trading motive decreases the spread to minimum level very quickly. We also observe that several students do not participate in the trading during the first several seconds of the game, expecting price discovery to take place before they trade.

Understanding the Difference Between a Market Order and Limit Order, and Building a Limit Order Trading Market such as an ECN

There are two ways students can trade. First, they can submit limit orders at the bid side for a price less than their expected value, and at the ask side for a price more than their expected value. This implies a profitable trading strategy where a student is willing to buy for less than their expected value and sell for more. As students submit limit orders, a limit order book is built which is visible on all screens.

Second, students can use a market order to sell (buy) when the best bid price (best ask prices) in the market is more (less) than their expected value of a security. By using limit orders and market orders, students create their own trading market based on the limit order book and gain a clear understanding of how limit order book trading functions.

The Price Discovery Process, Thinly Traded versus Frequently Traded Stocks, and Market Making Activity as Dealers

Students start trading at period 1 with some private information with which they estimate the value of each stock based on an expected dividend each period. Once the market opens, price also becomes a source of information, which influences students' predictions of the stock value. They begin learning about the value of each security from each others' quotes. By the beginning of period 2, they have information about the economic condition realized at period 1, probabilistic information for period 2, and information gleaned from the trading process during period 1.

By the end of period 2, the market price aggregates all information available to each student, with prices for both securities perfectly reflecting the true value of the security. Therefore, students understand how the price discovery process occurs via trading. This is the expected result given the design of the trading case and previous results in manual trading cases. Plott (1982) finds that "The overwhelming result is that these markets converge to the competitive equilibrium even with very few traders."[8] Maxam and Maxam (2003) report similar results: "Only rarely has the market not reached full efficiency (bracketed the true value known only to the instructor) and usually this is only because of time limitations."[9]

In addition, some students realize that they can profit simply by offering liquidity to the market. They post bid and ask prices, and earn the spread. This leads to a narrowing of the inside spread in the market and offers an opportunity for the moderator to explain the dealer market and the effect of competition on spreads.

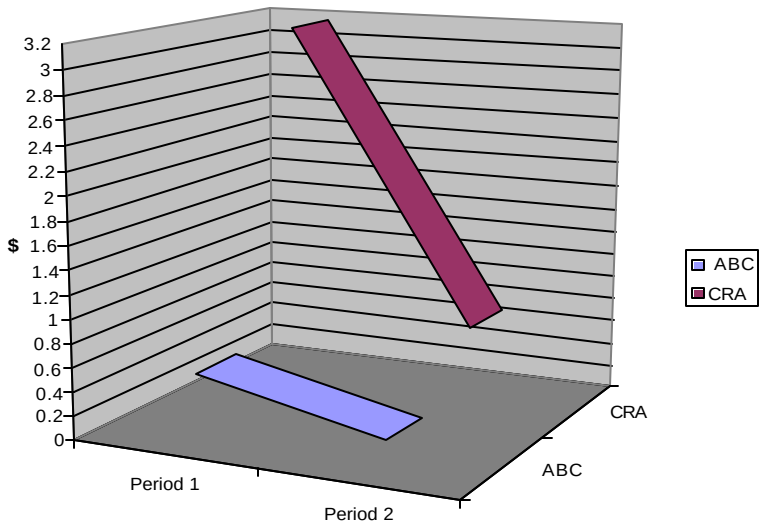
Figure 1 shows the average inside spread (i.e., the difference between the best ask price and the best bid price) at period 1 and at period 2 after the two simulation games. To obtain the inside spread numbers, we take four screen shots of the limit order book at each period for each stock. We repeat the screen shots for the second simulation game, yielding eight inside spread values for each period. Figure 1 shows the average of inside dollar spreads. It clearly indicates a narrowing of the inside spread due both to the price discovery process and to competition to earn the spread.

There are two main observations from Figure 1. First, the inside spread significantly narrows as trading continues for both securities. Again, this is consistent with other researchers, for example, Maxam and Maxam (2003) report that "… inevitably, students find that the effective bid/ask spread in the market narrows *purely* as a function of trading ..."[10]

Second, there is a significant difference in the patterns of price discovery and market making activity between ABC and CRA, driven by the difficulty students have in trading two stocks at the same time. During the simulation game, students first concentrate more on the first stock (ABC) because ABC appears above CRA and they receive private information first for ABC and then for CRA. CRA naturally becomes a "thinly" traded stock compared to the "frequently" traded ABC. As a result, it requires more time for CRA to reflect full information. In post-game survey results, more than half of the students agreed that it was difficult to concentrate on trading two securities (Table 3, question 7).

These discussions and the graph are also provided to students after the simulation game. Students were very interested in learning and observing their trading patterns as provided in Figure 1. This debriefing and discussion is as vital to the effectiveness of the trading simulations as the games themselves, as this after-the-fact discussion provides the instructor the opportunity to insure that, as a whole, the class noted the important points during the trading and fully understands the underlying concepts.

Figure 1: Inside Dollar Spread



Specialist Role in the Order-driven Market and the Discussion of Specialist's "Front Running" Public Limit Orders

The FTS simulation allows the moderator to pause the simulation at any time, providing a critical opportunity to emphasize important topics during the trading. One of those topics is the specialist role in an order-driven market. Students learn that specialists are bound by affirmative obligations: they must buy(sell) when no one else in the market is willing to buy(sell) and provide price continuity. During the simulation game, one side of the limit order book typically becomes empty primarily due to a student who trades heavily on one side, clearing out all liquidity on that side of the market. When this happens, students wait until someone provides liquidity on the side in

which there are no limit orders available. The moderator can pause the game and discuss with the class what has happened in the market and explain the role of the specialist in this situation.

Another topic that can be simulated by pausing the game is the alleged "front running" practices of specialists. The issue of specialists' front-running has been a central topic in the *Wall Street Journal* since the minimum tick size in U.S. markets was reduced to a penny. With a large limit order waiting on the book, the moderator can pause the game, ask students not to trade for a second when the game restarts so that she can submit a better priced limit order on the same side of the large order. Once the students resume trading, the moderator's order is executed and after prices improve on her side, she then trades with the large limit order. This scenario provides an opportunity for the moderator to discuss the front-running issue in the context of the specialist's access to the limit order book and the informational and operational advantages that access provides.

RESULTS AND CONCLUSIONS

In this paper we describe an equity trading simulation case designed to demonstrate fundamental microstructure concepts such as the price discovery process, the impact of information and learning on price convergence, the difference between quote-driven and order-driven markets, and the role of the specialist and market maker.

Our approach to the use of in-class simulations departs from previous works in three ways. First, we base our simulation case on Financial Trading Systems' Interactive Markets [11] component, thus employing a widely used and proven, commercially-available platform. Second, while providing students with the opportunity to experience and understand the basic mechanics of trading, our case also offers a setting designed to illustrate more illusive concepts such as price discovery and learning, as well as the opportunity to demonstrate currently controversial topics such as front-running. Finally, basic probabilistic valuation concepts are re-enforced through the use of the dividend discount model for equity valuation prior to each trading session.

Survey results from students participating in the Trading Simulation Case are recapped in Table 3. The survey used a 5-point Likert Scale with 5 =Strongly Agree, 1 = Strongly Disagree. Student responses average above 4.00 in answer to questions concerning their understanding of the trading process, the function and operation of the limit order book, market making activity and how front-running can occur. The average response to the statement "I enjoyed the simulation game" is 4.35. Student response was also very positive regarding the understanding of fundamental market microstructure topics via the simulation game. Students' average responses to Question 1 ("understanding of how trading occurs") is 4.55, and to Question 2 ("understanding of the operation of the limit order book") is 4.75. Moreover, the simulation was very successful in providing the students with a better understanding about recent market microstructure topics, with 12 students (of 20) strongly agreeing that they now understand how specialists can front-run outstanding limit orders (average is 4.45).

Overall these results are consistent with earlier findings regarding the use of simulations in the classroom, most closely with Alonzi, Lange, and Simkins (2000) whose results (also on a 5-point Likert scale) showed an average response greater than

4.00 to similar questions regarding the value of the simulation, how it assisted in understanding the trading and price discovery process and their enjoyment.

The use of trading simulations to teach microstructure concepts, whether in equity markets (our case) or futures markets (Alonzi et.al.), clearly meets the pedagogical objectives and expectations of increasing student enjoyment, motivation and participation while successfully enhancing traditional lecture and textbook coverage of difficult or complex concepts in finance.

---

[1] Angel, J.J."The Broker Game: An Enjoyable Way to Introduce Students to Financial Markets (and learn their names)" *Financial Practice & Education* (Spring/Summer 1994) pp.61-64

[2] Shrader, M.J. and J.G. Helgeson. "Using Experimental Financial Asset Markets in the Investments Curriculum." *Financial Practice & Education* (Fall 1993) pp. 97-103.

[3] Cooper, D.W. and B. Grinder. "Introducing Option Pricing Theory with a Classroom Game." *Financial Practice & Education* (Spring/Summer 1997) pp. 95-102

[4] Maxam, C.L. and M.B. Maxam. "Efficient Markets and Information Processing: A One-Hour Classroom Trading Simulation." Montana State University working paper (September 2003).

[5] FTS brochure

[6] We run two trading sessions that take a 90-minute class session including post-game discussion.

[7] We find that it is very important to provide students with an Excel worksheet that automatically calculates the expected values of both securities. We have found that it is difficult for students to concentrate on the simulation game if they are required to calculate the expected values in real-time, simultaneously by themselves.

[8] Plott, C.R. "Industrial Organization Theory and Experimental Economics." *Journal of Economic Literature* (December 1982) pp. 1485-1527.

[9] Maxam, C.L. and M.B. Maxam. "Efficient Markets and Information Processing: A One-Hour Classroom Trading Simulation." Montana State University working paper (September 2003).

[10] Ibid.

REFERENCES

Alonzi, P., D.R. Lange and B.J. Simkins, 2000. An Innovative Approach in Teaching Futures: A Participatory Futures Trading Simulation, *Financial Practice & Education,* pp. 228-238.

Angel, J.J., 1994. The Broker Game: An Enjoyable Way to Introduce Students to Financial Markets (and learn their names), *Financial Practice & Education*, pp.61-64.

Cooper, D.W. and B. Grinder, 1997. Introducing Option Pricing Theory with a Classroom Game. *Financial Practice & Education*, pp. 95-102.

Maxam, C.L. and M.B. Maxam, 2003. Efficient Markets and Information Processing: A One-Hour Classroom Trading Simulation. Montana State University working paper.

Plott, C.R., 1982. Industrial Organization Theory and Experimental Economics. *Journal of Economic Literature*, pp. 1485-1527

Shrader, M.J. and J.G. Helgeson, 1993. Using Experimental Financial Asset Markets in the Investments Curriculum, *Financial Practice & Education,* pp.97-103.

Table 3. Survey Results from Students participating in the FTS Trading Simulation

	FTS Trading Simulation Survey					
Questions:	5 **Strongly Agree**	4 -	3 **Agree**	2 -	1 **Strongly Disagree**	**Average**
1. I understand more about how trading occurs	13	5	2			**4.55**
2. I learned a lot about how the limit order book works	15	5				**4.75**
3. I know more about market making activity	9	10	1			**4.40**
4. I understand more about how price discovery occurs via trading	5	8	5	2		**3.80**
5. I understand more about how specialists can front run outstanding limit orders	12	5	3			**4.45**
6. It is difficult to understand the simulation game		3	4	9	4	**2.30**
7. It is difficult to concentrate on trading two securities rather than only one security	1	5	7	5	2	**2.90**
8. I enjoyed the simulation game	10	8	1	1		**4.35**
9. I would recommend the simulation game to be included in other finance courses	10	5	4		1	**4.15**
10. The instructions for the simulation game were clear and complete.	3	7	4	6		**3.35**

Appendix A: Description and Illustration of Probabilistic Equity Valuation

The possible economic conditions for ABC are given in Table 2 and repeated below:

Table 2. FTS Simulation Economic Conditions and the Dividends		
Firm ABC	**Economic Conditions**	**Dividend Amount**
Event X	**Poor economic conditions with labor strike**	**$ 0**
Event Y	**Poor economic conditions without labor strike**	**$ 12**
Event Z	**Fair economic conditions with good labor relations**	**$ 24**

The following outlines the possible dividend payouts under each set of Period 1 and Period 2 realizations:

Table A1: Dividend Realizations in $.			
$ Payout		**Period 2**	
Period 1	**X**	**Y**	**Z**
X	**0,0**	**0,12**	**0,24**
Y	**12,0**	**12,12**	**12,24**
Z	**24,0**	**24,12**	**24,24**

If the True Value for Period 1 is X and for Period 2 is Y, then, given a 2 period model with a zero interest rate, the true value of the security is $12.

With no information other than that given in Table A1 (without the shading), the expected value of the asset is given by the formula:

$$E(V) = \frac{\sum_{j=1}^{9} \left(\frac{DIV_{j,1}}{(1+i)^1} + \frac{DIV_{j,2}}{(1+i)^2} \right)}{9}$$

In our case, with a zero interest rate (discount rate) for simplicity:

The expected dividend in Period 1 = $E(D_1) = (0 + 12 + 24)/3 = \$12$
The expected dividend in Period 2 = $E(D_2) = (0 + 12 + 24)/3 = \$12$
The expected value of the asset = $E(V) = E(D_1) + E(D_2) = 12 + 12 = \$24$

For our example, assume we have 3 Teams, each of which receive private information prior to the first trading period concerning the value of the asset. The signals received by each team and their resulting valuation of the asset are shown in the table below:

Table A2: Signals at Period 1 for Periods 1 & 2 and resulting valuation at Period 1.

	Period 1 Signal	Period 2 Signal	$E(V_1)$
Team 1	**Not Y**	**Not X**	**$30**
Team 2	**Not Z**	**Not X**	**$48**
Team 3	**Not Z**	**Not Z**	**$24**

To illustrate how Team 1 arrives at their valuation, they have received a signal of "Not Y" for Period 1 and "Not X" for Period 2, eliminating one row and one column from the payoff matrix.

Table A3: Team 1's Potential Dividend Realizations in $ at Period 1

$ Payout		**Period 2**	
Period 1	**X**	**Y**	**Z**
X	**0.0**	**0,12**	**0,24**
Y	**12,0**	**12,12**	**12,24**
Z	**24,0**	**24,12**	**24,24**

This reduces Team 1's evaluation to:

$E(D_1) = (0 + 24)/2 = \$12$
$E(D_2) = (12 + 24)/2 = \$18$
$E(V_1) = E(D_1) + E(D_2) = \$30$

This illustrates how each team uses their private signals to arrive at an initial evaluation.

Obviously, as soon the teams post quotes bracketing their diverse individual valuations, each will immediately have a sense of what information the other teams have (and, if they had sufficient time and few enough teams, could work out what signals each team received, thus arriving at the true value). Given the initial valuations shown in Table A2, we can expect Team 1 to immediately begin buying from Team 3 and selling to Team 2, both of whom can be expected to quickly change their quotes.

Before trading begins in Period 2, all teams received the true realization (dividend payout) for Period 1 – "X" = $0. With this information, the teams again evaluate the asset, as shown for Team 1 below:

Table A4: Team 1's Potential Dividend Realizations in $ at Period 2			
$ Payout		**Period 2**	
Period 1	**X**	**Y**	**Z**
X	**0.0**	**0,12**	**0,24**
Y	**12,0**	**12,12**	**12,24**
Z	**24,0**	**24,12**	**24,24**

Now, Team 1's valuation is reduced further:

$D_1 = \$0$
$E(D_2) = (12 + 24)/2 = \$18$
$E(V_2) = \$18$

Team 2 – because they received the same Period 2 signal as Team 1, will reach the same valuation = $18. Team 3, however, will reach a different value:

Table A5: Team 3's Potential Dividend Realizations in $ at Period 2			
$ Payout		**Period 2**	
Period 1	**X**	**Y**	**Z**
X	**0.0**	**0,12**	**0,24**
Y	**12,0**	**12,12**	**12,24**
Z	**24,0**	**24,12**	**24,24**

Team 3's valuation:

$D_1 = \$0$
$E(D_2) = (0 + 12)/2 = \$6$
$E(V_2) = \$6$

At this point, all three teams are bracketing the true value with their valuations and, through trading, will quickly converge to the true value of $12.

To recap each team's signals and valuations:

Table A6: Signals at Period 1 for Periods 1 & 2 and Resulting Valuations at Periods 1 and 2.				
	Period 1 Signal	**Period 2 Signal**	**$E(V_1)$**	**$E(V_2)$**
Team 1	**Not Y**	**Not X**	**$30**	**$18**
Team 2	**Not Z**	**Not X**	**$48**	**$18**
Team 3	**Not Z**	**Not Z**	**$24**	**$6**