Experimental Markets Using the Electronic Market Place (EMP)

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ABSTRACT

A computer system for implementing electronic markets on networks of personal computers is described. The program allows a researcher or teacher to design market simulations to meet a variety of goals, and records a complete set of market activities for analysis. Illustrations of example markets are provided, and the classroom application of market simulations in teaching agricultural economics is discussed.

Key Words: computer software, experimental economics, simulations.

Experimental economics has an established position in the economics profession as a research tool for studying market institutions and for testing game theoretical hypotheses (Smith 1989). These methods have gained acceptance in large part for their ability to control factors that are confounded in natural market settings and thereby provide direct tests of hypotheses. Furthermore, experimental economics is being used increasingly in economics curricula for demonstrating economic principles and providing students with experience in making economic decisions (Wells).

There has been some use of experimental approaches in agricultural economics (a partial list of studies includes Buccola; Forster; Forster and Roberts; and Adam et al.). Growing interest by the agricultural economics profession was evidenced at a symposium held at the 1988 annual meetings of the American Agricultural Economics Association (Forster et al.) and by the half-day learning workshop held after the 1993 association meetings.

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For many economists, however, the cost/benefit ratio associated with experimental approaches may be unfavorable. In part, this reflects research methods in economics which emphasize analysis of secondary and, to a lesser extent, survey data. Econometrics texts, for example, typically offer little discussion of sampling and experimental design. Furthermore, textbooks, lab manuals, and other support materials for the use of experimental techniques are not widely available. Finally, the logistics of designing experiments with sufficient complexity to answer interesting questions or demonstrate complex concepts may be daunting. Economists will not adopt experimental techniques unless the cost/benefit ratio becomes more favorable.

One way to favorably influence this ratio is through the use of flexible computer programs. The Electronic Market Place (EMP) was developed toward this end. EMP is a system for implementing electronic double-auction markets for multiple goods on systems of networked IBM-compatible personal computers. It allows an experimenter considerable flexibility in designing markets and provides a complete record of experimental sessions.

Such a program can both increase the po-

tential benefits and reduce the costs of using market simulations. On the benefits side, electronic markets permit more complexity than do simulated markets employing open outcry or similar transaction methods. For example, it is difficult to set up face-to-face markets with several goods traded simultaneously, or markets where information access varies across participants. It is also difficult to simulate spatially separated markets or markets with different participants representing various links in a marketing chain (e.g., producers, processors, retailers, and consumers). These simulations are easily implemented through an electronic system such as EMP. Thus the variety of concepts and the depth with which they can be explored are increased through the use of electronic market simulations.

On the cost-reduction side, electronic markets eliminate many of the record keeping chores associated with experimental markets. During experimental sessions, participants are relieved of the task of computing net market positions and profits and can thereby concentrate on trading strategies and opportunities. Assistants are not needed to facilitate, monitor, or record transactions. Furthermore, complete records of bid, ask, and transaction prices and quantities can be generated, and payments to participants can be calculated automatically. These are typically the data needed for hypothesis testing and can be used with student subjects to facilitate discussion and analysis.

This article begins with a brief discussion of the experimental economics framework. The main features of the EMP program are then described. The program description includes the general characteristics of all EMP markets as well as those characteristics that are under the control of the experimenter, how participants interact with the program, and the nature of the output available to the experimenter and/or participants upon completion of an experimental session. Descriptions of some example markets are then provided, followed by a discussion of the use of the experimental framework in the classroom along with some results of an example market classroom session.

The Experimental Economics Framework

Experimental economics places human subjects in a controlled market situation. The market designer (either an experimenter or a teacher) determines the nature of the incentives provided to the participants and the institutional structure of the market, including how transactions are conducted, over what time period, and what information is available.[1]

Although the goods traded provide no inherent utility, value is induced through the incentive structure [Smith (1976) provides a rigorous treatment]. For example, any participant who prefers more to less and who is promised $1 for each unit of an asset held would be willing to pay up to $1 for each unit and would be willing to sell each unit for any amount over $1. Usually the goods are given nondescriptive names such as "units" or "widgets" to prevent prior beliefs from influencing subjective valuations (Davis and Holt); with preconceived ideas about the value of a good, participants may not base their decisions on market parameters provided by the experimenter.

The basic approach can be illustrated with a simple experiment, variations on which have been used extensively in classroom settings (Wells). Participants are provided with some money and five units of a homogeneous good. They also are promised a price at which the good can be redeemed from the experimenter. This price, which differs across participants, forms the basis for the market supply and demand schedules, with participants willing to sell at prices higher than their redemption price and to buy at prices below it. Participants trade the good by making bids and offers or by accepting other participants' bids and offers.

Extensive experience with such simple markets has demonstrated that the competitive outcome (prices and quantities sold) almost

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[1] The term experimenter is used here to denote the person conducting the simulation, whether it is done to test hypotheses or for pedagogical purposes. Similarly, persons participating in the simulations are referred to here as participants or subjects.

certainly will result if the experiment is replicated several times (Davis and Holt, p. 149). The experiments, therefore, can be an effective means of convincing students that economic concepts have something useful to say about how markets function.

In many cases, such an experiment is conducted in a classroom, with pieces of paper representing claims to assets. Trading can be carried out in various ways, including letting students mill around and conduct individual negotiations which then can be reported and recorded on the blackboard, or having students shout out offers to sell and bids to buy, or acceptances of offers and bids, thereby simulating the pit environment of a futures market. Indeed, such experiments provide students with an appreciation for the differences among alternative market institutions. It has been found, for example, that competitive prices are discovered more quickly and efficiently in the pit environment than with face-to-face negotiations (Davis and Holt, pp. 125–26).

In addition to the basic competitive double-auction market, numerous other market institutions have been examined experimentally, including single-sided auctions, oligopolistic and monopolistic markets, futures markets, and public goods markets. Furthermore, numerous studies have tested specific hypotheses from decision theory and game theory. Davis and Holt, and Kagel and Roth are useful references providing detailed discussion of the range and results of studies using the experimental economics paradigm.

The EMP System for Conducting Experimental Sessions

The logistics of running experiments in a classroom or research setting can be daunting. At a minimum, one must provide an accounting system so participants can keep track of trades; it also may be necessary to check participants' arithmetic, especially when payments are made. Assistants may be needed to record prices, monitor trades, and, if appropriate, act as auctioneers. Davis and Holt (p. 55) suggest that an instructor have four helpers to conduct even the simplest of market sessions.

In many cases, it would be challenging to run a session even with the help of assistants. Situations in which participants play different economic roles, where there are multiple goods being traded, where some participants are not allowed to trade certain goods, or where information must be provided privately can be difficult to arrange.

For instructional purposes it is useful, and for research purposes essential, that the results of a session be recorded for analysis. It is preferable that these results be entered into a computer, but this delays the analysis and adds to the burden.

The use of a computerized system can reduce many of the burdens and allow for more sophisticated markets to be implemented. The EMP system was developed to make it easy for an individual to design, run, and analyze double-auction experimental trading markets.[2] Among the characteristics that can be controlled using EMP are the number and length of trading periods; the number, names, and types of assets; the production possibilities, starting positions, and position limits on each asset (including negative limits for short selling); redemption values and depreciation schedules on inventory held across periods; and access to markets and market information.

EMP allows double-auction markets for up to 18 goods to be implemented on a system of networked IBM-compatible personal computers.[3] Up to 99 participants can access the

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[2] EMP also can be used to implement a variety of other market institutions, including single-sided auctions and posted-price markets.

[3] EMP makes no use of network-specific functions and therefore should run on any network system using DOS 3.3 or higher. It also has a stand-alone "practice" mode, which utilizes a random-number generator to simulate other traders' activities. In this mode, it can be run on a single IBM PC or clone using DOS 2.0 or higher. The practice mode can be used for demonstration or to allow participants to practice on their own time. The EMP system can be downloaded as a compressed (ZIP) file from the Internet for noncommercial purposes by accessing the following URL:

http://www2.ncsu.edu/ncsu/cals/ag_rec/emp/

and following the instructions. The compressed file contains the executable programs and a number of sample markets, as well as a detailed user's manual.

DAY 1	1:32			TRADER 1						CASH:1000.00	
		——— MARKET ———				—ORDER		——— TRADER ———			
	PORT-	BIDS		OFFERS		ENTRY—		BIDS		OFFERS	
ASSET	FOLIO	Q	P	Q	P	Q	P	Q	P	Q	P
WIDGETS	10	10	32	13	35			10	32	5	40
WHATNOTS	20	5	26	25	30						

Figure 1. Sample main screen

market during a session. Each computer serves as a trading station from which participants can buy, sell, and transform goods, and obtain information on their own positions and on market conditions.

Participant Interface and Market Design

The program interface consists of a set of screens: two activity screens, five information screens, and context-sensitive help screens. This section provides an overview of the main interface features as well as a description of other important market design features. Not all of these features need be used in a particular session or by all the participants of a session. When EMP is used repeatedly by participants, as in a classroom setting, the number of features can be increased as participants gain familiarity with the system.

The Main Screen

The main trading screen is used to interact with the market. Through this screen the participant can bid to buy or offer to sell goods and can accept market bids and offers. A sample screen, displayed in figure 1, represents a market with two goods (called *WIDGETS* and *WHATNOTS*). The first line of the screen shows that trading is 1 minute and 32 seconds into the first trading period (day 1) and that this screen is for Trader 1, who has $1,000 in cash.

The remaining lines of the main screen show the trader's current portfolio in the two goods (10 units of *WIDGETS* and 20 units of *WHATNOTS*) and the bids and offers on these goods. The trader has no bids or offers for *WHATNOTS*, but has bid $32 on 10 units of

WIDGETS and is offering five units at $40 (shown at the far right of the screen). The screen also reveals the best bid and offer prices (the market bid and offer are the highest bid and lowest offer) and the quantities available at these prices. For example, 25 units of *WHATNOTS* are being offered at a price of $30.

EMP maintains an order queue of bids and offers on each good, sorted first by price and then by the time a bid or offer was made. For the example in figure 1, Trader 1 has the best outstanding bid on *WIDGETS*, whereas at least one other trader has made a better offer. The program does not automatically match transactions; traders must accept an outstanding bid or offer to complete a transaction. For example, a bid of $40 on *WIDGETS* would not automatically result in a transaction (it would, however, create arbitrage opportunities). When a transaction is completed, the participating traders' portfolios and cash positions will automatically be adjusted. Thus if Trader 1 accepts two units of *WHATNOTS* offered at $30, the screen would be altered to reflect a portfolio position of 22 units and $940 in cash.

EMP has a number of features that allow the designer to constrain market access of individual traders. For instance, a trader can be prevented from making or accepting bids or offers on particular goods. This allows the designer to define different roles for the traders, such as producer, wholesaler, and retailer. Producers then may sell only to and retailers may buy only from the wholesalers. Traders also may be denied access to information on market bids or offers, forcing them to submit bids or offers without knowledge of other traders' prices. In addition, upper and lower position

DAY 1	3·32	TRADER 1			CASH: 956.00
# of Runs: ____	Remaining Capacity: 10	ENTER to process.	ESC to exit.		

ASSET	PORT-FOLIO	PROCESS NUMBER 1	2
WIDGETS	10	−1	−1
WHATNOTS	22	1	1
CASH	956.00	−25	−50

Figure 2. Sample transformation screen

limits can be imposed. A lower limit of zero, for instance, rules out short selling, whereas an upper limit can simulate capacity constraints or government-imposed regulation.

The Transformation Screen

EMP also allows goods to be produced or transformed. Experimenters can define up to 10 transformation processes through which, for example, one or more goods can be used to "produce" another good, or goods can be converted to cash or cash to goods. In addition, capacity constraints can be imposed on the transformation processes.

Participants can access this feature through a second screen, an example of which is shown in figure 2. This trader can select one of two processes and the number of production "runs" desired. Each run of the first process will transform one WIDGET into one WHATNOT at a cost of $25 in cash. The second process is similar except that it requires $50 in cash. In this case the second process is dominated by the first, but capacity constraints can be placed on each process. This facilitates production with increasing costs, as once the

low-cost transformation is used, production must occur through the next transformation at a higher cost.

The Information Screens

A number of information screens are available to traders, including summaries of purchases, sales, and prices, and logs of all individual and market transactions. The first information screen is the trader's summary screen. This screen shows the daily starting and ending positions, the amounts purchased and sold during the day, the average purchase and sales prices, and any payments (adjustments) made at the end of the day. The current and all previous trading days can be accessed. Figure 3 displays an example summary screen for a trader (denoted Trader 1) who consumes WHATNOTS, for which the trader is paid according to his/her WHATNOT payment schedule of $Q(50 - 0.5Q)$, and incurs a cost for holding WIDGETS of $-3Q$ (i.e., a negative payment on WIDGET holdings). Trader 1 sold WIDGETS but had no transactions in WHATNOTS on day 1 (note that the top line shows the current period is day 2). The adjustments column

DAY 2	0:00	TRADER 1					CASH: 1671.00
TRADER SUMMARY FOR DAY 1							
ASSET	STARTING POSITION	PURCHASES Q	P	SALES Q	P	ENDING POSITION	ADJUST-MENTS
WIDGETS	10	5	32.00	8	35.00	13	−39.00
WHATNOTS	20	—	—	—	—	20	800.00
CASH	1000.00					1881.00	

Figure 3. Sample trader summary screen

DAY 2	2:21		TRADER 1				CASH: 1671.00	
MARKET SUMMARY FOR DAY 2								
		PRICES					SUPPLY	
ASSET	HIGH	LOW	LAST	AVERAGE	VOLUME	VALUE	SHORT	LONG
WIDGETS	45	32	45	36.33	3	109	——	125
WHATNOTS	31	9	26	22 86	7	160	—	25

Figure 4.   Sample market summary screen

at the far right shows the values of the payments made at the end of day 1 (the negative payment on *WIDGETS* of $39 can be interpreted as a storage charge of $3 per unit, which we discuss further in the futures market example below).

A second information screen displays summary information for the entire market. This screen shows price information, transactions volume (i.e., the number of units bought and sold), the total transactions value (with average price equal to value/volume), and the total short and long supply in the market. An example is shown in figure 4. Traders also can access two other screens that display transaction logs—one for their own transactions and one for the whole market. These allow the trader to review the complete record of transactions over the course of a trading session.

Payment and Depreciation Schedules

Value is induced on the goods through payments made to participants. These payments occur at the end of each trading period and depend on the amounts of the various goods held by the participant. The payments may represent actual cash amounts or they may simply provide a score. In a classroom setting, the score might be used to form the basis of students' grades.

Although the schedules are provided by the experimenter, they can be thought of as the intrinsic value placed on the goods by the participants [see Smith (1976) for a discussion of induced value theory]. Typically, participants have no incentives guiding their behavior other than the payments they receive. There is, therefore, a direct correspondence between the

size of the payments and the utility derived from participation in the experiment.

An experimenter can create incentives for trade by varying the payment schedules across traders. Each schedule restates the quantity of the good held by the participant at the end of the trading period. The EMP system offers several ways for an experimenter to specify a payment schedule. The simplest of these is to specify a schedule which has the form:

$$Payment = Q(a - bQ),$$

where a and b are parameters set by the experimenter, and Q is the quantity held at the end of the trading day. This form of a payment schedule depends on only two parameters and covers a larger percentage of the schedules used in experimental settings. The quadratic payment schedule implies a linear marginal value function $(a - 2bQ)$, which in turn yields an individual demand function of $Q = a - 0.5bP$, where P is the price at which the good can be purchased.

More complex schedules can be implemented in EMP through the use of an auxiliary program provided by the experimenter. This program will be executed at the end of each trading period and the resulting payments credited to the participants' accounts. The *EMP User's Manual* (refer to footnote 3) contains detailed instructions on designing such a program.

The designer can set the depreciation rate on Q for instances of carryover from one day to the next. For example, in a market with consumers or end users, the depreciation rate would be 100%, so that all holdings of a good are redeemed at the end of the day and a pay-

ment is issued based on the payment schedule. A depreciation rate of zero would imply complete carryover from one day to the next and, if a storage charge is to be imposed, this could be done by making a negative to reflect cost of carry. The designer can change the a and b parameters across trading days and vary them across traders.

For many experiments, the complete schedule is provided to participants. For example, Davis and Holt (chapter 3) discuss a market with buyers and sellers. Buyer 4 can purchase up to two units, where the first can be redeemed for $4.60 and the second for $4.40. This can be implemented by a redemption schedule with $a = 4.7$ and $b = 0.10$. The market also includes a seller who must pay $4.30 for the first unit sold and $4.40 for the second unit. The associated redemption schedule, therefore, uses $a = -4.25$ and $b = 0.05$.[4] In this market, buyers also would be constrained to have between 0 and 2 units and sellers between -2 and 0.

Other Features of EMP and Some Example Markets

A significant feature of EMP for agricultural economists is its ability to handle futures and options contracts. Each traded asset can be specified as a spot good, a future, a put, or a call. Spot goods in EMP differ in two ways from the other types. First, the buyer must pay in full for the good at the time of the transaction, and second, end-of-day payment schedules apply only to spot goods. Futures, puts, and calls, on the other hand, all have a maturity date and an underlying asset associated with them. At the end of the maturity period, the selling trader (short) must deliver the underlying asset to fulfill the contract, which is credited to the account of the buying trader (long). Alternatively, the contracts can be cash-settled with no physical exchange of the underlying asset, but rather a cash payment based on the price of the underlying asset at

the end of the maturity period. Furthermore, futures, puts, and calls are marked-to-market, meaning that payments are made only on the capital gains or losses at the end of each trading period. These features enable experimenters to provide more realistic simulations of how futures and options markets work.

EMP creates a number of files that can be used to analyze an experimental session. The most important results are stored in files and can be easily accessed and analyzed. For example, the program creates a comma-delimited ASCII file that contains a complete record of bid, ask, and transaction prices. A file recording the end-of-day asset and cash positions for each trader is also created. In addition, each of the information screens available during trading sessions is written to output text files for analysis by the participants or experimenter. These files can be imported into a spreadsheet or statistical package for reviewing, analyzing, or graphing. To facilitate this process, a LOTUS 1-2-3 file with macros is available.

Several examples are presented below which depict the kinds of markets that can be easily implemented using EMP. In addition to demonstrating how some of the program features can be used, these examples illustrate how to achieve certain pedagogical goals (as discussed in the section that follows on using experimental markets in the classroom). We present only a small sample of the possible markets which may be implemented using EMP.

Vertical Market Relationships

The first example simulates a vertical marketing chain. There are two goods—*ROUGH* and *FINISHED*. There are three groups of participants—*PRODUCERS, PROCESSORS,* and *CONSUMERS.* The *PRODUCERS* have the ability to make units of *ROUGH,* and can buy or sell *ROUGH* but cannot redeem *ROUGH* and cannot deal in *FINISHED* at all. *PROCESSORS* can buy *ROUGH* and sell *FINISHED* and can convert *ROUGH* into *FINISHED*; they cannot redeem either product, however. *CONSUMERS* can buy, sell, and re-

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[4] Participants, of course, need not see these parameters. In this market, one would simply provide the values of the first and second units.

Table 1. Sample Payment Schedules

Trader	Payment Schedule	
Type	Day 1	Day 2
1	$-10Q$	$Q(100 - 0.5Q)$
2	$-5Q$	$Q(50 - 0.5Q)$

deem *FINISHED* but cannot deal in *ROUGH* at all.

Futures Markets

A simple futures market can be created consisting of two goods denoted *SPOT* and *FUTURES*. Trading takes place over two five-minute trading days. At the end of day 2, traders holding short (selling) positions in *FUTURES* must deliver *SPOT*, and traders holding long (buying) positions must take delivery of *SPOT*. Traders are divided into two different types with each type having a different payment schedule. These payment schedules are listed in table 1.

Each trader begins with $10,000 in cash and 30 units of *SPOT*. A lower position limit of zero in *SPOT* prevents short selling. Note that the day 1 payment schedule represents a storage charge on holding *SPOT* from day 1 to day 2; this can be interpreted as a per unit storage charge of $10 and $5 for Type 1 and Type 2 traders, respectively.[5] At the end of day 2, all *SPOT* goods held are redeemed according to the day 2 payment schedule. To maximize the net returns, traders would have individual demand functions of $Q = 100 - P$, and $Q = 50 - P$ for Types 1 and 2, respectively.

The competitive equilibrium is easily derived by determining the aggregate demand across the two trader types and computing the equilibrium *SPOT* price in each day in a two-period storage problem with no carryover beyond day 2. With an equal number (n) of each trader type, there is a total of $60n$ units of the commodity. The market demand is the sum of the demands of the two trader types:

$$D(P) = n(100 - P) + n(50 - P)$$
$$= n(150 - 2P).$$

For the market to clear, this demand must equal the total availability of $60n$, implying that the day 2 equilibrium price for *SPOT* is $45. At the end of day 1, all the *SPOT* goods should be held by Type 2 traders, who have lower storage costs. The day 1 equilibrium price is $40 (the expected price in day 2 less the storage cost of $5 for Type 2 traders), while the equilibrium *FUTURES* price on both days is $45.[6]

A Market with Risk and Information

The final example illustrates markets with asymmetric information about the value of a good. For example, farmers typically have better information on their own potential crop yields than they have about yields in other farming regions. Alternatively, consider a speculative market with informed and uninformed traders. In an asymmetric information market, all participants eventually come to know the value of goods, but the time pattern of information resolution can have significant impacts on the time path of prices.

For concreteness, suppose there are individuals that live in different regions, with delays or imperfections in the transmission of information among the regions. Specifically, traders may have better information about the demand in their own region than they have about demand in other regions. The following market captures some of the realities of this situation.

Consider a single-period, single-good market. Each trader starts with 30 *WIDGETS* and $10,000. The *WIDGETS* can be redeemed at the end of the period at a random per unit rate. To determine this rate, a coin is tossed 20 times prior to the beginning of trading; each head tossed adds $10 to the redemption value.

During the trading period, each trader receives information about the results of the

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[5] Although it cannot be determined from the payment schedule, the *SPOT* good does not depreciate from day 1 to day 2.

[6] The equilibrium is independent of risk preferences because a complete market in contingent claims exists, allowing all risk to be eliminated.

tosses (messages can be sent to individual participants with the EMP system). This information is not revealed to the traders in the same order, however. For example, after five coin tosses, one participant may be told that four heads and one tail were tossed; another trader may be told that two heads and three tails were tossed. Before trading ends, the results of all the tosses will be known to all the traders and each will have common valuations—equal to $10 times the total number of heads.

The coin toss framework implies that prior to any information revelation, all participants have equal priors concerning the redemption value of *WIDGETS* (this value is $10 times a 0/1 binomial random variable, with 20 trials having equal probability of a 0 or a 1). After revealing n outcomes of the tosses, the redemption value is a random variable equal to $10 times the number of heads thus far revealed plus $10 times a binomial random variable with $20n$ trials. This setup implies that all participants start with an expected redemption value of $100, and that each head revealed increases their expectations by $5 and each tail lowers expectations by $5.

The information provided differs across traders. It is possible, however, for participants to glean further information from the trading behavior of others. For example, a trader with private information of two heads and three tails would have an expectation of $95. If the trader observes that other traders are willing to buy *WIDGETS* for $105, a reasonable assumption is that some traders know at least three heads have been tossed. Classroom sessions implementing this market reveal that students differ considerably in how well they understand and make use of this trading behavior tool.

Using Experimental Markets in the Classroom

Significant educational benefits potentially can be obtained through the use of self-contained market simulations. Educational research suggests that individuals exhibit varied learning modes and that no one teaching style is effec-

tive for all students (Felder and Silverman). Market simulations can be used to provide students with a more direct experience than can be obtained through lectures alone, and can demonstrate the relevance of economic and management principles. By providing a setting in which economic concepts can be applied, simulations can enhance students' motivation to learn.[7] Such a setting makes use of the students' own competitive nature and harnesses it for educational purposes. Because the simulation design is under the control of the instructor, it can be tailored to specific pedagogical goals. At the most basic level, students in the authors' classes on agricultural markets and futures and options markets gain an understanding of institutional details, such as the distinction between bid and ask prices, marking-to-market, cost-of-carry, arbitrage, and delivery aspects of futures and options markets. In addition, economic concepts such as the gains from trade and efficiency can be illustrated.

Another use of experimental markets is in motivating optimization principles, equilibrium concepts, and comparative statics. For example, students should be able to construct their own demand and supply functions from either the payment schedule and/or the transformation schedule that the designer assigns them; indeed, if they are not able to do this, it is unlikely that the experimental market will produce predictable results. Profits in sessions run by the authors are typically quadratic in the amount held, so the necessary calculus for derivation of demand functions is fairly elementary.

In the remainder of this section, we discuss how EMP is utilized in a specific classroom setting. For the past two years, a junior/senior-level agricultural marketing course taught by one of the authors at the University of Maryland has used EMP as an integral part of the course content. Fourteen students participated

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[7] Many experimental economists have emphasized the importance of monetary rewards to enhance participant motivation. This can be impractical in a teaching situation, however. Making grades depend (in part) on performance in market simulations represents a practical alternative.

in six different sessions throughout the semester. No teaching assistants were used for these sessions, and the instructor had ample time both to run the EMP session and to address student questions. Each session emphasized the course content by taking the fundamentals from classroom lectures and highlighting them in trading sessions. Comparative statics effects were illustrated by changing the underlying demand/supply or marketing margin conditions from one day to the next. Thus, students experienced first hand the effects of changes in transport rates, for example, on the price they received as a producer or paid as a consumer.

The six sessions differed in content and complexity. The first and simplest session illustrated price discovery in a market with only consumers and producers. From there, later sessions addressed spatial markets and trade, intertemporal markets and storage, product form and derived demand, storage and futures markets, and production uncertainty with futures markets.

Prior to each EMP session, students were given information about the type of market, the number of trading days, the length of each day, and what their economic role would be on each trading day. Students, while aware of their own demand or cost structure, were unaware of other students' demands or costs so they could not infer the equilibrium price for each day.

Each EMP session is designed to illustrate comparative statics results. A "base" case is used for one trading day and then other trading days illustrate changes in the underlying cost or demand structures to accentuate price and quantity impacts from the base values. Students rotate throughout the session to assure that each serves a different economic role.

After each session, homework is assigned requiring computation of equilibrium prices and quantities for each trading day along with the theoretical equilibrium profits (surpluses) for each group. Students analyze the market and their own trading results based on the data generated by the EMP sessions and compare these to the theoretical values. Not only did this exercise reinforce the economic compar-

ative statics of the market, but it also allowed students to tie economic surpluses to a meaningful concept like trading profits.

A specific example from the spatial market EMP session is provided below, along with some of the results from the session.

A Spatial Market Example

The spatial market in this example EMP session consisted of two locations: Mayberry and Beverly Hills. Production of the commodity occurs only in Mayberry (the *STICKS*), while consumption occurs only in Beverly Hills (the *SLICKS*). To get the consumable good from the *STICKS* to the *SLICKS*, there are transporters (the *SHIPS*) which transform the commodity from Mayberry to Beverly Hills at a cost. Only *SHIPS* have access to both markets. Thus, in this market there are three distinct roles: *STICKS, SLICKS,* and *SHIPS*.

For the base case, the *STICKS* have a marginal production cost of $5 for the first 10 units, increasing by $10 for each additional 10 units produced. This is accomplished through the transformation process, where each transformation has an associated cost and capacity constraint. The capacity constraint allows for increasing marginal cost for higher production. The *SHIPS* have a constant marginal shipping charge of $10 (i.e., perfectly elastic supply of shipping services). Operationally, the shipments are achieved through the transformation screen by transforming the Mayberry commodity (which they purchase in the market) into the Beverly Hills commodity for a cash fee. Their capacity constraint is set to a very large number, giving them the ability to ship virtually unlimited quantities for the same cost.

For the base case, the consumers (*SLICKS*) have a payment schedule of $Q(100 - 0.5Q)$ which is paid to them at the end of the trading day and is based on their holdings of the commodity at that time. This payment is the revenue they generate. The cost of acquiring the good is $P \times Q$. Therefore, their profit-maximizing quantity is $Q = 100 - P$, which is their individual demand curve. As the market price changes throughout the trading day, they ad-
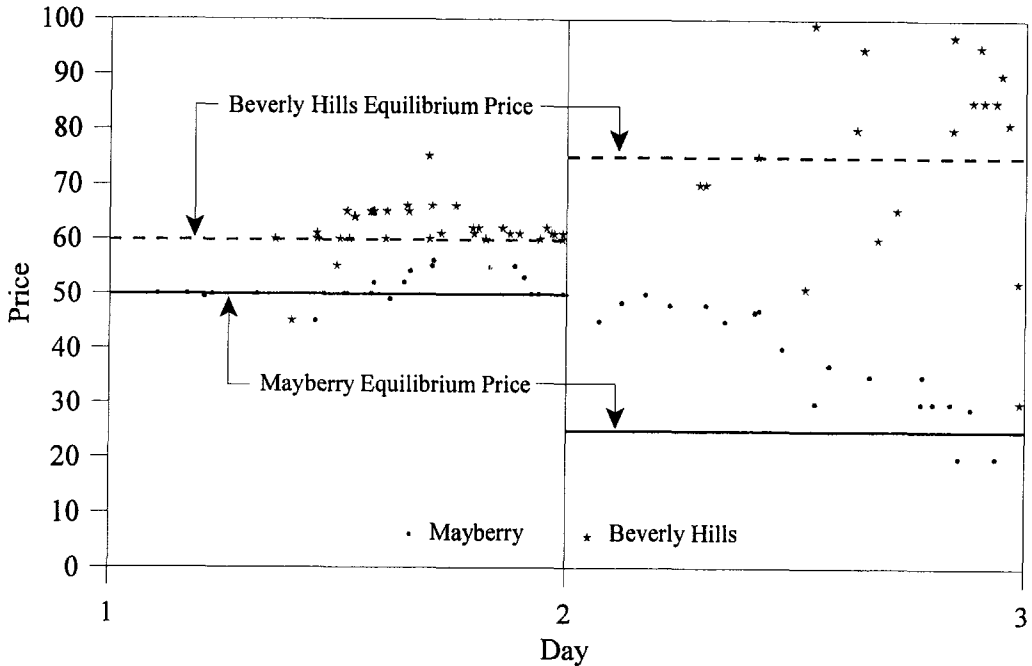
Figure 5. Transaction and theoretical equilibrium prices for spatial market

just their quantity by selling when the price increases and buying when the price falls.

From the base case, three comparative statics results were illustrated: (*a*) a change in the transport rate, (*b*) a demand change in Beverly Hills (a change in the payment schedule function), and (*c*) a supply change in Mayberry (a change in the cost of transformation). To allow for trader rotation, six trading days were used—three base days and one day for each comparative statics case. Thus, each trader served a specific role for two days and then rotated to a new trader group. Each day lasted seven minutes because two groups (*STICKS* and *SHIPS*) needed to make transformations to get the product from first producer to final consumer. When fewer groups make transformations, the day length may be shorter.

Figure 5 displays the transactions prices for Mayberry and Beverly Hills for two days of trading. Day 1 is the base case, while day 2 is the case when transport costs increase from $10 per unit to $50 per unit. These two days corresponded to the third and fourth days of the six-day lab session.

The equilibrium day 1 prices are $60 in Beverly Hills and $50 in Mayberry.[8] Indeed, for most of the day, prices in both locations were quite close to these theoretical values. This was the second replication of the base case and, as such, trader learning led to most of the transactions being at or near theoretical equilibrium prices. However, in day 2, the transport rate increased dramatically to $50 (for the first time in the lab) and traders adjusted slowly to this change. Initially, Mayberry (producer market) transactions took place at roughly the same price ($50) as in day 1, but *SHIPS* soon learned that Beverly Hills consumers were unwilling to pay the $100 price offered by *SHIPS*. Over the day, the Mayberry price declined and approached the theoretical equilibrium price of $25. The Beverly Hills price remained above the theoretical price of $75 for much of the day as *SHIPS* had to cover their high cost of buying in the

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[8] These are the equilibrium prices when there are four producers, five shippers, and five consumers. At these prices, all arbitrage opportunities for the *SHIPS* have been exhausted and the equilibrium quantity produced in Mayberry equals the quantity consumed in Beverly Hills.

Mayberry market. Ultimately, the prices in each market displayed the expected change from the base day: Mayberry (producer) prices decreased and Beverly Hills (consumer) prices increased as a consequence of higher transportation charges.

In addition to learning about comparative statics effects in spatial markets, this lab also introduced the concept of price risk. *SHIPS* face price risk in this market because of the time lag between purchasing the input (Mayberry commodity) and transforming it for sale in Beverly Hills. Although it took only about 10 to 30 seconds for the transformation to take place, the price in Beverly Hills could decrease over this time and result in a loss on the transaction. Students recognized the need for a market in forward commitments for delivery to Beverly Hills, and this set the stage for later lab sessions on futures markets.

Concluding Comments

The experimental economics framework has proven to be valuable in testing hypotheses for economic research. By creating self-contained environments in which economic decisions must be made, researchers can directly test economic hypotheses in a controlled setting.

For demonstrating economic concepts in classroom settings, self-contained economic environments like those developed in experimental economics have been beneficial. Although some students do well with the abstract, conceptual framework used in the standard lecture format, other students find the approach difficult. The lack of concrete experiences related to course subject matter can hamper students' ability to grasp conceptual material, leading to boredom or frustration.

For economic researchers or instructors, the costs of developing and implementing such methods can be a major constraint. We have described here a software tool that can significantly lower these costs and provide a flexible and useful means for achieving specific research or pedagogical goals.

A number of examples have been given to illustrate the sophistication and complexity of institutional arrangements that can be designed with this system—including the use of EMP experiments in the classroom, especially in the context of teaching agricultural market analysis.

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