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ABSTRACT

A market exchange simulation utilizing the PLATO computer-assisted instructional system at the University of Illinois has been designed to teach students the principles of a general equilibrium system. It serves a laboratory function which supplements traditional instruction by stimulating students' interests and providing them with illustrations of theoretical concepts. The model simulates a simple exchange economy; students order commodities and the computer computes the demands in each market, adjusting prices to supplies and demands. The process is then repeated until equilibrium is reached--i.e., until demands equal supplies. The course instructors provide post-simulation analysis and exposition by methods of their own choice. The simulation was generally well-received in the first course in which it was used, but formal validation remains to be undertaken in the future. (PB)

COMPUTER ASSISTED INSTRUCTION IN ECONOMICS:

AN APPROACH FOR ILLUSTRATING

GENERAL EQUILIBRIUM

CONCEPTS

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Introduction

One of the most difficult ideas to communicate at the elementary level is how all economic entities interact simultaneously through markets to determine prices, output, and the distribution of income. Even describing what constitutes a "general equilibrium system" is difficult; describing how it theoretically operates is doubly difficult.

Most expositions at this level are a variant of either the equations system approach or the 2x2x2 economy (2 factors, 2 goods, 2 individuals) exposited graphically. Neither method is without serious problems. Since the mathematical preparation of students and most instructors precludes developing analytical solutions, the equation system approach can only be used to describe the system. Furthermore, the equations are so formidable as to shock the mathematical innocence of many students. The result is that little may be communicated. The 2x2x2 model, while better suited to the technical equipment of the students, may nevertheless strain their credulity in being used to describe the multidimensional world which they observe. Given these pedagogical obstacles, alternative or supplementary approaches should be particularly attractive.

The purpose of this paper is to describe such an alternative or supplementary approach; it is a market exchange simulation utilizing a computer assisted instruction system developed at the University of Illinois - the PLATO system.[1]

The pedagogical strategy of the simulation is to first capture the student's interest through personal involvement and experience; this experience can then be used as a basis for subsequent elaboration by the instructor in the classroom. If successful, the student's interest will be raised to a point where it can sustain and absorb the more rigorous traditional approaches described earlier

Because the term 'computer simulation' is frequently used to describe business games it should be noted at the outset that the simulation to be described is in no meaningful sense a 'game'. Specifically, no index of individual performance, either implicitly or explicity, is computed, nor would any such computation have meaning. Hence, students cannot be ranked on any scale of merit. This is not to say, however, that a student will be unable to describe, in his own terms, whether the simulation worked to his advantage or disadvantage. Further, students in this simulation are not asked to assume unnatural roles such as "pretend you or the president of General Motors." They are asked only to be themselves in a role which is familiar to them - as consumers. In this role they are to be guided by their tastes and not any abstract decision rules.[2]

This simulation would be more accurately described as a "laboratory experience," the analogy being with the laboratory experience as used at the elementary level of the physical sciences. At this level the basic functions of the laboratory are to illustrate phenomena and to generate data for theoretical analysis. When a CAI system is used to achieve these same ends it could be described as being used in a 'laboratory mode.' This mode may be contrasted with the more frequently used 'tutorial or testing mode.'

When used in this laboratory mode, CAI systems have marked similarities to simulations carried out by, say, a batch process computer system. The CAI system, however, has several advantages over such systems. First, the CAI system permits students to interact with each other in an impersonal manner similar to the impersonal nature of a market. This interaction proceeds without any distracting logistical aspects, such as collecting punched cards or distributing intermediate results. Further, the personal computational needs of each participant, such as computing the net value of his order, are instantly performed for him by the computer as his needs require. All results are immediately and clearly displayed for him. Finally, the analysis of the data can be carried out from his same console as an immediate and natural extension of the simulation. In brief, a CAI system such as PLATO permits the student's attention to be focused upon his decisions with minimum distraction and loss of time.

Economic Model

The model simulates a simple exchange economy; supply is fixed, there is no credit market or futures market. The students are told that they have been invited to a picnic by their economics professor. The professor, however, is determined that although the food is free, it is to be efficiently allocated among students by a "market process." Each student then sees on his screen a list of food items, the prices of each, and how many of each item he has arbitrarily been given. He is permitted to revise this original allocation of food by buying and selling items at the posted market prices. The net revenue from these transactions is continually computed and its current value is displayed following each transaction.[3] When the student has optimized his order, he so indicates to the computer; the computer will not accept his order unless at that time his net revenue is non-negative. This, of course, reflects the assumption that there is no credit market.

When his total order is accepted, the student is asked to wait until all students have also placed their orders. When everyone has completed this task, this constitutes the end of a 'round.' As soon as the last student's order is received, the computer computes the excess demand in each market and adjusts the market price upwards slightly if this excess demand is positive, downwards if it is negative, or leaves the price unchanged if the excess demand is zero.

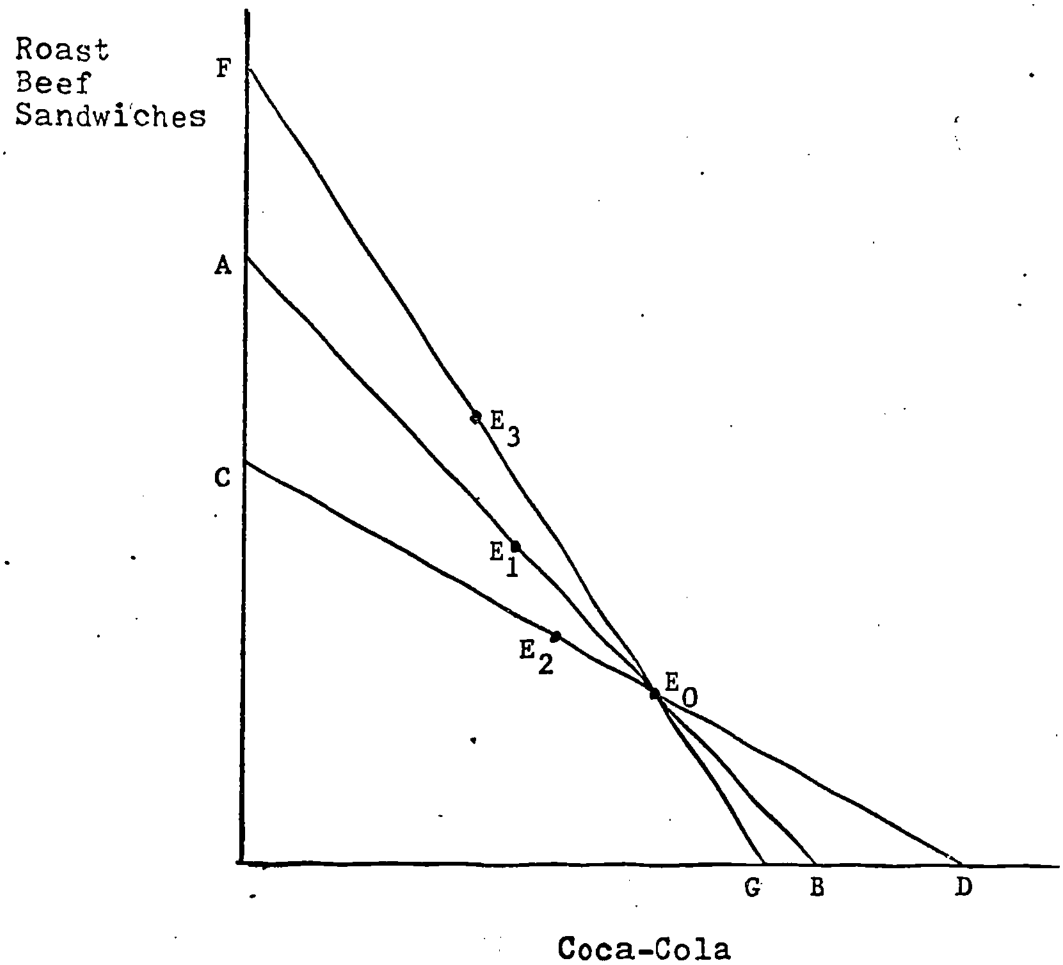
The model follows Walras' *tâtonnement* process in that each student's order is assumed to be only an offer to buy and sell; the actual execution of the order is contingent upon all markets clearing when all offers are compared.[4] If this happens, a general equilibrium has been found and the simulation ends.[5] If a round does not produce a general equilibrium, students are given the revised set of prices and a new value of their net revenue. Since their offers were not actually executed, they still have their original allocation of food, although it is stored in the mem[illegible] not displayed. Their last preferred allocation, however, is displayed on the screen. Their original allocation of items, value at the new prices, constitutes their total revised purchasing power; their last preferred allocations, which they still see on their screens, are also valued at the new prices. The difference between this value and their purchasing power is the new net revenue value they see. As soon as the new set of prices and new net revenue is presented, each student has an opportunity to revise his order again if he wishes. There is an incentive to do so because prices of items have changed and because the individual's purchasing power has changed. Only, however, if their new net revenue was negative is the student actually required to change his order.

This process can be illustrated graphically for a typical participant if we assume that there are only two items on the menu at the picnic--roast beef sandwishes and Coca Cola. (In fact, there are 10 items.) In Figure 1 point E_0 represents the student's original allocation of sandwiches and Coke.[6] Point E_0 and the initial set of market prices produce the budget line A-B. For most students point A will not be an optimum choice; we assume that the optimum is shown by point E_1. The student reaches E_1 by trading Coke for sandwiches. At E_1 his net revenue will be zero; the computer only requires that it be non-negative; any point on or within the relevant budget line constitutes an acceptable order. When all students have placed their orders a new set of prices will usually be generated. This new set and point E_0 produce a new budget line, C-D, and a new value of the student's net revenue, which given order E_1, will be negative. Because of this negative value the student will be required to alter his order to a choice on the new budget line, C-D. We assume this choice will be E_2. When all students have reported their E_2 another set of prices will be generated; these are shown by the budget line F-G. These prices will also produce a new, and in this case positive, value of our student's net revenue. In this case he could simply reenter E_2 as his order; more likely he would revise it to some point such as E_3. Adjustments such as these continue until either a general equilibrium is achieved or until the instructor terminates the simulation.

Post-Simulation Analysis

When the simulation is finished the method of subsequent exposition can be left to the discretion of the instructor. Two general choices are available to him, however. These are an on-line guided analysis of the data generated by the simulation by individual students and/or a more traditional classroom lecture expositing the concepts in a more rigorous manner but using the simulation-experience as a source of illustrations. Although the methods of analysis and content of classroom lectures will also vary according to the level of the class, some illustrative approaches may usefully be given here.

Figure 1



If one wishes to analyze in any detail the data generated by the simulation, some choices are called for because the amount of data produced is voluminous even for a class of only 20 students with only 10 markets. Two general levels of data can be used; first, data relating to the individual choices of each student round by round. With only 20 students and 10 markets, each round will generate observations on 200 choices. At the market level, if one restricts attention only to prices, quantities, and excess demand, there will still be 30 variables.

Fortunately, the PLATO system itself provides a powerful and versatile tool for data presentation and analysis. The simulation program not only stores in memory all of the data generated by the simulation but also provides three graphical presentations for on-line analysis. All of the data can also be obtained in hard copy form for more detailed off-line use.

Appendix A contains photographs illustrating each of the three graphical presentations. The most familiar form is, of course, a price quantity diagram for each market. Frame 7 illustrates such a diagram for market number 10. Each round produces a price and quantity coordinate; these are plotted using the relevant round number as the plot symbol. One can thus also easily follow the time path in the same diagram. Such data also provides a useful contrast between partial and general equilibrium analysis.

A second presentation of the market data is shown in Frame 8. This plots excess demand over 'time' - round by round. Since supply in each market is fixed, it is convenient to plot excess demand as a percent of this supply. The resulting variable is dimensionless; consequently, more than one market may be plotted simultaneously if desired. This diagram quickly shows the nature and extent of the disequilibrium in each market over time. Further, by examining more than one market simultaneously, possible consumption interdependencies may be explored.

The third presentation is shown in Frame 9. This tabular presentation includes both the individual student's and market price/quantity data. These data give initial and final values and are also presented in such a way as to facilitate computation of price indexes at both levels. Each of these three displays is available to each student independently of what any other student may be looking at. Further, these three presentations are by no means exhaustive; the only limitations on the variety of on-line data presentation and analyses are the ingenuity and programming resources of the instructor.

These three methods of presenting the data contain suggestive, if not final, answers to many interesting questions relating to the collective tastes of the students and to the dynamic behavior of this simple general equilibrium system. The nature of the questions will be limited by the economic knowledge of the class. To illustrate the use of these on-line presentations, a list of questions appropriate for a class in intermediate microeconomic theory is provided in Appendix B. The students were given the list of questions at the end of the simulation and then asked to use the data to answer them as best they could. Their answers were subsequently used as a basis for a classroom discussion. If desired, the questions could also be presented within the CAI system rather than being distributed separately. The students were permitted to proceed at their own pace; they were also encouraged to ask questions of their own and attempt to answer them using the data. These questions and approach are only illustrative of a wide range of questions and uses that could immediately follow the simulation.

Variations in the Model

Minor refinements in the existing model offer much scope for introducing new concepts. For example, markets could be segregated by classes of consumer. If beer were one of the commodities, the age of the participants could be used to restrict consumption only to those who were of age; this would illustrate the effect of numbers of consumers on the dynamics of individual markets. The simulation illustrates the role of market price formation in reallocating purchasing power income, but initial distribution of goods among participants is exogenous and arbitrary. In the simulation used to date, each person started with an identical allocation; this could be modified to, say, an explicitly random process. This is analogous to how some forms of wealth - hence income - are distributed in the real world.

In the model every attempt has been made to insure that Say's Law will apply: specifically, all goods are to be consumed at the picnic. This could be relaxed by introducing a store of value, e.g. candy bars. Data generated by classes with this variation would provide a useful contrast to data where no store of value was available.

Concluding Remarks

The major pedagogical question relating to this or to any other technological innovation is: "but does it teach?" Little systematic analysis has yet been completed to answer this question for this approach. The model has been used as an integral part of one course and it has benefited from the comments of colleagues who took the time to participate in several simulations. Several instructors have expressed an interest in utilizing it in their classes. However, because of the heavy use of the PLATO system, the lead time for scheduling has necessitated delaying their use until the next semester.

While the formal validation is important and will be carried out as time permits, it will not be surprising if the results are inconclusive. This follows in part from what is attempted by the use of the model. It is not designed to replace classroom presentation, but rather to supplement it in much the same way that laboratory sections supplement beginning courses in the physical sciences. The function of these laboratory sections is as much to illustrate and stimulate as to "teach" in any direct sense.

Consequently, to the extent this analogy is accepted, the long experience of the physical sciences provides general support for this approach. Nevertheless, as an economist one is bound to ask ultimately for a more precise measure of the educational benefit, since neither the hardware or software of CAI systems is a free good. This evaluation remains a project for the future.

APPENDIX A

FRAME 1

1)This is a simulation of a general equilibrium market system. You will participate in this system in a role that is familiar to you - as a consumer of food products. In this role it is important that your behaviour reflect as nearly as possible your true preferences.

The situation is this. Your economics professor has invited the class to a picnic. It seems, however, that the professor has his own special hang-up. Normal people get hung up on such things as organic food, zen buddism, cross-country snow shoeing, sex, etc. The professor, perhaps expectedly, is hung up on 'optimal' resource allocation.

PRESS -NEXT-

FRAME 2

2) In a moment you will be given an initial allocation of food. You will then be permitted to exchange this allocation for one that might better fit your own tastes. The allocation can be changed by selling some or all of any item and using the receipts to purchase more of others. All food, however, is to be consumed at the picnic and your complete order must be such that receipts are at least as large as your expenditures. There is no credit market!

When your order is placed, if all markets do not clear, you will be given a revised set of prices and be permitted to revise your order at the new prices.

PRESS -NEXT-

FRAME 3

3) Your allocation of any item can be changed be entering the amount you wish to sell- a negative number, or the amount that you wish to buy - a positive number. If you are satisfied with the amount you have, make no entry.

If you make an entry and then wish to change it, erase and enter the new amount. Note , if you do erase an entry it must be replaced with something if only a zero.

Money, is used only as a numeraire; money will not be used as a medium of exchange nor as a store of value - money balances are not carried forward if markets do not clear.

NOTE: You must press NEXT after each transaction to record it. An OK signifies it has been recorded.

PRESS -NEXT-

FRAME 4

-Menu- Item	Units	Mkt. price	You have	Order? +=Buy -=Sell
1. roast beef sandwich	1/2	$ 0.25	1	*
2. carrot sticks	each	0.05	10	
3. devilled eggs	1/2	0.10	1	
4. milk	oz.	0.02	4	
5. coke	oz.	0.02	4	
6. Kool aid	oz.	0.02	16	
7. ripe olives	each	0.05	6	
8. turkey sandwich	1/2	0.10	1	
9. brownies-	each	0.15	1	
10. ice cream	oz.	0.05	5	

Cummulative net revenue = 0.00

When your order is ready press the -DATA- key

FRAME 5

You must wait until all students have placed their orders. At that time your screen will change to reflect a new set of prices. You can then revise your order if you wish.

PRESS -NEXT-

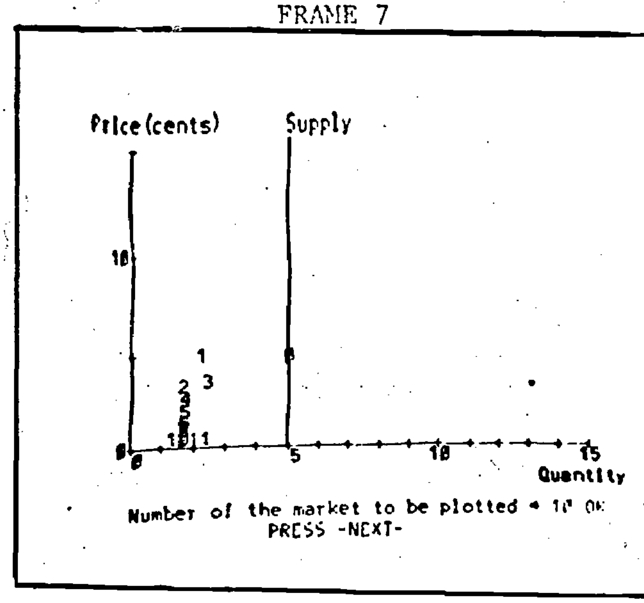
FRAME 6

Three analyses of market data produced by the simulation are available. The first analysis shows the path of market excess demand for specified markets . To see this analysis press the TERM key and type PLOTXD.
The second analysis presents price-quantity data generated by the simulation in a supply-demand form. To see this analysis press the

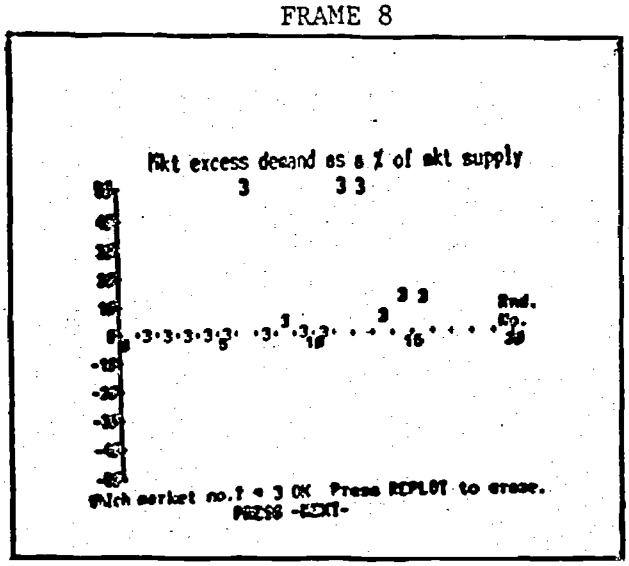
The final analysis presents initial and final price quantity data for all markets. To see these data press the TERM key and type SHOWMV.
When you have completed your analysis press the TERM key and type FINISHED.

PRESS -NEXT-

FRAME 7



FRAME 8



FRAME 9

	Initial Values:			Final Values:		
	Your QD_0	Mkt QD_0	Mkt P_0	Your QD_1	Mkt QD_1	Mkt P_1
MKT 1	2	16	0.25	0	15	0.50
MKT 2	5	40	0.05	0	38	0.00
MKT 3	1	8	0.10	0	13	0.00
MKT 4	8	64	0.02	0	56	0.00
MKT 5	8	64	0.02	0	57	0.00
MKT 6	8	64	0.02	0	48	0.00
MKT 7	6	48	0.05	0	40	0.06
MKT 8	2	16	0.10	0	15	0.00
MKT 9	2	16	0.15	0	15	0.05
MKT 10	5	40	0.05	0	41	0.00

	MKT QD	Your QD
$\Sigma P_0 \times QD_0 =$	19.04	2.38
$\Sigma P_1 \times QD_0 =$	3.98	0.00
$\Sigma P_0 \times QD_1 =$	17.97	0.00
$\Sigma P_1 \times QD_1 =$	3.44	0.00

PRESS -NEXT-

APPENDIX B

Questions Given to Students to Guide Their Analysis of the Simulation Data

1. Which markets, if any, failed to reach equilibrium? For each market that failed to reach equilibrium, describe the nature of the disequilibrium when the simulation ended.
   Market: Type of disequilibrium:

2. Did the behavior of price and/or quantity demanded seem to you to be counter intuitive, i.e., different than what you would have predicted? If so, name the market and briefly explain.

3. In which markets was there the most active trading? Upon what are you basing your answer?

4. Did any of the goods fail to follow the basic law of demand? (This is tricky!)

5. Was the price level different at the end than at the start? What evidence are you basing your answer on?

6. What is the definition of "excess demand"? What role do you think this variable played in price dynamics in each market?

7. Were any free goods revealed by the simulation? Which were they? Did any goods change from being an economic good to a free good and back to an economic good?

8. From the data, are there any pairs of goods which seemed to have either a complementary or substitute relationship? What are the pairs, if any, and what evidence do you have to support your answer?

9. Look at the initial and final economic situation of some other student. Can you deduce from looking at these data whether he was better off or worse off at the end than at the start?

10. Was the market value of your final bundle higher or lower than the market value of your initial bundle?

11. Was the utility to you of your final bundle higher or lower than your initial bundle?

12. Did any goods appear to have perfectly price inelastic demands?

Did you ask any other question of the data? If so note these below:

FOOTNOTES

[1]For a complete description of this advanced CAI system, see either D. Alpert and D. L. Bitzer, "Advances in Computer-Based Education," Science, Vol. 167 (20 March 1970), pp. 1582-1590; or D. L. Bitzer, B. A. Sherwood, and P. Tenczar, "Computer-Based Science Education," Proceedings of UNESCO Conference Utilization of Educational Technology in the Improvment of Science Education, 13-16 September 1972, Paris, France (forthcoming).

[2]One problem that arose regarding roles was the propensity of a few students (and instructors) to act as speculators rather than as consumers. This behavior appeared notwithstanding the fact that without actual and repeated buying and selling no meaningful speculation is possible. Following the tâtonnement process, all offers are contingent upon the prices turning out to be equilibrium prices. To discourage this 'speculative' behavior, large purchase orders of any given good are refused by the program and the student receives a message asking him to stop trying to speculate.

[3]Appendix A, Frames 1-5, shows how this information is actually presented to the students. Students communicate their decisions to the system by means of their own keyboards.

[4]In a correctly specified general equilibrium system, the numeraire must be a traded good, its price, of course, being unity by definition. In the simulation, money prices are used to conform

to the obvious fact that consumers think in money terms. But, in spite of the fact that money is not a traded good, it _is_ a numeraire in the sense of being the unit of account. A true numeraire could be defined by arbitrarily holding constant the money price of one of the traded goods regardless of the excess demand in the market for this good.

[5]The instructor may establish a less strict definition of general equilibrium at any point in the simulation. For example, the simulation could be programmed to end if in all markets excess demand as a percent of supply were within plus or minus 15% percent of zero, rather than being exactly zero.

[6]It should be noted that E_o is not true equilibrium in the sense of being a voluntary choice of the consumer, for given a set of prices and purchasing power; E_o is an arbitrary assignment. The other E's do represent equilibrium choices in the sense described.