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## **A Market-Clearing Classroom Experiment**

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# A Market-Clearing Classroom Experiment

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## Abstract

This paper describes a classroom experiment demonstrating the price mechanism and the clearing of markets in an endowment economy. Participants receive random endowments of two goods they may trade in order to maximize a given utility function. A market-clearing price is reached when no mutually beneficial trades are possible. The outcome is truly endogenous with no reservation prices or willingness to trade imposed on the participants. A problem set allows the participants to study the equilibrium outcome analytically. The experiment can be used in intermediate micro- and macroeconomic courses.

## Abstrakt

Tento článek popisuje experiment demonstrující mechanismus tvorby cen a tržní rovnováhy v přidělové (endowment) ekonomii. Účastníci obdrží náhodné přiděly dvou zboží, které mohou směňovat za účelem maximalizace užitkové funkce. Ceny nutné pro tržní rovnováhu je dosaženo v momentě, kdy žádná oboustranně prospěšná směna již není možná. Výsledek je zcela endogenní bez vyhrazení cen a bez kontroly obchodování účastníků experimentu. Přiložené cvičení dovoluje účastníkům studovat dosaženou tržní rovnováhu analyticky. Experiment může být použit ve středně pokročilých kursech mikro a makroekonomie.

## 1. Introduction

One of the most delicate tasks in teaching undergraduate micro and macroeconomic courses is the transition from partial equilibrium models to the general equilibrium framework. At the same time, the price mechanism and the clearing of markets is crucial for students' understanding of modern economic theory. This experiment provides the participants with an opportunity to see these economic principles in action.

The experiment is very simple: students receive random endowments of two goods and a simple utility function they may maximize by trading goods with each other. The only information available to each student is his or her own endowment, the existence of the two goods, the utility function, and the possibility of trading with other students. Each student knows neither the total supply of the goods nor the endowments of other students. Since the individual endowments are different, utility improving trades lead to an equilibrium with a market clearing price proportional to the ratio of the total endowments of both goods.

The spontaneous behavior of students corresponds to the invisible hand of the price mechanism which induces a truly endogenous equilibrium defined only by the total endowments and the form of the utility function. Compared to similar experiments, trading is not restricted by reservation prices or a willingness to trade imposed on the participants. Thus the students can personally experience the role of prices in the market clearing process. The experiment also illustrates important economic concepts such as "there is no trading in equilibrium", "the excess supply or excess demand for goods is zero" or the principle of "Pareto optimality". Students deepen their understanding of the classroom economy analytically through

a problem set.

The experiment suggests a way of using the classroom as an artificial closed economy with many agents. It makes economic theory more approachable to students not majoring in economics or to those students who prefer collaborative learning and concrete experiences to abstract conceptualization (see the discussion in Bartlett 1996). Its positive impact on students' learning and classroom participation reflects the recent evidence on learning types (Becker and Watts 1995, 1996 and Lage, Platt, and Treglia 2000).

The next section contains a description of the experiment. Section 3 summarizes the experience with the experiment so far. The fourth section concludes. Detailed instructions, a record sheet, and an example of a problem set can be found in the Appendices.

## 2. The Experiment

The market-clearing experiment is intended for intermediate micro- or macroeconomic courses with at least 20 students. Giving instructions and distributing endowments takes approximately 15 minutes (see the detailed instructions in Appendix A). The "classroom economy" clears in about 10 or 20 minutes depending on the number of participants, their motivation, and trading intensity. Material requirements are minimal and enumerated in Table 1.

Before the experiment begins, the instructor prepares endowments of two goods, such as red and green pieces of paper. The endowments are distributed by the instructor or drawn by the students from a hat. It is important that the total endowment of each color be different and that

students' individual endowments be sufficiently variable to ensure mutually beneficial trades: Table 2 displays the endowment distribution in one of the experiments run in an intermediate macroeconomic class at the University of Chicago. While students could in general observe the endowments of some of the other students, the total number of goods should not be revealed.

Having distributed the endowments, the instructor writes the following utility function on the blackboard:

$$U(r, g) = rg,$$

where  $(r, g)$  stands for the number of red and green goods, respectively, held by each student. The students write down their initial endowments and utility into distributed record sheets (see Appendix B for an example located on my website <http://home.cerge-ei.cz/Radim/experiment/index.html>). A prize, such as \$10 or \$20, is promised to the student who attains the highest utility level at the end of the class.<sup>1</sup> No other information or instruction is given to the students.

The monetary reward serves as an incentive to maximize the utility function. At least some students quickly figure out that an exchange of goods with other students increases their utility level. Moving around the classroom, individual students exploit the differences in prices (exchange rates) between different traders in the classroom market. If some students do not participate in the game, the actively trading students will seek the passive students out and trade with them. Initially, most students try to maximize the symmetric utility function by seeking a portfolio composed of equal amounts of each good. Thus, the initial exchange rate is usually one



red for one green good. Over time, the scarcity of one good induces the exchange rate to converge to the equilibrium value proportional to the ratio of the aggregate endowments. Trading stops when no mutually beneficial (Pareto improving) trades are possible.

Once the market has cleared, the instructor writes the market-clearing price (exchange rate) on the blackboard and the students record their final allocations into their record sheets. The instructor rewards the student with the highest utility. A problem set may be distributed immediately or during the next class (see Appendix C located on my website <http://home.cerge-ei.cz/Radim/experiment/index.html>). Topics for a classroom discussion can be found in the Problem Set; students can discuss their trading strategies. There is a classic interpretation of the price mechanism and the role of information in Hayek 1945.

There are many possible variations on the basic setup described above. The instructor may increase the curiosity of the students by announcing at the beginning of class that he or she knows the price that will prevail at the end of the experiment. To prove the claim, he or she ought to write the exchange rate on a sheet of paper, put it in an envelope, and open it at the end of the experiment.

The experiment can be also conducted with three (or more) goods. For example, with an additional blue good, the students can maximize a utility function  $U(r, g, b) = rg + b$ , or even  $U(r, g, b) = rg - b$  in which the blue good is a bad. In all cases, the utility function ought to be easily computable.

A government can be introduced to regulate trades and prices, or to tax the endowments and the gains from trade. For instance, the government can set a price ceiling on one of the goods.<sup>2</sup> The resulting

equilibrium can be then compared to that reached in the unregulated economy in terms of allocations and welfare of individual students as well as of the whole economy.

Also, an open or growing economy can be simulated by distributing additional goods of one color into the economy after the market has cleared. This setup can provide students with intuition on how the relative scarcity of one good affects the price and the allocations. Students would experience a transition process from one steady state to another. Market failures can be simulated by a low or random enforceability of trades with a stress on the role of traders' reputations. Students can also be heterogeneous in their utility functions: for example, one group of students may prefer green to red goods and vice versa for a second group.

In my opinion, however, the cost of such variations might outweigh the benefits from the transparency of the basic setup. Compared to the literature, the main contribution of this experiment lies in its simplicity, its true endogeneity, and the uniqueness of the resulting equilibrium. For instance, a related experiment proposed by Schotter and Corns 1997 has been used by a colleague as a complementary experiment. The Schotter-Corns "In-Class Experiment 2: Exchange" lets two participants bargain over two goods that are very unequally distributed. Since the core is large, numerous outcomes are possible depending on bargaining or computational mistakes. Such an outcome cannot arise in this market-clearing experiment.

### 3. Experience with the Experiment

In the four experiments conducted so far, the trader with the highest final utility always started from a very low endowment and gained by exploiting price differences around the classroom. In one experiment, some students sold their goods to other students who wanted to win the monetary prize for the highest utility at the end of the experiment. In two experiments, a few students pooled their resources and traded as a group.

Although such spontaneous behavior might lead to unexpected situations during the experiment, the market-clearing process is not affected. I decided not to prevent or prepare students for such situations. Not only do they provide for stimulating questions in the problem set (see question 10 in Appendix C) but more importantly it is worthwhile to preserve the informational and procedural purity of the experiment. Compared with many other experiments in Delemeester and Brauer 2000, this experiment has no induced values imposed on individual students (willingness to trade or number of goods to exchange) in order to control the result. Except for the randomly drawn endowments, all students have the same (lack of) information, the same objective function, and an equal opportunity to increase their utility level by trading. The result of the experiment is a consequence of students' optimal decisions subject only to the resource constraints and the form of the utility function.

The instructor may wish to ask the students to record their individual trades in their record sheets. However, the students trade very actively (they indeed resemble stock market brokers) and might not have enough patience and time to record each trade they make. On the other hand, such a detailed trade record would provide useful feedback for the Problem Set

or the classroom discussion.

## 4. Conclusions

In their valuable survey, Delemeester and Brauer 2001 classify only 11 of 113 surveyed classroom experiments as being relevant to macroeconomics. Modern macroeconomic theory is based on two principles: the optimal behavior of utility-maximizing rational agents (the micro-foundations of macroeconomics), and the equilibrium in the economy (the clearing of markets). This experiment focuses exactly on these two principles. Given the price, all agents behave optimally (in this sense, the price determines agents' behavior). On the other hand, given the decision rules of the agents, the market clearing condition determines the price (in this sense, agents' behavior determines the price). The assumption of rational expectation closes the system: the market clearing price implied by the agents' behavior is assumed to be the same as the price on which agents' decisions are based.

Students' understanding of this equilibrium system is one of the most important aspects of teaching macroeconomics at any level of abstraction and difficulty. This experiment provides a first-hand and very intuitive experience of the price mechanism and the clearing of markets. It became a reference point in teaching more advanced concepts of monetary theory (the role of money), the macroeconomics of open economies (gains from trade), labor economics (the equilibrium search process), social security policy (generations of trading agents), rationality, and the role of information.

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## Notes

1. Instead of the highest utility level criterion, the instructor may opt for the largest difference (or ratio of) the final and initial utility level. Although the latter criterion seems to be fairer, it would require that the initial endowments be recorded by the instructor. This may inhibit students' spontaneous participation in the experiment (with recorded endowments they might worry about their performance). Of course, the instructor can reward the best two or three traders. Alternatively, the instructor may randomly choose one student at the end of the experiment and pay that person some fraction of his or her utility. This would motivate students to maximize absolute rather than relative utility. I thank the anonymous referee for suggesting this incentive scheme.
2. The maximal allowed price must be smaller than the market-clearing price of that good. Interestingly, a black market might arise in the classroom. Monitoring, enforceability, and related issues can be discussed in the class and in the Problem Set.

## Appendix A. Instructions

This Appendix offers a full script of how to conduct the experiment. Instructions to students are in italics; comments and suggestions for the instructor are in square brackets. I suppose that the classroom has 20 students in an intermediate macroeconomics class. The instructor prepares packages for all students in the amount of 300 red and 100 green goods as in Table 2. An example of a record sheet is shown in Appendix B.

*Today we are going to conduct an experiment in which our classroom becomes a closed endowment economy with many agents. The experiment will demonstrate how an equilibrium in such an economy emerges. First, each of you will receive a record sheet for our experiment and draw an endowment of red and green pieces of paper that represent the goods available in the economy.* [Instructor distributes the record sheets and goes around the class and lets students draw random endowments from a hat. The instructor then writes the utility function on the blackboard.]

*Each of you values the goods in the economy as follows:  $U(r, g) = rg$ , where  $r$  stands for the number of red goods and  $g$  for green goods you hold. Goods are indivisible. Please record your endowment and your current utility level in the record sheet. At the end of the class, the student with the highest utility level will receive a prize in the amount of \$10.* [Alternative schemes of student motivation and monetary rewards can be used as discussed in the paper.] *During the experiment, you may leave your seat and trade goods with other agents in the economy.*

[If the instructor wants to put any restriction on students' behavior (coalitions) he or she should inform them at this moment. The instructor should not directly tell the students to maximize the utility function or how

exactly the experiment will end. After questions have been answered, the instructor attaches a ten dollar bill to the blackboard.] *Here is the reward. The experiment has begun.* [Students will soon realize that an exchange of goods may increase their utility. There is no need to encourage passive students: the actively trading students will seek these students out and trade with them. Over time, the initial exchange rate (usually one red good for one green good) will converge to the equilibrium exchange rate. If time is pressing, the instructor may want to announce the local exchange rates to the whole class in order to speed up the convergence to the market-clearing exchange rate. When the market-clearing exchange rate is attained, the trading intensity will slow down and eventually stop. ]

*What is the exchange rate? Is anyone interested in trading at this rate?* [If no trade is made for about one minute, the instructor writes the last exchange rate,  $p_g^* = 3, p_r^* = 1$ , on the blackboard.] *This is the exchange rate at which trading has stopped. It is called the market-clearing price and we express it as the number of red goods you have to give away in order to obtain one green good. Please record now your final holdings of both goods and compute your final utility level.* [The instructor rewards the student(s) and may distribute the Problem Set. A Problem Set related to actual situations that occurred during the experiment would have to be distributed next class. Alternatively, a classroom discussion based on the questions in the Problem Set in Appendix C may begin.] *This Problem Set asks you to analyze the experiment more formally. Please use the data from your record sheet: the initial and final holdings of goods and utility levels. Your grade on the Problem Set will not be related to these data or your actual performance in the experiment.*



Table 1: Summary of the Market-Clearing Classroom Experiment

A Market-Clearing Classroom Experiment	
Course:	Microeconomics, macroeconomics
Level:	Intermediate
Subject:	General equilibrium, market clearing, price mechanism
Material requirements:	Endowments of two goods such as red and green paper: for a class with $n$ students, use $15n$ red goods and $5n$ green goods. The $n$ individual endowment packages are prepared before the experiment and put into a hat. Most of the individual endowment packages should be very different from the average endowment.
Class size:	20 or more students
Time:	One class period (30-45 minutes)
Variations:	Different utility functions, more than two goods price regulation

Table 2: Data from an experiment conducted in Intermediate Macroeconomics 202, the University of Chicago, in 1999.

Example of an Experiment	
Students	20 students
Aggregate endowments	300 red and 100 green goods
Individual endowments (red/green goods)	15/5, 10/4, 5/12, 20/3, 25/2, 12/3, 16/3, 15/5, 11/2, 20/2, 17/4, 12/3, 19/8, 8/13, 15/5, 22/5, 15/2, 15/10, 10/6, 18/3
Equilibrium price	3 green goods for 1 red good
Time (minutes)	35 total: 15 introduction, 20 convergence

## Appendix B. Record Sheet for the Experiment

Record Sheet	
Market-Clearing Classroom Experiment	
(Please keep for future reference)	
Initial allocations:	
Endowment of red goods	$e_r =$
Endowment of green goods	$e_g =$
Initial utility	$U_e(e_r, e_g) \equiv e_r \cdot e_g =$
Final allocations:	
Number of red goods	$r =$
Number of green goods	$g =$
Final utility	$U(r, g) \equiv r \cdot g =$

## Appendix C. Problem Set

This Appendix contains an example of a Problem Set on the particular market clearing experiment described in the instructions (Appendix A) and Table 2. The Problem Set contains several questions related to the actual experiment and was distributed to students during the next class. Recall that 20 students participated in the experiment and that the aggregate endowments were 300 red and 100 green goods. During the experiment some students pooled their endowments and formed trading coalitions which they called “cartels”. There are many other possible questions that can be asked about the experiment, for example, analyzing the properties of the objective function, or applying the two welfare theorems.

### Problem Set

#### A Market-Clearing Classroom Experiment

This Problem Set is related to the market clearing experiment we conducted in class. While the experiment was designed to provide you with some intuition on the price mechanism and the clearing of markets in an endowment economy, here you are asked to formalize it and solve it analytically. Some of the questions will ask about *your* participation in the experiment: it is in your interest to report the true quantities. Your grade on this assignment will not be related to your actual performance in the experiment.

Recall that each agent (student) received a random endowment of green and red goods,  $e_r$  and  $e_g$ , respectively. Each agent then could exchange his or her endowments with any other agent in order to maximize

the utility function

$$U(r, g) = rg,$$

where  $r$  and  $g$  are the quantities of the red and green goods. Recall also the market-clearing exchange rate announced at the end of the experiment, namely,  $p_g^* = 3$  and  $p_r^* = 1$ . Thus the price of the red good is already “normalized” to one and we can think of the price of one green good as the number of red goods you have to give away in order to obtain it.

As a reference only, please write down your data. Initial endowments:  $e_r = \dots$  and  $e_g = \dots$ . Initial utility level:  $U_e = \dots$ . Final allocations:  $r = \dots$  and  $g = \dots$ . Final utility level:  $U = \dots$

**1. Information** Describe the relevant facts you knew or could observe just before the trading started. More importantly, write down the information you did *not* have at that point.

*Answer:* Public information includes the existence of two goods; a common utility function; students in a closed economy with similar endowments; the reward; and the knowledge that other students have the same information. Private information includes a student's own endowment and trading strategy. Information lacking includes total endowments, the endowments of other students, and the behavior and strategy of other students.

**2. Model** State a formal description of the decision problem *you* faced just before the trading started. Be clear about what the objective function, budget constraint, and their variables are. Use the equilibrium prices. Do not use numbers; do not solve it yet.

*Answer:*  $\max_{\{r, g\}} U(r, g) = rg$ , subject to  $p_r r + p_g g \leq p_r e_r + p_g e_g$ .

3. **Analytical solution** Solve your decision problem analytically. Draw a diagram of the optimal allocation on the  $(r, g)$  plane. Do not use numbers.

*Answer:*  $r/g = p_g/p_r$ . See Figure C1.

4. **Numerical solution** Solve for the optimal consumption allocation and utility level using your initial endowments and the market-clearing price announced in class at the end of the trading.

*Answer:* Plug actual numbers into the formulas from 2) and 3).

5. **Comparison** Compare the above numerical solution to the quantities you actually achieved in the experiment. Are they different? Why? Under which circumstances would they be equal?

*Answer:* They would have been equal if each trade were perfectly rational at the market-clearing price and if the divisibility of goods was perfect.

6. **Pareto improvement** Pareto improvement is defined as a change in the allocation of goods which makes some agents better off but does not make any agent worse off. Was each of your trades Pareto improving?

*Answer:* Yes, provided that the goal was the maximization of the given utility function. If not, it was a mistake in calculating the utility before and after each trade.

7. **Rationality** It looked like some agents did not behave rationally (optimally) in their trading. Did it affect the resulting market clearing price? Under which conditions would it do so?

*Answer:* Some students stopped participating in the experiment, or

made trades that were not beneficial for them, or made deals although better deals were available elsewhere. It did not affect the market-clearing price. The market clearing price would have been attained with only one rational student. He would buy goods from irrationally behaving students at a price which would make him better off.

8. **Market-clearing price** The final price announced in class is called the market-clearing price. Why did trading stop at this price? Or, in other words, in what sense was the market “cleared”?

*Answer:* The trading stopped because there was no mutually beneficial trade available. At the market-clearing price, the excess supply or the excess demand for goods was zero.

9. **Reward** Recall the reward of \$10 given to the student with the highest after-trade utility level. Looking at the experiment afterwards, describe a good trading strategy and a few conditions under which it would work. Notice that the winning final portfolio (around 26 green and 65 red goods) was not optimal: why could the winner not optimize it?

*Answer:* If a student correctly guessed the market-clearing price (or the total supply of each good), the correct strategy was to sell the scarce good at a price above the market-clearing price and to sell the abundant good at a price below the market-clearing price. The final portfolio was not optimal because of the low divisibility of goods.

10. **“Cartels”** I was surprised to see ‘cartels’ in the experiment. In fact, these were not cartels but coalitions of agents who pooled their resources. Could such coalitions prevent the market-clearing price,

and would it be better if we regulated the market in order to prevent such coalitions? Describe one condition under which the formation of a coalition was *your* optimal strategy.

*Answer:* The coalitions did not prevent the market-clearing outcome. If there was one big coalition, i.e. if the whole class pooled the endowments and then redistributed them to maximize each student's utility, it would have distributed them in ratio of three red goods to one green good and attained the social planner's solution. As far as the coalition had the same utility function it would not have led to a Pareto inferior solution. Making a coalition would be your optimal strategy if you could trade a larger volume of goods at an advantageous local price or if you could achieve a number of goods divisible by the current price.

11. **Total endowment** The total endowment of the red good was 300 units and 100 units for the green good. How is this fact related to the final market-clearing prices?

*Answer:* Given that the goods entered the utility function in a symmetrical way, the scarcity of one good is exactly reflected by its relative price. In other words, if the endowment of one good was three times lower than the endowment of the other good, its price in equilibrium is three times higher than of the other good.

12. **Social Planner** What would you have to know and what would your optimal allocation be if you were a benevolent social planner? Carefully define the social planner's objective function and his constraints.

*Answer:* The social planner's objective function is the sum of



weighted utilities of all agents. His constraint is the total endowment of both goods. Assuming that the social planner weights agents equally, the optimal allocation is to confiscate all endowments and redistribute them in equal amounts among the students. This allocation would be Pareto optimal. The social planner has to know each agent's utility function, and must be able to confiscate, calculate, and redistribute the endowments.

13. **Market regulation** Suppose there exists a government that can regulate all features of an economy. Design such a regulation and discuss its effect on the equilibrium allocation and price.

*Answer:* For example, the government can put a ceiling on the exchange rate: "the exchange rate shall not exceed two red for one green good". This would lead to Pareto inferior allocations at the end of trading, an excess demand for green goods and an excess supply of red goods. On the other hand, a regulation "the maximum of goods exchanged in one trade shall not exceed 10" would have no effect on the equilibrium allocation and price.

14. **Market failure** Define the concept of market failure. Then design, interpret and discuss its effect on the equilibrium allocations and price.

*Answer:* For example, suppose that the exchange of goods happens five minutes after the deal is made and the contracted amount is not enforceable. In this case, traders might default on their promise to trade with the original partner and trade meanwhile with someone else at better price. This might prevent trades and lead to traders developing a reputation for not defaulting on contracts.

15. **Design your perfect market** In one paragraph, describe an “alternative” market system that would deliver optimal, market clearing quantities. Does your plan make some agents better off/worse off at any/all stages of the process?
  
16. **Reading assignment** Read the article by Friedrich A. von Hayek “The Use of Knowledge in Society” in the *American Economic Review* published in 1945, volume 35, number 4, pages 519-530.

Figure C1. Analytical solution.

