The Hayek Hypothesis and the Production Decision: An Experimental Analysis

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Abstract

The Hayek Hypothesis holds that prices contain enough information to direct the resources in the economy to their most efficient use. In a series of experiments, Vernon Smith [1982a] found that with the right trading institutions, a market with agents that know only their own valuations of a good will converge quite rapidly to the competitive equilibrium price and trading volume. In the series of experiments reported here, the extension of the Hayek Hypothesis to an economy with production is explored. When agents can choose between autarkic production and specialization, they have the opportunity to hedge against market risk. A coordination problem is also created, interfering with the ability of the system to converge on the theoretical Richardian equilibrium.

1 Introduction

The fact that the outcomes generated by a competitive market are efficient is an essential component of conventional economic theory. Experimental economists have shown that with the appropriate economic institutions, near competitive outcomes can be consistently generated [Kagel and Roth, 1995]. However, the efficient distribution of goods in an economy is only one of the conditions necessary for an economy to be efficient. In an economy with production, if economic agents do not specialize and trade, then the competitive market cannot work its wonders. This intimate connection between production and exchange decisions is well known, and can be found in most introductory texts.

The argument that gains from trade are a consequence of differences in comparative advantage is credited to David Ricardo (1772-1823). The logic is very simple. Agents with different relative abilities can, through trade and specialization, realize greater profits than if they relied strictly on their own devices. Given no impediments to trade, and rational, profit maximizing agents, all potential gains should be exploited. There are two actions we would expect to see in an economy that satisfies these conditions. First, we would expect to see agents specialize in those activities where they have a comparative advantage. Second, we would expect to see trade between these specialists.

Experiments which investigate market behavior are common. Holt provides an overview of various market institutions, while Kagel provides a summary of research that has been conducted on auction markets. Several institutions are remarkable in their ability to converge on a stable price and trading quantity. The double auction is one of these, and is commonly the best at reproducing results that are consistent with economic theory. For this reason, the double auction is much used in experimental work.

Experiments which investigate the production decision are less common. Frequently the production decision itself serves as the action which the applied incentives are expected to modify. For example, van Dijk et al. [2001] engaged pairs of subjects independently in a mentally demanding task, exploring different compensation schemes (individual vs team). In their literature review, they find few studies, either field or experimental, that consider the relationship between payment schemes and effort. Integrating the production decision with incentives generated by a market is even less common. This is somewhat surprising, as Ricardo's theory of comparative advantage is almost as fundamental to economics as the view that competitive markets lead to efficient allocations. Those that have been conducted seem to be principally educational in nature.

Haupert [1996] conducted a classroom experiment in comparative advantage. Subjects were assigned different productive abilities in two goods - guns and butter. Each subject was given a production target, which could not be attained without specialization and trade. Trading was decentralized, in that subjects searched the room for partners to trade with. If the target was attained, the subject earned a particular number of points toward the course grade. Subjects who failed to attain their target received no reward. Of those that surpassed the target, a subset of the best performers received a bonus. Five rounds were conducted, with varying degrees of trade restrictions in each round, and a tariff added in the final round. Since the purpose of this experiment was to motivate classroom discussion, no detailed analysis of the results was provided.

In the Haupert experiment, subjects tended to find one partner each round, and traded exclusively with them. The production possibilities were set up so that such pairing would allow every student to find a partner with whom to trade. In effect, this was an experiment in decentralized search and matching. Although the gains to finding the right type of partner were a consequence of the marginal productivities assigned, one could just as well have assigned each subject a type and a reward schedule related to their finding another subject of a particular type. Further, without a centralized trading institution, the agreed to terms of trade need not bear any relation to those predicted by the theory of comparative advantage. Thus, it is unclear what predictions of the theory this experiment was testing. In spite of these shortcomings as an experiment, it is acknowledged that this experiment is an innovative and likely engaging exercise in the classroom.

In their principles textbook, Bergstrom and Miller [1999] conduct a trading experiment where subjects produce 'fish' and 'loaves'. Subjects are divided into two groups, representing producers in two different countries. The payoff earned is the minimum of the number of loaves or fish that the subjects have after each round of the experiment. Subjects choose how to allocate a twenty hour labor endowment between the production of each good, where their productive abilities depend on which country they are in. In the first round of the experiment, subjects cannot trade outside their own country. Given that within the country they have the same productivities, there are no gains from trade. In the further rounds, subjects again choose how to allocate their labor endowment, but are able to trade with subjects in the other country. The objective of the exercise is to demonstrate that gains from trade follow from comparative advantage, as one country has an absolute advantage over the other. The experiment developed in this paper shares the Leontief profit function. However, it is conducted in a more controlled environment where no subject has complete information about the production possibilities and communication cannot occur between subjects to facilitate coordination of the production decision.

The absence of complete information is a departure from the classic treatment of market efficiency, in the spirit of Hayek [1945]. Hayek's fundamental argument was that the specific situations that individuals find themselves in is such that no single authority could collect the requisite information to effectively manage societies resources. However, the price mechanism, by creating signals that reward individuals for making the 'right' decisions, is capable of doing so. Beckmann and Werding [1994] provide an overview of tests in experimental stock markets of the "Hayek hypothesis," the label given to the hypothesis that the price alone is sufficient to coordinate activities in the economy and ensure an efficient outcome. They assert that there are three key propositions implied by the Hayek hypothesis:

1. Competitive markets lead to allocations which fully exhaust the available gains from trade.

2. Competition co-ordinates individual activities in such a way that individuals decide as if they had access to society's entire stock of information, although each of them possesses but a tiny fragment of it. ...

3. Competition provides incentives for individuals to discover (or create) new pieces of information. Moreover, price signals, which encapsulate all of society's present knowledge, guide individual research efforts in the right direction.

In the Richardian trading environment of the reported experiment, the first two propositions can be tested.

Although the basic theory of comparative advantage and gains from trade is familiar to most readers, it will be reviewed both to ensure that familiarity, and clearly highlight the implications of that theory which were being tested. For a two good economy, a production possibilities set can be drawn to map out the various possible combinations of the two outputs, given a fixed set of inputs. The outer boundary of the production possibilities set is the production possibilities frontier (PPF). Along the PPF no resources are idle, and to produce more of one good, the amount of the other good produced must be reduced. If an economy is producing on its PPF, it is productively efficient.

For the economy to be Pareto efficient, it must be producing at a point where it is not possible to choose another production point such that one person can be made better off without making anyone else worse off. At a Pareto efficient point, the economy is both productively and allocatively efficient. The slope of the PPF at a particular point represents the opportunity cost to the economy of producing one more unit of one of the goods in terms of the amount of the other that must be foregone. At the Pareto efficient point, this slope represents a tradeoff between the two goods that, at the margin, would leave 'society' equally well off.

Where the economy includes many producers, each producer should specialize in that activity where she has a comparative advantage. So long as her own opportunity cost is different from the opportunity cost at the Pareto efficient point, she should increase her production of that good for which her opportunity cost is lower. When all producers act in this way, then the economy will attain the Pareto efficient point. However, so long as producers do not specialize according to their comparative advantage, the economy will be operating at a point inside the PPF. Aggregate welfare is then not maximized.

For the individual producer to be better off by specializing, they must be able to trade what they are producing for the good they desire. The ratio at which they can trade must be 'better' than their own opportunity cost. If not, then they would be better off not to specialize, or to specialize in the opposite direction. The production point which is optimal for the individual occurs where the opportunity cost to the individual is equal to the trading ratio that they face, unless they are at a corner. At the Pareto efficient point, the trading ratio will also be equal to the slope of the PPF.

Figure 1 illustrates the description just given, in the case where preferences are identical and can be represented by Leontief indifference curves. In both frames the PPF represents two types of producer. In figure 1.a, one producer can

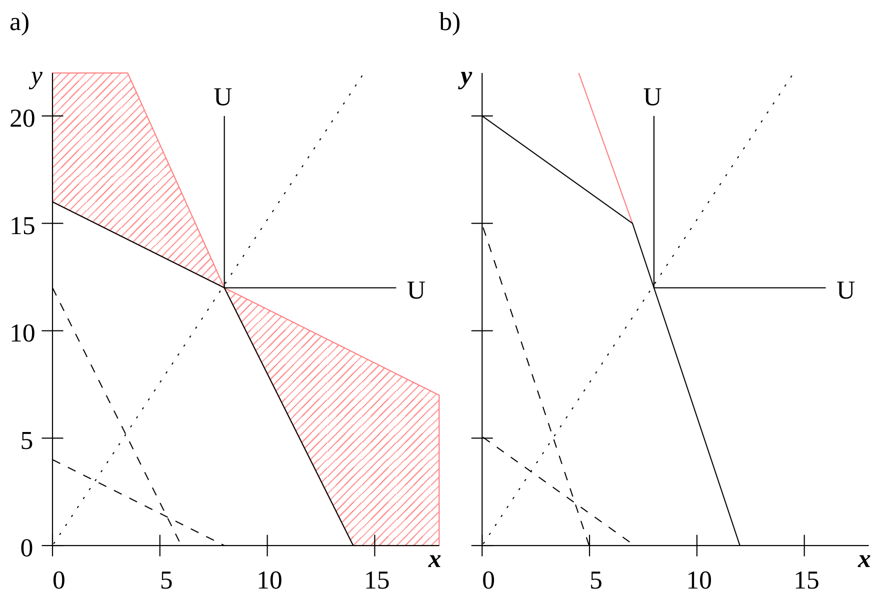


Figure 1: Production Possibilities Frontiers, Indifference Curves, and equilibrium price ratios. 'L' shaped lines labeled 'U' mark Leontief indifference curve with single point of contact on PPF. Dashed lines mark production possibilities for individual producers. Unmarked solid lines identify combined production possibilities frontier for both producers. Dotted line markes expansion path for Pareto efficient points. Grey line and hatched region marks mutually acceptable trading ratios that support Pareto efficient point.

produce 6 units of good x or 12 units of good y, or linear combinations thereof. The other producer can produce 4 units of good y or 8 units of good x, or linear combinations thereof. Without specializing and trading, each individual would be producing at the intersection of their own PPF and the expansion path of the indifference curves, generating a total of 5.4 units of good x and 8.1 units of good y. If both producers fully specialize, then together they can produce 8 units of good x and 12 units of good y. As long as the trading ratio falls somewhere between 2 units of x for 1 unit of y and 1 unit of x for 2 units of y, both producers will be better off specializing and trading than by producing a mix of both goods.

Figure 1.b shows the case where the kink in the PPF does not fall conveniently on the expansion path of the indifference curve. In this example one producer can produce 7 units of good x or 5 units of good y, or linear combinations thereof, while the other producer can produce 5 units of good x or 15 units of good y, or linear combinations thereof. Without specializing and trading, these two producers generate a total of 5.6 units of good x and 8.4 units of good y. To achieve the Pareto efficient production point, one producer fully specializes, producing 7 units of good x. The other producer produces one unit of good x and 12 units of good y. Since this second producer is not fully specialized, the trading ratio must be equal to the slope of this person's PPF, one unit of good x in exchange for 3 units of y. However, notice that at this particular trading ratio, the second individual is no better off by specializing and trading than they could be without trading.

In this environment, classical theory makes several predictions about the equilibrium outcome. For the case where the kink in the PPF falls on the expansion path of the indifference curves, both agents will fully specialize and the trading ratio will lie between the slopes of the PPF on either side of the kink that falls on the expansion path. When the expansion path crosses the PPF on a straight segment, producers with an opportunity cost equal the slope of the PPF segment that intersects the expansion path will not specialize. All other producers will. The trading ratio will equal the slope of the PPF at the intersection of the PPF and the expansion path. These predictions will form the basis of the tests of the model.

The Hayek hypothesis holds that the price alone is sufficient to lead to economic efficiency, inducing producers to specialize in those goods where they have a comparative advantage. In this experiment, subjects will either have only their own productive abilities and the observed trading ratio, or their own productive abilities, the aggregate productive abilities, and the trading ratio. They will not know the productive abilities of other subjects in their group, nor the inventories that those subjects have chosen to produce for trading. The aspect of the Hayek hypothesis being tested is that the price alone contains sufficient information to direct the agents to specialize in that which they have a comparative advantage.

The Hayek hypothesis will be tested in three principle environments. In one environment, the trading ratio is 'obvious', being equal to 1:1 for the goods subjects can produce. In the others it is 1:2 or 1:4. The 1:1 case is also 'easy' in the sense that there are a range of trading ratios that are mutually beneficial. In the 1:2 case there is only one trading ratio that is consistent with the theoretical equilibrium, and that ratio leaves half of the individuals indifferent between trading and producing at their autarkic point. For the 1:4 case there is a range of ratios that are mutually beneficial. However, the productive abilities are such that both types of subject have a personal relative advantage in the same good. For the 1:1 case, specialization and trading is most likely to occur. However, for the 1:2 case and the 1:4 case it is not as clear.

2 Methods

Three experiments were conducted at Acadia university in November 2002, January 2003 and March 2003. All students at Acadia University are provided with laptop computers, the hardware that was used in these experiments. All experiments were conducted in a lecture theater between 9:00 and 12:00 am on a Saturday. Student subjects were recruited during the week before the experiment, and required to register. They could only register if they were able to install the Java™Runtime Environment on their laptop computers. They were required to bring their computers to the experiment location on the day of the experiment, along with their power supply and network cable.

The lecture hall has movable chairs. To limit the extent to which subjects could observe each other's display [Friedmand and Sunder, 1994], every second chair was placed upside down on the table, creating a partial barrier between students at the same table. The text on the laptop screen was small enough that subjects were not likely to be able to read the information on the display of subjects in the row in front of them. The author and a research assistant monitored behavior during the experiment and did not observe any signs of communication or cooperation.

During the first ten minutes of the experimental session subjects were instructed to turn on their computers and connect them to the network. They were then directed to a web site from which they could connect to the system[1]. Instructions were available to the subjects upon connecting to the system (Appendix A). The author read the instructions for the subjects, answering questions after completion. Subjects were then directed to a self-test to re-

[1]During the November 2002 session, instructions were read through a web browser and subjects connected to the system after reading the instructions. The later implementations had the instructions delivered through a window generated by the client interface. This permitted computer issues to be dealt with by a research assistant while the instructions were being read.

inforce their understanding of the instructions. The self-test responses were graded by a server script, and explanations for any incorrect answers provided to the subject. When all subjects had been given about 10 minutes to complete the self test, an opportunity to ask questions was again given. When there were no further questions, the experiment was begun. The server randomly assigned subjects to groups with between four and six members. Groups were fixed for the duration of the experiment.

Each round of the experiment had two phases. During the first phase, subjects chose one from a set of production bundles by moving a slider (table 1). Each bundle contained a particular number of left and right socks. The bundles ranged from extremes with only one type of sock to bundles with almost equal numbers of each type. The set of bundles reflected opportunity costs that were not one to one, giving each subject a bias in favor of a particular type of sock. Subjects were paid cash in accordance with the number of pairs of socks they were able to produce. They could produce pairs by choosing bundles containing both left and right socks, and/or by trading for socks they needed. Subjects only had one type of sock in their inventory at any given time. At the end of the 'production' phase, all possible pairs were produced using the socks in the selected bundle, and any remaining socks were available for trading.

The 'trading' phase was managed as a double auction with subjects offering trading ratios. The double auction mechanism has been shown to most reliably produce theoretically consistent competitive equilibrium result [Smith, 1982b], thus reducing the likelihood of a mechanism introduced bias. Since classical trade theory relies on terms of trade, a currency was not used. There was also no inventory carryover. At the end of the round, any remaining inventory was lost. Each round was identical.

Three treatments were investigated, variations in comparative and abso-

Table 1: Production Bundles and Opportunity Cost. Type labels subject types. Bundles indicate combinations of left and right socks that can be chosen. Opportunity cost shows the tradeoff between left and right socks for each subject type.

Type	Bundles (Left, Right)							Opportunity Cost
A	16,0	14,5	12,10	10,15	8,20	6,25		5:2
					4,30	2,35	0,40	
B	40,0	35,2	30,4	25,6	20,8	15,10		2:5
					10,12	5,14	0,16	
C	40,0	35,1	30,2	25,3	20,4	15,5		1:5
					10,6	5,7	0,8	
D	80,0	70,5	60,10	50,15	40,20	30,25		1:2
					20,30	10,35	0,40	
E	60,0	54,3	48,6	42,9	36,12	30,15		1:2
			24,18	18,21	12,24	6,27	0,30	
F	20,0	18,3	16,6	14,9	12,12	10,15		3:2
			8,18	6,21	4,24	2,27	0,30	

lute advantage, group size, and knowledge of aggregate production possibilities. During the November 2002 experiment, the production phase lasted 30 seconds and the trading phase ran for 210 seconds. In the first experiment some idle time was observed, so it was decided to slightly reduce the length of the phases. During the other two experiments, the production phase lasted 20 seconds and the trading phase 180 seconds. Table 2 shows the treatments conducted for the three experiment dates. The November experiment was concluded within two hours. The experiments in January and March were concluded in slightly more than three hours. The second sessions conducted in January and March were conducted with the same subjects as used during the first sessions, but randomly assigned to new groups, with random assignment of new types.

Table 2 also shows the expected trading ratio for each group. For those groups where there are a range of trading ratios consistent with the theoretical equilibrium, the minimum and maximum ratio are displayed. The mean ratio is calculated as $(\overline{p}+1)/(1/\underline{p}+1)$, where $\overline{p}$ is the maximum trading ratio and $\underline{p}$ is the minimum trading ratio. This is the slope of a line joining the intersection of the steeper PPF segment with the horizontal axis and the intersection of the less steep PPF segment with the vertical axis. Where there is only one trading ratio consistent with the theoretical equilibrium, it is displayed in the mean column.

Subjects were provided one cash payment at the end of the experiment. For the experiments with two sessions, subjects were paid once after both sessions. However, they were privately informed of their earnings at the end of the first session. For all experiments subjects received six Canadian dollars for participation. The conversion rate from pairs to dollars was adjusted so that if the theoretical equilibrium was realized, subjects would earn \$28 for the three hour experiment, slightly more than they could earn at Acadia's mandated wage for undergraduate students, \$8 per hour. Actual earnings were considerably less than that, averaging \$9.33 during the two hour November experiment, and \$16.97 for the two three hour experiments in January and March. Individual earnings ranged between \$7.15 and \$13.10 for the November experiment, and between \$9.75 and \$25.60 for the two experiments in January and March.

Table 3 lists the socks produced by each type and total number of pairs that each type of subject is predicted to have produced at the theoretical equilibrium. The outcome for symmetric groups with six members is identical to that for symmetric groups with four members. Predictions are therefore only displayed for the treatments with four members. Actually observed production levels must be integers, and are restricted to the sets shown above.

Table 2: Treatments. Session number, subject types, number of rounds, whether or not group info is provided, and trading ratios consistent with the theoretical equilibrium.

					Trading Ratio (R:L)		
Num	Sess	Subjects	Rounds	Info	Min.	Mean	Max.
			November 2002				
1	1	A,A,B,B	12	N	2:5	1:1	5:2
2	1	A,B,B	10	N	-	2:5	-
3	1	C,C,D,D	12	N	1:5	1:4	1:2
4	1	C,C,D,D	8	N	1:5	1:4	1:2
5	1	E,E,F,F	12	N	-	1:2	-
6	1	E,E,F,F	12	N	-	1:2	-
			January 2003				
7	1	C,C,C,D,D	20	Y	-	1:5	-
8	1	E,E,F,F	20	Y	-	1:2	-
9	2	C,C,D,D	10	N	1:5	1:4	1:2
10	2	E,E,E,F,F	10	N	-	1:2	-
			March 2003				
11	1	A,A,A,B,B,B	14	N	2:5	1:1	5:2
12	1	C,D,D	14	N	-	1:2	-
13	1	C,C,C,D,D,D	14	N	1:5	1:4	1:2
14	1	E,E,F,F	14	N	-	1:2	-
15	1	E,E,E,F,F	14	N	-	1:2	-
16	2	A,A,B,B	7	Y	2:5	1:1	5:2
17	2	C,C,D,D	7	Y	1:5	1:4	1:2
18	2	C,C,C,D,D,D	7	Y	1:5	1:4	1:2
19	2	E,E,F,F	7	Y	-	1:2	-
20	2	E,E,E,F,F,F	6	Y	-	1:2	-

Table 3: Predicted production combinations and total pairs produced. Predictions based on mean prices, as reported in table 2.

	Specialization							
Subjects	Type	Left	Right	Pairs	Type	Left	Right	Pairs
A,B,B	A	0	40	28.57	B	25.71	5.71	11.43
A,A,B,B	A	0	40	20	B	40	0	20
C,D,D	C	40	0	13.33	D	13.33	33.33	26.67
C,C,D,D	C	40	0	20	D	0	40	20
C,C,C,D,D	C	28.29	2.22	6.67	D	0	40	33.33
E,E,F,F	E	40	10	20	F	0	30	20
E,E,E,F,F	E	33.33	13.33	20	F	0	30	20

3 Results

Table 4 reports the mean trading ratio for each group and two simple regressions, one for a linear trend and one for an asymptotic trend, for each group. The coefficients are estimated using weighted least squares regressions, where the weight on each observation is $w_i = L_i / \sum L$, where L_i is the number of left socks exchanged in transaction i and $\sum L$ is the total number of left socks traded in that round. All the trading ratios are reported as Right:Left, so that with R_i being the number of right socks exchange in transaction i we have that $\sum w_i(R_i/L_i) = \sum R_i / \sum L_i$ for each round for the relevant group. The trend variable is based on the round number, with the first round assigned zero. This implies that the intercept for the trend is the mean trading ratio for the first round. For the asymptotic trend, the trend variable is the reciprocal of the round number, with the first round assigned the number one. The intercept of this regression is the asymptote towards which the trend is converging. A Davidson and MacKinnon J-test [Davidson and MacKinnon, 1981] was used to compare the two models. Each model's predicted values was found to add significantly to the explanatory power of the other, so that neither model is clearly superior.

As the objective is description, both models are reported below. Since the 20 treatments can be divided into 7 groups of treatments that are identical in terms of expected theoretical outcomes – trading ratios and specialization – restricting the parameters to be equal for all groups was also tested using a likelihood ratio test. This restriction was found to cause a significant change in the regression results for all three cases. In terms of price, the 20 treatments cannot be analyzed as 7 groups of replicates.

The overall mean trading ratios tend to lie in the neighborhood of 1:1. From the linear trend, over the course of the experiment, the trading ratio moves in the direction of the theoretical trading ratio for 14 of 20 groups. However, only a small number of these are significant. From the asymptotic trend, 7 asymptotes fall within two standard errors of the theoretical value, with six of these being values that are different from one. This compares with the linear trend intercepts, where in six cases the intercept – the starting value for the trend – falls within two standard errors of the theoretical value. Three cases are within two standard errors for both, and in three other cases the calculated asymptote is not inconsistent with a trend that is approaching the theoretical value.

For the majority of the trials, the observed trading ratio is significantly different from the theoretical trading ratio. With a linear trend, the sign on the estimated coefficient suggests that the trading ratio is moving in the direction of the theoretical value for many of the trials. However, this relationship is weak. For the asymptotic case, the result is similar. In a minority of cases, the estimated asymptote is within two standard errors of the theoretical value. However, the majority remain significantly different. It is noteworthy that the three cases where the initial trading ratio and asymptotic trading ratio remained within two standard errors of the theoretical value were cases where subjects

Table 4: Mean trading ratio and rate of change. Mean trading ratios calculated as coefficients on weighted least squares regression of ratio on dummy variables identifying each group. Linear trend is calculated as coefficients on a weighted least squares regression with intercept and trend terms for each group. Trend variable is round number. Asymptotic trend is calculated similarly, with the trend variable being the reciprocal of the round number. The weight is share of total left socks traded in each round represented by the observation. Astrices indicate significance at 95% or higher.

	Theory	Mean	Linear Trend		Asymptotic Trend	
Group	Ratio	Ratio	Intercept	Trend	Asymptote	Trend
1	1.0	1.27*	1.29*	-0.004	1.28*	-0.026
2	0.4	2.21*	4.60*	-0.341*	0.36	13.86*
3	0.25	0.75*	1.00*	-0.083	0.55*	0.539
4	0.25	0.71*	1.22*	-0.098*	0.43*	1.086*
5	0.5	0.99*	1.00*	-0.001	0.98*	0.022
6	0.5	0.87*	0.87*	-0.001	0.92*	-0.196
7	0.2	0.54*	0.82*	-0.030*	0.30*	1.334*
8	0.5	1.25*	1.39*	-0.014	1.47*	-1.134*
9	0.25	0.70*	0.54*	0.039	0.86*	-0.516
10	0.5	0.59*	0.63*	-0.009	0.54*	0.150
11	1.0	1.28*	1.25*	0.004	1.42*	-0.707*
12	0.5	1.85*	1.71*	0.024	2.11*	-1.048*
13	0.25	0.84*	0.33*	0.063*	1.04*	-0.992*
14	0.5	1.00*	0.91*	0.012	0.99*	0.070
15	0.5	1.07*	1.15*	-0.011	1.00*	0.346
16	1.0	1.09*	1.18*	-0.028	1.08*	0.036
17	0.25	1.20*	1.30*	-0.043	1.20*	0.007
18	0.25	0.92*	1.05*	-0.039	0.85*	0.218
19	0.5	0.43*	0.64*	-0.081	0.21	0.523
20	0.5	0.80*	0.88*	-0.042	0.72*	0.166
df		3688		3668		3668
R^2		0.54		0.55		0.56

were participating in the second experiment of one sitting[2]. Further, one of the cases that began near the theoretical value and one with an asymptote close to the true value were also in this recently experienced group. For the experiment dedicated to experienced subjects[3], the observed trading ratio was within two standard errors of the theoretical value for two of the four treatments. This held true for the initial values of the asymptotic trend regression, with the same treatments having an asymptotic trading ratio within two standard errors of the theoretical value. For the linear regression, both of the treatments in the second experiment began with a ratio within two standard errors of the theoretical values, while neither of the first experiment treatments were. This is somewhat unexpected, as it was during the first experiment that the aggregate productive abilities were public knowledge.

Nine of the twenty treatment groups were designed to have a theoretical equilibrium with a range of possible trading ratios, almost all of which would leave both types of subjects better off[4]. For the overall means, only two of the observed trading ratios were within two standard errors of the theoretical ratio. One of these two continued to remain in the neighborhood of the theoretical ratio for both the asymptotic and linear trend regressions. For the linear trend, four of the nine treatments with an equilibrium trading range remain within two standard errors of the mean theoretical value, while only two are that close for the asymptotic trend. If the entire range is considered, then we find that three of the overall mean trading ratios fall within the range consistent with the equilibrium. However, this occurs when the range of consistent ratios is between 2:5 and 5:2. For those cases where the equilibrium trading ratio lies between 1:5

[2]treatments 9 and 10 were conducted immediately following treatments 7 and 8, while treatments 16, 17, 18, 19 and 20 occurred immediately after treatments 11, 12, 13, 14, and 15. See table 2 for details.

[3]Groups 7, 8, 9 and 10 were recruited from subjects who had previously participated in this experiment, either during an earlier session or in a classroom setting. See table 2 for details.

[4]Groups 1, 3, 4, 9, 11, 13, 16, 17 and 18. See table 2 for details.

and 1:2, none of the observed overall mean trading ratios fall within this range. For the linear trend regression, there is one case where the observed initial trading ratio falls within the 1:5 and 1:2 range, and one where the boundary is within two standard errors. The situation is the same for the asymptotic regression, although for different treatments. This is also a surprising result, as it was expected that with a range of trading ratios where both types of agents could fully specialize and trade, and gain from doing so, that the system would converge at a relatively rapid pace. For treatments with a single equilibrium price, on type of agents cannot benefit by trading at the theoretical equilibrium. We would not expect this case to result in much trading.

From the trading ratio results alone, it does not appear that the system converges very quickly towards the price predicted by theory. Another prediction of the basic theory is that agents will specialize in producing that good where they have a comparative advantage. To measure the degree of specialization, a 'specialization ratio' is calculated, $SR = (S_i - S_i^A)/(S_i^* - S_i^A)$. This is the ratio of the excess over autarky production in that sock for which the agent has a comparative advantage, $(S_i - S_i^A)$, to the excess that is consistent with the theoretical equilibrium, $(S_i^* - S_i^A)$. If the subject chooses self-sufficiency, then the ratio equals zero. If they choose a production level consistent with the theoretical equilibrium, then the ratio will equal one. For interior equilibria, the ratio can exceed one as the subject may specialize too much. Table 5 reports the mean specialization ratios for each type of treatment, as well as coefficients estimated for linear and asymptotic regressions. A Davidson and MacKinnon J-test was again used to compare the linear and asymptotic models based on the data for the original groups. Both test were again significant. However, the fitted values of the linear trend added to the asymptotic trend regression was significant at the 0.0267 level, while adding the asymptotic fitted values to the

Table 5: Level of specialization

	Mean	Linear Trend		Asymptotic Trend	
Group	Ratio	Intercept	Trend	Asymptote	Trend
1	0.359*	0.345*	0.002	0.383*	-0.092
2	0.459*	0.728*	-0.041	0.250	1.302
3	0.038	0.045	-0.001	0.040	-0.007
4	0.298*	0.215*	0.013	0.343*	-0.172
5	0.584*	0.367*	0.023*	0.668*	-0.471
6	0.648*	0.474*	0.029*	0.782*	-0.540
7	0.303*	-0.023	0.047*	0.625*	-1.455
df	1039		1032		1032
R^2	0.291		0.305		0.310

linear trend resulted in a significance level of 0.000407. This suggests that the linear model adds less to the asymptotic model than the asymptotic adds to the linear. However, since both are significant, both results are reported. The results are reported only for the regressions where treatments are grouped as in table 3, as a likelihood ratio test indicated that the model was not significantly changed with these restrictions.

If the price induces subjects to specialize, as suggested by the Hayek Hypothesis, then we expect to see a positive slope on the linear trend, and an upward approach to an asymptote in the neighborhood of one. The results of the regressions show that the specialization ratio is significantly different from one for all groups, except group 2. Further, none of the estimated asymptotes are within two standard errors of one. Asymptotically, 6 of 7 trend coefficients are estimated with a negative sign, indicating that the asymptote is being approached from below. However, all but two of the linear tred terms are positive, and 3 are significant, showing that the degree of specialization is increasing. This suggests that the level of specialization is initially falling and then increasing.

To explore the possibility of initially high specialization which then falls

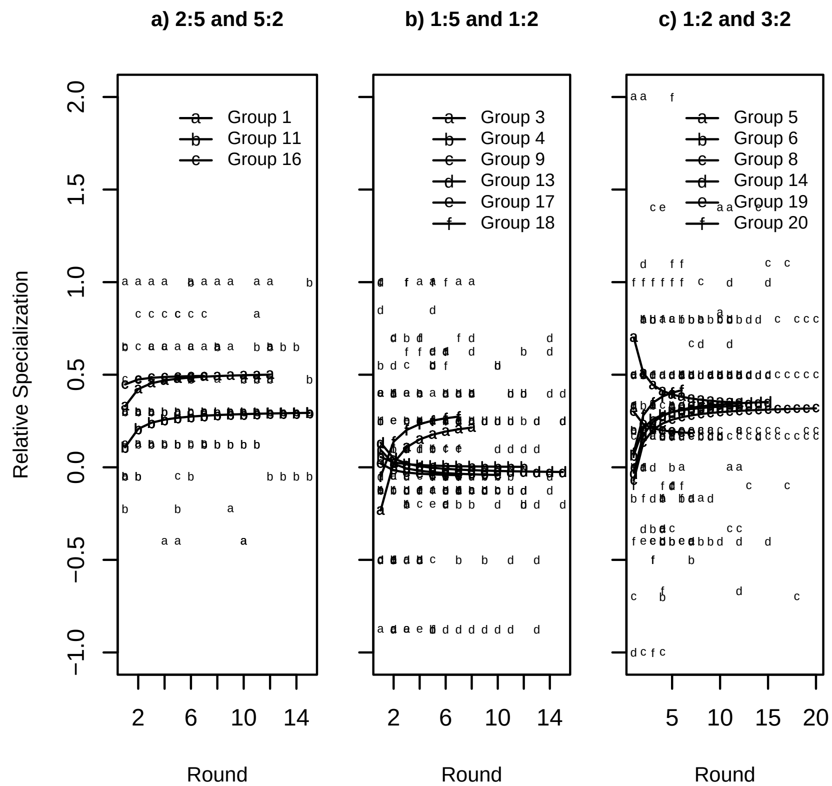


Figure 2: Specialization ratio with asymptotic trend for selected groups. Lines mark estimated asymptotic trend for each treatment group.

before beginning to increase, two additional regressions were run. In one, the linear and asymptotic trends were both present. Conceptually, the series is then asymptotically approaching a trend. In the other a quadratic term was added. However, the only case where the augmented model is significantly different is when the asymptotic trend is added to the linear trend, and then only barely. Since there was no clear pattern in significance or the estimated values, the results are not reported.

Figure 2 plots the specialization ratio against round for three sets of groups.

The types '2:5 and 5:2' groups (panel a) are groups 1, 11, and 16, symmetric combinations of subject types A and B, with a theoretical equilibrium of complete specialization and a trading ratio that falls between 2:5 and 5:2. For the asymptotic regression, these groups approach from below. Although the asymptote for all three cases is significantly below one, in two of the three cases it is higher than for either of the other sets displayed. The types '1:5 and 1:2' plot (panel b) displays the specialization ratio for 6 groups where the theoretical equilibrium has complete specialization, with a trading ratio that falls between 1:5 and 1:2. Four of six groups show asymptotes that are close to zero. The final plot is for the types '3:2 and 1:2' groups (panel c), where the subjects have opportunity costs of 3:2 or 1:2. For these groups, the equilibrium trading ratio is 1:2. These groups lie between the other two in their behavior, with asymptotes in the neighborhood of 0.3.

The group of symmetric traders with both a range of mutually beneficial trading ratios and a theoretical ratio of 1:1 is the case where specialization was considered the most likely. The trading ratio could be considered 'natural', and at that ratio both types of subjects could gain by specializing and trading. This case did show the highest degree of specialization, but it was only about half of that which would be consistent with theory. The symmetric traders with a theoretical equilibrium trading ratio of between 1:2 and 1:5 was expected to have some difficulty. Both subjects are individually relatively better at producing left socks than right socks. They do not have any information about the abilities of other traders, and therefore must rely on the price to suggest which way to specialize. As can be seen in the center pane of figure 2, a negative specialization ratio persists for many rounds, indicating that some subjects are producing a type of sock inconsistent with their comparative advantage. Without being able to find a mutually beneficial trading ratio, there would not be anything

Table 6: Relation between relative number of pairs produced and degree of specialization. The relative number of pairs produced is the total number of pairs the individual has at the end of the round divided by the number of pairs that are predicted by theory.

Group	1	2	3	4	5	6	7
Intercept	0.490*	0.652*	0.694*	0.661*	0.694*	0.719*	0.760*
Spec.	0.257*	0.055	0.090*	0.149*	0.358*	0.082*	0.088*

to induce subjects to correctly specialize. As they repeatedly ended the round with unsold inventory, it is not surprising that they then gravitated towards self-sufficiency. For the groups with a single equilibrium price of 1:2, the degree of specialization was less than for the 1:1 group, but it did not tend towards zero. It was relatively easy to identify the appropriate direction of specialization, as both types were individually superior in producing that good in which they also had a comparative advantage. However, at the theoretical equilibrium price, one type of agent would be indifferent between trading and being self-sufficient. It would therefore be difficult for the price to induce the right amount of specialization by this type of subject, and without it the trading opportunities for the other type would be limited.

Table 6 shows the relationship between the degree of specialization and the relative number of pairs produced. The relative number of pairs produced is the total number of pairs the individual has at the end of the round divided by the number of pairs that are predicted by theory. This ratio is equal to zero if the agent does not produce any pairs, which would require the agent to fully specialize and then not engage in any trades. It would equal one for any subject that attains the theoretical number of pairs. This is a proxy for the profit that the individual earns, as the conversion rate from pairs to dollars was scaled to equalize the expected earnings for each subject. Of the replicate treatments, whose results are in groups, 1, 3, and 4, group 3 has the weakest relationship between pairs produced and specialization ratio. In group 3 both types of traders had an R:L opportunity cost less than one. For this group, specialization was only barely profitable. This is consistent with the observation that the price was unable to attain the theoretical equilibrium, so that the price would not be able to indicate what type of specialization was appropriate.

A different way to look at the experiment is as a coordination game. In this game, subjects are trying to coordinate their production decisions so that the remaining inventory is minimized. This remaining inventory has no value. Out of a total of 235 rounds reported, in 70, less than 30%, was the final inventory positive in both types of sock. However, there was only one case where subjects were able to coordinate on production levels that resulted in a final inventory of zero for both types of sock. From the results so far, testing the predictions of classical Richardian trade theory seems at best to be inconclusive. However, if the coordination is improving, then we may see a reduction in the amount of unused inventory as the number of rounds increases.

Table 7 reports the results of constant, linear, and asymptotic regressions of coordination efficiency on round. Coordination efficiency is defined as $1 - I/(P - I)$ where $I = |L - R|$ is the inventory after trading, independent of sock type, and P is the total number of pairs produced. This number is calculated for each round. The coordination efficiency is equal to one if all produced socks are assembled into pairs, and equals zero if no pairs are produced. If the coordination efficiency is improving, then this value will trend upward with an increase in round number.

The results in table 7 shows a consistent upward trend in the linear case, and an approach from below in the asymptotic case. This shows that for almost all treatments, the amount of unused inventory in each group fell as the experiment

Table 7: Coordination efficiency. The coordination efficiency is the defined as $1 - I/(P - I)$, where $I = |L - R|$ is the type independent inventory at the end of each round and P is the number of pairs produced during the round. Astrices indicate significance at 95% or higher.

		Linear Trend		Asymptotic Trend	
Group	Mean	Intercept	Trend	Asymptote	Trend
1	0.646*	0.446*	0.036*	0.744*	-0.378*
2	0.598*	0.382*	0.048*	0.735*	-0.468*
3	0.512*	0.343*	0.048	0.603*	-0.269
4	0.659*	0.517*	0.026	0.713*	-0.208
5	0.701*	0.564*	0.025	0.824*	-0.474
6	0.701*	0.596*	0.019	0.708*	-0.029
7	0.707*	0.524*	0.019*	0.777*	-0.393*
8	0.739*	0.625*	0.012	0.775*	-0.200
9	0.721*	0.475*	0.055*	0.912*	-0.652
10	0.760*	0.650*	0.025	0.786*	-0.088
11	0.835*	0.676*	0.023*	0.916*	-0.367*
12	0.632*	0.582*	0.007	0.713*	-0.366*
13	0.607*	0.574*	0.005	0.626*	-0.083
14	0.759*	0.691*	0.010	0.823*	-0.290
15	0.714*	0.801*	-0.012	0.645*	0.311
16	0.774*	0.977*	-0.068*	0.603*	0.463*
17	0.618*	0.354*	0.088	0.735*	-0.316
18	0.633*	0.563*	0.023	0.637*	-0.011
19	0.686*	0.691*	-0.002	0.613*	0.198
20	0.772*	0.691*	0.032	0.899*	-0.312
df	215	195		195	
R^2	0.942	0.958		0.955	

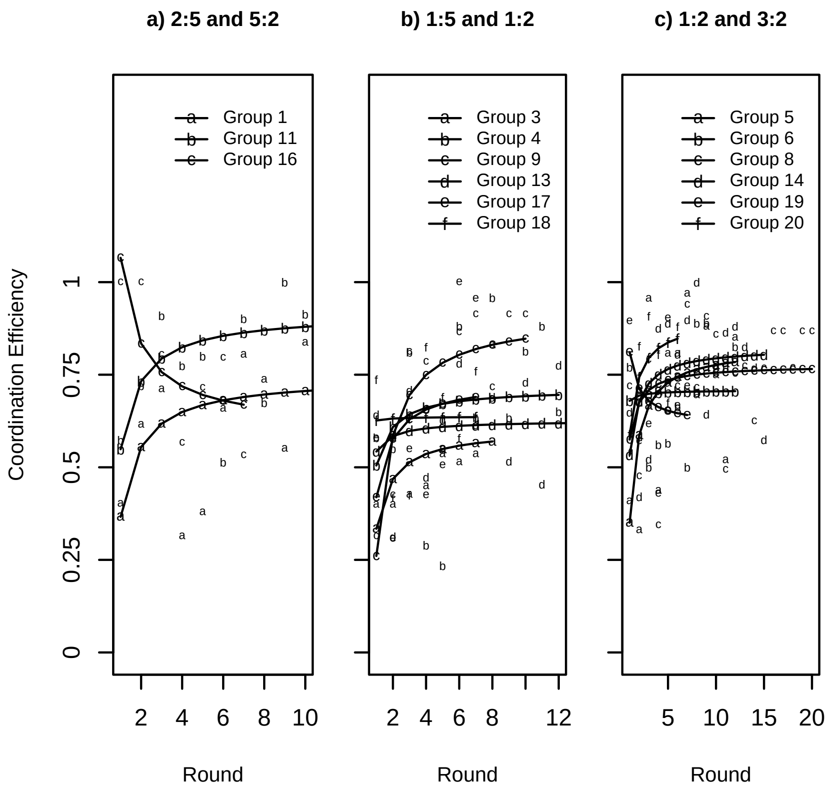


Figure 3: Coordination Efficiency.

proceeded.

Figure 3 plots the coordination efficiency for the three groups with three or more replicates. In all but two cases the coordination efficiency approaches the asymptote from below. The coordination efficiency only occasionally approaches one. The average level is lower for the 'Types 1:5 and 1:2' group than the other two groups. This group had the highest average number of pairs produced, 65.17 per round. The other two groups had averages of 56.88 and 58.83. Of these totals, the 'Type 2:5 and 5:2' group traded for 24.44 pairs on average, or 43% of total production. The 'Type 1:2 and 3:2' group traded for 14.81 pairs, or 25% of total production. The remaining group traded for 11.07 pairs, or 17% of total production. Together with the previous results, this suggests that coordination of production is difficult when the only source of information is the price.

To explore the impact of group size, availability of aggregate information, and previous experience, a separate regression was run with dummy variables identifying those groups which differed in these characteristics. This regression was run with group 1 as the base case, with deviations of the other groups thus estimated as coefficients. Overall, only the coefficient estimated on the slope of the linear trend for groups with six members was significant at the 6% level. The remaining coefficients for group size, information, and experience were insignificant for the linear trend. For the asymptotic trend, only the coefficient on the intercept for the information treatment was significant, and this at the 4% level. The estimated asymptote for the information treatment is then statistically equal to one. This suggests that for the information treatment – knowledge of the aggregate productive abilities – increased the ability of this group to coordinate on an equilibrium where ending inventory was minimized. However, together with the other results reported here, it does not appear that information, group size, or experience is able to move the experimental economies substantially closer to economic efficiency.

4 Discussion

This experiment was designed to simulate as closely as possible a classical Richardian trading economy with limited information. There was no currency, no inventory, no shocks to production abilities, etc. Each subject had a fixed production technology and interacted with a group of other producers, some of whom had a different production technology. Informationally, in most treatments subjects knew only their own productive technology and the ratio at which socks were being traded between members in the group. A small subset of the experiments also reported to the subjects the aggregate productive abilities of the group. However, productive abilities of each group member, as well as their inventories, and the identity of the source of a trading offer, was not public. If the equilibrium of classical theory was realized, it would have been strong support for the Hayek hypothesis in an economy with production.

The results reported here neither strongly support nor clearly refute the Hayek hypothesis in an economy with production. Most treatments generate a trading ratio that is significantly different from the trading ratio predicted by theory. However, many of them are trending toward the theoretical equilibrium. This can be interpreted either as a challenge to the Hayek hypothesis, or an indication that more time is required for the economy to converge. The level of specialization was also considerably lower than predicted by theory. It was highest for those treatments where the appropriate type of specialization was 'obvious' and lowest when this was not the case. This can also be interpreted as a refutation of the Hayek hypothesis, or simply a reflection of the fact that without prices reaching their theoretical values, the incentives are not in place to reward the specialization consistent with theory. This latter interpretation is borne out by the relationship between specialization and the number of pairs produced. For those groups where specialization was relatively high, the payoff to specialization was too. However, for those groups that did not specialize, the return to specialization was low. This result can be interpreted as supportive of the Hayek hypothesis, in the sense that the incentives generated by the price system are inducing specialization in those environments where it in fact pays to specialize.

Although designed to test the Hayek hypothesis in an economy with produc-

Table 8: Normal form game. Payoffs in pairs, with strategies as production bundles of right and left socks.

		Producer Type A	
		20,8	25,6
Producer	8,20	14,14	14,12
Type B	6,25	12,14	15.5,15.5

tion, this experiment may in fact have become an experiment in coordination. Consider the normal form game shown in figure 8. The payoffs are pairs, calculated under the assumption that all possible pairs are assembled and the trading ratio is 1:1 for each strategy. The strategies shown are two of the production bundles that subjects of type A and type B can choose. There are two Nash equilibria for this subset of the strategy combinations, 20,8 with 8,20, and 25,6 with 6,25. The strategy combination 25,6 with 6,25 is Pareto superior to the combination 20,8 with 8,20. However, if the system is at the 20,8 with 8,20 equilibrium, a unilateral defection by either type of producer will leave that type of producer worse off. Consequently, without a mechanism of coordination, it is unclear which Nash equilibrium will be chosen.

Initial implementations of the experiment in a classroom setting suggested that the use of a trading ratio may have been confusing. Most people in developed economies commonly deal in currency. Bargaining over a trading ratio is far less familiar. Without a visual representation of the amount being given up in exchange for a particular amount to be received, the idea of a 'higher' ratio might be difficult for subjects to understand. The instructions and self-test were carefully written to educate the subjects in this trading method, but some subjects continued to indicate confusion. An experimental currency was not implemented for two reasons. First, the design was intended to be consistent with a classical Richardian economy, which does not require a currency. Second, if subjects are making currency based offers, two markets must be run, one for each type of sock. This would complicate the programming task, and likely add a further cognitive burden as the incentives to specialize would flow from the relationship between the prices in the two markets, not from a single terms of trade. However, a logical extension of this work is the implementation of a currency based system. An initial version of this experiment was implemented using a currency. The results were generally consistent with those found here, specialization was far less than that predicted by classical theory.

The experiment may also have been 'too much fun'. Subjects felt that this experiment was very enjoyable, and indicated an eagerness to participate again. Thus, rather than a serious effort to earn money, the experiment may have been more of a recreational activity. Subjects may have been producing a small amount of inventory to 'gamble' with, production which they were not relying on for earnings. Any pairs produced by trading was 'gravy' on the earnings realized during the production phase. The fact that specialization declined in those groups unable to find a mutually beneficial price, and the fact that earnings and specialization were correlated, suggests that the monetary incentive was at least partially effective. If dominance of the monetary incentive was not achieved, then a clear extension is conducting the experiment again with a higher payment. An obvious barrier of course is securing the financial support to do so.

Beyond higher payments and the use of a currency, several other extensions of this experiment suggest themselves. First, complete information. This experiment developed in the spirit of Smith's [1982a] work on the Hayek hypothesis, extending the concept from an economy with only trading opportunities to one with production and trading. Thus, information was kept to a minimum. From this base, elements of information can be progressively added – individual production technologies, aggregate inventory, individual inventories, etc. – to see their impact on the resulting equilibrium. Alternatively, a set of full information experiments could be conducted, followed by a set with intermediate levels of information. Both approaches seek to discover which pieces of information are most critical in moving a Richardian production economy to efficiency.

The coordination problem and its relationship to risk aversion can be explored through a couple of further modifications of this experiment. One approach is to increase the number of bundles from which the subjects can choose. This would allow the subjects to take smaller chances, in terms of specialization. Subjects may thereby be more willing to take a small specialization risk. If all do so, then the system is more likely to move towards the theoretical equilibrium. Another approach is to allow inventory carryover between rounds. With inventory carryover, subjects would be able to recover from a specialization 'mistake' through later production decisions. Those who specialize early could also wait for others to 'catch up' in terms of their willingness to specialize. Finally, a 'safety net' could be introduced. If types of traders are conceived of as producers in a country, as in the experiment by Bergstrom and Miller [1999], then a country based pooling of earnings may induce a greater degree of specialization. The incentive to free ride on the earnings of others would work in the opposite direction to the incentive to play it safe with ones own production.

The interaction of risk aversion and the coordination problem in this experiment suggests that social safety nets may in fact encourage economic efficiency. Specialization is costly. The largest investment in specialization that most people make is their education. When and/or where the welfare state is strong, students may be more inclined to pursue studies that interest them, in contrast to societies with weak welfare states. In this latter case, one would expect students to be far more inclined to pursue an education that has a high probability of leading to a paid employment. An econometric analysis of the strength of the welfare state and the program choices being made by students would provide an interesting expansion of the results of this experiment. A related, and likely more difficult, analysis would be an estimation of the efficiency with which the educational resources are being used.

5 Conclusion

In this paper the results of an experimental implementation of a Richardian economy with limited information was used to assess the Hayek hypothesis. Rapid convergence to the equilibrium predicted by theory was not observed, and in many cases the system was not even moving towards the theoretical equilibrium. However, it is unclear whether this is a failure of the Hayek hypothesis or indication that in an economy with production price signals simply act somewhat more slowly. When production is present, a coordination problem is created that does not exist in an experimental market. Consequently, Hayek's hypothesis may stand un-assailed, but with groups being unable to coordinate on the theoretical equilibrium of the Richardian economy.

A Instructions

Please read these instructions carefully. These instructions will also be read to you before the experiment begins. You will have an opportunity to ask questions after the instructions have been read. Please do not ask any questions until you are prompted to do so.

You are about to participate in an experiment studying decision making. In this experiment you will be assembling pairs of virtual socks. You assemble socks by choosing bundles with different numbers of left and right socks and/or by trading socks you have for socks you need. You will be trading in a group of four people, to which you will be randomly assigned when the experiment begins. You will be paid for each pair you produce. The amount you will be paid for each pair will be reported to you as the experiment begins. You will be paid in cash at the conclusion of the experiment.

Software Requirements

This experiment runs through your web browser, using an applet written in Java. If you have registered for this experiment, then you must have already installed the Java Runtime Environment on your computer.

You should be viewing these instructions through a window that was generated by the experiment applet. You should not be viewing these instructions in a web browser such as netscape. If these instructions are not visible to you, contact one of the facilitators NOW!.

The various components of the interface before you are managed by the Java Virtual Machine. If the contents of any component change, the interface may be redrawn, and some components will shrink or vanish. If this occurs, maximizing the interface should restore all components. To avoid these problems, you should maximize your display at the start of the experiment.

Your participation in this experiment depends on your computer remaining connected to the server computer. If your computer crashes, or if network traffic is interrupted between your computer and the server, then you will be unable to resume participation in the experiment. You will only be paid for those rounds during which you remain connected. To minimize the risk of your connection going down, you should not use any other applications while the experiment is in progress. This is particularly true for other applications which use the network, such as web browsing, file downloading, or chatting.

If the system goes down, either due to a network or software failure, the experiment will be terminated. You will be paid in accord with the time during which the system functioned successfully, and invited to participate in a future implementation of this experiment.

Specific Instructions

Each round of this experiment is divided into two parts. In the first part of each round, you must choose a bundle containing a particular number of left and right socks. Almost all bundles will have unequal numbers of the two types of socks. Your choice will leave you with a certain number of pairs and an inventory with either left or right socks. You will have thirty seconds to make your choice.

In the second part of the round you can trade the socks in your inventory for complementary socks. To solicit trades, you post offers that are visible to other members of your group. An offer consists of a trading ratio you are willing to accept, e.g. 5 left socks for 3 right socks, and a maximum number of socks you will part with at this ratio. You can only post an offer if the ratio being offered is higher than that being offered by anyone else. Your offer will result in a trade if your ratio is equal to or higher than the ratio being offered by someone with the socks you are seeking. You will have 3.5 minutes to trade socks. The next round will begin as soon as the trading period is over. At this point any remaining socks in your inventory will disappear, and you will once again have to choose a bundle of left and right socks.

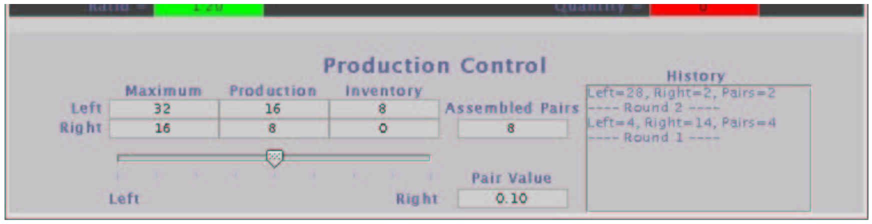
For example, suppose that you have left socks to trade and someone else with left socks is offering to provide 1 left sock in exchange for 2 right socks. An offer of 2 left socks in exchange for 5 right socks would not be accepted, while an offer of 2 left socks for 3 right socks would be. The computer will not allow you to submit offers that are too low Now, suppose that someone with right socks is offering to provide 3 right socks in exchange for 7 left socks. If you offer to provide 3 left socks in exchange for 4 right socks, then a trade will not occur. However, if you offer to provide 5 left socks in exchange for 2 right socks, then a trade will occur. The computer will indicate when a ratio is high enough for a trade to occur. The number of socks traded will be the lesser of the maximum indicated by each party to a trade.

As soon as a trade does occur, all offers are cleared and the process begins again. You can make as many trades as your inventory will allow before the round expires. You will only ever have one type of sock as inventory to trade with. If you acquire socks of the opposite type to those in your inventory, the computer will immediately calculate the number of pairs you can produce, and adjust your inventory accordingly.

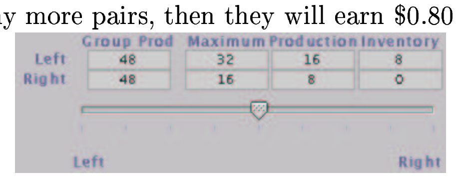
Example

The following images illustrate the actions you can take in this experiment. The interface has three parts, a countdown timer at the top, a trading panel in the center, and a production control panel at the bottom. The trading and production control panels will be dark grey and inactive until the experiment begins. While the experiment is running, only one of these two panels will be active at any time; the production control panel during the first part of each round, and the trading panel during the second part.

During the first part of each round you choose a bundle of left and right socks. This is your 'production'. You choose a bundle by moving the slider in the production control panel. Moving the slider towards the left increases the number of left socks in your bundle and reduces the number of right socks. Sliding it to the right has the opposite effect. The numbers in the **Maximum** column show the maximum number of each type of sock for the bundles available to you. Each tick mark on the slider represents one of the bundles you can choose. The **Production** column shows the number of socks of each type in the bundle that corresponds to the slider position. The **Inventory** column shows the number of socks that will be left in inventory if this bundle is chosen. You can only have positive inventory in one type of sock.



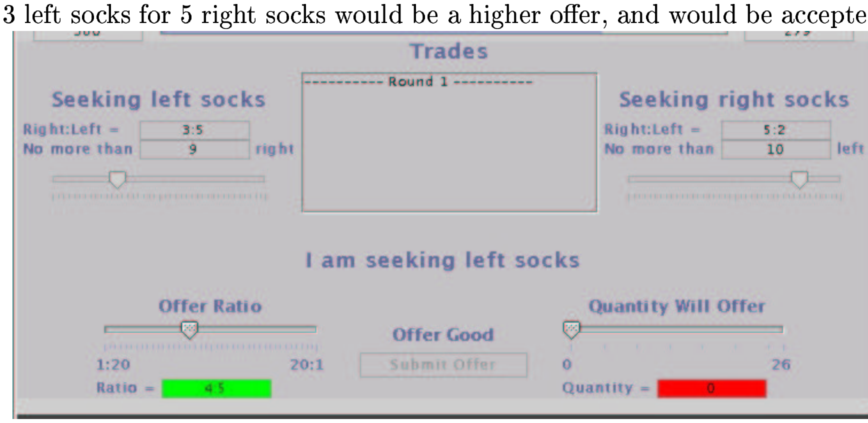
The image shows the production panel during the first phase of the round. The **History** pane on the right shows the composition of the selected bundle in each of the previous rounds, as well as the total number of pairs assembled. This total includes any pairs that are assembled as a result of trading. The **Assembled Pairs** box shows the number of pairs assembled during this round. It is updated as you slide the production slider, and whenever a trade occurs. The **Pair Value** box shows the number of dollars you will be paid for each pair of socks you assemble. In this case, if the slider is moved completely to the left, the bundle will contain 32 left socks and no right socks. No pairs will be assembled and the inventory at the end of the production phase will contain 32 left socks. If the slider is moved all the way to the right, then 16 right socks will be produced and no left socks. At the end of the production phase, no pairs will be produced, and there will be an inventory of 16 right socks. At the current position, 16 left socks and 8 right socks are produced. This generates 8 pairs of socks, leaving an inventory with 8 left socks. If this person is unable to assemble any more pairs, then they will earn $0.80 for this round.



For some groups, the total productivities for the group are also shown. These values will be shown in an extra column, as shown in the image above. For this example, if the members of the group all chose to produce left socks, then 48 left socks would be produced and no right socks. Likewise, if all the members of the group chose to produce right socks, 48 right socks would be produced and no left socks.

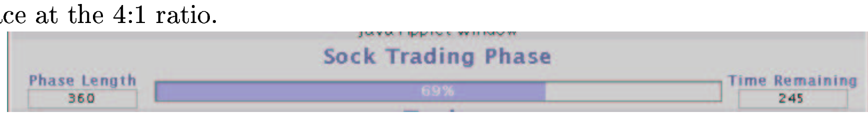
After the production phase is completed, the production panel will turn dark grey and become inactive. However, the inventory and assembled pair entries will be updated if trades are made. The trading panel will turn light grey and become active. There are two controllers in the trading panel, the offer ratio slider and the quantity slider. The offer ratio slider controls the trading ratio that you will accept. The quantity slider controls the maximum number of socks you will give up at this trading ratio. This panel also indicates what type of sock you are looking for. In this case, this person is looking for right socks. Therefore, this person must have left socks in their inventory. The upper left panel shows the ratio being offered by others who are seeking right socks, while the upper right panel shows the ratio being offered by those seeking left socks. The field in the center reports the trades which have occurred.

In the example image, the offer slider position represents an offer to give up 2 left socks if 5 right socks are received. This offer ratio is the same as the offer being made by someone else with right socks. Since this person's offer is not higher than the offer reported in the top right, the 'submit offer' button is inactive. The inactive slider in the top left of the panel shows the position of the slider that corresponds to this trading ratio. For this person's offer to be higher the slider must be further to right than the position shown in the top left. Note that an offer is higher if you are willing to give up more of the socks you have for each complementary sock you get. In the example shown, an offer of 3 left socks for 5 right socks would be a higher offer, and would be accepted.



This example represents a person with a right sock inventory. They are seeking left socks. In the top right of the panel is shown the lowest trading ratio that anyone with left socks is willing to accept. In this case, this person would have to give up 5 right socks to get 2 left socks. The slider in the top right of the panel shows how far over the offer ratio slider must move for a trade to occur. The offer ratio slider currently represents an offer ratio that is higher than the highest offer being made by anyone else with right socks, 3 right socks provided in exchange for 5 left socks. As soon as the quantity slider is moved to a position above zero, the 'Submit Offer' button will become active, allowing the offer to be submitted. Note that every time an offer changes, either for the sock you are seeking or for the sock you have, part of the display will flash. When the offer for the sock you have changes, the top left corner will flash, while when the offer for the sock you are seeking changes, the top right corner will flash.

In this example, the offer ratio slider has been moved far enough to the right for an offer to occur. The **Ratio** = box turns yellow if the ratio will result in a trade. With the quantity slider indicating that up to 8 socks will be traded, the 'Submit Offer' button is active. Comparing the offer ratio slider on the lower left to the slider in the upper right of the panel, the offer ratio slider is further to the right. The ratio being offered is therefore higher than it needs to be for a trade to occur. This person is offering to give up 4 right socks in exchange for one left sock. Someone with left socks is asking for 5 right socks in exchange for 2 left socks, a lower offer. If the submit button is pressed, a trade will take place at the 4:1 ratio.



The top of the display shows the time remaining, and the phase that is currently underway. The box on the left shows the total length of the phase, while the box on the right shows the time remaining. The bar counts down as the time remaining falls.

If you have any questions, as the facilitators now.

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