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 (1992) 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 Ricardian equilibrium.

JEL: C9, D8, F1

Keywords: experimental economics, Hayek hypothesis, trade

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

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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 [1995] provides an overview of various market institutions, while Kagel [1995] 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 such that every student could 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. Within one country, all students have the same opportunity costs, so that there are no gains from trade. In 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 with Bergstrom and Miller [1999]. However, it is conducted in an environment with greater control over subject communication as a means of facilitating coordination. Further, no subject has complete information about the production possibilities and inventories of any other subject. All information about the decisions of others is conveyed through the observed trading ratios.

The absence of complete information is a departure from the classic treatment of market efficiency, a change 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 society's 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 Ricardian 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 therefore 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 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

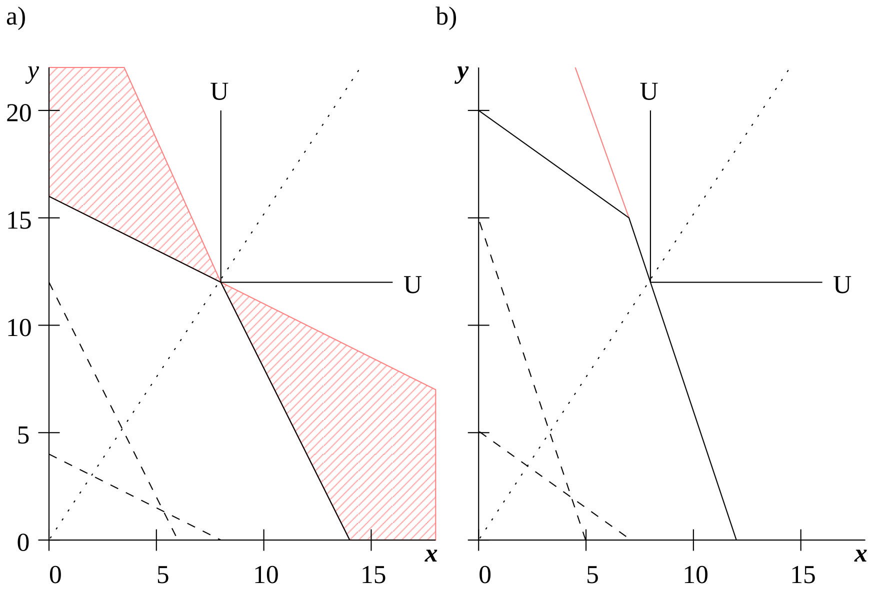

Figure 1: Production Possibilities Frontiers, Indifference Curves, and equilibrium price ratios. 'L' shaped lines labeled 'U' mark a Leontief indifference curve with single point of contact on PPF. Dashed lines mark production possibilities for individual producers. Unmarked solid lines identify combined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

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 to 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 form the basis of the tests of the model.

The Hayek hypothesis holds that 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 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 average 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. For the 1:2 case and the 1:4 case however, 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 successfully installed the Java^{TM}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 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 reinforce 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 from a set of production bundles by moving a slider (display graphics are part of the instructions shown in Appendix A). Each bundle contained a particular number of left and right socks. The bundles ranged from extremes

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[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.

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 the type of sock they needed. Subjects had only 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, 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 absolute advantage, group size, and knowledge of aggregate production possibilities. During the November 2002 session, the production phase lasted 30 seconds and the trading phase ran for 210 seconds. In the first session some idle time was observed, so it was decided to slightly reduce the length of the phases. During the other two sessions, the production phase lasted 20 seconds and the trading phase 180 seconds. Table 1 shows the three treatments. The November session was concluded within two hours. The sessions in January and March were concluded in slightly more than three hours. The second experiments conducted in January and March were conducted with the same subjects as used during the first experiments, but randomly assigned to new groups, with random assignment of new types.

Table 1 also shows the range of trading ratios consistent with the theoretical equilibrium for each treatment, and the mean equilibrium trading ratio. 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 session. For the sessions with two experiments, subjects were paid only after the second experiment. However, they were privately informed of their earnings at the end of the first experiment. For all sessions, 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

Treatments:		1	2	3
Characteristics				
Opportunity Cost	Type #1	5R:2L	1R:2L	1R:2L
	Type #2	2L:5R	1R:5L	3R:2L
Extremes	Type #1	40R or 16L	40R or 80L	30R or 60L
	Type #2	16R or 40L	8R or 40L	30R or 20L
Autarky Pairs	Type #1	11.43	26.67	20
	Type #2	11.43	6.67	12
Bundles		9	9	11
Equilibrium				
Range of Trading Ratios		2:5 to 5:2	1:5 to 1:2	1:2
Mean Trading Ratio		1:1	1:4	1:2
Specialization	Type #1	40R, 0L	40R, 0L	10R, 40L
	Type #2	0R, 40L	0R, 40L	30R, 0L
Pairs	Type #1	20	32	20
	Type #2	20	8	20
Total Pairs		40	40	40
Reps (rounds)		3 (7-14)	6 (7-14)	6 (6-20)

Table 1: Treatment summary. 'L' and 'R' indicate left and right socks respectively. The characteristics assigned to each type of subject, the opportunity cost or slope of the subject's PPF, limits of the subjects' PPF, autarky pairs and number of bundles along PPF, are reported. Theoretical equilibrium outcomes, trading ratios, specialization and number of pairs at mean trading ratio, and total pairs, are also reported. At the bottom of the table, the number of replicates for each treatment and the range of rounds for those treatments is shown. Subjects in replicates with less than ten rounds were experienced in an earlier experiment.

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.

There were some variations between the groups. The different number of rounds is due partly to computer problems, which lead to the experiment being terminated early during its first run. In this case, 12 rounds of usable data were collected. The second experimental session involved only subjects who had participated during the first session. Thus, the participants in this second session were more experienced. The first experiment of a session ran for at least 12 rounds. Those experiments with fewer rounds were second experiments of a session. It was expected that convergence would be more rapid in these situations, as subjects were familiar with the display and the process. Preliminary analysis of the data from the first session showed that behavior was far from that predicted by theory. Two possible reasons for these results were entertained, and modifications of the experiment implemented. The first modification was a change in group size. During the first session, all groups had four subjects, two of each type. This size was selected as it has been shown that a double auction can consistently find the competitive equilibrium, and that near competitive outcomes are commonly observed in duopoly and even monopoly situations [Davis and Holt, 1993]. However, given the first session results, groups with six subjects were included in later sessions. In an effort to accelerate movement towards equilibrium, a further 'treatment' was also included in some groups, common knowledge of the aggregate productive abilities. This was implemented as an additional field added to the production control part of the display. Several additional small treatments were also created as the result of network connection failures. These last groups have not been included in the analysis reported below.

3 Results

If the Hayek hypothesis is correct, then the critical means of communication is the trading ratio. Figure 2 shows the overall trading ratio for each replicate, the total right traded divided by the total left traded, and the average trading ratio for each treatment. The average for treatment #1 is the highest in 14 of 15 rounds shown. The average for treatment #2 is the lowest in 11 of 15 rounds shown. The average for treatment #2 is always below treatment #1, and appears to be trending downward for much of the time that there are at least two replicates present. However, it remains well above the mean trading ratio predicted by theory, and only falls within the theoretical range in 3 of 15 rounds. The mean trading ratio for treatment #3 generally falls between the mean trading ratio for treatments #1 and #2. Over much of its range it is trending upward, remaining close to 1:1 for much of the latter half of the data shown. This mean ratio is far from the predicted equilibrium ratio of 1:2. Visually, it does not appear that the trading ratios are rapidly converging on the theoretical equilibrium price. The graphs may even suggest that the trading ratio 1:1 is acting as a focal point.

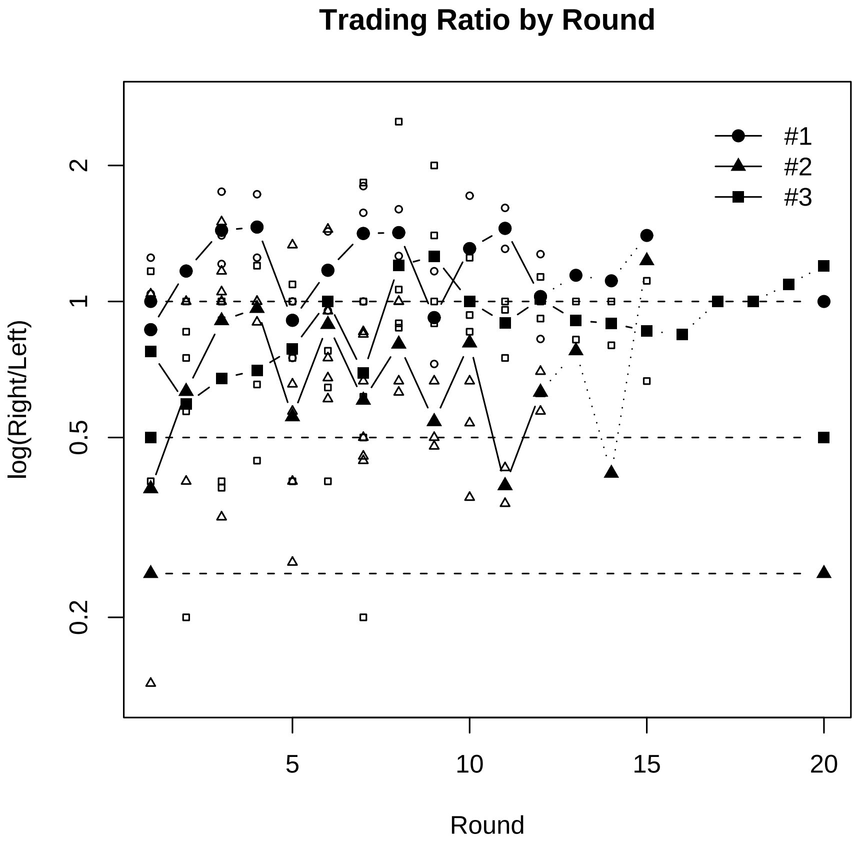

Figure 2: Trading ratio against round. Dotted segments show when only one replicate remains in treatment. Open symbols indicate trading ratio for each group. Ratio calculated as total quantity of right traded divided by total quantity of left traded during round. Dashed lines represent mean theoretical trading ratio.

$$\log(Right_{i,t}/Left_{i,t}) = \beta_1 D_{1,t} + \beta_2 D_{2,t} + \beta_3 D_{3,t} + \epsilon_{i,t}$$

Treatment	β_i	e^{β_i}	Theory	SE	P
#1	0.211	1.235	0.4 - 2.5	0.0834	0.0128
#2	-0.341	0.711	0.2 - 0.5	0.0665	0.0000
#3	-0.105	0.900	0.5	0.0601	0.0838

$R^2 = 0.2246$

$H_0 : \beta_1 = \beta_2 = \beta_3 = 0$ $F_{3,123} = 11.88$ $P = 6.97 \times 10^{-7}$

$H_0 : \beta_1 = \beta_2 = \beta_3$ $F_{2,123} = 13.39$ $P = 5.49 \times 10^{-7}$

Table 2: Dummy variable regression of log trading ratio on treatment.

Table 2 reports the results of an ANOVA regression comparing the mean trading ratio for each treatment. The normality of the residuals was tested using the Shapiro-Wilk test [Royston, 1982], and found to be violated ($P = 0.00011$). Therefore, P values close to the significance cutoff are suspect. The column labeled e^{β_j} contains the mean trading ratios for each group. The order of the mean trading ratios follows the order of the predicted mean trading ratios. However, only the mean trading ratio for treatment #1 falls inside the predicted range of trading ratios. The mean trading ratio for the other two groups do not fall within two standard errors of the range of theoretically consistent trading ratios. The trading ratios for treatments other than #1 are 'too' close to a trading ratio of one, suggesting that a ratio of 1:1 may be serving as a focal point. However, this focal point does not appear to be too strong, as the mean trading ratio for treatment #2 is strongly significant, indicating that in the log regression it is different from zero.

The results of a pairwise comparison of the coefficients is shown in Table 2. The final column in the table reports the P values, adjusted using the method suggested by Holm [1979] and implemented in the software package R [Ihaka and Gentleman, 1996]. Given the failure to reject normality for the residuals, the only treatments that may be significantly different are treatments #1 and #2. The ordering of the trading ratios is consistent with the predictions of theory, but the differences are not obviously significant. An asymptotic regression was also conducted (not reported). The intercepts (asymptotes) for two of three treatments are not significantly different from 1:1. For treatment #2 the asymptote is significantly different from zero, but does not lie within the predicted range. Only one slope term is significant, for treatment #3, showing that the asymptote is being approached from below. The only trend evident is trending away from the predictions of theory.

Given the failure of the normality test on the residuals, and the fact that there were variations between the groups, a non-parametric comparisons of the distributions of trading ratios is reported in table 4. By this test, all three treatments have different distributions of the log trading ratio. The replicates within treatments #1 and #2 do not differ significantly. However, there is high variation within treatment #3. A Kruskal-Wallace rank sum test was used to

Test	$\beta_i - \beta_j$	SE	P	Holm P
#1 vs #2	0.551	0.161	0.0004	0.0012
#1 vs #3	0.315	0.155	0.0218	0.0436
#2 vs #3	-0.236	0.135	0.0415	0.0436

Table 3: Pairwise comparison of log mean trading ratios. P values adjusted as suggested by Holm (1979).

Test	U	df	P	Holm P
All replicates	54.59	14	0.0000	-
#1	3.02	2	0.2206	0.2206
#2	9.36	5	0.0956	0.1913
#3	14.73	5	0.0116	0.0347
#1 and #2	34.58	8	0.0000	0.0002
#1 and #3	29.74	8	0.0002	0.0012
#2 and #3	33.59	11	0.0004	0.0017

Table 4: Kruskal-Wallace rank sum test for differences between groups. P values adjusted as suggested by Holm (1979).

pairwise compare all the replicates in treatment #3. The variation within this treatment is due to one replicate. This replicate had 4 subjects, total productivity information, and was the second of two experiments conducted during one session. The mean trading ratio for this group was 0.336, considerably below the theoretical ratio of 0.5, but also considerably closer to 0.5 than the overall mean of 0.900. Another replicate was identical to this one in all respects except for group size, having six members. However, this replicate was not significantly different from the any of the other replicates.

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. If the Hayek hypothesis is correct, then the trading ratio generates opportunities which make it profitable for agents to specialize in that type of trade consistent with the theoretical equilibrium. Since the trading ratio was not consistent with the theoretical equilibrium in treatments #2 and #3, these are likely to have less specialization than treatment #1. 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 $(S_i = S_i^A)$, then the ratio equals zero. If they choose a production level consistent with the theoretical equilibrium $(S_i = S_i^*)$, then the ratio will equal one. For interior equilibria, the ratio can exceed one as the subject may specialize too much.

Figure 3 plots the specialization ratio for each replicate and the mean specialization ratio for each treatment. There is little difference in the trends for treatments #1 and #3. Both show a slightly increasing trend during the early rounds followed by a relatively flat trend during the remainder of the experiment, generally below 0.5. Treatment #2 follows a different path, remaining in the neighborhood of 0.0. Between period 3 and 8, this treatment's average specialization ratio remained above 0.0, but for the remainder of the experiment it oscillated around zero.

Some individual subjects chose production levels consistent with the theoretical equilibrium, as evidenced by the presence of open symbols on the 1.0 line in Figure 3. However, the frequency of this behavior diminishes as the experiment proceeds. The tendency for subjects to choose their autarky point, the 0.0 line, is also low. However, this is in part a consequence of the fact that only one type of subject in treatment #3 had the option to exactly choose the autarky point. This restriction ensured that in all treatments there would be some inventory available to trade, and therefore almost surely offers being made. There were no rounds without offers. However, there were rounds in treatment #2 for some replicates when subjects all specialized in the same type of sock and no trades occurred. For one replicate, all subjects specialized in left socks during one round, in right socks during the next round, and then again in left socks. The information in the trading ratio was sufficient to induce this switch, suggesting subjects were taking it into account in their decisions. After this oscillation, differences in behavior appeared.

Table 5 reports the results of a dummy variable regression (ANOVA) of the specialization ratio on treatment type. The F tests indicate that equality of the means and all means equal to zero can be strongly rejected. However, the mean for treatment #2 is only just significant at the 5% level. Since normality of the residuals is also strongly rejected (Shapiro-Wilk, $W = 0.9729$, $P = 3.44 \times 10^{-9}$), the accuracy of this particular inference is unclear. These results do suggest that treatments #1 and #3 are not at their autarky points, while it is unclear whether treatment #2 is. In table 6 the results of a pairwise comparison of mean specialization ratios is reported. These results reflect the results of the ANOVA, treatments #1 and #3 are significantly different from treatment #2, while no significant difference can be detected between them.

Since the residuals do not satisfy the normality assumption, the results of a nonparametric comparison are also reported (Table 7). Between treatments the results are similar to those for the ANOVA, treatments #1 and #3 are strongly different from treatment #2, while the difference between them is less pronounced. However, using the Kruskal-Wallace rank sum test, treatments #1 and #3 are significantly different. Within treatments, the replicates for treatments #2 and #3 are not significantly different from each other. However, for the replicates of treatment #1, there are significant differences between them. The differences within treatment #1 are due to one replicate being different from the other two. This replicate included six subjects while the other two contained four. Total productivity information was not provided, and subjects

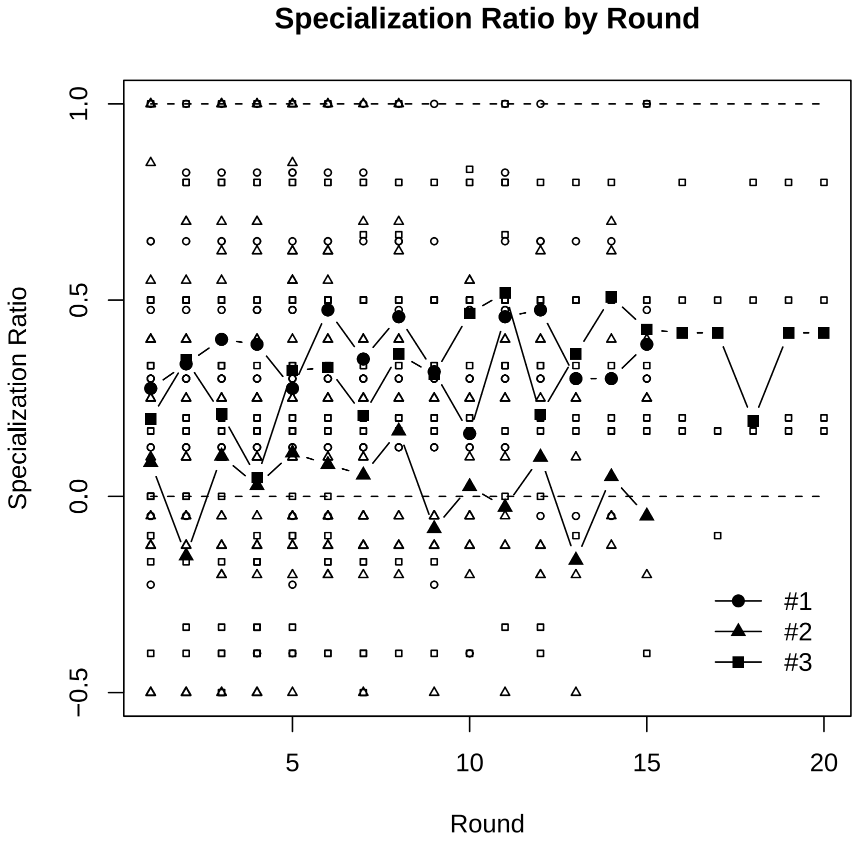

Figure 3: Specialization ratio by round. Open symbols mark specialization ratios for individual subjects. Close symbols and solid lines mark treatment averages. 1.0 indicates specialization that matches theoretical prediction. 0.0 indicates selection of the autarky point.

$$SR_{i,t} = \beta_1 D_{1,t} + \beta_2 D_{2,t} + \beta_3 D_{3,t} + \epsilon_{i,t}$$

Treatment	β_i	SE	P
#1	0.3698	0.0361	0.0000
#2	0.0558	0.0283	0.0493
#3	0.3039	0.0269	0.0000

$R^2 = 0.2801$

$H_0 : \beta_1 = \beta_2 = \beta_3 = 0$ $\quad F_{3,607} = 78.73$ $\quad P =< 2.0 \times 10^{-16}$

$H_0 : \beta_1 = \beta_2 = \beta_3$ $\quad F_{2,607} = 30.15$ $\quad P = 3.28 \times 10^{-13}$

Table 5: Dummy variable regression of specialization ratio on treatment type.

Test	$\beta_i - \beta_j$	SE	P	Holm P
#1 vs #2	0.3139	0.0705	0.0000	0.0000
#1 vs #3	0.0658	0.0692	0.1707	0.1707
#2 vs #3	-0.2481	0.0600	0.0000	0.0000

Table 6: Pairwise comparisons of mean specialization ratios. P values adjusted as suggested by Holm (1979).

Test	U	df	P	Holm P
All replicates	86.51	14	0.0000	-
#1	21.81	2	0.0000	0.0001
#2	12.31	5	0.0308	0.0615
#3	3.05	5	0.6922	0.6922
#1 and #2	81.53	8	0.0000	0.0000
#1 and #3	21.48	8	0.0060	0.0179
#2 and #3	47.79	11	0.0000	0.0000

Table 7: Kruskal-Wallace rank sum test for differences between treatments in specialization ratios.

were not experienced, either from a previous session or an earlier experiment in this session. This larger group was less specialized ($SR = 0.28$), than the other two groups ($SR = 0.48$). Having two extra members in the replicate does not, at least in this treatment, seem to contribute to an increase in specialization and trade.

An implication that follows from Ricardian trade theory is that in an economy with gains to trade, agents who specialize and trade will not be worse off than without trading, and some will be better off. Table 8 reports results of a regression of the relative number of pairs produced against the specialization ratio. The relative number of pairs produced is defined as $RP = P/P^*$, where P is the number of pairs produced and P^* is the number of pairs that would be produced if the theoretical equilibrium occurred. This regression is conducted for each type of agent, as each type has a potentially different number of autarky pairs and pairs should specialization occur. If in all periods all subjects had the same specialization ratio, and as a group moved to different specialization ratios, then the intercept of these regressions should be the relative number of pairs in autarky, and the sum of the intercept and slope should equal one, the value that $RP_{i,t}$ should take on at the theoretical equilibrium. However, when subjects are not coordinated to this degree, then we would not expect the results to hold this precisely.

For the regression shown in Table 8, the Shapiro-Wilk test is again strongly rejected, making inferences suspicious. The results suggest that the slopes are positive for all treatments and subject types except treatment #2, type #1,

$$RP_{i,t} = \sum_{j=1}^{3} \left[(\beta_j^L + \beta_j^L SR_{i,t})D_{j,t}^L + (\beta_j^R + \beta_j^R SR_{i,t})D_{j,t}^R\right] + \epsilon_{i,t}$$

Treatment	Type	α_j	SE	P	β_j	SE	P
1	1	0.454	0.0362	0.0000	0.2214	0.0789	0.0052
	2	0.532	0.0380	0.0000	0.2758	0.0781	0.0004
2	1	0.688	0.0194	0.0000	0.0544	0.0346	0.1161
	2	0.667	0.0234	0.0000	0.1996	0.0603	0.0010
3	1	0.500	0.0220	0.0000	0.1531	0.0531	0.0041
	2	0.845	0.0213	0.0000	0.0868	0.0320	0.0069

Table 8: Regression of the relative pairs individual traders are able to produce on specialization ratio for each treatment and each type of subject.

which is positive but not significantly different from zero. These results are inconsistent with the trading ratio results presented above. In this case, for those treatments where the trading ratio fell outside the range of trading ratios consistent with the theoretical equilibrium, specialization consistent with theory should have lead to a reduction in the relative number of pairs produced. This is not the result found. Rather, gains from specialization are never negative. However, they are on average lower for treatments where the average trading ratio remained significantly different from that predicted by theory. An alternative explanation is that the problem subjects are solving is a coordination problem. Individual replicates may be seeking to coordinate on an equilibrium where, given the prevailing trading ratio, each is better off than they would be by changing their production bundle.

To measure how coordinated the outcomes are for the different replicates, a coordination efficiency measure is defined. For this paper, coordination efficiency is defined as $CE = 1 - I/(P - I)$ 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.

Figure 4 plots the coordination efficiency against round. Visually, there is no clear difference between the groups. However, there does appear to be an upward trend as the round number increases. Table 9 reports the results of a Kruskal-Wallace rank sum test comparing the distribution of coordination efficiencies between the replicates. There is no significant difference in the distribution of the coordination efficiency within any of the treatment groups. There may be a difference between treatments #1 and #2. However, the other two possible pairwise comparisons do not show a significant difference.

Table 10 reports the result of an asymptotic regression of the coordination efficiency for each treatment. In this case the residuals are not statistically different from normal (Shapiro-Wilk $W = 0.983$, $P = 0.0917$), providing greater confidence in the calculated significance levels. All three intercepts are 'close' to one, with the intercept for treatment #1 falling within two standard errors

Test	U	df	P	Holm P
All replicates	31.57	14	0.0046	-
#1	7.44	2	0.0243	0.1213
#2	9.57	5	0.0883	0.1766
#3	4.91	5	0.4266	0.4266
#1 and #2	20.69	8	0.0080	0.0482
#1 and #3	16.62	8	0.0343	0.1371
#2 and #3	20.75	11	0.0361	0.1371

Table 9: Kruskal-Wallace rank-sum test comparing treatments on coordination efficiency.

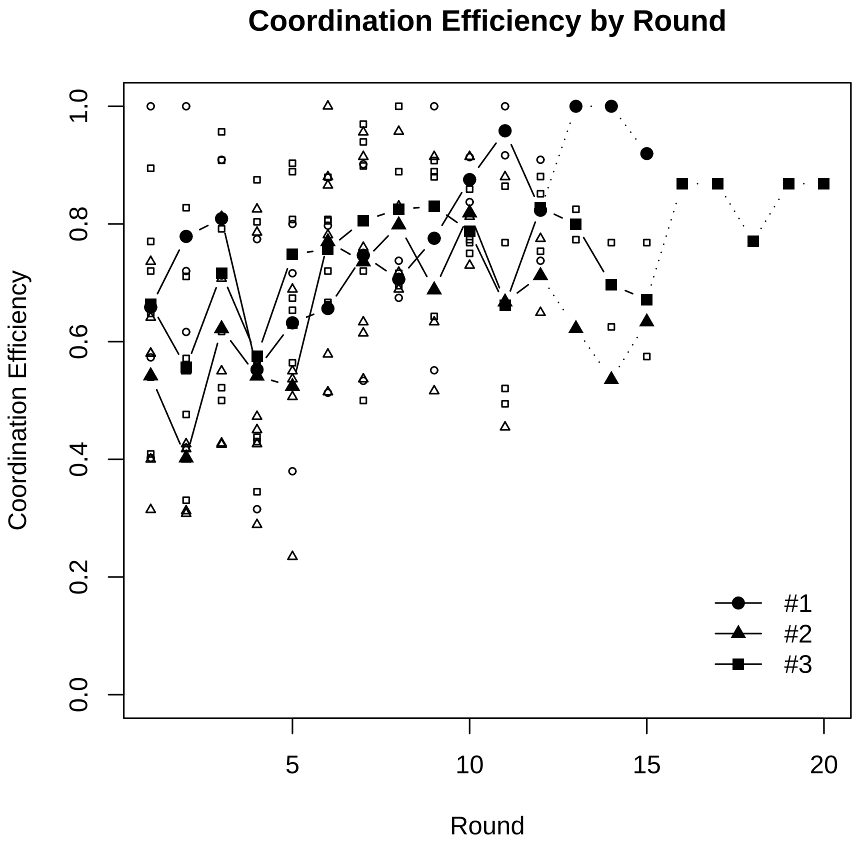

Figure 4: Coordination efficiency by round for all treatments.

$$CE_{i,t} = \sum_{i=1}^{3} \left[\alpha_i + \beta_i(1/t)\right] D_{i,t} + \epsilon_{i,t}$$

Treatment	α_i	SE	P	β_i	SE	P
1	0.9006	0.0702	0.0000	-0.8486	0.3901	0.0314
2	0.7812	0.0585	0.0000	-0.6414	0.3034	0.0364
3	0.8279	0.0448	0.0000	-0.4978	0.2581	0.0560

Table 10: Coordination efficiency against round for all groups.

of one. The slope terms are all negative, and all are significant at slightly over the 5% level. All three treatments are approaching their asymptotic value from below. This result suggests that for all groups the coordination efficiency is increasing as the experiment proceeds.

4 Discussion

This experiment was designed to simulate a classical Ricardian 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.

Beckmann and Werding [1994] described three postulates that they felt capture the core of the Hayek hypothesis. This experiment was designed to test two of these, specifically:

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. ...

As written, the results of this experiment do not confirm these postulates in an economy with production. The available gains from trade were not realized, if those gains are defined to include the gains from specialization. Further, since the first postulate was not supported, the second postulate is also not supported. However, if exact conformity with these postulates is not required, but rather movement in the right direction, then these results may not so cleanly reject the Hayek hypothesis.

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

Table 11: Normal form game. Payoffs in pairs, with strategies as production bundles of right and left socks.

Most of the results of this experiment can be interpreted either as supportive of or challenging to the Hayek hypothesis. Two of three treatments did generate a trading ratio that is significantly different from the trading ratio predicted by theory. However, the ranking of the three trading ratios follows the same pattern as predicted by theory. This result can be interpreted as a challenge to the Hayek hypothesis if the trading ratios are considered, or an indication that more time is required for the economy to converge if the ranking is considered. However, there is no clear support for a trend in the trading ratio.

The level of specialization was 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 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 lower. 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 production, this experiment may in fact have become an experiment in coordination. Consider the normal form game shown in figure 11. 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.

van Huyck et al. [1990] explored a coordination problem where subjects in a group were paid in accordance with the minimum contributed by any group member. Even though the game was common knowledge, subjects were generally unable to coordinate on the Pareto optimal equilibrium, but rather focused on the maximin outcome. While the game was common knowledge, subjects had no communication. In this experiment the environmental details were not common knowledge, but the price could potentially provide information about other subject's choices and inventories. It did not appear to do so very effectively. Cooper et al. [1990] also found that coordination on the Pareto dominant equilibrium is not guaranteed, and that off-equilibrium payoffs are important. For the groups with a single theoretical equilibrium trading ratio, the Pareto dominant Nash equilibrium is not Pareto superior for one type of player. Thus, it is not surprising that specialization in these groups is less. What is surprising is how much specialization actually occurred in treatment #3, in spite of the fact that the average trading ratio was not consistent with theory.

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. Giving subjects the opportunity to participate in a second experiment, either in the same session or in a second session, was expected to improve performance. However, this was also insufficient to produce a detectable difference in behavior.

An experimental currency was not implemented for two reasons. First, the design was intended to be consistent with a classical Ricardian 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.

Another factor may be the gain from specialization, which differed considerably between groups. In treatment #2, subjects could earn at least 80% of their potential earnings at the autarky point, while for treatments #1 and #3, at least one type of agent could not earn much over 50% of their potential earnings at autarky. Using a payment calculation method like that of Isaac et al. [1990] would equalize the difference between autarky returns and returns from specialization. However, it cannot be implemented for agents who are indifferent between autarky and specialization, such as in treatment #3. The precise implementation would also need to deal with a potential for bankruptcies.

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 Ricardian production economy to efficiency.

The use of socks as the experimental good was chosen to enforce the fact that only pairs have value. However, this may also have created a focal point at a trading ratio of 1:1. Perhaps subjects somehow saw left and right socks as equal, and therefore should be traded one for one. The fact that trading ratios were apparently moving in the direction predicted by theory could therefore be interpreted as strong support for the Hayek hypothesis, as it was overcoming the attraction of the 1:1 focal point. A more generic set of commodities, 'commodity one and commodity two', could reduce this focal point effect. The Leontief payoff function that follows from the use of socks itself increases the risk associated with not being able to trade. Un-traded inventory has no value. Using an indifference curve that results in a payoff for unbalanced inventories might overcome this. However, such a payoff function adds a level of complexity to an already complex environment.

Moving beyond Hayek, the impact of communication on the ability to coordinate in a production economy could be investigated. How much and what type of communication is required? Unlike a prisoner's dilemma, there is no gain related to defecting from an agreed production level. The value of a commitment mechanism lies in its reduction of the uncertainty surrounding trading opportunities. Thus, a very limited set of messages - planned production - may be sufficient to produce a greater likelihood of coordinating on the Pareto-optimal solution.

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.

In this experiment, subjects were unable to coordinate on the Pareto optimal equilibria. The structure of the experiment created a set of sub-optimal Nash equilibria, and subjects appeared to coordinate on these. One important implication of this result is that removing barriers to trade is in itself not a guarantee that potential gains from trade will be realized. It is likely that in an economy with many traders, communication, the ability to form binding contracts, and repetition, the tendency to exploit the gains from trade will be high. As outlined above, extensions of this experiment in these directions would highlight which features are most important. However, in situations where markets are thin, communication is absent, and commitment is not possible, the coordination problem might be more serious. The career choice decision, particularly those careers requiring substantial investment in education, may have these characteristics. Markets, particularly geographically, may be thin. Further, communication and commitment with future traders is difficult or impossible. As discussed above, in these situations social safety nets may in fact encourage economic efficiency. 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 Ricardian 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 without production. Consequently, Hayek's hypothesis may stand un-assailed, but with groups being unable to coordinate on the theoretical equilibrium of the Ricardian economy.

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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.

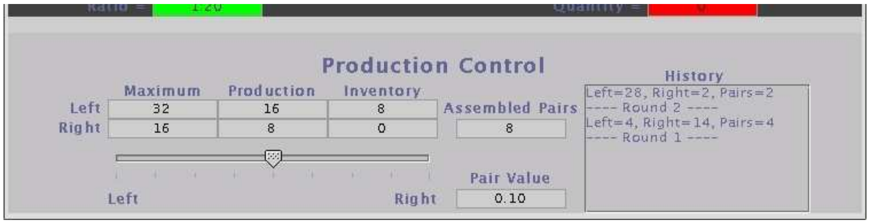
For example, suppose that you have left socks to trade and someone else with left socks is offering to provide 1 left sock in exchange for 2 right socks. An offer of 2 left socks in exchange for 5 right socks would not be accepted, while an offer of 2 left socks for 3 right socks would be. The computer 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.



Production Control

	Maximum	Production	Inventory
Left	32	16	8
Right	16	8	0

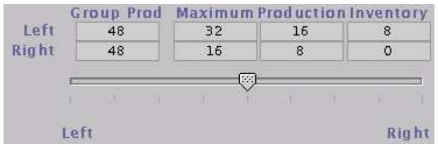
Assembled Pairs: 8

Pair Value: 0.10

History

```
Left=28, Right=2, Pairs=2
---- Round 2 ----
Left=4, Right=14, Pairs=4
---- Round 1 ----
```

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.



	Group Prod	Maximum Production		Inventory
Left	48	32	16	8
Right	48	16	8	0

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.

Trades

---------- Round 1 ----------

Seeking right socks

Left:Right = 2:5

No more than 6 left

Seeking left socks

Left:Right = n/a

No more than n/a right

I am seeking right socks

Offer Ratio

Ratio = 2:5

Offer Too Low

Quantity Will Offer

Quantity = 0

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.

---------- Round 1 ----------

Seeking left socks:
Right:Left = 3:5
No more than 9 right

Seeking right socks:
Right:Left = 5:2
No more than 10 left

Ratio = 4:5
Quantity = 0

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.

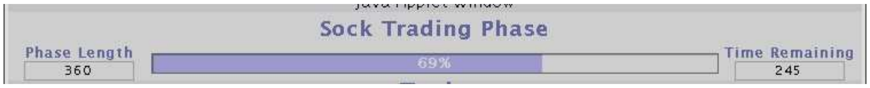
Seeking left socks: Right:Left = 3:5, No more than 9 right

Seeking right socks: Right:Left = 5:2, No more than 10 left

Ratio = 4:1

Quantity = 8

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.



Phase Length: 360

Time Remaining: 245

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.