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Fragility of Comparative Advantage in Higher Dimensions:

An Experimental Investigation

by

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Abstract

Noussair et al (1995) invoked a trading environment similar to the 2 x 2 Ricardian model and observed the law of comparative advantage. In this experiment, we apply the same experimental setting but increase the number of goods and countries. We report an experiment to test a 3 x 3 Competitive Ricardian Model (CRM). The patterns of trade and output predicted by the law of comparative advantage are not observed evolving within the experimental markets

Outline

1. *Introduction*
2. *Models*
3. *Experimental Design*
4. *Theoretical Predictions*
5. *Statistical Methodology*
6. *Results*
7. *Efficiency*
8. *Conclusions*

Non-Technical Summary

The aim of this work is to analyse the fragility of comparative advantage in a laboratory setting. David Ricardo formally developed the theory of comparative advantage, since it has become one of the principles most widely accepted among professional economists. Noussair et al (1995) created an experimental environment motivated by the two–country two–good Competitive Ricardian Model (CRM) and showed that comparative advantage held in this setting.

In this paper, we create an experimental environment motivated by the three-country three- good CRM. It has often been argued that the CRM generalises easily to more than two of either goods or countries though not quite so easily to more than two of both together. Mckenzie (1954) and Jones (1961) were among the first economists to extend the CRM of trade to many goods and countries. They showed that in addition to satisfying bilateral comparative advantage, an optimal assignment minimises the product of labour coefficient. It came to be known as the optimal assignment condition.

We compute a three-country three good CRM which satisfy the optimal assignment condition. The trading model is operationalised in a laboratory setting. Our laboratory world is divided into three countries where each is characterised by its own labour endowment and production technology. There are three output goods which can be produced at a predetermined rate. One input good, labour is required to produce any of the outputs resides in each of the three countries. Labour is immobile among countries. International trade occurs when output goods produced in one country are sold in the other two. There are two types of agents in each country: Type P and Type C, agents are divided equally among countries. Type C agents are owners of labour and have induced preferences for consuming the output goods. So, they sell labour in their respective country and buy units of output goods in any country. Type P traders buy labour in their own country and produce the output goods in all three countries. Type C traders get utility from consumption and trading activities whereas Type P traders get utility from production/trading activities.

Test of the trading model is based on the ability of the experimental data to converge to equilibrium prices and quantities. Although, out theoretical model satisfies the optimal assignment condition, our main conclusion from the experiments is that comparative advantage holds for trade pattern in one but not all countries. Thus, our results reveal that when we increase the dimensionality from two–country two–good to a three-country three- good, the laboratory data is not consistent with the law of comparative advantage. As such, the robustness of comparative advantage is fragile when both the number of goods and countries are increased, at least in this laboratory setting.

1. Introduction

Noussair et al (1995) created an experimental environment motivated by the 2 x 2 Competitive Ricardian Model (CRM) and showed that the law of comparative advantage held in this setting. Deardorff (2005) argued that CRM generalises easily to more than two of either goods or countries though not quite so easily to more than two of both together. Jones (1961) provided a complete specification of the patterns of specialisation and trade in the CRM with many goods and countries. He showed an efficient assignment[1] of countries to goods in a many-good, many-country CRM require minimisation of the product of countries' unit labour requirements. Specialisation is associated with low unit labour requirements where "low" must be interpreted in comparison to other goods since the model requires that each country produce something, and thus contributes at least one of its labour requirements to one of these goods.

The growing literature in experimental economics shows that market convergence generalise to a wide class of experimental economies, including those with multiple markets, small as well as large numbers of traders, robot traders or human traders, and markets with externalities. Although experimental economies converge towards equilibrium predictions, this process is not immediate. Convergence is achieved through a dynamic process that leads the variables in the economy towards equilibrium values. As experimental economies become more complex, the attainment of equilibrium becomes slower and less comprehensive. However, the equilibration process interacts with the specific interdependencies in different microeconomic structures to produce consistent and replicable results. There are many authors who have studied different complex environments including market interdependencies. Examples include Goodfellow and Plott (1990), who include production with derived demand, Chen and Plott (2001) who induced an exchange economy with two or more commodities and Lian and Plott (1998) who induced a small general equilibrium system with a circular flow of income.

In this paper, we compute a 3 x 3 CRM which satisfy the optimal assignment condition. We operationalise the trading model in a laboratory setting. Our laboratory world is divided into three countries where each is characterised by its own labour endowment

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[1] Jones (1961) defined an assignment as a pattern of complete specialisation and argued that there is a unique optimal assignment which is the one that lie on the world efficiency locus. An efficient/optimal assignment occurs when it is impossible to increase world output of any goods without reducing the output of at least one other good by moving labour from one assignment to the other.

and production technology. There are three output goods (*X*, *Y* and *Z*) which can be produced in any of the three countries at a predetermined rate. One input good, labour (*L*) is required to produce any of the outputs and reside in each of the three countries. Labour is immobile among countries. International trade occurs when output goods produced in one country are sold in the other two countries. Markets exist for all output goods (3 in each country) and all input goods (1 in each country). Thus, there are 12 markets in operation. There is no market for currencies as the exchange rate is set to 1. We observe consumption, production and trade in the experiments which occurs simultaneously in each country. Ultimately, we are interested in whether our market system converges to the theoretical predictions when the Ricardian environment becomes more complex. Hence, we check for the robustness of the law of comparative advantage in a laboratory setting when both the number of goods and countries are increased.

The structure of the paper is as follows: Section 2 explores in more details the 3 x 3 CRM which will be invoked in the laboratory; Section 3 illustrates the experimental parameters; the theoretical predictions are given in Section 4; Section 5 describes the statistical methodology; the results are reported in Section 6; Section 7 discusses efficiency. We conclude in section 8.

2. Models

2.1 *3 x 3 Competitive Ricardian Model*

In the 3 x 3 CRM, there are three final goods, *X*, *Y* and *Z* which can be produced by a single input *L*. There are three countries which differ in their endowment of *L*. *L,* which is supplied inelastically, is mobile across sectors in a particular country but immobile across countries. The three countries are assumed to have different production function so that each has comparative advantage in the production of one of the goods. Assume that the constant labour costs of producing a unit of good *j (j=X, Y, Z)* in country *i (i= 1, 2, 3), i.e.* a_{Lj}^{i} are as follows:

|		*Country*		
		1	*2*	*3*
	X	a_{LX}^{1}	a_{LX}^{2}	a_{LX}^{3}
Good	*Y*	a_{LY}^{1}	a_{LY}^{2}	a_{LY}^{3}
	Z	a_{LZ}^{1}	a_{LZ}^{2}	a_{LZ}^{3}

In this case, how do we determine in which good country i has comparative advantage? Mckenzie (1954) was among the first to extend the CRM of trade to the case of many goods and countries. An efficient pattern of production must satisfy two conditions, first the bilateral comparisons for all possible pairings of goods and countries and second minimisation of the product of labour coefficient.

Country 1 will produce and export good X if the following bilateral comparison is satisfied: $a_{LZ}^1 / a_{LX}^1 > a_{LZ}^3 / a_{LX}^3$, i.e. it has bilateral comparative advantage in producing X compared to country 3 and $a_{LY}^1 / a_{LX}^1 > a_{LY}^2 / a_{LX}^2$, a comparative advantage in good producing good X compared to country 2. Country 2 will produce good Y if $a_{LX}^2 / a_{LY}^2 > a_{LX}^1 / a_{LY}^1$ and $a_{LZ}^2 / a_{LY}^2 > a_{LZ}^3 / a_{LY}^3$ and Country 3 will produce good Z as $a_{LX}^3 / a_{LZ}^3 > a_{LX}^1 / a_{LZ}^1$ and $a_{LY}^3 / a_{LZ}^3 > a_{LY}^2 / a_{LZ}^2$. McKenzie (1954) illustrates the concept of bilateral comparative advantage through the '*goods triangle*'. Assume that the constant labour costs of producing a unit of j in i are as follows

		Country		
		1	*2*	*3*
	X	1/4	1	2
Good	Y	1	1/3	1/2
	Z	1	1/2	1/3

We can use these to rank the bilateral comparative costs in three lines as shown in figure 1A where the numbers denote countries. If only Z and X are produced, then all countries produce Z. Country 1 has the highest bilateral comparative advantage in producing X relative to Z, next is country 2 whereas country 3 has the lowest bilateral comparative advantage (1/4 < 2 < 3). If only X and Y are produced, country 2 has the highest bilateral comparative advantage in producing Y relative to X and country 1 has the least (1/3 < 1/2 < 4). If only Y and Z are produced, then country 3 has the highest bilateral comparative advantage in Z relative to Y and country 2 the least (2/3 < 1 < 3/2). Thus, bilateral comparative advantage considerations reveal that country 1 will produce X, country 2 will produce Y and country 3 will produce Z.
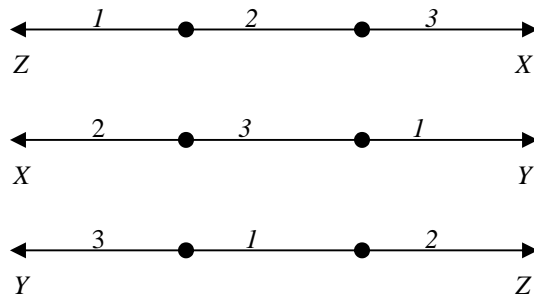
These lines represent the edge of the goods triangle shown in figure 1B.

Figure 1B: Goods Triangle
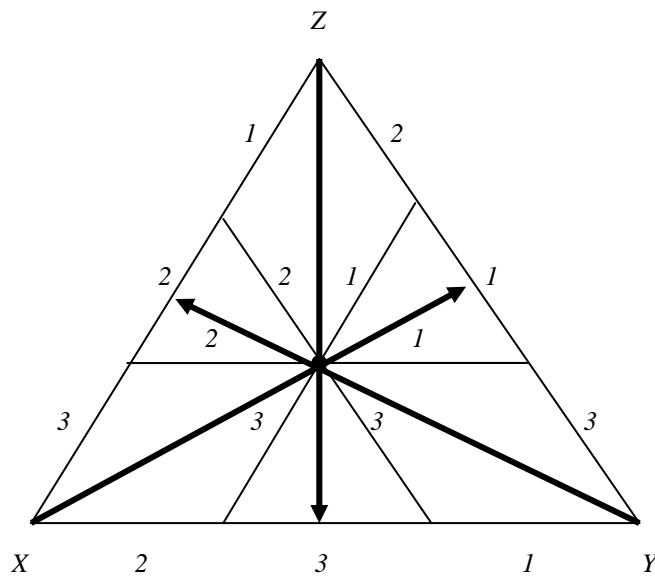
In addition to satisfying bilateral comparative advantage, an efficient optimal assignment pattern minimises the product of labour coefficients. Jones (1961)'s criterion for optimal assignment is

$$\prod_{i=1}^{3} a_{Li}^{i} < \prod_{i=1}^{3} a_{Lj}^{i} \text{ for } j \neq i \text{ and all } j \text{ is different from each other}$$

Consider figure 1B, at the *X*-origin, assume there is an increase in demand for *Y* and *Z* at the expense of *X*. The ordering of countries along the borders of the good triangle indicates country 1 is the last country to transfer resources from production of *X* to *Y* and *Z*. Similarly, if demand for either good *X* and *Z* increases, at the expense of *Y*, country 2 is the last country to pull resources out of production of *Y*. Country 3 is particularly good at producing *Z* in the sense that if demand for *X* and *Y* relative to *Z*, country 3 is the last to

move resources away from production of Z either X or Y. There are six possible assignments in which three goods are produced and the efficient one has X produced by country 1, Y produced by 2 and Z produced by 3. In a competitive equilibrium, any commodity actively produced in a country must have unit labour costs equal to price so that profits are competed away. There is a simple general rule for locating the assignment that is efficient in its class. Reconsider the interior class in which each country is specialised completely to a different good. In the efficient specialisation, country 1 was assigned X, country 2 Y and country 3 Z, so that:

$$
\begin{aligned}
w^1 a_{LX}^1 &= p_X \\
w^2 a_{LY}^2 &= p_Y \quad \text{or} \quad w^1 w^2 w^3 a_{LX}^1 a_{LY}^2 a_{LZ}^3 = p_X p_Y p_Z \\
w^3 a_{LZ}^3 &= p_Z
\end{aligned}
$$

where w^i is country i's wage rate. We also require that

$$
\begin{aligned}
w^1 a_{LY}^1 &\geq p_Y \\
w^2 a_{LZ}^2 &\geq p_Z \quad \text{or} \quad w^1 w^2 w^3 a_{LY}^1 a_{LZ}^2 a_{LX}^3 \geq p_X p_Y p_Z \\
w^3 a_{LX}^3 &\geq p_X
\end{aligned}
$$

and

$$
\begin{aligned}
w^1 a_{LZ}^1 &\geq p_Z \\
w^2 a_{LX}^2 &\geq p_X \quad \text{or} \quad w^1 w^2 w^3 a_{LZ}^1 a_{LX}^2 a_{LY}^3 \geq p_X p_Y p_Z \\
w^3 a_{LY}^3 &\geq p_Y
\end{aligned}
$$

If the assignment that X is produced by country 1, Y by 2 and Z by 3 is efficient/ optimal the product $a_{LX}^1 a_{LY}^2 a_{LZ}^3$ must not exceed $a_{LY}^1 a_{LZ}^2 a_{LX}^3$ as well as the product $a_{LZ}^1 a_{LX}^2 a_{LY}^3$. The first product is 1/36, the second 1/2 and the third 1/2. Therefore, the CRM model predicts that countries 1, 2 and 3 would produce exclusively X, Y and Z respectively and each of the three countries would be a net exporter of the good it produces. Several properties of figure 1B can be found in Jones (1985). This includes among others uniqueness of the optimal 'internal' assignments.

2.2 Autarky Model

Under autarky, goods are produced for home consumption only. The autarky model is useful because it characterises one benchmark of the potential behaviour a system might exhibit. There is no complete specialisation. All countries produce the three goods in

different quantities, there are no international trade. However, the wage-price ratios are identical to that of the competitive model.

3. Experimental Design

3.1 Parameters

A generalized CRM with three countries and three goods motivates our environment. Trade in all markets followed the continuous double auction rules that were implemented through the MUDA software, details of which are available in Plott (1991) and Plott and Gray (1990). Table 1 shows the experimental parameters. We assume that continuous approximation of the utility functions of both consumers and producers are quadratic and additively separable[2]. The idea of separability is of fundamental importance. If utility is directly additive, then the marginal utility of any good varies with the quantity of that good alone. This representation of utility is also consistent with the goods being normal. In addition, given any income, the ratio of the income elasticity to its price elasticity is taken to be constant. In our case, it also makes it easy to determine redemption values of consumers. Each country has an equal number of producers and consumers and is endowed with a given amount of labour. Countries differ in their level of endowment and production technologies. Total endowment in each country is four times the amount listed in the table.

Our experiment will feature three "countries" (1, 2 and 3), three final goods: *X*, *Y* and *Z* - one factor, labour denoted by *L*. There are two types of agents in each country: Type C (Consumers) and Type P (Producers). Furthermore agents are divided equally among countries (4 each) and each has equal number of C and P agents. *L* is immobile among countries whereas *X*, *Y* and *Z* can be traded no matter where they are produced.

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[2] Assume that $U(a)$ is well behaved if it is defined, strictly monotonic, and twice continuously differentiable on the nonnegative orthant $a \geq 0$. Then, U (a) is additively separable if it can be written as

$$U(a) = U(a^1, \ldots a^T) = \sum f^t(x^t), \qquad T > 2 \text{ in an appropriate normalization.}$$

Preferences:

$$U (X, Y, Z) = 600X - 45 X^2 + 720Y - 45Y^2 + 840Z - 45Z^2$$

	Country 1	*Country 2*	*Country 3*
Endowments of input factor (L):			
Consumers	2	3	4
Producers	1	1	1
Number:			
Consumers	2	2	2
Producers	2	2	2
Total Endowment	6	8	10
Production	*X=4L*	*X=L*	*X=L*
	Y=L	*Y=3L*	*Y=2L*
	Z=L	*Z=2L*	*Z=3L*

The market system works as follows: Type C are owners of *L* and have induced preferences for consuming *X*, *Y* and *Z*. So they sell *L* to Type P in their respective country and then buy units of *X*, *Y* and *Z* in any country. Type P traders buy *L* from Type C in their own countries. Then, they use *L* to produce *X*, *Y* and *Z*, according to their respective production schedule, which they sell to consumers in all three countries. Type C traders get utility from consumption of goods *X*, *Y* and *Z* and from profits made in market activities. Any units of *X*, *Y* and *Z* bought by Type C agents are assumed to be consumed. The redemption value sheet determines the amount Type C agents receive through consumption and are given in Appendix 1. For the first unit of *X* that Type C consumes in a trading period, he/she receives the amount listed on his/her Redemption Value Sheet (In this case 600, first row in the *X* unit value column). Type P gain utility from production /trading activities only. Any units of *L* not used to produce goods *X/Y/Z* are worthless to Type P agents. Similarly any unit of *X*, *Y* and *Z* not sold is valueless. All market transactions are denoted in an experimental currency "franc".

Subjects were given 100,000 francs at the start of each period of the experiment. Subjects were paid according to a conversion rate; we used 4000 francs to £1 for some experiments and 3000 to £1 for others. At the end of each period, subjects filled a Record Sheet to record the profit made in a particular period. Type P's record sheet consists of one section, trading which is the cash on hand at the end of the period minus the cash on hand at the beginning of the period. Type C's record sheet consists of two sections, trading and consumption. Consumption records the units consumed and earnings made from those units consumed. Total profits are given by net change in cash on hand and total earnings made from consumption.

Figure 2 shows the operation of the market system. The upper part shows the circular flow in country 2, the lower left and the lower right show the circular flows of countries 1 and 3 respectively. Output markets were numbered 1 to 9. Markets 1/2/3 denote market *X/Y/Z* in country 1. Markets 4/5/6 denote market *X/Y/Z* in country 2. Markets 7/8/9 denote market *X/Y/Z* in country 3. Markets 10/11/12 denote labour market in countries 1, 2 and 3 respectively. Trade occurs when output goods are sold to agents in countries where production of these output goods did not take place and since labour is immobile among countries, this implies market restrictions are as follows:

Country 1- Type C: Market 11 and 12; Type P – Market 4, 5, 6, 7, 8, 9, 11 and 12.
Country 2- Type C: Market 10 and 12; Type P – Market 1, 2, 3, 7, 8, 9, 10 and 12.
Country 3- Type C: Market 10 and 11; Type P – Market 1, 2, 3, 4, 5, 6, 10 and 11.

Subjects access the output markets on the first page of the computer screen and input markets on the second page of the screen.

Figure 2: The Market System

Country 2

Type C $\longrightarrow$ Type P

Market 11 (L = 3)   Market 11 (L = 1)

Produce

X   Y   Z
Market 4   *Market 5*   *Market 6*

Country 1   *Country 3*
Type C $\longrightarrow$ Type P   Type P $\longleftarrow$ Type C

Market 10 (L = 2)   Market 10 (L =1)   Market 12 (L=1)   Market 12 (L= 4)

Produce   *Produce*

X   Y   Z   SELL X, Y AND Z TO   X   Y   Z
Market 1   Market 2   Market 3   TYPE C IN ALL   Market 7   Market 8   Market
                                        COUNTRIES

9
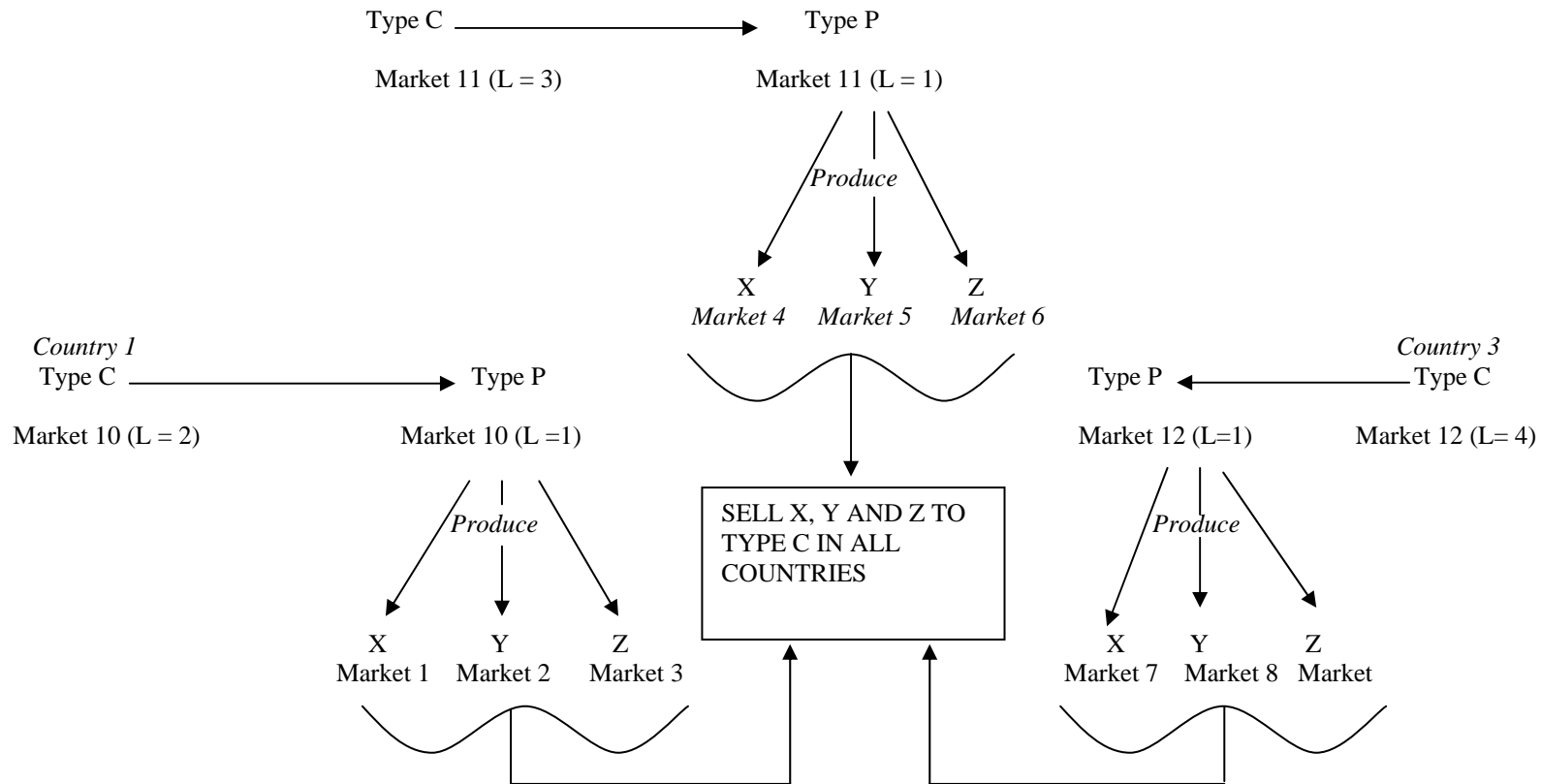
3.2 Procedures

Five experiments (Experiment 1- Experiment 5) were conducted in the CeDEx laboratory at the University of Nottingham. The experiments involve 12 subjects (4 in each country). Subjects were undergraduates from the University of Nottingham. Most were non - economics students. Subjects had training in the use of MUDA prior to the experiment, for which they were paid a fixed fee of £5. Subjects were not allowed to participate in more than one experiment.

Each experiment was divided into 5 periods of 10 minutes. Once assembled for the first time, subjects were randomly assigned as either Type C agents or Type P agents and kept the same role over subsequent periods. Instructions were given to both types. The instructions consisted of eight sections. These gave information about: subject's type and number of goods in the computerized market; information about endowment and cash on hand; the operation of the market system; information about the production schedule and redemption values; information about trading profits, earnings and market restrictions. Full details of these instructions are given in Appendix 2. Basic information about MUDA included how to buy/ sell units, what numbers in the boxes meant and transformation. The first period of Experiment 1 was a practice session where accounting records were checked carefully for errors and subjects were reminded of the production and consumption process. In later periods and sessions spot checks were undertaken to verify accounting information. Subjects were also asked to check changes in cash on hand, endowments and contract history of the experiment using several keystrokes. The redemption values and production schedule were the same for each period; subjects received new endowments at the beginning of each period.

4. Theoretical Predictions

We made predictions about two environments: the autarky environment where countries only produce for self- consumption and the trading environment based on the 3 x 3 CRM.

The Competitive Ricardian Environment

If trade occurs among the three countries, given labour endowments, comparative advantage dictates that country 1 produces and exports only *X,* country 2 produces and exports only *Y* and country 3 produces and exports *Z*. Substituting labour endowment of *X,*

Y and *Z* of country 1, 2 and 3 in their respective production function gives total production. We differentiate the utility function to get marginal utilities of each good, from which we derive aggregate demand for the whole system and thus free trade prices. Input prices equal their marginal revenue. Net exports are derived from the excess demand equations in each country evaluated at the competitive prices. The theoretical derivations can be found in Appendix 3A.

Table 2: CRM Predictions

Variables	Country 1	Country 2	Country 3
Production			
X	24	-	-
Y	-	24	-
Z	-	-	30
Export			
X	16	-	-
Y	-	16	-
Z	-	-	20
Prices			
X	240	-	-
Y	-	360	-
Z	-	-	390
L	960	1080	1170

The Autarky Environment

In this environment, each country produces all 3 goods. Prices of all goods would be different in the three countries and. Also, there are no payments-imbalances such that the total expenditure spent on goods *X*, *Y* and *Z* is equal to the total income earned by labour. The derivation of the predictions for the autarky environment is derived in a similar manner as the CRM and can be found in Appendix 3B.

Table 3: Autarky Predictions

Variables	Country 1	Country 2	Country 3
Production			
X	12	1	2
Y	1.5	12	6
Z	1.5	6	15
Prices			
P_X	60	615	510
P_Y	652.5	180	450
P_Z	772.5	570	145
P_{LX}	240	615	510
P_{LY}	652.5	540	900
P_{LZ}	772.5	570	4950

Efficiency

Efficiency measures the extraction of social surplus. Following, Smith (1962), efficiency of a market is the total profit actually earned by all agents divided by the maximum total profit at equilibrium that could have been earned by the subjects. Participants in a fully efficient system will extract the theoretical maximum social surplus. In our case, the market system is 100 % efficient in a given period if and only if competitive equilibrium is attained. To calculate the level of efficiency in a particular period, we compared the total profits made by both Type C and Type P traders in this particular period as a proportion of the competitive equilibrium profit.

Based on our theoretical predictions, we test the following hypotheses:

Hypothesis 1: The competitive model is an accurate representation of the general data

Hypothesis 2: Aggregate production patterns converge to the predictions of the CRM.

Hypothesis 3: The law of comparative advantage accurately predicts trade pattern

Hypothesis 4: Individual consumption converges to the predictions of CRM.

Hypothesis 5: Output prices converge towards the predictions of CRM.

Hypothesis 6: Input / Output price ratio converges toward the marginal physical product.

5. Statistical Methodology

We check for convergence in quantity and price variables. There are many different definitions of price/quantity convergence in the double auction literature[3]. In our case, it is important to account for within and across period changes as the CRM is a static equilibrium model whereas our data are generated by a dynamic process. Hence, we apply a simple statistical dynamic model called Ashenfelter-El-Gamal model used first in Noussair et al. (1995).

$$A_{it} = B_{11}D_1\left(\frac{1}{t}\right) + \ldots\ldots + B_{1i}D_i\left(\frac{1}{t}\right) + \ldots\ldots B_{1n}D_n\left(\frac{1}{t}\right) + B_2\left(\frac{t-1}{t}\right) + u_{it}$$

A_{it} is the variable of interest in period t for experiment i, $i = 1\ldots.n$. D_i are dummy variables that take a value of 1 for experiment i, and 0 otherwise. The random error u_{it} is distributed normally with zero mean. Assume we are interested in production of Y; when $t = 1$, production of Y in experiment i equals B_{1i} which can be interpreted as the initial production of Y for experiment i. However, its impact reduces over time, as $\left(\frac{1}{t}\right)$ tends toward zero when t increases. Compared to B_{1i}, when t increases the impact of B_2 increases as $\left(\frac{t-1}{t}\right)$ gets larger. Thus, the coefficient B_2 can be interpreted as the common asymptote of the variable production of Y. To observe strong convergence of variable A_{it}, it suffices to test whether or not the estimates of B_2 are significantly different from the predictions of the model. If not, we say that the variable is strongly converging to the predicted values. However, as pointed out by Noussair et al (1995), we can also observe weak or partial convergence. Weak convergence is present if B_2's are quantitatively closer to the predictions than B_{1i}. In our case n = 5, so the model is:

$$A_{it} = B_{11}D_1\left(\frac{1}{t}\right) + B_{12}D_2\left(\frac{1}{t}\right) + B_{13}D_3\left(\frac{1}{t}\right) + B_{14}D_4\left(\frac{1}{t}\right) + B_{15}D_5\left(\frac{1}{t}\right) + B_2\frac{t-1}{t}$$
$$+ u_{it}$$

---

[3] For example, Gode and Sunder (1993) argue that convergence occurs if the final market price is closer to the predicted price than early price. According to Gjerstad and Dickhaut (1998), convergence occurs if, after several periods, the mean deviation of all trades from equilibrium is small.

6. Results

At the end of each experiment, a series of input and output prices are generated. These include ask prices, bid prices and contract prices. Figures 3 (a), (b) and (c) show the output contract time series for countries 1, 2 and 3 respectively. Figures 4 *(a)*, *(b)* and *(c)* shows the input contract time series for countries 1, 2 and 3 respectively. The data are from Experiment 3.

Figure 3: Output Price Time Series- *Experiment 3*

Price- Market *X*

(a)

Price- Market *Y*

(b)

Price- Market *Z*

(c)
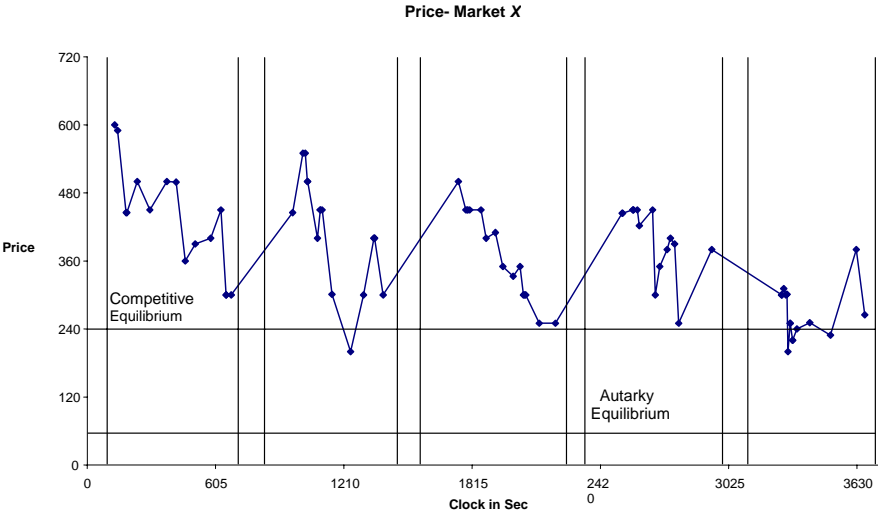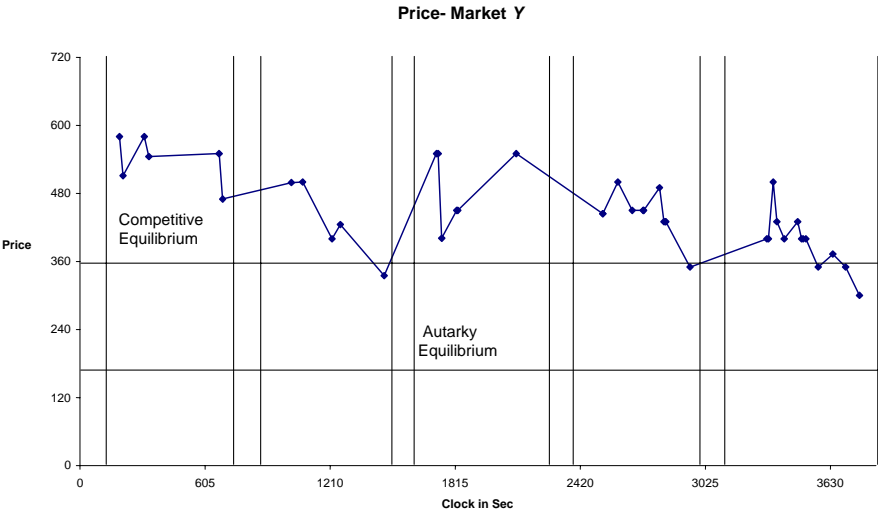
Figure 4: Input Price Time Series- *Experiment 3*

Price of *L* - Country 1

(a)

Price of *L* - Country 2

(b)

15

Price of *L* - Country 3

(c)

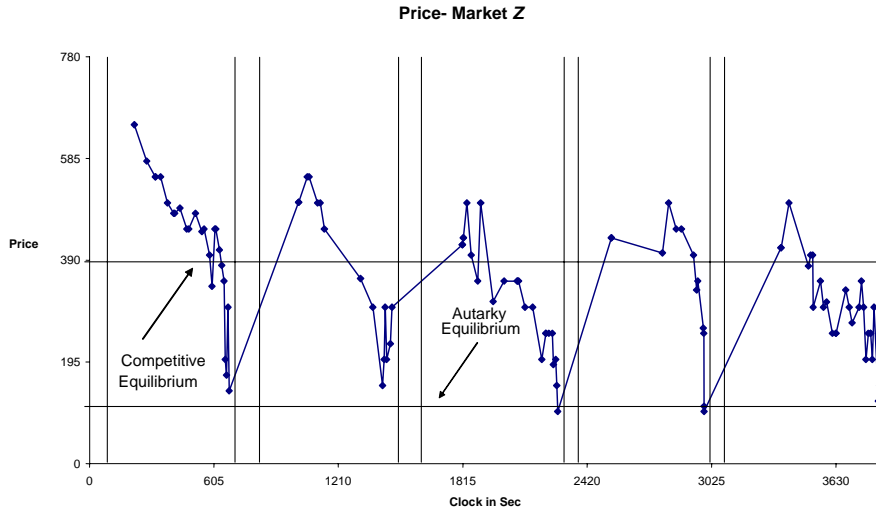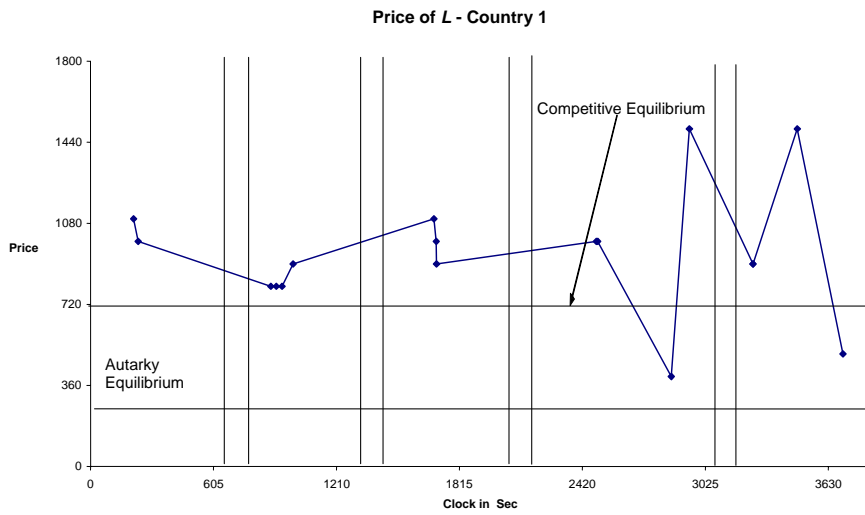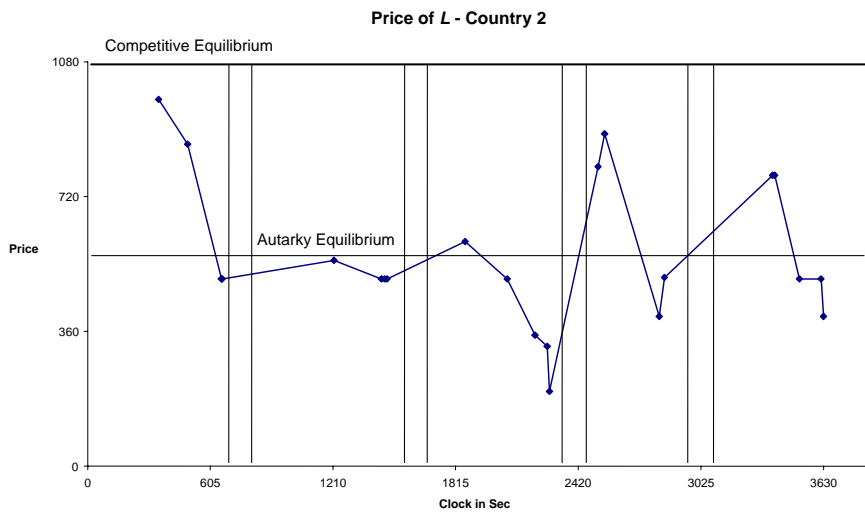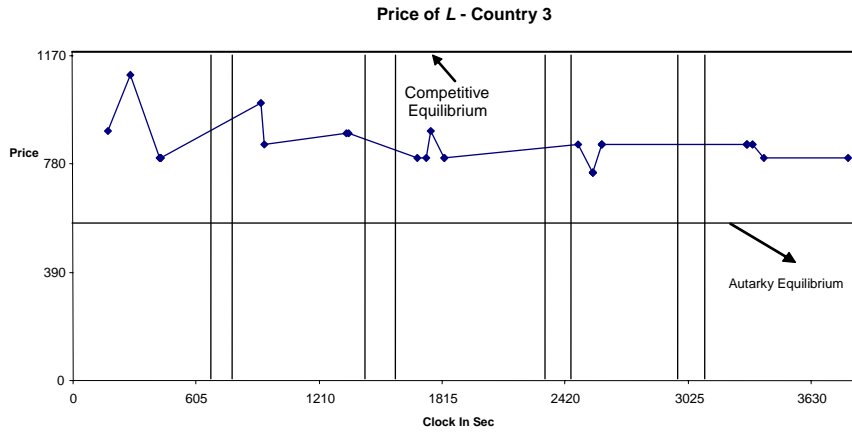The *x*-axis denotes time measured in sec and which gives the exact second of accepted bids or asks. The *y*-axis denotes prices. The vertical lines show the beginning and end of each period. The first line shows the beginning of the first period whereas the second denotes the end of period one. The gap between two lines shows the time interval between the end of a period and start of another. Nothing happens during this interval and subjects filled their record sheets. Spot checks were also undertaken. Although all observed contract prices do not automatically clustered towards the competitive equilibrium, there is an indication of convergence in some markets. As we move towards later periods of the experiment, prices in market *X* and *Y* (figure 3) *(b)* and *(c)*) converge towards the competitive equilibrium. Prices in market *Z* experience slight convergence to the competitive equilibrium in period 5. Compared to outputs prices, input prices have a tendency to be both below the competitive equilibrium for country 2 and 3 whereas there is slight indication of convergence in the case of country 1. Thus, from the data of experiment 3 we can conclude that there is tendency for the competitive equilibrium price to be a better predictor in output than in input markets.

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Table 4 : Convergence Patterns over time of Production, Exports and Market Prices

$$Y = B_{11} D_1 1/t + \ldots\ldots\ldots\ldots B_{15} D_5 1/t + B_2 (t-1)/t + u$$

Dependent Variables	B_{11}	B_{12}	B_{13}	B_{14}	B_{15}	B_2	Competitive Equilibrium		Autarky		R^2
							Predictions	*Sig*	*Predictions*	*Sig*	
Production:											
Country 1											
X	12.55	15.28	22.39	14.19	17.37	19.23	24	ns	12	<0.001	0.62
	4.94	*2.37*	*4.73*	*4.97*	*4.16*	*2.08*					
Y	0.64	0.87	0.95	1.18	0.7	0.37	0	ns	1.5	<0.001	0.57
	0.98	*0.45*	*0.39*	*0.52*	*0.84*	*0.27*					
Z	0.68	0.72	1.02	1.25	1.02	0.23	0	ns	1.5	<0.001	0.66
	0.87	*0.78*	*0.24*	*0.71*	*0.24*	*0.23*					
Country 2											
X	1.6	2.7	0.14	0.56	0.12	0.39	0	ns	1	<0.05	0.62
	1.7	*3.56*	*0.52*	*1.55*	*0.54*	*0.53*					
Y	11.73	9.99	9.68	8.87	17.41	13.93	24	< 0.001	12	ns	0.57
	9.17	*3.04*	*6.67*	*8.67*	*2.56*	*2.14*					
Z	3.76	3.44	4.67	5.67	6.03	4.42	0	< 0.001	6	ns	0.66
	0.87	*1.87*	*2.37*	*4.64*	*5.59*	*1.06*					
Country 3											
X	2.27	0.26	0.2	0.48	0.054	0.55	0	ns	2	<0.05	0.6
	2.01	*0.76*	*0.63*	*1.35*	*0.3*	*0.34*					
Y	0.18	6.54	1.89	2.14	2.37	7.1	0	< 0.001	6	ns	0.81
	4.96	*1.6*	*1.5*	*0.94*	*1.38*	*1.27*					
Z	18.39	15.04	25.43	14.67	24.71	18.82	30	< 0.001	15	ns	0.93
	9.86	*8.32*	*5.11*	*7.3*	*6.3*	*2.69*					
Net Exports:											
X	7.9	4.23	8.19	4.47	7.2	13.24	16	ns	0	<0.05	0.62
	10.8	*2.64*	*7.6*	*4.27*	*3.65*	*2.14*					
Y	1.65	3.56	1.9	8.16	13.97	7.74	16	< 0.001	0	<0.05	0.57
	4.02	*4.11*	*3.31*	*5.13*	*1.63*	*1.85*					
Z	1.65	11.49	18.97	9.23	19.17	10.14	20	< 0.001	0	<0.05	0.66
	3.86	*4.45*	*1.68*	*1.1*	*2.44*	*1.46*					
Market Prices:											
Country 1											
X	508.06	526.07	448.6	440.8	286.3	327.2	240	< 0.001	60	<0.05	0.9
	88.2	*88.01*	*30.64*	*39.2*	*99.4*	*23.5*					
L	2069.7	1501.6	1074.6	465.7	664.7	794.9	960	ns	240	<0.05	0.66
	1850	*349.4*	*563.6*	*571*	*190*	*250*					
Country 2											
Y	855.64	852.55	486.35	418.53	313.1	491.1	360	<0.05	180	<0.005	0.82
	92.32	*521.96*	*63.7*	*75.36*	*61.79*	*62.45*					
L	1369	1591.6	464.6	576.59	584.3	801.8	1080	<0.05	540	<0.05	0.86
	640.29	*222.94*	*204.0*	*205.76*	*103.09*	*117.25*					

Country 3											
Z	1074.7	505.98	323.84	388.51	333.6	476.7	390	<0.05	165	<0.001	0.89
	428.47	*38.66*	*98.72*	*80.79*	*73.93*	*44.86*					
L	3364.8	1484.3	789.8	635.9	833.7	969.5	1170	ns	495	<0.005	0.91
	547.04	*119.51*	*122.28*	*158.53*	*129.85*	*154.81*					

RESULT 1: *Both the autarky model and the competitive model are rejected as a representation of the data but the competitive model performs better than the autarky model.*

Table 4 reports the estimates of the parameters of the econometric model described in section 5 for production, net export and market prices respectively. Estimates of the origin of each experiment, as captured by B_{1i}, are reported as well as the common asymptote (captured by B_2) for each variable. Standard errors, given in italics, are corrected for heteroscedasticity (to account for stabilization, which would decrease the variance of the error terms for later periods in the sessions) as well as serial correlation. R^2 is also reported for each equation. The sig column give the significance level at which the null hypothesis is rejected, ns denotes non-significant. The null hypothesis being the asymptote of a particular variable is the same as its theoretical prediction. We cannot reject the hypothesis that a variable converges to its competitive equilibrium if the estimated B_2 is not statistically different from the predicted value. We accept the models as appropriate representations of the data if sig for all the variables are non-significant (ns).

We made predictions for 12 quantity variables and for 6 price variables. For the competitive model, B_2 is not statistically different from the predicted value in 8 cases out of 18. The autarky model on the other hand succeeds to predict 4 variables out of the 18. Thus, both the autarky model and the competitive model are rejected as a representation of the data but the competitive model performs considerably better than autarky.

RESULT 2: *The CRM does not predict production patterns.*

The CRM predicts that country 1 will devote all its endowments to production in sector *X*. Thus, no *Y* and *Z* will be produced at any particular time. From table 4, production of *X* in country 1 as captured by B_2 is 19.2 units compared to 24. A test of significance revealed

that we cannot reject the hypothesis that the asymptote, B_2 is statistically different form the predicted value. This indicates proof of strong convergence.

From table 4, it can be deduced that as more experiments are carried out production of Y and Z inclined towards zero. B_{1i}'s are nearer to zero in later experiments indicating presence of weak convergence. Furthermore, there is also strong convergence; B_2's are not statistically different from zero. Compared to the CRM, the autarky model performed badly. There are sign of neither strong nor weak convergence when it comes to production of X, Y and Z. The asymptotes of the production variables are significantly different from the predicted values of the autarky model. At $p < 0.001$, we reject the null hypothesis that the asymptote B_2's is similar to the predictions of the autarky model. From these two observations, we can draw the conclusion that the CRM predicts the pattern of production in country 1.

From table 4, we found no evidence of strong convergence in production of Y and Z for country 2. B_2's are statistically different from the equilibrium values. Production of Y is 13.93 units as opposed to 24 units and production of Z is 4.42 units as opposed to zero. At $p < 0.001$, we reject the null hypothesis that the asymptote B_2's is similar to the predictions of the CRM model. Similarly, B_{1i} are quantitatively closer to the predicted value indicating absence of weak convergence. Similar conclusions are reached when production in country 3 is considered. Production of Y is 7.1 units as opposed to zero and production of Z is 18.82 as opposed to 30 units. However, the CRM accurately predicts the level of production of good X in both countries. Based on our t-test, we find evidence of strong convergence. The hypothesis that production in later periods converges towards zero cannot be rejected at $p < 0.001$ level of significance.

Surprisingly, the autarky model is a better predictor for production of Y and Z in countries 2 and 3. We found proof of strong convergence. In country 2, production of Y is 13.93 units as opposed to 12 and production of Z is 4.42 units as opposed to 6. In country 3, production of Y is 7.1 units as opposed to 6 and production of Z is 18.82 units as opposed to 15.

RESULT 3: *The law of comparative advantage fails to predict the pattern of trade*.

      With reference to table 4, the observed value of net exports of good *X* is 13.24 as opposed to 16 units. Statistically, the asymptote of net exports of good *X* is not different from the prediction of the CRM. Table 4 also reveals that $B_{1i} > B_2$ (for $i = 3$ to 5) indicating that the regression line is negatively sloped and experiment *i* converges from above. Thus, the flow of international trade is not only in the direction predicted by comparative advantage but the magnitude is converging to the predicted value of the competitive environment. RESULTS 2 and 3 suggest that the pattern of production and trade are consistent with the directions predicted by the CRM for country 1.

      From RESULT 2, we infer that the CRM predicted production quantities for countries 2 and 3 are not consistent with the observed asymptote values. From table 4, net exports of *Y* and *Z* are respectively 7.74 and 10.14 units compared as opposed to 16 and 20. We fail to accept the null that the observed values are similar to the predicted value at *p*<0.001 indicating no evidence of strong convergence. Similarly, no evidence of weak convergence is found. RESULTS 2 and 3 indicate that the CRM fails to predict both production and net export quantities for countries 2 and 3.

      McKenzie (1954) and Jones (1961) show that when we increase the dimensionality of goods and countries in the CRM, countries will produce and export those goods where the bilateral comparisons of unit labour coefficient holds for all possible pairings of goods and the product of the labour requirement in efficient assignment of goods must be less that the corresponding product of all possible assignments that allocate the same number of countries to each commodity as the efficient assignment. In our case, this generalization implies that country 1 will produce and export good *X;* country 2 will produce and export *Y* and country 3 will produce and export *Z*. Our results reveal existence of complete specialisation for good *X* but not for good *Y* and *Z*. Similarly, while country 1's net exports of *X* are in accordance with the predictions of the CRM this is not the case for net exports of *Y* and Z.

RESULT 4: *Individual Consumption of X, Y and Z converge to the predicted values of the CRM.*

Table 5: Average Individual Consumption

Good	Period				
	1	2	3	4	5
X	2	2.9	2.9	2.5	3.2
Y	1.7	1.1	1.4	1.5	2.8
Z	3.1	2.3	2.3	2.4	3.6

Table 5 gives the average individual consumption per period. We can see that individual consumption in Period 5 is higher than in other periods. However, individual consumption in any period is not equal to the theoretical prediction of 4, 4 and 5 units of goods *X*, *Y* and *Z* respectively.

We used mean deviation and standard deviation statistics to analyze individual consumption patterns, computed as:

Mean Deviation: $\mu = \sum_i \frac{(x_r - \hat{x}_r)}{N}$

Standard Deviation: $\sigma = \sqrt{\sum_i \frac{(x_r - \hat{x}_r)^2}{N}}$ where x_r denotes actual consumption of agent *r*;

$\hat{x}_r$ denotes competitive equilibrium consumption of agents *r* and N is the number of observation (consumers times experiments), in our case N = 30.

Table 6 reports values of these for the five periods. Individual consumptions in period *t* are pooled across experiments and the difference between the observed and predicted consumption value for period *t* (*t = 1…5*) computed for goods *X*, *Y* and *Z*. In this way we can observed whether individual consumption levels converge to the equilibrium consumption values as period *j* is replicated.

Table 6: Deviations of Individual's Holding from CE Predictions (by Period)

Output	Statistics	Period				
		1	2	3	4	5
	Mean Deviation	-2	-1.07	-1.1	-1.47	-1.08
X	Standard Deviation	4.75	3.33	3.02	3.41	1.9
	Mean Deviation	-2.3	-2.8	-2.6	-2.5	-1.16
Y	Standard Deviation	5.24	6.46	5.9	5.7	2.74
	Mean Deviation	-1.93	-2.7	-2.63	-2.56	-1.43
Z	Standard Deviation	4.85	6.14	5.96	5.9	3.7

Evidence of convergence requires that the absolute value of the mean deviations and standard deviation in later periods are smaller than that of the early periods. From table 6, the mean deviation of period 5 is 1.08, 1.16 and 1.43 for *X*, *Y* and *Z* respectively, the lowest of all observed periods. Furthermore, the mean deviation from the competitive value falls consistently over the first three periods for *X* and the second four periods for *Y* and *Z*. Standard deviations fall consistently over the first three periods for *X* and the second four periods for *Y* and *Z*. Standard deviations of later periods are lower than early periods, falling consistently for good *Y* and *Z*. The hypothesis that the absolute deviations for the early period are smaller or equal to that of late periods (period 3-5) can be accepted at the 5% level of significance, providing support for convergence towards the individual competitive equilibrium consumption level.

RESULT 5: *Output prices are not converging toward the competitive equilibrium.*

From table 4, we observed that the asymptote of price of *X* is 327.2 francs. We do not find evidence of strong convergence as B_2's are statistically different from the predictions of the CRM model. Also, there is no evidence of weak convergence. Similar observations are made for prices of *Y* and *Z* at the 5% level of significance. The observed asymptote of price of *Y* is 491.1 francs. As such, B_2 is statistically different from the CRM prediction of 360 francs. The asymptote of price of *Z* is 476.7 francs. It does not tend to converge towards the equilibrium of 390 francs. Also, there is no indication of weak convergence in either price of *Y* or *Z*. Thus, there is non-existence of price convergence toward the competitive equilibrium.

RESULT 6: *Input/ Output prices ratios are below the marginal revenue product.*

As pointed out by Noussair et al (1995), determinations of input prices are more complex because of the nature of derived demand. As such, deviation of input prices from the competitive equilibrium is not only due to a lack of equilibrium in the output market; but the factors have their own independent dynamic adjustment. Under the CRM conditions we expect input prices to equal output prices multiplied by the marginal physical product, which is a constant as technologies are linear. It means that the ratio of factor price to output price, when compared to the marginal physical products, can then be used to determine whether the input conditions are satisfied.

Table 7:Convergence Patterns Input/Output Price Ratios

	$Y = B_{11} D_1 1/t + \ldots\ldots\ldots\ldots B_{15} D_5 1/t + B_2 (t-1)/t + u$					
Dependent Variables	B_{11}	B_{12}	B_{13}	B_{14}	B_{15}	B_2	*Competitive Equilibrium*		*Autarky*		R^2
							Predictions	*Sig*	*Predictions*	*Sig*	
Country 1											
P_L/P_x	5.09	2.8	2.37	0.92	2.26	2.48	4	ns	4	ns	0.62
	9.97	*2.5*	*0.85*	*1.23*	*1.59*	*1.31*					
Country 2											
P_L/P_Y	1.77	2.84	0.98	1.5	1.84	1.59	3	< 0.05	3	<0.05	0.88
	2.45	*1.7*	*0.717*	*0.58*	*0.41*	*0.38*					
Country 3											
P_L/P_Z	4.1	2.88	2.36	1.63	2.37	2.13	3	< 0.05	3	<0.05	0.92
	1.38	*0.26*	*0.78*	*0.2*	*0.32*	*0.28*					

Table 7 reports estimates of the time path of ratios of output to input prices. We estimate an econometric model of the same form as described in section 5.4. The B_{1i} in this case measures the ratio during the first period which is permitted to differ among experiments. B_2 measures the asymptote of each ratio as time goes to infinity. Evidence of convergence requires that B_2 is not statistically different from the ratio of factor price to output price. We found evidence of strong convergence for country 1 as B_2 is not statistically different from the ratio of factor price to output price. Neither strong nor weak evidence are found for countries 2 and 3.

A similar relationship was found in the economies studied by Noussair et al (1995). This relationship also emerged in the laboratory economy created by Riedl and Van Winden (2001). Noussair et al (1995) give the Risk Compensated Input/ Output Price Adjustment Property as an explanation of this observation. In their experiments, as in ours,

producers purchase inputs that have no value other than being used in production of output goods. However, they do not have information about the price they earned for these produced goods, hence they face a risk. To compensate for this risk, producers earned a premium over the amount they will earn in the competitive equilibrium. Although we observe strong convergence in the case of country 2 and country 3, the observed marginal physical products tend to be lower than the predicted value as the number of periods increase, hence we can argue that this property is also present in countries 2 and 3.

7. Efficiency

Finally, to calculate the level of efficiency in a particular period, we compared the total amount of profits made by both Type C and Type P traders as a percentage of the maximum profit that can be earned at competitive equilibrium.

OBSERVATION 1: *Efficiency is higher in later sessions than earlier*

Market efficiency for the pooled data is reported in Figure 5. Efficiency in early periods is lower than that of late periods. Efficiency in periods 1-3 averaged 61.6% whereas efficiency in periods 4-5 averaged 70.3%. Efficiency level in period 5 is 76.6%.

Figure 5: Market System Efficiency
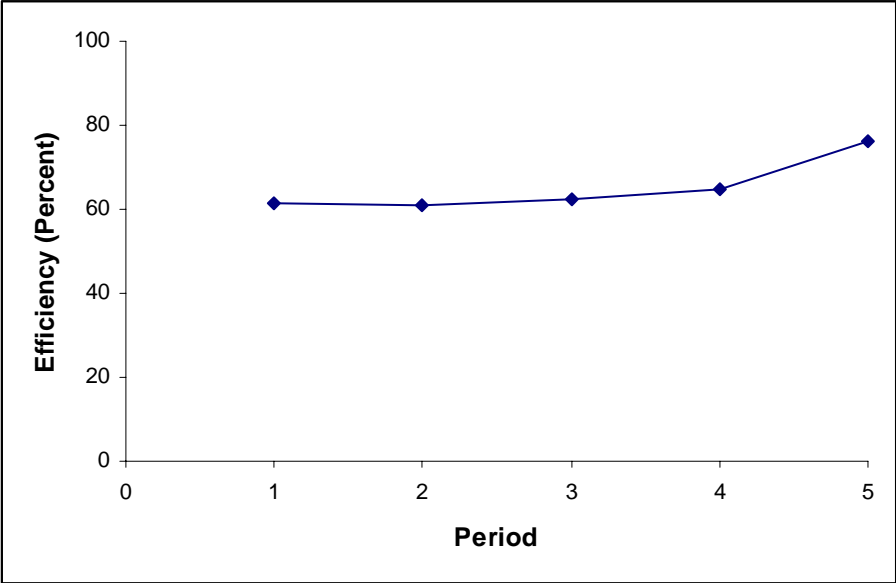
8. Conclusions

We construct a three- goods three- countries Ricardian model in an experimental environment. Jones (1961) argued that regardless of the number of countries or goods, the law of comparative advantage should hold if the product of labour requirement in the efficient assignment of commodities to countries is less than the corresponding product in all other possible assignments that allocate the same number of countries to each commodity as does the efficient assignment (the optimal assignment condition). Although our theoretical model satisfies this condition, our main conclusion of the experiments is that comparative advantage holds for trade patterns in one but not all countries.

We must not overlook the fact that the competitive model is rejected as a representation of the experimental data. Convergence is present in 6 out of the 12 quantity variables and 2 out of the 6 price variables. There is no convergence (strong or weak) in output prices whereas there is also a tendency for factors of production to trade at prices below their marginal products. There is less support for the autarky model.

While, Noussair et al (1995) observe comparative advantage motivated by the 2 x 2 CRM in a laboratory setting, our results reveal that when we increase the dimensionality from 2 x 2 to a 3 x 3, the laboratory data is not consistent with the law of comparative advantage. As such, the robustness of comparative advantage is fragile when both the number of goods and countries are increased, at least in this laboratory setting.

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APPENDIX 1

REDEMPTION VALUES

Consumer 1	Unit	X Unit Value	X Total Value	Y Unit Value	Y Total Value	Z Unit Value	Z Total Value
	1	600	600	640	640	680	680
	2	510	1110	550	1190	590	1270
	3	420	1530	460	1650	500	1770
	4	330	1860	370	2020	410	2180
	5	240	2100	280	2300	320	2500
	6	150	2250	190	2490	230	2730
	7	60	2310	100	2590	140	2870
	8	10	2320	10	2600	50	2920
Consumer 2	Unit	X Unit Value	X Total Value	Y Unit Value	Y Total Value	Z Unit Value	Z Total Value
	1	555	555	595	595	635	635
	2	465	1020	505	1100	545	1180
	3	375	1395	415	1515	455	1635
	4	285	1680	325	1840	365	2000
	5	495	2175	235	2075	275	2275
	6	105	2280	145	2220	185	2460
	7	15	2295	55	2275	95	2555
	8	5	2300	20	2295	50	2605

APPENDIX 2
INSTRUCTIONS-*TYPE P/ TYPE C*
You are participating in an experiment of market decision making. The instructions are simple and if you follow them you can earn considerable amount of money which will be paid to you in cash. In this experiment, we are conducting a market in which you will be designated as one of two types of traders: *Type C* or *Type P*. The experiment will run for 5 periods of 10 minutes each. You can find your type at the top of the instructions.

You are classified as Type P and you are given a Record Sheet for each period of the experiment and a Production Schedule Sheet (these are on your desk).

The Production Schedule Sheet will help you determine the value of any decision that you might make. ***This information is private to you and should not be revealed to anyone.***

There are 4 types of goods (one input and three outputs) which can be traded in these markets: W, X, Y and Z. You can make profits through trading of the goods. Unlike the practice session (practice 2) where you were allowed to buy and sell in the same market, here in each market you can either buy or sell but not both. When you move the order box between market you will see either F1-BUY if you are a buyer or F2-SELL if you are a seller.

Trading in all markets is in terms of francs; however your final payoff will be in terms of pounds. Your conversion rate is 4000 francs to £1 (for every 4000 francs profits you make, you earn £1). You will be paid at the end of the experiment according to how much profit you make. In this handout it is explained how to calculate profits

ENDOWMENTS/ CASH ON HAND
At the beginning of the experiment you will receive 100000 francs cash on hand. At the beginning of each period, you will be given an endowment of W. This is the same for each period. However, you are free to buy more endowment from anyone who might want to sell it.

HOW THE SYSTEM WORKS
Type C traders are endowed with W but would like to consume X, Y and Z. They can sell W to Type P to increase their cash in order to buy X, Y and Z. Thus, Type C is a seller in market for W and buyer in market for X, Y and Z.

Type P traders are also endowed with W, but they may purchase units of W from Type C traders in order to produce. They can produce X, Y, Z from W and sell them to Type C traders to increase their cash on hand. Thus, Type P is a buyer in market for W and seller in market for X, Y and Z.

SPECIFIC INSTRUCTIONS TO TYPE P
PRODUCTION
During each market period, you are free to buy as many units of W which you use to produce and sell units of X, Y and Z from units of W. Production is done by using the transformation key F4 (as you were shown in practice training session). When producing units of X, Y and Z, you have to use the table labelled Production Schedule. This table reflects the number of units of X/ Y and Z that you can produce from given amounts of W

for the whole period. You have already been instructed in how to read the production schedule, but the following example may remind you further.

Note that you have to fill the transformation box (F4) based on the production schedule.

PRODUCTION SCHEDULE *(for Production Decision)*

Units of W (Input)	1	2	3	4	5	6	7	8	9	10
Units of X (Output)	6	4	2	1	0	0	0	0	0	0
Total Output	6	10	12	13	13	13	13	13	13	13

Units of W (Input)	1	2	3	4	5	6	7	8	9	10
Units of Y (Output)	5	3	2	1	0	0	0	0	0	0
Total Output	5	8	10	11	11	11	11	11	11	11

Units of W (Input)	1	2	3	4	5	6	7	8	9	10
Units of Z (Output)	7	5	4	2	0	0	0	0	0	0
Total Output	7	12	16	18	18	18	18	18	18	18

Suppose you have two units of W. Based on the above production schedule, you can produce one of these combinations:

1. 10 units of X (first unit produces 6 and the second produces 4)
2. 6 units of X and 5 units of Y
3. 6 units of X and 7 units of Z
4. 5 units of Y and 7 units of Z
5. 8 units of Y (first unit produces 5 and the second produces 3)
6. 12 units of Z (first unit produces 7 and the second produces 5)

You make profit by selling those units of X/Y and Z produced to Type C traders. For example assume you produce 1 unit of X (using 1 unit of W) which is sold to Type C trader at 180. If the purchase price of W was 150, then you make a per-unit profit of 180-150 =30. Thus, your profit on par unit sold is (Selling price- Cost [Buying price of W].

TRADING PROFIT
You can earn profit through trading and consumption. Selling increases your cash on hand by the amount of total sales revenue. Buying decreases your cash in hand by the value of purchases.

EARNINGS
Your profits per period is equal to:

(Cash in hand at the end of the period) – (Cash in hand at the beginning of the period)

At the end of each period you must complete a record sheet.

Record Sheet

Period No:

Trading

(1) Cash on hand at end of the period   ——————

(2) Cash on hand at beginning of period   ——————

(3) Net Change in cash on hand (1) – (2)   ——————

TOTAL PROFITS FOR THE PERIOD

In line (1) fill the cash on hand at the end of the period. In line (2) fill the cash on hand at the beginning of the period. Line (3) is simply line (1) minus line (2) which is your net change in cash on hand and also your total profits for the period.

MARKET RESTRICTIONS

Some of you may not be able to trade in all markets. You may not trade in MARKET NO: 4, 5, 6, 7, 8, 9, 11, 12

SPECIFIC INSTRUCTIONS TO TYPE C
CONSUMPTION
During the experiment you are free to sell as many units as you wish of W and buy as many units of X, Y and Z as you wish. Each unit of X, Y and Z you buy is assumed to be consumed by you.
Your Redemption Value sheet determines the amount you receive through consumption. You have already been instructed in how to read the redemption value sheet in the practice session. For the first unit of X that you consume for a given trading period, you receive the amount listed on your Redemption Value Sheet – the first row in the X unit value column (500, for example). For the second unit of X that you consume, you receive the amount listed in second row of the X unit value column (480 for example). The total amount that you receive from the consumption of both is found in the second column of X total value column (500 + 480 = 980). The amount you receive from consumption of Y and Z are

found in a similar way by reading the final 4 columns. The redemption value you received from W is always zero.

Whenever you trade you should take account of those redemption values. Your per unit profit is given by: (redemption value- purchase price).

Note: You are not allowed to produce: DO NOT HIT F4 AT ANYTIME.

REDEMPTION VALUE SHEET- in francs (*for Consumption Decisions*)

Unit	X unit Value	X total Value	Y unit Value	Y total Value	Z Unit Value	Z total Value
1	500	500				
2	480	980				
3						
4						
5						

INSTRUCTIONS TO BOTH TYPES
TRADING PROFITS
You can earn profits through consumption and trading. Selling increases your cash on hand by the amount of total sales revenue. Buying decreases your cash in hand by the value of purchases.

EARNINGS
Your profits per period exactly is equal to

(Cash in hand at the end of the period) – (Cash in hand at the beginning of the period) + (Redemption value of units that you consume).

At the end of each period you must complete a record sheet.

Record Sheet

Period No:

Trading

(1) Cash on hand at end of the period _____

(2) Cash on hand at beginning of the period _____

(3) Net Change in cash on hand (1) – (2) _____

Consumption

(4) Units Consumed: X _____ + Y _____ + Z _____

Earnings from consumption

(5) X   _____

(6) Y   _____

(7) Z   _____

*(8) Total Earnings from consumption
        (5) + (6) + (7)*   _____

(10) <u>TOTAL PROFITS FOR THE PERIOD: (3) + (8)</u>   ══════════

Your record sheet is divided into two sections: Trading and Consumption. In line (1) fill the cash on hand at the end of the period. In line (2) fill the cash on hand at the beginning of the period. Line (3) is simply line (1) minus line (2). In line (4) enter the number of units that you consume of W, X, Y and Z. In line (5) - (7), fill in the earnings from the consumption X, Y and Z and Y based on your redemption values sheet.   In line (8) add the total of lines (5), (6) and (7). In line (9) add the total of line (3) and (8), this is your profit for the period (in francs). You should aim to maximise your profits since this value will determines your earnings at the end of the experiment.

MARKET RESTRICTIONS

Some of you may not be able to trade in all markets. You may not trade in <u>MARKET 11 and MARKET 12.</u>

Appendix 3: THEORETICAL DERIVATIONS

Appendix 3A: The Competitive Ricardian Environment

Country 1/2/3 specialise in good X/Y/Z, so that total productions of X, Y and Z will be as follows:

$$X^* = 4L = 4 \, (2 * 3) = 24$$
$$Y^* = 3L = 3 \, (2 * 4) = 24$$
$$Z^* = 3L = 3 \, (2 * 5) = 30$$

Differentiating the utility function

$$U\,(X,\,Y,\,Z) = 600X - 45\,X^2 + 720Y - 45Y^2 + 840Z - 45Z^2 + m \tag{1}$$

gives the marginal utilities of each good, i.e.

$$MU_X = \frac{\partial U}{\partial X} = 600 - 90X$$
$$MU_Y = \frac{\partial U}{\partial Y} = 720 - 90Y \tag{2}$$
$$MU_Z = \frac{\partial U}{\partial Z} = 840 - 90Z$$

From equation (2), we can derive aggregate demand for the whole system. As there are six consumers in the system, aggregate demand is given by:

$$AD^*(X) = 600 - 15X$$
$$AD^*(Y) = 720 - 15Y \tag{3}$$
$$AD^*(Z) = 840 - 15Z$$

Substituting competitive equilibrium output, i.e. X*= 24; Y*=24 and Z*= 30 in equation (3) yield the competitive prices:

$$P_X^* = 600 - 15(24) = 240$$
$$P_Y^* = 720 - 15(24) = 360$$
$$P_Z^* = 840 - 15(30) = 390$$

Input prices equal their marginal revenue product. Therefore,

$$P_L^1 = \frac{\partial X}{\partial L} * P_X^* = 240 * 4 = 960$$

$$P_L^2 = \frac{\partial Y}{\partial L} * P_Y^* = 360 * 3 = 1080$$

$$P_L^3 = \frac{\partial Z}{\partial L} * P_Z^* = 390 * 3 = 1170$$

At the free trade price, net exports can be computed by considering the excess demand equations in each country valued at the competitive price:

$$AD^i(X) = P_X^* = 600 - 22.5(NX)$$

$$AD^i(Y) = P_Y^* = 720 - 22.5(NY)$$

$$AD^i(Z) = P_Z^* = 840 - 22.5(NZ)$$

where NX, NY and NZ denotes net export of X, Y and Z respectively.

This implies $NX= 16$, $NY=16$ and $NZ = 20$

Appendix 3B: Autarky Environment

Given there are 2 consumers in the country i, aggregate demand in each country is given by (from equation (3)):

$$AD^i(X) = P_X^i = 600 - 45X$$

$$AD^i(Y) = P_Y^i = 720 - 45Y$$

$$AD^i(Z) = P_Z^i = 840 - 45Z$$
where $i = 1, 2, 3$ (4)

Input prices equal their marginal revenue product. Therefore,

$$P_{LX}^i = \frac{\partial X}{\partial L} * P_X^i$$

$$P_{LY}^1 = \frac{\partial Y}{\partial L} * P_Y^i \qquad (5)$$

$$P_{LZ}^i = \frac{\partial Z}{\partial L} * P_Z^i$$

<u>*Country 1*</u>

$L_X = 3$; $L_Y = 1.5$ $L_Z = 1.5$

Production Function: $X = 4L_X$; $Y = L_Y$; $Z = L_Z$

Production = Consumption

$X = 12$
$Y = 1.5$
$Z = 1.5$

Prices and Wages

Substituting values of *X, Y* and *Z* in equation (4) gives

$P^1{}_X = 600 - 540 = 60$
$P^1{}_Y = 720 - 67.5 = 652.5$
$P^1{}_Z = 840 - 67.5 = 772.5$

From equation (5) we can derive the price of labour in each sector.

$P^1{}_{LX} = 240$
$P^1{}_{LY} = 652.5$
$P^1{}_{LZ} = 772.5$

<u>*Country 2*</u>

$L_X = 1; L_Y = 4\ L_Z = 3$

Production Function: $X = L_X; Y = 3L_Y; Z = 2L_Z$

Production = Consumption

$X = 1$
$Y = 12$
$Z = 6$

Prices and Wages

Substituting values of *X, Y* and *Z* in equation (4) gives

$P^2{}_X = 600 - 45 = 615$
$P^2{}_Y = 720 - 540 = 180$
$P^2{}_Z = 840 - 270 = 570$

From equation (5) we can derive the price of labour in each sector.

$P^2{}_{LX} = 615$
$P^2{}_{LY} = 540$
$P^2{}_{LZ} = 1140$

Country 3

$L_X = 2$; $L_Y = 3$ $L_Z = 5$

Production Function: $X = L_X$; $Y = 2L_Y$; $Z = 3L_Z$

Production = Consumption

$X = 2$
$Y = 6$
$Z = 15$

Prices and Wages

Substituting values of X, Y and Z in equation (4) gives

$P^3{}_X = 600 - 90 = 510$
$P^3{}_Y = 720 - 270 = 450$
$P^3{}_Z = 840 - 675 = 165$

From equation (5) we can derive the price of labour in each sector.

$P^3{}_{LX} = 510$
$P^3{}_{LY} = 900$
$P^3{}_{LZ} = 495$