An Experimental Investigation of the Patterns of International Trade

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This paper studies a laboratory economy with some of the prominent features of an international economic system. The patterns of trade and output predicted by the law of comparative advantage are observed evolving within the experimental markets. Market prices and quantities move in the direction of the competitive equilibrium, but the quantitative predictions of the (risk-neutral) competitive equilibrium are rejected. Considerable amounts of economic activity occur as disequilibria. Factor-price equalization is observed, but there is a universal tendency for factors of production to trade at prices below their marginal products. (*JEL* D50, F00, F30)

This study is the first attempt to create and study a laboratory economy with some of the prominent features of an international economic system. The purpose is to investigate some of the economic profession's fundamental assumptions about the nature of international trade. The concept of multiple "countries" in which each country has its own technology, preferences, and resource endowments, is introduced and operationalized. The questions posed in the study are related to the law of comparative advantage, factor-price equalization, terms of trade, efficiency in production, and exchange as guided by multiple and interacting markets and the effects of tariffs on international transactions. The study builds on previous work in the experimental study of general equilibrium phenomena.[1]

Because this paper carries laboratory experimental research to a new dimension of complexity and into a new field, it might be useful to address what would be the obvious concern of a skeptic. Since the world's international economies are vastly more complicated than the economies created for this study, of what relevance are laboratory-generated data? The answer is that laboratory experiments are not attempts to simulate field situations, as that question of the skeptic seems to presume. Laboratory research deals with the general theories and the general principles that are supposed to apply to all economies, the economies found in the field as well as those created in a laboratory. The laboratory economies are very simple and are special cases of the broad class of (often complex) economies to which the general theories are supposed to be of relevance. If a general theory does not work successfully to explain behavior in the sim-

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[1] Jessica Goodfellow and Plott (1990) investigate the simultaneous determination of input and output prices. Peng Lian and Plott (1993), create a macroeconomy which includes one input and one output as well as fiat money and bonds.

ple and special cases of the laboratory, then it is not general. When a model is found not working, opportunity exists to modify the theory to account for the data or to reject the theory. Thus, the laboratory provides an arena in which competing notions and theories about the nature of human (and market) capacities can be joined with data. Clearly laboratory experimental work is constrained by technology and by background experimental work. When very little background work exists, the experimental research strategy is first to explore what seem to be the most basic and general theoretical ideas. Then, as technology permits, successful ideas can be challenged with increasingly complex experimental environments in follow-up experiments. Any laboratory experiment should be viewed as only one of the many steps needed to learn what we would like to know. This study is no different.

The focus of the study is the behavior of the entire economic system, rather than the behavior of individual agents. Two behavioral models, "competitive equilibrium" and "autarky," can be applied to the experimental environments. Both models make precise predictions of the magnitude of every variable in the system, which number in the dozens. The existence of such a large number of predictions creates methodological and expositional problems. With a large number of predictions, some predictions will almost certainly be wrong. The sheer size of the undertaking makes it very easy to reject the models statistically. Therefore, after making a clear statement of the negative result that the models are rejected, the analysis of the data focuses on the general properties of interdependent markets that are suggested by the models, as opposed to a focus on the accuracy of the specific predictions of each model. In the context of the broad implications of the models, a number of results are stated.

The paper is organized in the following manner. We begin by discussing in Section I the existing support found in field data for the basic principles we test. In Sections II and III, the design of the experiments is described. In Section IV, the theoretical models are discussed. In Section V, the data are presented and analyzed, and in Section VI, the conclusions are summarized.

I. Field-Data Support for Major Principles

The propositions that we propose to explore are so basic to accepted theory and are applied so universally, that some might wonder why we would bother. Is it the case that the law of comparative advantage and the principle of factor-price equalization are well documented and not controversial? We think not. Nagging doubts linger because no direct evidence exists. Empirical results in support of the most basic principles of international-trade theory are clouded as they always are when the data are from field sources. As Michael P. Porter (1990 p. 12) writes, "Evidence hard to reconcile with factor comparative advantage is not difficult to find."

In his handbook chapter on testing trade theories, Alan Deardorff (1984) discusses the general problem of testing trade theories using field data. He cites two types of problems. First, simple trade models omit important features of the world economy, so model specification is an inherent problem. For example, the models usually assume only two countries, and they typically ignore transport costs. On the other hand, field data are generated by countries trading with many other countries in a world in which transportation costs exist and are often thought to be important. The second general problem is that theories tend to be stated in terms of variables that are not observable, so that testing these theories directly with field data is not possible. An example is the theory of comparative advantage.

The theory of comparative advantage is a general theory which states that countries will export that good which has the lowest relative price in autarky. However, attempts to test and assess the theory have only been indirect. In principle, this theory cannot be tested directly with field data because conditions of autarky and thus autarky prices are rarely, if ever, observed. In order to cope with this problem, researchers have developed more specific models like the Ricardian and Heckscher-Ohlin models. The purpose of these models is to build theoretical relationships from observables, like labor productivity or endowments, that can be extended to nonobservables, like autarky prices, and then to use the latter as the benchmarks against which trade flows are measured. Thus, tests of the Ricardian model, or the Heckscher-Ohlin model, are actually joint tests of comparative advantage and the particular specification (i.e., the Ricardian model or the Heckscher-Ohlin model).

Unfortunately, these indirect tests have failed to distinguish between competing theories. For example, empirical tests of the Ricardian trade model (and the related law of comparative advantage) using field data date back to the early work of G. D. A. MacDougall (1951, 1952). His procedure was to look at U.S. and U.K. exports to third countries and to see whether the pattern of exports is explained by differences in the two countries' labor requirements. He found that the ratios of U.S. to U.K. exports and U.S. to U.K. labor productivity are highly correlated, which is consistent with the predictions of the Ricardian model and, therefore, suggests the operation of the law of comparative advantage. But, as observed by Deardorff, the tests fail to distinguish between the Ricardian model and the Heckscher-Ohlin model, and as a result, the role and support for the law of comparative advantage remained unclear.

Thus, from the beginning there has not been a clear test of the comparative advantage that is so fundamental to theory. Similarly, there have been relatively few studies testing factor-price equalization theory. Alfred Tovias (1982) and Hans Gremmen (1985) look at the EEC countries to see if there is evidence that factor prices converge as trade becomes freer within the EEC. Their results are quite mixed. They find periods in which factor prices seem to converge, but later, as the economies become more integrated, factor prices do not seem to be converging. A later paper by Manouchehr Mokhtari and Farhad Rassekh (1989) looks at a bigger sample of countries and gets more positive results. They consider all of the OECD countries and use more sophisticated techniques. Their findings suggest that factor prices are converging within the OECD if countries are properly grouped into high-wage and low-wage countries. Furthermore, their evidence suggests that it is trade liberalization that accounts for much of this convergence. The evidence on factor-price equalization is far from conclusive.

The experimental data do not have many of the problems that are associated with field data. The experimental data are generated by only two countries. Transportation costs are under the control of the experimenter. The underlying structure is known. Variables unavailable in the field, like autarky prices, are known in the experiment. Factor prices can be observed under autarky and under free trade. In the field, neither can be observed. The field data on labor, for example, involves a great deal of aggregation across different types of labor. This means that one actually compares average wages of a group of workers in one country with the average wage of a different group in another country. If there is much variation across countries in groups, or if these groups change over time, a bias is introduced which may affect the results. No such problems exist in experiments.

Of course, experimental data are generated by much simpler economic environments than those found in the field. The preconditions for the operations of the principles have been introduced by the experimenters. The experiments are able to provide some insights into how models, based on the basic principles, are able to organize the data, given that the situation is one in which the model can be meaningfully applied. The experiment cannot, however, answer the equally important questions about the relative likelihood that nature has created a situation for which the parametric and institutional features of the model are relevant.

II. Experimental Design: Parameters

This section consists of a description of the market conditions within which the economic activity occurs. The description in-

TABLE 1—EXPERIMENTAL PARAMETERS

Preferences:[a]

Consumers, environment 1:
$U(Y, Z) = 600Y - 40Y^2 + 700Z - 40Z^2$

Consumers, environment 2:
$U(Y, Z) = 600Y - 100Y^2 + 600Z - 100Z^2$

Producers, environment 2:
$U(L, K) = 600L - 100L^2 + 600K - 100K^2$

			Franc/dollar conversion rate, experiment numbers:				
Parameter	Environment 1	Environment 2	030591 040191	041191	041391A	032091 041091 041391B	112890 113090 011891
Endowments:							
Consumers, country 1	$L_1 = 2, L_2 = 0$	$L_1 = 5, L_2 = 0$ $K_1 = 3, K_2 = 0$	1,000	800	900	800	800
Consumers, country 2	$L_1 = 0, L_2 = 2$	$L_1 = 0, L_2 = 3$ $K_1 = 0, K_2 = 5$	1,000	800	900	800	800
Producers, country 1	$L_1 = 1, L_2 = 0$	$L_1 = 0, L_2 = 0$ $K_1 = 0, K_2 = 0$	1,000	400	400	300	300
Producers, country 2	$L_1 = 0, L_2 = 2$	$L_1 = 0, L_2 = 0$ $K_1 = 0, K_2 = 0$	1,000	400	400	1,000	300
Production:							
Country 1	$Y = 3L, Z = L$	$Y = L, Z = K$					
Country 2	$Y = L, Z = 2L$	$Y = L, Z = K$					
Number:[b]							
Consumers, country 1	4	4					
Consumers, country 2	4	4					
Producers, country 1	4	4					
Producers, country 2	4	4					

[a]Utility functions are in franc units.

[b]The experiments in environment 1 involved either a 16-person design or 8-person design. In the 16-person design, consumers and producers were all different people. In the 8-person design, each factor owner in country i was also a producer and a consumer of final goods in country $j \neq i$. Thus, the number of agents identified by function was 16, but the number of people was 8.

cludes the environment, the parameters, and the form of market organization used to facilitate transactions. There are two environments: the first is motivated by the environment of the Ricardian Model of international trade;[2] the second is a similar environment, within which the robustness of results can be investigated and in which the properties of input markets can be considered in greater detail. All markets were organized through the computerized multiple unit double auction (MUDA). For details of the operation of this form of market organization, the reader can consult Plott (1991).

Money exists in both environments. Thus, the first environment, although similar to that of the Ricardian model, differs in that the purchase of any good requires money. Money is included in the design because it is an obvious feature of any well-functioning market process, including international economies, and it is certainly useful in experimental environments in facilitating equilibration. In both environments, there is

[2]For a clear exposition of the Ricardian model see Richard Caves et al. (1990 Ch. 5). For a fascinating account of the development of the Ricardian model see John S. Chipman (1965).

TABLE 2—REDEMPTION VALUES, ALL AGENTS, TWO ENVIRONMENTS, ONE COUNTRY (IDENTICAL COUNTRIES), ALL UNITS

Environment 1			Environment 2					
Consumer	*Y*	*Z*	Consumer	*Y*	*Z*	Producer	*L*	*K*
1	600	620	1	600	450	1	600	450
	520	540		250	400		250	400
	440	480		200	50		200	50
	360	400						
	280	320	2	550	500	2	550	500
	200	240		300	350		300	350
	120	160		150	100		150	100
	40	80						
2	560	660	3	500	550	3	500	550
	480	580		350	300		350	300
	400	500		100	150		100	150
	320	420	4	450	600	4	450	600
	240	340		400	250		400	250
	180	260		50	200		50	200
	100	180						
	20	100						
		20						
3	560	660						
	480	580						
	400	500						
	320	420						
	240	340						
	180	260						
	100	180						
	20	100						
		20						
4	520	700						
	440	620						
	360	540						
	280	460						
	200	380						
	120	300						
	40	220						
		140						
		60						

only one currency, and it has value as a commodity. All experimental currency held by subjects at the end of the experiment could be converted into dollars that the subject keeps as compensation for participation in the experiment. Since the focus of experimentation is international trade rather than finance, the complicating feature of multiple currencies has been omitted from the design.

Table 1 presents the experimental parameters for both of the environments that will be discussed below. Continuous approximations of the utility functions of both consumers and producers are quadratic and additively separable as shown in Table 1. The actual redemption values that were induced are contained in Table 2. Production technologies are linear as in Table 1. In the tables, valuations are given in francs (a common name for an experimental currency). The francs are converted into dollars according to ratios known privately to agents. These conversions can differ across agents and are contained in Table 1. The variables L_i and K_i refer to the factors L and K residing in country i and Y_i and Z_i refer to the outputs Y and Z produced in country i. The endowment listed in the table is the amount each individual agent possesses at the beginning of each market period. A country's total endowment is then four times the amount listed in the table, since each of the same type of agent has the same endowment.

A. *Environment 1*

Environment 1 is motivated by the Ricardian model. In environment 1, there are two output goods (final goods) called Y and Z and an input called L. There are two types of agents: consumers and producers. Consumers are owners of the factors of production and have induced preferences for consuming the outputs Y and Z. Producers also have an initial endowment of the input and can earn profits by using the input L to produce and then sell Y and Z. All agents can also attempt to earn profits by speculating in any input or output. Neither consumers nor producers have preferences for L other than its value as an input.

Agents are divided in equal numbers into two countries. Each country includes as members equal numbers of consumers and producers. The factor of production is not mobile between countries. The final goods Y and Z can be traded in either country, not only the one in which they were produced. The two countries differ only in their production technologies.

The economy works in the following way. Consumers sell their endowment of L to producers in their own country and then buy units of Y and Z produced in either country. Consumers get utility (U.S. dollars) from consumption and any profits made in price speculation. Producers in each country buy L from the consumers in their own country and can use L to produce Y and Z which they can sell to consumers in either country. Producers get utility (dollars) from profits earned from market and production activities.

In some experiments, free international trade was permitted; in others a tariff was imposed on the imports of Z to country 1. When a tariff was in effect, it took the form of a tax of 400 francs on international transactions of the final goods. The tariff revenue was not redistributed to citizens in either country but instead was taken by the experimenter. Thus, the tariff operated similarly to a transportation cost.

B. *Environment 2*

In environment 2, the two countries have different endowments of the inputs. In addition, the inputs are endogenously and elastically supplied to producers in the sense that resources could also be consumed. Environment 2 operated as a control on environment 1 to ensure that any properties of input markets observed in environment 1 were not simply due to the completely inelastic supply of the input. The endogenous-resource property of environment 2 is a natural feature to add as a check on robustness of a model's ability to capture observed behavior because it is a general property of the field economies in which the competitive and autarky models are regularly applied.

In environment 2 there are two output goods called Y and Z and two inputs called L and K. There are also two types of agents: consumers and producers. As in environment 1, consumers are also owners of the factors of production. Consumers are endowed with some of both of the inputs L and K. Consumers have induced preferences for consuming the outputs Y and Z. Producers of the final goods are also consumers of the factors of production. They have no initial endowment but have preferences induced for consuming the inputs L and K and also for the money they might get by producing Y from L and Z from K and selling the output.

Participants are divided equally into two countries. Each country has an equal number of consumers and producers. Both types of agents can trade the inputs L and K only with agents in their own country. The final goods Y and Z can be traded internationally. No tariffs existed in any of the experiments in which environment 2 was implemented.

TABLE 3—SUMMARY OF EXPERIMENTS

Experiment number (date)	Tariffs Y/N	Periods	Environment	Subject pool	Number of subjects
030591	N	11	1	Caltech	8
040191	N	10	1	Caltech	8
041191	N	9	1	U. Iowa	16
041391A	N	10	1	U. Iowa (exper.)[a]	16
032091	Y	10	1	Caltech	8
041091	Y	9	1	U. Iowa	16
041391B	Y	10	1	U. Iowa (exper.)[a]	8
112890	N	9	2	Caltech	16
113090	N	11	2	Caltech	16
011891	N	10	2	Caltech	16

[a]Subjects had experience in one of the earlier experiments listed here.

Consumers sell their endowment of inputs to producers in their own country, and consumers buy units of Y and Z produced in either country. Producers can buy L and K from consumers in their own country. Producers can consume any part of the purchases of L and K and can use the remainder to produce Y and Z, which they can then sell in either country.

III. Experimental Design: Procedures

A total of ten experiments were conducted. Table 3 provides a summary of treatments. Experiments are indexed by the date of the experiment. Two subject pools were used. The experiments involved either 8 people or 16 people. The use of 8 people for some experiments was dictated by cost and difficulties in recruiting subjects.

In the conditions of environments 1 and 2, there were six and eight markets, respectively, operating simultaneously.[3] Each variable had its own market (e.g., output Y_i, Y produced in country i, had its own market). The production process allowed subjects to transfer units from and to inventories of certain markets in fixed ratios. Production was accomplished through a series of keystrokes. To consume units, subjects held them in their inventory at the end of a market period.

Subjects, undergraduates at the California Institute of Technology and at the University of Iowa, had at least one half hour of prior training in use of MUDA.[4] The MUDA software is accompanied by a tutorial that explains the key functions to subjects and lets subjects practice using the keys in an environment containing randomly behaving robots. The Appendix contains instructions read to subjects. During period 0 and period 1, accounting records were checked carefully for mistakes, and spot checks were conducted in later periods.

The experiment was divided into trading periods or trading "days." At the beginning of each, subjects received new endowments and redemption values which were the same each period. At the beginning of the experiment there was a long practice period (period 0) for 15 minutes in which no money was paid. Market periods averaged 10 minutes in length.

[3]The names L and K were not used to label the markets in any experiments because they might suggest behavior to the subjects if they thought that L and K represented labor and capital. The labels used in markets are explained in the Appendix.

[4]Although Caltech subjects were only allowed to participate in one experiment in this particular line of experimentation, some of the Caltech subjects had been in other market experiments. None of the University of Iowa subjects had been in other market experiments previously, although experiments 041391A and 041391B used only subjects who had been in one of the previous experiments in the series.

IV. Models

The models described below rely on strong assumptions. The complex environments of the experimental markets are much richer than those that the models describe. However, experimental economics has demonstrated that models frequently have surprising power even when applied to environments much more complex than the structure of the models. The questions that will ultimately be posed concern the identification of models that can provide intuition needed for help with the interpretation of market data.

A. *The Competitive Model*

This section contains a brief elaboration and review of the competitive model. The computation and description of the competitive equilibria for both environments are in a technical appendix which is available from the authors upon request. Recall that the first environment has two outputs, both of which can be produced with the same input, paralleling that of the Ricardian model of international trade. In the Ricardian environment there are two final goods, Y and Z, each of which is produced using one factor, L. There are two countries which may differ in their endowments of the factor. The factor cannot cross national boundaries and is supplied inelastically to the markets. The two countries are assumed to have different production functions so that each country has a comparative advantage in production of one of the goods. Without loss of generality, call the country with a comparative advantage in the production of Y country 1. The two countries have identical aggregate demand for both goods. In autarky, the price ratio P_Z/P_Y should be greater in country 1 than in country 2. That is, country 1 can produce good Y more cheaply in terms of good Z then can country 2. If trade between the two countries is permitted, then comparative advantage dictates that country 1 specializes in and exports good Y. Similarly, country 2 specializes in and exports good Z. If the final goods are traded without restrictions, the prices of the final goods, Y and Z, will be the same across countries and the price of L generally will be different in each country.

Thus, for environment 1, the competitive model predicts that countries 1 and 2 would produce exclusively goods Y and Z, respectively, and that each of the two countries would be a net exporter of the output which it produces. In particular country 1 would produce only Y, and country 2 would produce only Z. The prices of the outputs would be equal in each country according to the model, and the prices of inputs would equal their marginal revenue products.

If a tariff were imposed on the country-1 imports of Z in environment 1, then according to the competitive model international trade of Z would decline. The price of Z in country 1 would increase, and the price of Z in country 2 would fall. The input price in country 2 would also decline, since its marginal revenue product would be lower. The tariff imposed was 400 francs.

In environment 2, the competitive model predicts that each country would produce both output goods. Country 1, however, would be a net exporter of Y, and country 2 would be a net exporter of Z. Under conditions of free trade, the prices of outputs would be equal across countries. Since derived demand would be identical in both countries, then the factor prices would also be the same and would equal the factors' marginal revenue product. The price of each of the four types of goods in country 1 would equal its price in country 2. The prediction of the equality of input prices across countries in environment 2 will be referred to as the factor-price equalization principle. Notice that for the parameter values imposed in this environment, factor-price equalization is predicted even though the factors cannot be traded internationally.

B. *Autarky*

A natural alternative model to use is the autarky model. It is useful because it characterizes one benchmark of the potential behavior which a system might exhibit. Its predictions are based upon the proposition that no trade will occur across national

TABLE 4—SPECIFIC PREDICTIONS OF THE TWO MODELS: PRODUCTION AND EXPORT QUANTITIES AND PRICES IN FRANCS WITH AND WITHOUT TARIFFS

	Environment 1				Environment 2	
	Competitive		Autarky			
Variable	With tariff	No tariff	With tariff	No tariff	Competitive	Autarky
Production:						
Y_1	36	36	21	21	12	10
Y_2	0	0	5	5	4	6
Z_1	0	0	5	5	4	6
Z_2	32	32	22	22	12	10
Exports:						
Y_1	18	18	0	0	4	0
Y_2	0	0	0	0	0	0
Net Y (from 1 to 2)	18	18	0	0	4	0
Z_1	0	0	0	0	0	0
Z_2	16	6	0	0	4	0
Net Z (from 2 to 1)	16	6	0	0	4	0
Prices:						
L_1	720	720	600	600	200–250	150
L_2	760	360	520	520	200–250	300–350
K_1	—	—	—	—	200–250	300–350
K_2	—	—	—	—	200–250	150
Y_1	240	240	200	200	200–225	150
Y_2	—	—	520	520	200–225	300–350
Z_1	—	—	600	600	200–225	300–350
Z_2	380	180	260	260	200–225	150

boundaries. This model predicts the prices and production levels in each country which would occur in a competitive equilibrium with no international transactions permitted. This model thus offers specific predictions of prices, patterns of production, international trade, and the effects of tariffs.

For environment 1, the autarky model predicts that specialization would not occur in either country, and that there would be no international trade or payment imbalances. Since there is no trade across national boundaries, the predictions of this model are unaffected by the imposition of tariffs. According to the autarky model, prices of all goods would be different in the two countries.

The autarky model also makes predictions concerning production and trade in the two countries in environment 2. Both countries produce both goods but in different quantities than in the competitive equilibrium. Autarky predicts that there will be no international trade and that both input and output prices will be different across countries. The wage–price ratio predictions are identical to those predicted by the competitive model. There should be no payment imbalances. The predictions of the autarky model are computed in a similar way to the competitive model. The computations are available from the authors upon request.

The specific predictions of the two models in the two environments are given in Table 4. An illustration of the autarky model and the competitive model is given in Figure 1 from an individual's point of view for environment 1. In the figure, if trade between countries does not occur, an individual in country 1 achieves his highest indifference curve given initial endowments, by consuming 5.25 units of Y and 1.25 units of Z. Similarly, an individual in country 2 reaches his highest possible utility level by consuming 1.25 units of Y and 5.5 units of Z. In the experimental environment, money, which has value to all agents, may be borrowed costlessly in large quantities from the experimenter. For this reason, there is no budget constraint. The optimal consumption bundle is determined by the prices of Y and Z and by the consumer's utility for Y, Z, and money. The autarky consumption bundles of individual consumers in the two countries are labeled with A's in the figure. If free trade occurs, then each country can achieve a higher utility level by specializing in the commodity in which it has a comparative advantage and then trading internationally at the world competitive equilibrium price. The competitive-equilibrium individual consumption bundles are labelled with C's. In the competitive equilibrium, each country consumes 18 units of Y and 16 units of Z.

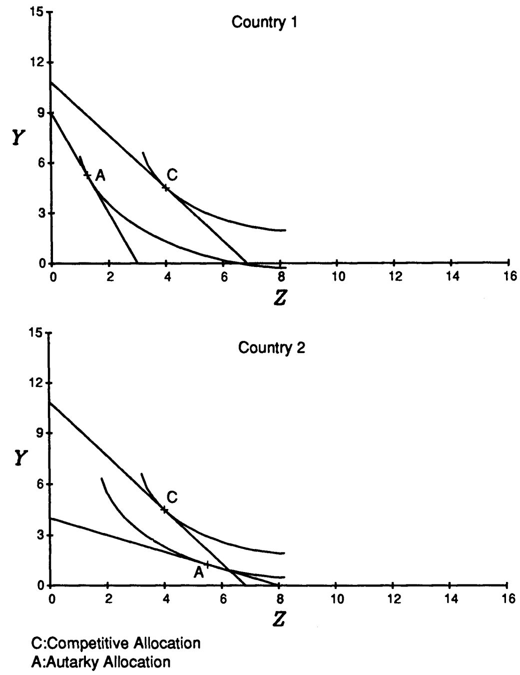

FIGURE 1. CONTINUOUS APPROXIMATION OF REPRESENTATIVE CONSUMER'S INDIFFERENCE CURVE AND RELATIVE PRICES UNDER AUTARKY AND FREE TRADE

C. *Efficiency*

The efficiency measurements in our experiments were first developed by Plott and Smith (1978). In a single market the system is operating at 100-percent efficiency if the total profit that all subjects make in an experiment is at a maximum. It is similar to maximizing consumer plus producer surplus.

In a general-equilibrium system the problem becomes a little tricky. Because of the single currency in these experiments, the gains from exchange are exhausted at the maximum of system profits in terms of the experimental currency, francs. Actual profits divided by the maximum possible becomes the measure of system efficiency. Efficiency is 100 percent if the competitive equilibrium is attained. When tariffs were imposed, the government revenues were treated the same as were the profits of individuals and, therefore, included as part of the "consumer surplus" that was created by exchange.

V. Results

The principal observations are summarized in Results 1–9. A typical price time series from environment 1 (no tariffs) is represented in Figures 2 and 3. The vertical axis measures price in terms of the currency of the experiment. The horizontal axis measures time in seconds. All markets were organized electronically with the bids, asks, and contracts made via computerized interactions. Thus market activity took place in real (clock) time, and the data are recorded in terms of the second at which actions took place. Thus, "Clock (sec)" on the horizontal axis means the exact second that the action took place. Vertical lines represent the beginning or the end of periods or "days" as described in Section III. Thus, the interval between the end of one period and the beginning of the next appears as an empty vertical band representing seconds in which nothing happened in the markets because the markets were closed while subjects did their accounting. Contract prices are represented as circles and are connected by lines so that the time sequence can be more easily identified. The input prices for each country separately are shown in Figure 2.

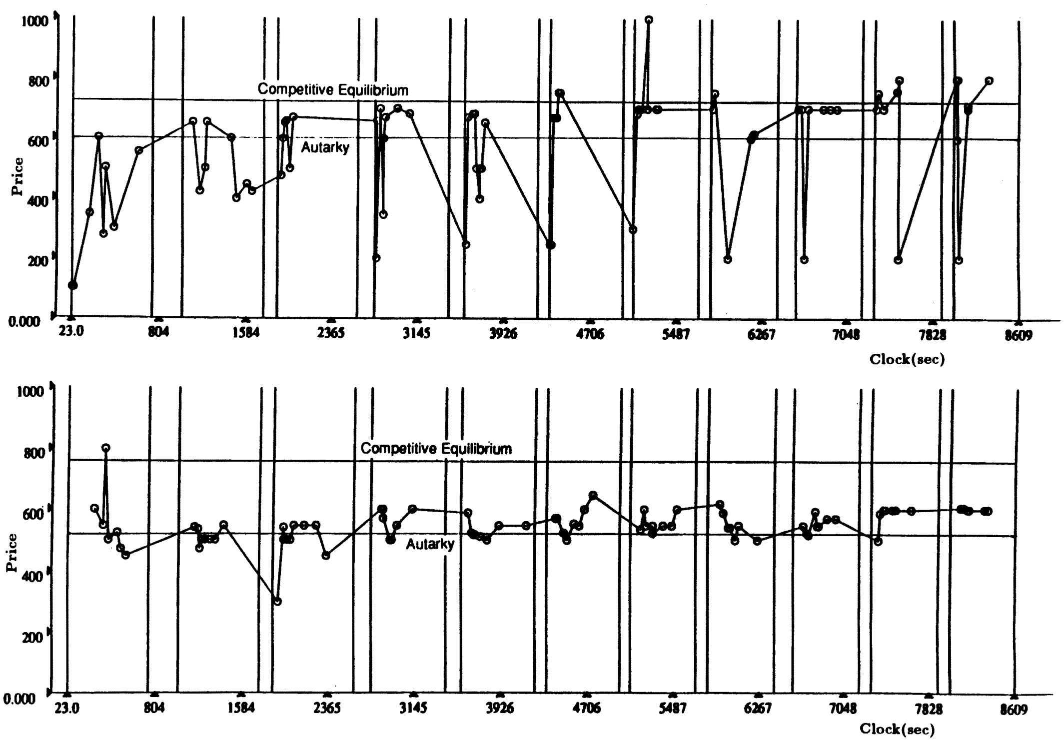

FIGURE 2. INPUT-PRICE TIME SERIES, EXPERIMENT 041391A: COUNTRY 1 (UPPER GRAPH) AND COUNTRY 2 (LOWER GRAPH)

The output prices are pooled across countries for each of the two outputs and are given in the two graphs of Figure 3. Horizontal solid lines are drawn at the level of the theoretical competitive prices and also the autarky prices as marked.

Several useful impressions can be drawn from the figures. First, the data are not automatically clustered at the competitive equilibria. This is perhaps no surprise to those who have studied the properties of experimental markets, but the fact that markets are not always automatically at the competitive equilibrium is of substantial importance to those who must use equilibrium theories as a specification tool in the interpretation of field data. Secondly, the prices over time move toward the competitive equilibria. This power of the competitive-equilibrium model in predicting the direction of the movement in these complicated markets is also observed in simpler economic environments. The formal statements of results in this section will make these general impressions precise.

The analysis of the data of this section encounters some classical problems that exist in the analysis of almost all data produced in experimental markets. Markets exhibit a convergence process that is not understood theoretically. From a practical point of view, this means that serial correlation is present, and heteroscedasticity may be present. In the absence of a well-developed theory of a convergence process, such statistical complications create substantial problems with any attempt to summarize succinctly the patterns that may exist in the data. With these qualifications in mind, the following model, motivated by the model of Orley Ashenfelter et al. (1992), is used repeatedly to analyze the effect of time

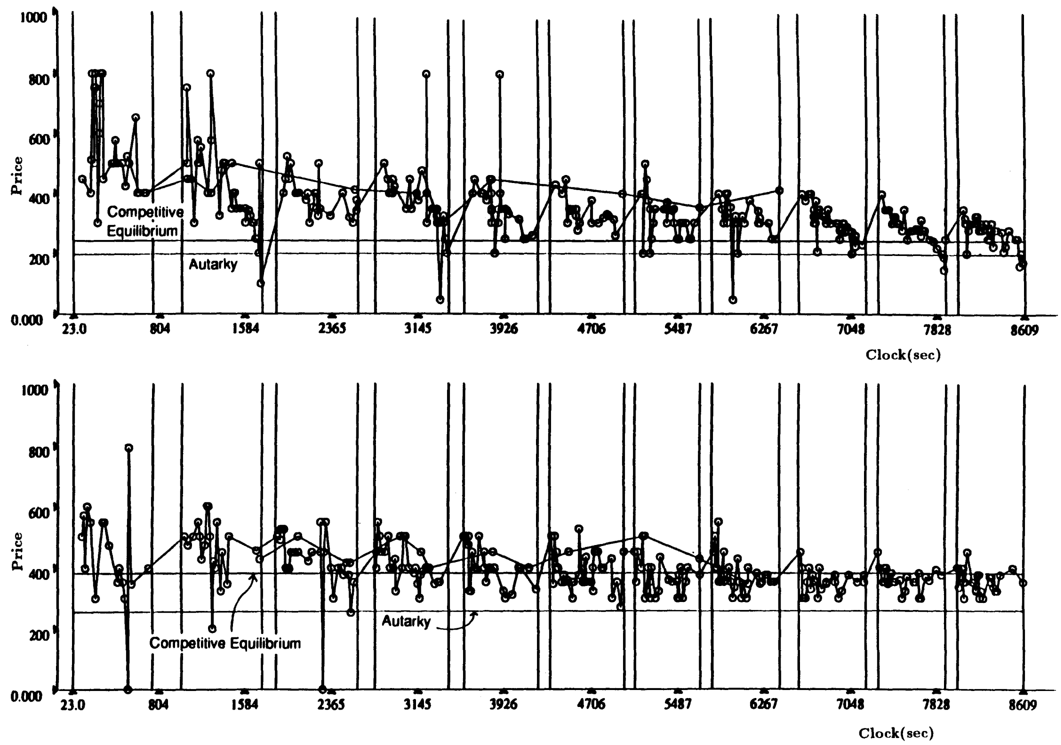

FIGURE 3. OUTPUT-PRICE TIME SERIES, EXPERIMENT 041391A: PRICES OF Y IN BOTH COUNTRIES (UPPER GRAPH) AND PRICES OF Z IN BOTH COUNTRIES (LOWER GRAPH)

on the outcome variables in the experiments:[5]

$$(1)\quad y_{it} = B_{11}D_1(1/t) + B_{12}D_2(1/t) + \cdots + B_{1i}D_i(1/t) + \cdots + B_{1n}D_n(1/t) + B_2(t-1)/t + u$$

where i indicates the particular experiment, t represents time as measured by the number of market periods in the experiment, D_i is a dummy variable that takes a value of 1 for i and a value of 0 otherwise, and B_{1i} is the origin of a possible convergence process. Notice that if $t=1$ then the value of the dependent variable is equal to B_{1i} for experiment i. B_2 is the asymptote of the dependent variable. As t gets large the

[5]We benefited from several discussions with Mahmoud El-Gamal who suggested the specification that we used, along with others. The estimates in the tables are corrected for first-order autocorrelation, which is present within the experimental sessions. In addition to the estimates of the equations given in the text, two alternative specifications were also used to analyze the data. They were

$$z = B_{11}D_1\frac{1}{t} + \cdots + B_{1k}D_k\frac{1}{t} + B_{21}D_1\left(\frac{t-1}{t}\right) + \cdots + B_{2k}D_k\left(\frac{t-1}{t}\right) + u$$

and

$$z = B_{11}D_1\left(\frac{1}{t}\right)^{\alpha_1} + \cdots + B_{1k}D_k\left(\frac{1}{t}\right)^{\alpha_k} + B_2\left(\frac{t-1}{t}\right)^{\gamma} + u$$

where z is any of the dependent variables, such as quantity produced, quantity exported, or price of a commodity. Refer to the last two equations as specifications 1 and 2, respectively. Specification 1 assumes a linear functional form but allows the time series to

TABLE 5—CONVERGENCE PATTERNS OVER TIME OF PRODUCTION, EXPORTS, AND MARKET PRICES, ENVIRONMENT 1 (NO TARIFF)

$$y = B_{11}D_1\frac{1}{t} + \cdots + B_{14}D_4\frac{1}{t} + B_2\frac{t-1}{t} + u$$

						Competitive equilibria		Autarky			
Dependent variable	B_{11}	B_{12}	B_{13}	B_{14}	B_2	Model predictions	Significance (p)	Model predictions	Significance (p)	ρ	R^2
Production:											
Y_1	17.73	21.56	13.44	28.15	32.70	36	< 0.005	21	< 0.005	0.13	0.69
	(3.32)	(1.32)	(2.10)	(1.86)	(0.70)						
Y_2	4.81	6.92	2.68	3.29	0.68	0	ns	5	< 0.005	0.45	0.71
	(0.85)	(1.11)	(1.16)	(0.42)	(0.47)						
Z_1	4.81	4.90	7.73	2.28	0.87	0	< 0.005	5	< 0.005	0.02	0.66
	(0.92)	(0.32)	(0.70)	(1.00)	(0.18)						
Z_2	18.73	18.10	26.84	25.42	30.93	32	ns	22	< 0.005	0.48	0.76
	(1.20)	(2.28)	(2.50)	(0.87)	(1.04)						
Net exports:											
Y	1.93	5.88	11.78	14.16	14.35	18	ns	0	< 0.005	0.58	0.73
	(2.62)	(2.05)	(2.47)	(2.80)	(2.14)						
Z	5.32	9.08	15.72	12.48	16.06	16	ns	0	< 0.005	0.49	0.62
	(2.78)	(1.47)	(4.47)	(1.77)	(1.61)						
Market prices:											
P_{L_1}	429.7	501.7	600.1	420.6	700.9	720	ns	600	< 0.05	0.42	0.48
	(79.3)	(66.0)	(231.1)	(43.0)	(49.8)						
P_{L_2}	415.1	300.9	580.6	501.3	601.9	760	< 0.005	520	< 0.05	0.59	0.69
	(91.0)	(65.1)	(48.6)	(47.0)	(44.7)						
P_{Y_1}	405.4	279.3	812.6	439.7	295.9	240	< 0.005	200	< 0.005	0.33	0.89
	(29.6)	(40.1)	(59.0)	(25.8)	(12.8)						
P_{Z_2}	439.6	484.6	745.7	426.8	439.6	380	< 0.005	260	< 0.005	0.34	0.77
	(26.9)	(28.8)	(76.9)	(33.6)	(14.6)						

Note: Estimates were corrected for AR(1).

weight of B_{i1} is small because $1/t$ approaches zero while the weight of B_2 is large because $(t-1)/t$ approaches 1. Notice that B_2 is common to all experiments. Finally, u is the random error term that is distributed normally with mean zero. We allow for heteroscedasticity and first-order autocorrelation.

The model is equipped to answer questions about the direction of convergence. Each experiment might have a different starting point, but according to the intuition of competitive-market theory, the processes should converge, and the ultimate point of convergence should be the same (the competitive equilibrium quantities). For purposes of describing the data, the term "weak convergence" is used when the start of the data, as measured by B_{1i}, is further from the predictions of the model than is the asymptote, as measured by B_2.

The model was estimated for each of the relevant dependent variables, and the results of the estimates are contained in Tables 5, 6, and 7. The standard errors are corrected for heteroscedasticity using White's method (see Halbert White, 1980), as well as first-order autocorrelation. The model was estimated for each of the treat-

converge to a different value for each experimental session. Specification 2 is nonlinear; we estimate the B, α, and γ terms. The functional form was based on an *ex post* inspection of the data. It allows the time series to converge at different rates in the different experimental sessions but requires all of the data to converge to a common asymptote. The estimates of the alternative specifications are not given here, because they do not improve upon the specification used in the text. Specification 1 yields adjusted R^2's, estimated coefficients, and standard errors close to those of the specification given in the text. The nonlinear specification 2 also yields comparable adjusted R^2's but very large standard errors, especially for the price variables, so that usually neither the competitive model nor the autarky model could be rejected.

TABLE 6—CONVERGENCE PATTERNS OVER TIME OF PRODUCTION, EXPORTS, AND MARKET PRICES, ENVIRONMENT 1 (WITH TARIFFS)

$$y = B_{11}D_1\frac{1}{t} + \cdots + B_{13}D_3\frac{1}{t} + B_2\frac{t-1}{t} + u$$

Dependent variable	B_{11}	B_{12}	B_{13}	B_2	Competitive equilibria: Model predictions	Competitive equilibria: Significance (p)	Autarky: Model predictions	Autarky: Significance (p)	ρ	R^2
Production:										
Y_1	27.17	32.33	14.42	27.97	36	ns	21	ns	0.61	0.62
	(3.37)	(4.67)	(5.48)	(5.45)						
Y_2	2.13	9.14	9.56	3.96	0	< 0.005	5	ns	0.40	0.63
	(1.41)	(0.93)	(2.23)	(0.87)						
Z_1	3.06	1.26	7.03	2.57	0	ns	5	ns	0.64	0.66
	(1.22)	(1.74)	(1.67)	(1.82)						
Z_2	25.60	5.56	11.79	24.51	32	< 0.01	22	ns	0.56	0.77
	(1.94)	(1.99)	(4.31)	(2.70)						
Net exports:										
Y	7.16	14.05	−1.77	13.06	18	ns	0	< 0.005	0.52	0.57
	(1.82)	(5.11)	(3.41)	(3.28)						
Z	1.23	1.85	0.72	1.42	6	< 0.005	0	ns	0.43	0.31
	(1.03)	(1.57)	(0.75)	(1.20)						
Market prices:										
P_{L_1}	500.8	391.5	413.7	677.5	720	ns	600	ns	0.51	0.42
	(56.9)	(130.5)	(68.1)	(75.6)						
P_{L_2}	268.4	247.0	−24.3	473.3	360	ns	520	ns	0.88	0.68
	(646.5)	(959.9)	(938.2)	(964.5)						
P_{Y_1}	297.9	1,002.9	434.0	289.2	240	< 0.01	200	< 0.005	0.22	0.84
	(37.0)	(103.5)	(48.4)	(18.7)						
P_{Z_2}	166.4	1,003.0	606.5	283.6	180	< 0.005	260	ns	0.00	0.73
	(38.1)	(140.6)	(95.7)	(21.7)						

ment environments and for each of the variables, separately. The significance levels for various hypothesis tests are also in the tables.

Notice from Figures 2 and 3, that the transaction prices seem to be moving toward the competitive-equilibrium prices over time. While this tendency of convergence will ultimately be shown to be true, the first pass at the data holds to strict standards. As can be seen the prices are not at the competitive equilibrium. As we indicated earlier, in economic systems as complicated as these, it is very easy to statistically reject the benchmark models. This indeed proved true.

The first result is important because it shapes the entire discussion. It demonstrates that neither the competitive model nor the autarky model accurately represents the data generated by the experiments. Such a result is not particularly surprising to those who have studied the behavior of experimental markets. The market prices and quantities traded, as predicted by the competitive model, are often rejected, and the autarky model is usually rejected as well. The models are static, while the actual markets exhibit considerable dynamic and adjustment behavior, the very existence of which is sufficient to reject the models. However, Result 1 is especially interesting because of the power brought to the analysis by the econometric model introduced above. The result says that, even after the model has been modified to incorporate differential adjustment rates in different experimental sessions, both models can still be rejected.

RESULT 1: *Both the competitive model and the autarky model can be rejected as accurate representations of the data.*

SUPPORT:

Rejection of the models rests on the fact that each of the models makes numerous predictions. Of course, rejection only re-

TABLE 7—CONVERGENCE PATTERNS OVER TIME OF PRODUCTION, EXPORTS, AND MARKET PRICES, ENVIRONMENT 2

$$y = B_{11}D_1\frac{1}{t} + \cdots + B_{13}D_3\frac{1}{t} + B_2\frac{t-1}{t} + u$$

Dependent variable	B_{11}	B_{12}	B_{13}	B_2	Competitive equilibria: Model predictions	Competitive equilibria: Significance (p)	Autarky: Model predictions	Autarky: Significance (p)	ρ	R^2
Production:										
Y_1	6.69	7.79	7.68	11.53	12	ns	10	< 0.05	0.29	0.41
	(1.86)	(0.66)	(0.86)	(0.72)						
Y_2	5.74	7.58	3.11	4.72	4	< 0.05	6	< 0.005	0.13	0.25
	(1.87)	(0.84)	(0.93)	(0.39)						
Z_1	6.23	4.20	4.78	6.15	4	< 0.005	6	ns	0.09	0.06
	(0.83)	(1.82)	(1.54)	(0.51)						
Z_2	6.44	11.76	5.06	10.50	12	< 0.05	10	ns	0.16	0.27
	(0.92)	(2.04)	(2.96)	(0.64)						
Net exports:										
Y	−2.68	0.14	4.96	3.72	4	ns	0	< 0.005	0.12	0.48
	(1.16)	(1.42)	(1.70)	(0.49)						
Z	0.68	3.80	2.65	4.16	4	ns	0	< 0.005	0.30	0.19
	(1.89)	(1.68)	(2.45)	(1.11)						
Market prices:										
P_{L_1}	408.6	187.8	388.8	227.4	200–250	ns	150	< 0.005	0.12	0.89
	(16.9)	(8.5)	(15.7)	(5.6)						
P_{L_2}	390.9	307.9	514.4	220.8	200–250	ns	300–350	< 0.005	0.35	0.62
	(12.7)	(35.6)	(82.3)	(15.1)						
P_{K_1}	327.1	227.2	260.2	233.5	200–250	ns	300–350	< 0.005	0.37	0.58
	(44.6)	(7.2)	(34.5)	(11.0)						
P_{K_2}	349.4	301.7	281.8	220.0)	200–250	ns	150	< 0.005	0.27	0.47
	(23.8)	(28.0)	(49.2)	(9.9)						
P_{Y_1}	583.9	322.9	497.7	256.7	200–225	< 0.005	150	< 0.005	0.37	0.92
	(15.0)	(23.2)	(32.9)	(10.5)						
P_{Y_2}	525.2	382.9	534.5	255.6	200–225	< 0.005	300–350	< 0.005	0.31	0.87
	(18.9)	(34.9)	(17.8)	(10.0)						
P_{Z_1}	528.6	342.0	475.5	257.0	200–225	< 0.005	300–350	< 0.005	0.24	0.24
	(40.9)	(17.0)	(18.5)	(8.2)						
P_{Z_2}	448.3	377.0	331.5	276.7	200–225	< 0.005	150	< 0.005	0.00	0.71
	(13.2)	(18.6)	(16.8)	(5.3)						

quires that one prediction be wrong, but we reject the model's predictions of many of the outcome variables. Testing of the models is focused only on the variable B_2, which represents the long-term (asymptotic) tendency of the magnitude of the variables. The estimates are in Tables 5, 6, and 7 for each of the treatment conditions, environment 1 with and without tariffs, and environment 2. A summary of significance tests of the two models and variables is provided in each of the tables. As can be seen in Table 5, the autarky model is rejected for every variable in environment 1 (no tariff) at the $p < 0.005$ level of significance for eight of the ten variables and at the $p < 0.05$ level for the other two variables. As shown in Table 7, all price predictions of the autarky model are incorrect in environment 2, as are its predictions of exports and of production of Y in both countries. The autarky model performs best under environment 1 (tariff), as shown in Table 6, but even in this case, two of the variables are significantly different from the predictions of the model at the 0.005 level of significance.

Under the conditions of environment 1 (no tariff) the competitive model fails to predict two of the four production variables, the prices of L_2, Y, and Z. Under the conditions of environment 1 (tariff), the competitive model fails to predict three of the six aggregate production and export levels, as well as the prices in two of the four markets. In all cases, the significance level supporting rejection is at least 0.05. As for environment 2, the competitive model is rejected for seven of the 14 variables at the 0.05 level of significance.

It is important to note, as is clear from the tables, that the competitive model has some merit when one compares the coefficients B_{1i} to B_2. The remaining results are attempts to summarize those aspects of the competitive and autarky models that are successful. The general theme is that convergence of the data over time, with replication of the market, is in the general direction of the competitive equilibria and that the autarky model is firmly rejected. In particular, several qualitative features of the competitive model are very prominent in the data and are described by the next series of results.

Result 2 summarizes observations concerning whether or not the law of comparative advantage can be seen in operation. The notion is that countries export the output in whose production they have a comparative advantage. Recall that when applied to the parameters of environment 1, the law of comparative advantage holds that country 1 should specialize in and be a net exporter of good Y. Country 2 should specialize in and be a net exporter of Z.

RESULT 2: *The law of comparative advantage accurately predicts trade patterns.*

SUPPORT:

Refer to Tables 5, 6, and 7. Under the conditions of environment 1 (no tariff), neither the net exports of Y nor the net imports of Z by country 1 are statistically different from the predictions of the competitive model of 18 units and 16 units, respectively. Thus, within this environment, the flow of international trade is not only in the direction predicted by the law of comparative advantage, but the actual magnitudes are converging to near those predicted by the competitive model. Net exports of Y and net exports of Z are 14.4 units and 16.1 units, respectively. Under the tariff condition, the directions of trade patterns are those predicted by the law, but exports of Z are significantly less than predicted by the competitive model. That is, the net exports of Y by country 1 are 13.1 units as opposed to the 18 predicted by the competitive model. Exports of Z by country 2 are 1.4, as opposed to the 6 units predicted by the competitive model. Under the conditions of environment 2 the net exports are not significantly different from those predicted by the competitive model (i.e., 3.7 units net exports of Y by country 1, compared with the competitive equilibrium of 4; 4.2 units of net exports of Z by country 2, compared with the 4 units predicted by the competitive model). In summary, under all conditions, the patterns of trade are consistent with the directions predicted by the law of comparative advantage.

Implicit in the discussion above is the fact that the law of comparative advantage can be viewed as an independent principle or it can be viewed as a consequence following from the assumptions of the general competitive model. Thus, since the result lends support to the competitive model, it is natural to inquire about other features of the model. The competitive model not only predicts the direction of net exports, as captured by the law of comparative advantage as discussed in Result 2, it also predicts patterns of production. For environment 1 the competitive model predicts that no units of Y would be produced in country 1 and that no units of Z would be produced in country 2. Result 3 reflects considerations of those precise implications of the competitive model under both tariff and no-tariff conditions.

The support for Result 3 can be seen in Figures 4 and 5 for environment 1. The figures contain world aggregate production for early periods and for later periods. The world production frontier is shown in the figure. The competitive model predicts that world production will be at the "kink" in the frontier. Figure 4 contains data from environment-1 experiments in which there were no tariffs. Figure 5 contains the data from environment-1 experiments in which tariffs existed. As can be seen in both

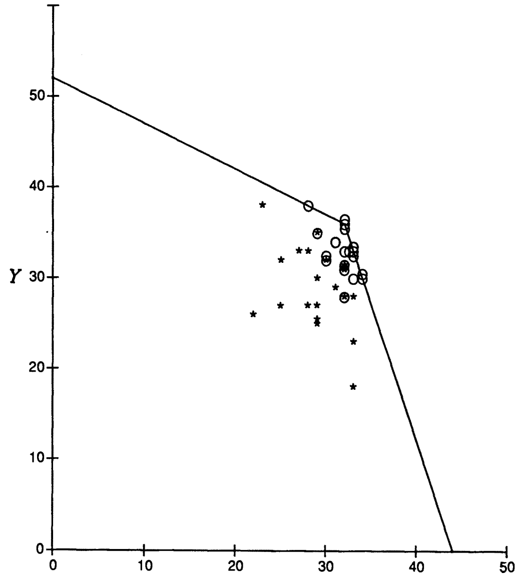

FIGURE 4. TOTAL SYSTEM PRODUCTION: ALL EXPERIMENTS, ENVIRONMENT 1, NO-TARIFF CONDITION

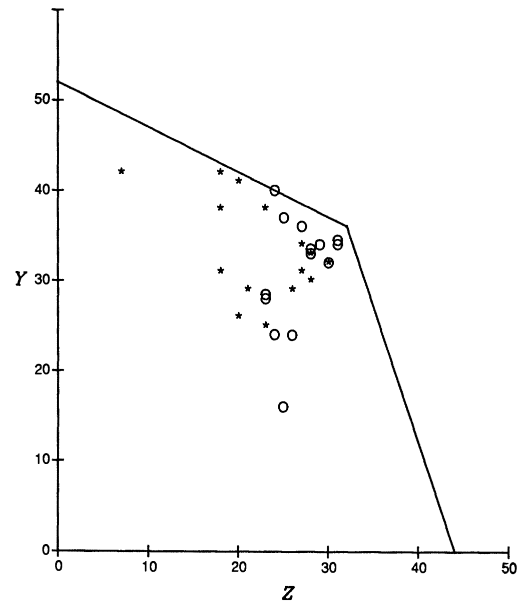

FIGURE 5. TOTAL SYSTEM PRODUCTION: ALL EXPERIMENTS, ENVIRONMENT 1, TARIFF CONDITION

of the figures, aggregate production is nearer the competitive equilibrium in the later periods.

RESULT 3: *Aggregate production patterns are converging toward those predicted by the competitive model under free trade.*

SUPPORT:

As was mentioned at the beginning of this section, a weak definition of the phrase "converging toward" is that the data are either at (statistically) the competitive equilibria at the end of the experiment or closer to the competitive equilibria at the end of the experiment than they were at the beginning. A stronger definition is that the data are converging to quantities that are not significantly different from the competitive-equilibrium predictions. As we stated in Result 1, we reject the notion that the outcome variables are converging to the competitive predictions in the strong sense. However, under the environment-1 (no-tariff) condition Result 3 holds in the weak sense for most experiments and countries and variables. In every case B_2 is closer to the competitive equilibrium than all of the B_{1i}'s. The results under the conditions of environment 1 (tariff) are not so uniformly supportive of the result. For example, the production of Y_1 is converging in only two of the three experiments for which coefficients B_{11} and B_{13} equal 14 and 27, respectively, B_2 is 28, and the competitive equilibrium is 36 units produced. In summary, for the tariff experiments, of the 12 cases (two countries, two commodities, and three experiments), only eight support the result. In environment 2, the movement in nine of the 12 cases is toward the competitive equilibrium. As for the autarky model, in environment 1, without tariffs, none of the 16 production levels is converging in the weak sense. Under tariffs, however, nine of the 12 variables converge to autarky in the weak sense. In

TABLE 8—DEVIATIONS OF INDIVIDUALS' HOLDING FROM COMPETITIVE-EQUILIBRIUM PREDICTIONS (BY PERIOD)

		Period								
Output	Statistic	1	2	3	4	5	6	7	8	9
Y	μ	−0.91	−0.46	−0.58	−0.45	−0.46	−0.40	−0.24	−0.18	−0.28
	σ	1.63	1.49	1.29	1.38	1.09	1.11	0.91	0.98	1.05
Z	μ	−0.95	−0.79	−0.60	−0.40	−0.30	−0.31	−0.21	−0.23	−0.39
	σ	1.84	1.64	1.15	1.55	1.25	1.26	1.06	1.07	1.16

Notes: The statistics reported in the table were calculated as follows:

$$\mu = \sum_i (x_i - \hat{x}_i)/N$$

$$\sigma = \left[\sum_i (x_i - \hat{x}_i)^2/N\right]^{1/2}$$

where x_i = actual holdings of agent i, $\hat{x}_i$ = competitive equilibrium holdings of agent i, and N = total number of observations (consumers times experiments).

environment 2, 11 of the 12 variables are moving toward autarky.

Result 3 is focused on production. The next result considers consumption patterns. Do individual consumption levels converge with replication of periods to the competitive-equilibrium model? For this result a different statistical model is chosen for convenience. For each individual in each experiment, the difference between actual consumption and the competitive equilibrium is computed for each variable. These deviations are then pooled across all the experiments.

RESULT 4: *Individual consumption patterns are converging to those predicted by the competitive model.*

SUPPORT:

The deviation in individual consumption from the quantities predicted in the competitive model are diminishing over time (see Table 8). In the table, the data are pooled for all of the experimental sessions. From the table, it is evident that the absolute values of the deviations are smaller in the later periods than in the earlier periods. For example, the mean deviations from the competitive equilibrium fall consistently over the first four periods for both Y and Z. Similarly, the standard deviations during the first periods are higher than those in the last periods. The hypothesis that the absolute value of the deviations for periods 1–3 are smaller than or equal to those for periods 7–11 can be rejected at $p < 0.01$.

The addition of tariffs on imports of country 1 changes the predictions of the competitive model. According to the model, the tariff discourages the export of Z by country 2 and encourages the home consumption of Z by country 2. Figure 6 demonstrates the differences in consumption patterns in environment 1 that were caused by the tariff. The figure shows aggregate consumption for each country, with the top panel containing data from country 1 and the bottom panel containing data from country 2. The production-possibilities curve is shown for each country as a point of reference. Note that the consumption of Z is shifted from country 1 to country 2 with the imposition of the tariff.

The change in consumption that is apparent in the figure reflects a deep interaction between principles of economics and the parameters of these economies. The tariff, 400 francs per unit of Z imported by country 1, is not so high as to prevent specialization in both countries in the same levels of output as would occur under free trade

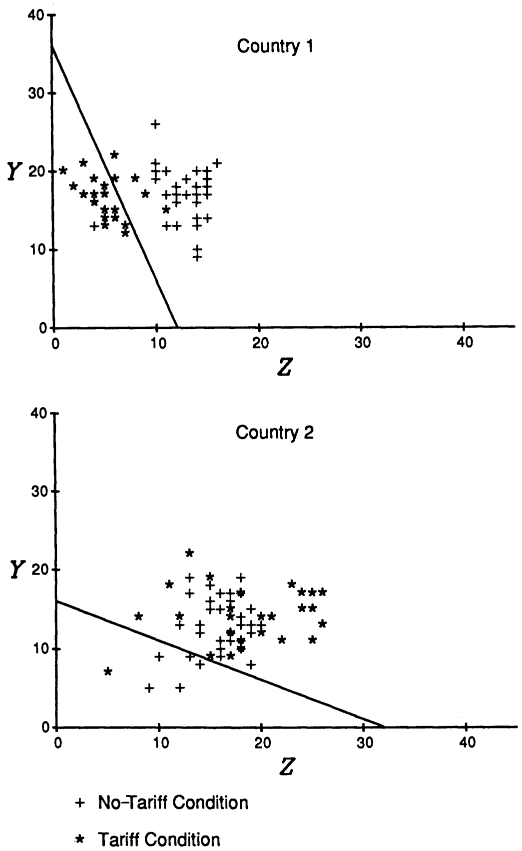

FIGURE 6. CONSUMPTION BY COUNTRY: ENVIRONMENT 1, ALL EXPERIMENTS, ALL PERIODS, TARIFF AND NO-TARIFF CONDITIONS

according to the competitive model. That is, the world patterns of production should not be altered by the tariff in this version of the Ricardian model. However, the competitive model predicts that the reduction in exports of Z would lead to lower system efficiency.[6] The impact of the tariff is to block some gains from international exchange. System efficiency thus falls due to the imposition of a tariff. This property is captured by the

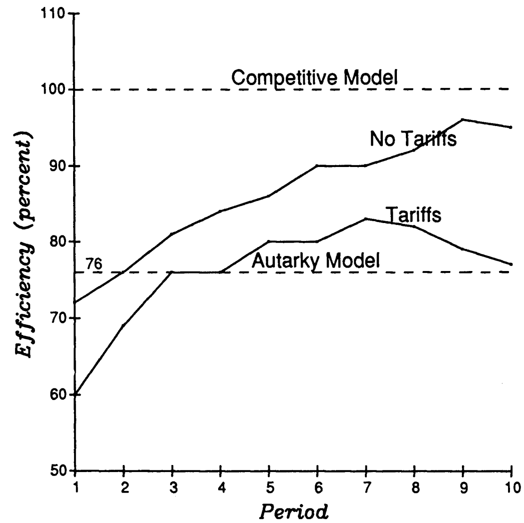

FIGURE 7. PREDICTED AND OBSERVED SYSTEM EFFICIENCIES: ENVIRONMENT 1, ALL EXPERIMENTS, ALL PERIODS, TARIFF AND NO-TARIFF CONDITIONS

next result. Generally, we find that the tariff affects trade volume, efficiency, and prices in the way that the competitive model predicts.

RESULT 5: *Tariffs reduce international trade and market efficiency, as predicted by the competitive model. Prices also differ in the manner predicted by the competitive model.*

SUPPORT:

The relevant data are for environment 1. Average net exports per period are 10.3 without the tariffs and 2.8 under tariffs. We reject the hypothesis at the $p < 0.01$ level that exports of Z are lower or equal under free trade than under tariffs. Refer again to Figure 6, which depicts consumption in the two countries in all experiments in the condition of environment 1 with and without tariffs. Market efficiency under tariffs is compared to that without tariffs for the pooled environment-1 data in Figure 7. As can be seen for each period, average efficiency under the no-tariff condition is higher than average efficiency of the tariff condition. We reject the hypothesis that efficiency is equal in the two conditions or

[6]System efficiency is measured as actual social income (in francs) divided by social income at the competitive equilibrium under free trade. The tariff revenue is included as social income in our calculation of actual social income. See Plott and Smith (1978) for a discussion of this concept in a single-market economy. In a multiple-market economy the measure can be influenced by scale choices.

TABLE 9—THE EFFECTS OF TIME ON INPUT/OUTPUT PRICE RATIOS: ALL ENVIRONMENTS

$$y = B_{11}D_1\frac{1}{t} + \cdots + B_{14}D_4\frac{1}{t} + B_2\frac{t-1}{t} + u$$

Environment	Dependent variable	B_{11}	B_{12}	B_{13}	B_{14}	B_2	Competitive equilibria: Model predictions	Competitive equilibria: Significance (p)	Autarky: Model predictions	Autarky: Significance (p)	ρ	R^2
1 (NT)	P_{L_1}/P_{Y_1}	1.157	1.919	0.696	0.837	2.232	3	< 0.005	3	< 0.005	0.56	0.66
		(0.207)	(0.388)	(0.237)	(0.184)	(0.235)						
1 (NT)	P_{L_2}/P_{Z_2}	0.947	0.616	0.865	1.141	1.383	2	< 0.005	2	< 0.005	0.54	0.69
		(0.243)	(0.190)	(0.197)	(0.101)	(0.114)						
1 (T)	P_{L_1}/P_{Y_1}	1.611	−0.058	1.300	—	2.090	3	< 0.025	3	< 0.025	0.62	0.66
		(0.334)	(0.451)	(0.448)	—	(0.432)						
1 (T)	P_{L_2}/P_{Z_2}	1.324	0.220	0.344	—	1.383	2	< 0.025	2	< 0.025	0.64	0.71
		(0.087)	(0.305)	(0.343)	—	(0.301)						
2	P_{L_1}/P_{Y_1}	0.711	0.571	0.763	—	0.873	1	< 0.005	1	< 0.005	0.25	0.49
		(0.060)	(0.076)	(0.048)	—	(0.028)						
2	P_{L_2}/P_{Y_2}	0.731	0.815	0.863	—	0.884	1	< 0.005	1	< 0.005	0.28	0.17
		(0.057)	(0.041)	(0.176)	—	(0.041)						
2	P_{K_1}/P_{Z_1}	0.640	0.662	0.561	—	0.868	1	< 0.005	1	< 0.005	0.34	0.52
		(0.045)	(0.046)	(0.040)	—	(0.036)						
2	P_{K_2}/P_{Z_2}	0.783	0.795	0.868	—	0.799	1	< 0.005	1	< 0.005	0.29	0.12
		(0.037)	(0.086)	(0.189)	—	(0.040)						

Note: For environment 1, NT denotes no tariffs, and T denotes tariffs.

higher under tariffs ($p < 0.05$). We also reject the hypothesis, using the rank-sum test, that the prices of L_2 or the prices of Z_2 are equal under the tariff and in the absence of the tariff. The average prices of L_2 and Z_2 are 550 and 467, respectively, under no-tariff conditions and are respectively 402 and 380 under tariffs. As the competitive model predicts, they are both lower in the tariff case.

Result 5 can be viewed as a type of comparative-static result, but the comparisons are not exactly like those that are studied in theory. In the theory of comparative statics, a comparison is made between the equilibrium state before a tariff and the equilibrium state after a tariff. The comparison made in Result 5 is between the disequilibrium states as opposed to equilibrium states, with and without tariffs. The next results initiate an inquiry about the nature of this disequilibrium behavior. Result 6 is a statement about the behavior of output prices, the prices of Y and Z.

RESULT 6: *Output prices are converging (in the weak sense) toward the competitive equilibrium from above.*

SUPPORT:

Reference to Tables 5, 6, and 7 reveals that, for environment 1 (no tariff) and environment 1 (tariff), both output prices are above the competitive equilibrium (as well as the autarky prediction) during the late periods of the experiment. This is true for both outputs. The convergence path is revealed by a comparison of B_{1i}'s and B_2. In six of the eight possible cases under environment 1 (no tariff) and five of the six cases in environment 1 (tariff), the value of B_{1i}'s is above or equal to the value of B_2 and is not as close to the competitive equilibrium as is the value of B_2. For environment 2, prices are converging from above toward the competitive equilibrium in all 12 of the possible cases. Thus, the prices in early periods tend to be above the late-period prices, and the direction of movement over time is toward the competitive-equilibrium price.

While output prices move in a consistent way, as summarized by Result 6, input prices are more complex because of the nature of derived demand. The next result suggests that the deviation of factor prices from the competitive equilibrium is not only due to a lack of equilibrium in the output market prices, but factors have their own independent dynamic structure of adjustment. However, the direction of adjustment in the factor markets is toward the equilibria of the competitive model.

TABLE 10—CONVERGENCE PATTERNS OF INTERNATIONAL DIFFERENCES IN FACTOR PRICES, ENVIRONMENT 2

					Competitive equilibria		Autarky			
Dependent variable	B_{11}	B_{12}	B_{13}	B_2	Model predictions	Significance (p)	Model predictions	Significance (p)	ρ	R^2
$P_{L_1} - P_{L_2}$	10.44	−115.00	−126.59	6.37	0	ns	[−200, −150]	< 0.005	0.35	0.38
	(21.23)	(42.10)	(95.66)	(19.50)						
$P_{K_1} - P_{K_2}$	−15.46	−73.22	−23.62	12.92	0	ns	[150, 200]	< 0.005	0.32	0.27
	(37.93)	(28.79)	(78.13)	(15.73)						

Note: Estimates were corrected for AR(1).

RESULT 7: *Factor prices are below marginal revenue products. That is, all of the input/output price ratios are below marginal products. The convergence is in the direction of the competitive-equilibrium relationship.*

SUPPORT:

The condition for profit maximization under competitive conditions is simply that factor price equals marginal physical product times output price. Since production technologies are linear, the marginal physical product is a constant. It follows that the ratio of factor price to output price, when compared to marginal products, can then be used to determine whether the input conditions are satisfied.

Table 9 contains estimates of the time path of ratios of output prices to input prices. The econometric model is of the same form as described earlier. The B_{1i} variables measure the ratio during the first period, which is permitted to differ among experiments. The variable B_2 measures the ratio as time goes to infinity. In 25 of the 26 possible cases, the B_{1i}'s are less than B_2, and B_2 is less than the competitive equilibrium. This indicates that, convergence to the competitive-equilibrium input/output price ratio, in the weak sense, is always present.

Two reasonable explanations of the observed input/output price behaviors summarized in Result 7 are consistent with behaviors found in other experimental markets. The first is that the asymmetry of rents received by sellers and buyers of the factors (sellers receive more rents) leads to lower transaction prices because rents are split (see Smith and Arlington W. Williams, 1982). However, if this is the explanation, then the factor prices should approach equilibrium from below. In all environments, as long as output prices are at or above the competitive-equilibria prices, producer surplus is greater than consumer surplus in the appropriate partial-equilibrium model. As is evident in Table 6, factor prices in environment 2 do not approach the competitive equilibria from below.

Since factor prices do not approach equilibria from below in environment 2, this first (rent-splitting) explanation must be rejected. The other possible explanation is that the buyers of the factors face a market risk. The buyer may not be able to sell the final goods produced with the factor. In the experiments, producers must buy the input, then produce and sell the output. This takes time, and the possibilities that prices could change or that time could run out create real risks for producers. As a compensation to the producer for bearing this risk, a "return for risk-bearing," the factor/output price ratio starts low and adjusts upward. Risk of this type might be a general property of interdependent markets, and if it is, then the input/output price adjustments observed in the experiments might also be observed in the field. Regardless of the interesting separate dynamics, the most fundamental theoretical property derived from the competitive-equilibrium model still holds, as is captured by Result 8.

RESULT 8: *Factor prices adjust across countries (in environment 2) as predicted by the factor-price-equalization principle.*

SUPPORT:

In environment 2, competitive-equilibrium output prices are all the same (200–250), and competitive equilibrium in-

TABLE 11—CONVERGENCE PATTERNS OF PRODUCER PROFITS OVER TIME: ALL ENVIRONMENTS

$$y = B_{11}D_1\frac{1}{t} + \cdots + B_{14}D_4\frac{1}{t} + B_2\frac{t-1}{t} + u$$

						Competitive equilibria		Autarky			
Environment	B_{11}	B_{12}	B_{13}	B_{14}	B_2	Model predictions	Significance (p)	Model predictions	Significance (p)	ρ	R^2
1 (NT)	7,479	6,93	24,200	13,778	5,798	0	< 0.005	0	< 0.005	0.54	0.82
	(817)	(2,953)	(1,935)	(879)	(1,381)						
1 (T)	5,300	35,336	12,699	—	1985	0	< 0.005	0	< 0.005	0.07	0.87
	(875)	(3,713)	(2,550)		(648)						
2	3,730	3,085	3,179	—	1271	0	< 0.005	0	< 0.005	0.20	0.47
	(378)	(868)	(1,128)		(188)						

Notes: For environment 1, NT denotes no tariffs, and T denotes tariffs. Estimates were corrected for AR(1).

put prices are all the same (200–225). A natural test is, thus, whether or not the difference between the factor prices in the two countries is zero. Table 10 contains the estimates which show that, for both input factors, the hypothesis that the prices are equal as t gets large cannot be rejected.

The equality of factor prices for our parameters in environment 2 is a theoretically sound result. Since the outputs trade internationally they must trade at the same price in the two countries. Therefore, because production technology is linear and identical in the two countries, the marginal revenue product of the inputs and therefore their wages should be the same even though the inputs themselves do not trade internationally. Interestingly, in our experiment, we observe equality of input prices across countries even though these input prices are not equal to the marginal revenue product of the inputs.

Since profits can be viewed as a return to a special input (risk-bearing), the pattern of profits is worthy of special investigation. In the competitive model, equilibrium profits from production are zero. The next result demonstrates that the patterns of profits follow the laws suggested by the competitive model.

RESULT 9: *Profits from production are positive but fall over time.*

SUPPORT:

Table 11 contains estimates of the time path of profits. As can be seen the B_{1i} terms in every experiment are greater than the B_2 term. Furthermore, B_2 is significantly greater than zero. Since the B_{1i} terms measure initial profits and the B_2 term measures profits as time goes to infinity, the conclusion is obtained. Profits are higher at the beginning than later, and profits are positive.

Finally, we make three observations. The first is a summary about the autarky model which is included for completeness. Observations 2 and 3 are different. Neither observation has particular foundation in theory. However, following the statement of the observations, we provide a conjecture about the nature of the dynamics at work in these markets. If the conjecture is correct, then the third observation can be explained.

OBSERVATION 1: *The competitive model explains the data better than does the autarky model.*

SUPPORT:

The support is contained in previously stated results. In Results 2 and 3 the production data from environment 1 reveal that the systems of production and export for all goods are moving toward the competitive equilibrium and away from autarky. The production data from environment 2 seem to favor neither model. From Result 5, we see that tariffs had effects predicted by the competitive model, while autarky predicted that tariffs would have no effects. From Result 6 we find that output prices are converging to the competitive equilibrium,

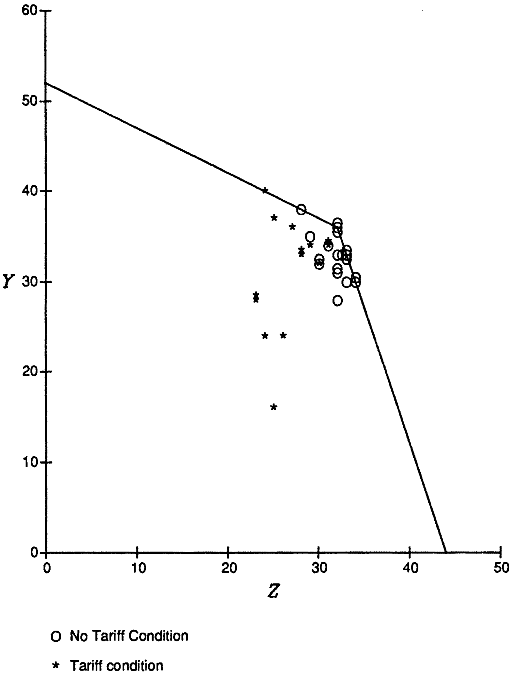

FIGURE 8. TOTAL SYSTEM PRODUCTION: ALL EXPERIMENTS, ENVIRONMENT-1 TARIFF VERSUS NO-TARIFF CONDITIONS, PERIOD 6 AND AFTER

as opposed to the autarky levels. The only input prices that move toward autarky and away from the competitive equilibrium are those for L_2 under the tariff condition.

OBSERVATION 2: *In the no-tariff condition, a large amount of exporting going back and forth between the two countries was observed. The trading appeared to be international speculation and seemed to help markets converge.*

SUPPORT:

Net exports constitute only 63.8 percent of total international trade under free trade in environment 1. The rest of the volume comprised units which had been or were being returned to their country of origin. When tariffs were imposed, the cross trading in Z was essentially eliminated.

OBSERVATION 3: *Contrary to the prediction of the competitive model, the tariff reduced production efficiency.*

SUPPORT:

Figure 8 contains world production data for the last few periods of experiments with tariffs and experiments without tariffs. These are periods after which some equilibration has taken place. Recall that in this version of the Ricardian model the tariff should have no influence on production. As is clear from the figure, production was less when the tariff existed.

Observation 3 indicates that the tariffs have costs beyond those predicted by the static competitive model. A review of some of the results presented above provides surprisingly strong support for a conjecture about the nature of the dynamics at work in these markets. Collecting Results 6, 7, 8, and 9, along with Observation 3, reveals a pattern of the disequilibrium dynamics. The system appears to be moving toward the competitive equilibria along a qualitatively distinctive path. The term "conjecture" is used because the path cannot be deduced from accepted theory, even though it is supported by much theoretical intuition.

An explanation of the dynamics, which we shall call the "risk-compensated input/output price-adjustment process," begins with the observation that markets have an inherent randomness as part of the general equilibration process. This randomness creates a risk for producers who must commit to the purchase of resources and who face the possibility of losses if the product produced from the resources cannot be sold at sufficiently high prices. Accordingly, producers restrict purchase of resources and thus restrict production as they gather information about market conditions. The results are higher (than equilibrium) market prices in output markets due to restricted supplies and lower (than equilibrium) input prices due to restricted input demand. As the experience that producers gain from the market advances with the repetition and stationarity of parameters, the uncertainty diminishes (due to the accumulation of information about the market) and the randomness decreases (due to equilibration). Output expands, output prices fall, and input prices rise. The results are an increasing input/output price ratio over time and falling profits. The conjecture that follows is simply that disequilibrium behavior is characterized by such a process.

CONJECTURE: *Equilibration in the experiments follows the risk-compensated input/output price-adjustment process.*

SUPPORT:
All of the properties of the path, as described, are contained in the market data. Output prices converge toward the competitive equilibrium from above (Result 6). Input prices converge toward the competitive equilibrium (Results 7 and 8). Finally, producers' profits fall over time (Result 9) as the input/output price ratio increases.

The fact that input prices converge to the competitive equilibrium from below in environment 1 and converge from above in environment 2 is also consistent with the hypothesis. In environment 1 producers faced greater risks than in environment 2. In environment 2 producers were also consumers of factors, so factors unused in production were valuable to them as consumption. In environment 1 producers had no such alternatives, so the "down side" losses to producers were greater in environment 1 than in environment 2. The greater risk to producers in environment 1 would then be manifest in lower input prices.

Observation 3 is also consistent with the hypothesis that the disequilibrium is characterized by such a path. A tariff imposed on the imports of Z in country 1 (which has a comparative disadvantage in Z and thus consumes only imported Z in equilibrium) constitutes a major perturbation of the system. The natural tendency is for the price of Z in country 1 to be higher as a result of the tariffs. The risk-compensated input/output price-adjustment process exacerbates the increase of the price of Z in country 1 in the early period of an experiment. With the price of imported Z very high in country 1 due to the combined effects, some Z gets produced in country 1. On the other hand, in country 2, market demand for Z is reduced because there is reduced demand for exports. Thus, in country 2 the price of Z falls, making Z less profitable for country-2 producers relative to the production of Y, whose market supply is reduced because some of the resources in country 1 are diverted to the production of Z. Some Y gets produced in country 2. Thus, along this disequilibrium path, country 1 (inefficiently) shifts production from a full specialization in the production of Y to include the production of some Z. Country 2 shifts from a complete specialization in the production of Z to include (inefficiently) the production of some Y. The resulting inefficiencies are captured in the data from the experiments as summarized by Observation 3 and are shown in Figure 8.

Of course, there is nothing theoretically new about profits being a return to producers for bearing market uncertainty. The new and difficult (theoretical) challenge stems from the fact that markets seem to have a natural but inexplicable random component that is not captured by modern theory. The intuition that should support a theory seems clear, but no formal statement of such a theory currently exists. The natural reaction of agents to the inherent randomness would seem to be similar for any portfolio adjustment. The system adjustment to the individual hedging behavior appears natural enough. Since the path has such clearly distinguishable features, it will be of interest to explore other experiments as well as field data to see whether system adjustments, along the risk-compensated input/output price path, is found in other places as well. It will also be of interest to learn whether the intuition captured by the explanation given above can be placed on solid theoretical footing.

VI. Conclusion

The main result of the paper is that we observe experimentally for the first time that the law of comparative advantage predicts patterns of trade and output. This result would not have been completely unanticipated by trade theorists, because it is so embedded in modern economic models.

However, the experiments, like naturally occurring economies, are complex, with mistakes, trading out of equilibrium, limitations on information, considerable uncertainty about the future, and other prominent features that are not present in existing stylized models. Furthermore, the recent debates on U.S. competitiveness suggest that many people outside the economics research community do not believe that the law of comparative advantage works and are prepared to base policy on much different principles of system behavior. We find it remarkable that this fundamental principle operates with such strength and robustness even though the competitive model is statistically rejected. Were it not found operating, we would be forced to reexamine one of the deepest aspects of modern theories of the nature of trade, and the existence of that very real possibility was an important consideration in the research design.

While there are many positive ways to look at these data, there is one fundamental fact that must not be overlooked. The competitive model is rejected. Considerable variation in these data remains to be explained. The quantitative predictions do not work so well.

Generally, the qualitative predictions of the competitive model are upheld. Convergence processes are present, so the competitive model receives better support in the later periods after equilibration takes place. This convergence takes place more quickly and strongly for quantities than for prices. The support of the competitive model extends itself to the qualitative impacts of a tariff. Support of this nature is very interesting since comparative-statics models generally assume that the system is moving from one established equilibrium to another. In real markets, such as those studied here, disequilibria exist. There is little support for the autarky model in these experiments. International trade occurs in a natural way and must be considered in the application of models to any of the interacting countries.

Factor-price equalization is a remarkable and unintuitive property. While this property is characteristic of only specialized environments, it is important in helping us to see and understand that the principles of economics can lead to unintuitive results. That wages should equalize as a result of competition in output markets alone is such a proposition. Under the strong conditions in which theory suggests it will exist, we actually found it.

Although it was diminishing over time, there was a universal tendency for the factors of production to trade at prices below their marginal revenue product. The most plausible explanation is that the output prices adjusted upward and the input prices adjusted downward to compensate producers for the risk they undertook in producing the output. In later market periods, as output prices stabilized and the natural randomness that exists in markets tended to diminish, the producers' risk declined, input prices increased, output prices decreased, and producer profits fell. The process is well described by the term "risk-compensated input/output price-adjustment process." This somewhat surprising pattern is so plausible in retrospect that it leads to a conjecture about whether it may be a general property of production economies observable in the field, especially those with extreme output-price uncertainty, such as centrally planned systems in transition to market economies.

Appendix

Several different instructions were used during the course of these experiments. Environments 1 and 2 differed because producers had redemption values for input goods in environment 2 but not in environment 1. There were also two input goods in environment 2 and only one input good in environment 1. The experiments with eight subjects had instructions that differed slightly from those with 16 subjects. In the 16-subject experiments, a distinction was made between agent "type" (type 1 or type 2), while no such distinction was made between agents in the eight-person experiments because the activities (producer and consumer) were combined. Then, there were the experiments in which an import tax

TABLE A1—LABELS OF OUTPUT AND INPUT ACTIVITIES BY SOURCE: PAPER, INSTRUCTIONS, DATA SETS (MARKETS)

Environment	Paper	Instructions	Data (market)
1	L_1	W	1
	L_2	X	2
	Y_1	Y_1	3
	Y_2	Y_2	4
	Z_1	Z_1	5
	Z_2	Z_2	6
2	L_1	W_1	1
	L_2	W_2	2
	K_1	Y_1	3
	K_2	Y_2	4
	Y_1	X_1	5
	Y_2	X_2	6
	Z_1	Z_1	7
	Z_2	Z_2	8

existed. In reviewing the material that follows, the reader should appreciate that each of these several instructions was generated by only a few word changes (e.g., "and/or" vs. "or"). A single paragraph added to the instructions explained the tariff in those experiments in which a tariff was operative.

The instructions hold two additional sources of potential ambiguity. The first is the labeling of markets. Three sets of labels exist throughout the series. For example, in the text of this paper the input from country 1 is labeled as L_1. However, in the instructions read to subjects, this input was called W, and the trading activity of W took place in market 1 and is recorded that way in the data sets. Table A1 lists all of the relationships. The word "paper" refers to the manuscript version of the text preceding this appendix; the word "instructions" refers to what subjects saw; and "data/markets" indicates the index as presented on computer screens during the experiment and in the data sets.

The second source of possible confusion is the assignment of subjects to agent types, such as consumer/producer. In 16-person experiments there is no confusion. Subjects in country i control resources and/or consume and/or produce in country i. In the eight-person sessions, the roles were different. The lack of subject numbers required functions of producer, consumer, and resource owner to be combined. Because of the small numbers, an oligopoly problem presented itself. If the producers own resources in their own country, then they could influence the activities of their competition by refusing to sell him/her the resources. In order to avoid this complicating factor, firms were producers/consumers in one country but owned resources in the other country. Thus, producers/consumers in country i were resource owners in country j. Of course resource owners still could not transport the resources from one country to another.

The set of instructions that follows is for the 16-person environment-1 experiments. The forms for the redemption value sheets (for consumption decisions) were the same for all treatments, as were the accounting forms. Blank examples of both are included at the end of the instructions. Of course, the redemption value sheets are filled in by the experimenter and the accounting sheets by the subject.

General Instructions [Exact Transcript]

This is an experiment in the economics of market decision-making. The instructions are simple, and if you follow them carefully and make good decisions, you might earn a considerable amount of money which will be paid to you in cash.

In this experiment, we are going to conduct a market in which you will be designated as one of two types of traders in a sequence of trading periods (either a type 1 or a type 2). Find your type at the top of the instructions. In your folder you have a sheet entitled Record Sheet. If you are a type 1, you will also have a Redemption Value Sheet. If you are a type 2 you will have a Production Schedule. These sheets will help you determine the value to you of any decisions that you might make. YOU ARE NOT TO REVEAL THE INFORMATION ON THESE SHEETS TO ANYONE. They are your own private information.

The currency used in this market is francs. All trading will be in terms of francs. Your final payoff will be in terms of dollars. The conversion rate is ________________ francs to 1 U.S. dollar. You will be paid at the end of the experiment.

There are four types of goods which can be traded in our market: W, X, Y, and Z. You may make profits in two ways, through consumption and through trading of the four goods.

Production Schedule

(Each Period)

Identification No: ____

Units of X (Input)	0	1	2	3	4	5	6	7	8	9	10	11	12
Unit Output (Y)	0	5	3	1	0	0	0	0	0	0	0	0	0
Total Output (Y)	0	5	8	9	9	9	9	9	9	9	9	9	9

Units of X (Input)	0	1	2	3	4	5	6	7	8	9	10	11	12
Unit Output (Z)	0	5	3	1	0	0	0	0	0	0	0	0	0
Total Output (Z)	0	5	8	9	9	9	9	9	9	9	9	9	9

Specific Instructions to Type-1 Traders [Exact Transcript]

CONSUMPTION

During each period you are free to purchase and sell as many units of W, X, Y and Z as you might want. Any units that you hold in your inventory at the end of the period are considered to be consumed by you. For the first unit of Y that you consume during a trading period you will receive the amount listed on your Redemption Value Sheet the column labelled Y Unit Value in the 1st row. If you consume a second unit you receive the amount listed in the column labelled Y Unit Value in the second row. The total amount that you receive from the consumption of both units is found in the column labelled Y Total Value in the second row. Notice that if you have unit values of zero in a space or a column that the corresponding units are worthless to you. The amount you receive from consumption of Z is found in exactly the same way. The redemption value received from consumption of W and X is always zero.

Specific Instructions to Type-2 Traders [Exact Transcript]

PRODUCTION

During each market period type two traders are free to produce units of Y and Z from units of W and X. This is done with the Transformation Key (F4). When producing units of Y and/or Z from units of W and X use the table labelled Production Schedule. This table reflects the number of units of Y and/or Z that you can produce from

REDEMPTION VALUE SHEET

(For Consumption Decisions)

Unit	W unit value	W total value	X unit value	X total value	Y unit value	Y total value	Z unit value	Z total value
1								
2								
3								
4								
5								
6								
7								
8								

given amounts of W and X for the whole period. You have already been instructed in how to read the production schedule, but the following hypothetical example may provide further clarification.

Example: Suppose that you have 2 units of X and you have the Production Schedule shown on the next page [previous page in this appendix]. You can produce either:

a) 8 units of Y
b) 5 units of Y and 5 units of Z
c) 8 units of Z

Instructions to Both Types [Exact Transcript]

TRADING PROFITS

Another source of profits is from buying and selling the four types of goods. Selling increases your cash on hand by the amount of the sale price. Buying reduces your cash on hand by the amount of the purchase. Thus you can either gain or lose money on the purchase and resale of units.

EARNINGS

Your profits each period are computed by taking the redemption values of the units of W, X, Y, and Z that you consumed that period, adding the total sale price of the units of that you sold during the period and then subtracting the total of the prices you paid for the units that you bought during the period. The profits that you make exactly equal the change in your cash on hand from the beginning to the end of the period plus the redemption values of the units you consume.

At the end of the period enter the total number of units that you consume of W, X, Y, and Z at the top of your Record Sheet. Then, fill out the rest of your record sheet as follows. In line 2, fill in your Cash on Hand at the beginning of the period. In line 1, fill in your cash on hand at the end of the period. In line 3 fill in line 1 minus line 2. In lines 4–7 fill in your earnings from the consumption of W, X, Y, and Z. In line 8 add the total of lines 4–7. In line 9 add the total of lines 3 and 8. This amount is equal to your profits for the period (in francs).

ENDOWMENTS

1) At the beginning of each period you will be given an endowment of either W or X. This endowment will appear in your inventory and will remain the same every period. You are free to sell any part of this endowment to anyone who might want to buy it.

2) At the beginning of the experiment you will receive 100000 francs cash on hand.

Record Sheet

Period = 1

W ________ X ________ Y ________ = ________

(1)	Cash on hand at end of period	________	
(2)	Cash on hand at beginning of period	________	
(3)	Net change in cash on hand (1)-(2)		________
	Earnings from consumption		
	(4) W	________	
	(5) X	________	
	(6) Y	________	
	(7) Z	________	
(8)	Total earnings from consumption (4)+(5)+(6)+(7)		________
(9)	TOTAL PROFITS FOR THE PERIOD		________

HOW THE SYSTEM WORKS

Type 1 people are endowed with W or X but would like to consume Y and Z. They can sell W or X to type 2 people to increase their cash in order to buy Y and Z. Type 2 people are endowed with W or X but may purchase additional units from type 1 people. They can produce Y and Z from W or X and sell them to type 1 people to increase their cash.

MARKET RESTRICTIONS

Some of you may not be able to trade in all markets. You may not trade in markets ________________. Unless you are informed otherwise these markets will be closed to you for the entire experiment.

You may be taxed for trading in market 6. The tax that you pay is ________________ francs for each unit that you buy or sell in that market. Unless you are informed otherwise, the tax will remain the same for the entire experiment.

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