ARBITRAGE IN SPATIALLY SEPARATE MARKETS

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Economic theory provides a context for problem definition and a guide for empirical analysis. When interregional trade is examined in the context of market economies, theory often assumes perfect competition and no barriers to trade. Transportation and transactions cost can be accommodated as can other explicit costs. Bressler and King's graphical representation of the two-region case has become a standard presentation of the equilibrium price and quantities resulting from trade. Yet nowhere in this theoretical treatment is the number of arbitragers discussed. Rather the supposition is:

> That traders from region Y make contact with region X. They discover that the price for this commodity is lower in Y than in X and that, ignoring transfer costs, they can buy in X and sell in X at a profit .... Eventually, the flow of the commodity from region Y to region X will be large enough to result in the equalization of product prices and the establishment of a single market (Bressler and King, p. 87).

Contact is crucial because of the information that is transferred between markets. This information relates specifically to the different supply and demand curves that make trade between the regions profitable. But it is traders who, in fact, transfer the product from regions. These traders are arbitragers in the most simple context.

An empirical question is "What number of arbitragers is necessary to generate the results from the simple interregional model?" This question was the impetus of an economic laboratory experiment designed to examine the effect of different numbers of arbitragers on interregional

equilibrium prices. What follows is a brief review of the theory of markets, the design of the experiment, some results from the experiment, and some preliminary conclusions.

Price Equilibrium in Spatially Separated Markets

In two spatially separate markets, there is potential for trade if the equilibrium prices for each market differs by at least transaction and transportation costs. This is shown graphically in Figure 1. Region X has excess demand (ED, ES_x on graph) while region Y is in excess supply (ES_y). To incorporate transfer cost, an ED-ES curve is developed and used to determine the amount traded between regions and the resulting equilibrium prices. Notice the higher the transfer cost the less trade transpires between regions.

Prices are determined as a result of supply and demand curves and transfer costs. Perfect competition is assumed, therefore, perfect information is a requisite to figure 1. Another assumption is a large number of buyers and sellers, but the number of traders moving between the markets is not mentioned. There is an underlying assumption that since there is perfect information persons will arbitrage the different markets and equilibrate markets. But is one person doing this enough? Furthermore, does the required number of arbitragers to bring about interregional equilibrium depend on the size of the markets?

Experiment Design

An experiment was designed to examine the relationship between the number of arbitragers in a two-region market and the resulting market prices. College students were the subjects and rewards for trading were

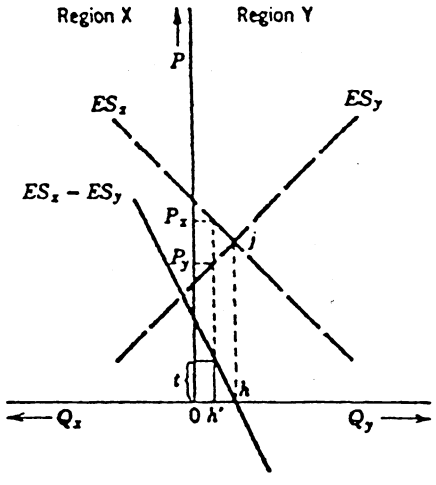

Figure 1. Equilibrium price and trade by using differences between excess supply curves. (Source: Bressler and King, p. 91)

nonmonetary. Profitable trading was rewarded through higher grades. The experiment was separated into two sets, each with three trading sessions lasting eight minutes. The three trading sessions had different numbers of arbitragers; low (2), medium (4), and high (7 or 8). Each session had two markets with different supply and demand schedules.

These markets were in different rooms that were connected by a hallway. Arbitragers were selected randomly and only designated arbitragers could move between the markets. A double oral auction price discovery method was used. A set of instructions was given to traders and arbitragers (appendix 1). Buyers were instructed to buy up to 20 units at prices below their reservation price while sellers were instructed to sell up to 20 units at prices above their reservation prices. A limit of four units could be traded in any one transaction. Profits were derived from differences between transaction and reservation prices.

Arbitragers were allowed to buy and sell in either market but a $.05 transfer cost was incurred in taking a unit from one market to another. To encourage arbitragers to clear markets, a $.03/unit inventory fee was assessed for units untraded at the end of the trading session. Arbitrager profits were generated from their ability to detect and exploit market differences.

Results

Two sets of three trading sessions were performed in the spring of 1988. These two sets are labeled MAY and JUNE. For each set, there are low, medium, and high numbers of arbitragers. A summary of trading

results that includes comparison of average prices with equilibrium prices is presented in table 1.

Results from the two markets are reported as well as the markets combined. Combined markets results are compared to theoretical results without transfer costs (1&2^{a}) and with transfer costs (1&2^{b}). What is evident from the results are the wide discrepancies between theoretical and actual results. In no case was the equilibrium price of each market with trade between regions close to the average price within that region. When ending prices are examined rather than the average price there is little improvement toward interregional equilibrium values. The striking difference between actual and theoretical prices can be further examined in table 2 where arbitrage is viewed as reducing differences in price between markets. No clear pattern emerges. It does appear that for the May set, which had fewer traders, the low level of arbitration resulted in the most price reduction (.66). For the June set, the medium level of arbitration resulted in the most price reduction. These results would lead to a hypothesis concerning the necessary number of arbitragers. It appears that ratios of arbitragers to traders as low as .05 to .10 could prompt significant price reduction. From this experiment, it appears that ratios of lower than .05 lead to less price reduction, ceterus paribus. Of course, the skills of the arbitragers must be considered. Since arbitragers here were chosen randomly, it could be expected that the results are subject to some learning bias.

Table 1. A Summary of Arbitrage Experiments in Two Spatially Separate Markets with Low, Medium, and High Number of Arbitragers

Item	Set											
	May Market											
	1			2			1&2[a]			1&2[b]		
	Number of Arbitragers											
	2	4	7	2	4	7	2	4	7	2	4	7
Equilibrium Price	4.25	4.75	5.02	3.05	3.37	6.10	3.65	4.06	5.56	3.625 3.675	4.03 4.08	5.53 5.58
Quantity	300	120	70	300	140	40	120	137	107	115	132	102
Average Price	4.04	4.57	5.12	3.38	3.44	5.98	3.715	4.00	5.51	4.04 3.38	4.57 3.44	5.98 5.12
Last Price	4.10	4.20	5.00	3.60	3.40	5.20						
Number of Transactions	38	27	31	37	28	26	75	55	57	75	55	57
Units Traded	144	99	120	144	112	104	288	211	224	288	211	224
Percentage of Transactions Involving Arbitrager	21	70	74	19	46	92	20	58	82	20	58	82

	June Market											
	1			2			1&2[a]			1&2[b]		
	Number of Arbitragers											
	2	4	8	2	4	8	2	4	8	2	4	8
Equilibrium Price	3.20	5.10	4.37	4.52	3.75	5.77	3.87	4.42	5.075	3.90 3.85	4.40 4.45	5.10 5.05
Quantity	220	300	230	230	220	210	132	135	140	125	130	135
Average Price	3.17	4.88	4.34	4.40	3.88	5.59	3.79	4.38	4.96	4.40 3.17	4.88 3.88	5.59 4.34
Last Price	3.20	4.25	4.40	4.35	3.80	5.70						
Number of Transactions	62	61	60	58	56	54	120	117	114	120	117	114
Units Traded	224	240	236	213	203	216	437	443	452	437	443	452
Percentage of Transactions Involving Arbitrager	11	21	33	8	19	37	10	20	35	10	20	35

[a]With 0 transfer costs
[b]With .05/unit transfer costs

Table 2. Arbitrage as Reducing Differences in Prices Between Markets

Level of Arbitration	Number of Traders	Number of Arbitragers	Expected Difference Without Arbitrage	Actual Difference With Arbitrage	Reduction
Low	47	2	1.32	1.22	.08
Low	28	2	1.20	.66	.45
Medium	46	4	1.35	1.00	.26
Medium	29	4	1.37	1.13	.17
High	47	8	1.40	1.25	.10
High	28	7	1.07	.85	.20

Conclusions

An experiment was conducted to examine the effect of different numbers of arbitragers on interregional exchange prices. Tentative results indicate large differences between average exchange prices and theoretical equilibrium prices. Several caveats are in order concerning these results. First, monetary rewards were not used. Future experiments of this kind will carry more validity if monetary rewards are generated. Second, the important feature appears to be the ratio of arbitragers to the total markets. A key point for future investigation is what ratio threshold must be reached before price reduction between markets ceases. Thus, the key factor is not so much the number of arbitragers but the ratio of arbitragers to market participants.

Finally, it should be apparent that this experiment is in the adolescent stage. Further investigation into this topic should shed brighter light on the price discovery process itself. It is apparent there is a difference between price discovery and price determination. Arbitragers are crucial to price discovery between markets. Perhaps they have a vested interest in maintaining price differentials between markets.

References

Bressler, R. G., Jr., and R. A. King. Markets, Prices, and Interregional Trade. New York: John Wiley and Sons, Inc., 1963.

Appendix I

Experiment 2 - Spatially Separate Markets

INSTRUCTIONS FOR TRADERS

This experiment is designed to examine trading in 2 markets separated by space. You will be randomly selected to trade in either Room 307 or Room 309. Some of you will be allowed to buy and sell in both markets. The rest of you will only be allowed to trade in your market.

Each of you will receive a form assigning you a trader identification number and a reservation price. This form will indicate whether you are to trade as a buyer, seller, or arbitrager.

In case of buyers, your reservation price is the maximum price you can pay for any unit you purchase. Do not pay more than your reservation price if you are a buyer. Similarly, for sellers your reservation price is the minimum price at which you can sell your units. Sellers must not sell for less than their reservation price.

Arbitragers will be allowed to buy and sell. There will be a $.05 transfer cost for each unit taken from one market to another. That is, if you buy 20 units in one markets and sell 10 units in the other market, your transfer cost is $.50. Arbitragers make money by trading in two separate markets that have different equilibrium prices.

During each trading session you have 20 units to buy or sell. You may trade less than 20 units. The total number of units from all transactions during a trading session must not exceed 20 units. The maximum amount that you may trade in one transaction is 4 units. This applies to all traders.

Fill out a trade form for each trade you make. For each transaction record:

(1) Time of transaction
(2) Buyer, seller, or arbitrager identification numbers
(3) Quantity being traded
(4) Price

At the end of the trading session, these forms will be collected. Each of you will fill out a form for each trade you make.

As you trade, there are some things to keep in mind.

(1) Your goal is to earn the greatest profit you can. If you can't make a trade at a favorable or breakeven price, don't trade.

(2) Don't reveal your reservation price to other traders. When you go to buy a car, you wouldn't tell the salesman how much you are willing to pay for the car. The same principle holds true for these trades.

(3) Remember that you only have 20 units to buy or sell and the maximum number you may trade in one transaction is 4 units. When you have traded all 20 units, stop trading and check your trade forms.

Experiment 2 - Spatially Separate Markets

Instructions for Arbitragers

You are an arbitrager. Your goal is to maximize your profit by taking advantage of price differences in spatially separated markets. You may buy or sell as many units as you like but not over 4 units at a time. But remember, to make a profit you must clear out all your trades. You may buy and sell within a market or between the two markets. You must discover which is the "high cost" (import) market and which is the "low cost" (export) market on your own.

There is a $.05/unit transfer cost when you trade between the markets. That is, if you buy one unit in market 1 @ $3.05 and sell one unit in market 2 @ $4.00, your profit is $.90 (4.00 - 3.05 - .05).

You may buy and sell, or sell and buy, but you must close out your position. If you have an open position at the end of trading, you will be assessed a $.03/unit inventory fee to hold that unit until the next trading experiment.

You will keep a running trade sheet during the trading session. On this sheet, you will record all trades, which market you bought and sold in, the time of trade, opposite trader's number, price, and quantity.

Trading Summary:

At the end of trading, you will fill out a trading summary form. Record the time, type, and number of opposite trader, price, and quantity.

Experiment 2 - Spatially Separate Markets

Market 1 Trading Summary

Name _____

Seller / Buyer (circle one)

Number _____

Reservation Price _____

Estimated Equilibrium Price _____

TIME	OPPOSITE NO. (Buyer/Seller/Arbitager)	PRICE	QUANTITY	WEIGHTED PRICE

SUM OF WEIGHTED PRICE (= AVG. PRICE) _____

TO CALCULATE WEIGHTED PRICE:

PRICE X (QUANTITY ÷ TOTAL QUANTITY) = WEIGHTED PRICE

example: $3.40 x (2/10) = .68

Experiment 2 - Spatially Separate Markets

Market 2 Trading Summary

Name _____

Seller / Buyer (circle one)

Number _____

Reservation Price _____

Estimated Equilibrium Price _____

TIME	OPPOSITE NO. (Buyer/Seller/Arbitager)	PRICE	QUANTITY	WEIGHTED PRICE

SUM OF WEIGHTED PRICE (= AVG. PRICE) _____

TO CALCULATE WEIGHTED PRICE:

PRICE X (QUANTITY ÷ TOTAL QUANTITY) = WEIGHTED PRICE

example: $3.40 x (2/10) = .68

Arbitrager Trading Sheet

Name _____

Arbitrager Number _____

Estimated Equilibrium Price Between Markets _____

Buy					Sell				
MARKET	TIME	Opposite No. (Seller)	PRICE	QUANTITY	MARKET	TIME	OPPOSITE NO. (Buyer)	PRICE	QUANTITY

Total

Market 1
Estimated equilibrium = _____

Market 2
Estimated equilibrium = _____