Market Concentration, Price Dispersion, and Inefficient Cross-hauling in the Laboratory*

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Abstract

This paper presents experimental evidence suggesting that persistent price dispersion that violates the law of one price may be a disequilibrium phenomena. Increasing market concentration increases the pecuniary incentive to give a best response and satisfy the law of one price, that is, a few large firms have a larger pecuniary incentive to solve the allocation coordination problem than many small firms. In the two firm treatment, the law of one price holds. However, in both treatments with small firms or transportation costs we observe persistent price dispersion. The paper also finds evidence of inefficient cross-hauling for purely strategic reasons.

Keywords: Market concentration, optimization premium, strategic suppliers, cross-hauling, price dispersion, human behavior, the law of one price.

1 Introduction

A fundamental result in economics is the law of one price: a homogeneous good sold at different locations will sell for the same price net of transportation costs. For example, if the price of a homogeneous good sold at two locations with zero transportation costs differs, then the allocation can not be a Nash Equilibrium, because suppliers to the low priced location would want to switch to the high priced location. Hence, the law of one price is a necessary condition for a Nash Equilibrium.

Most empirical investigators find persistent violations of the one price law. Isard [1977] describes the law as being "...flagrantly and systematically violated

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by empirical data" and argues that violations in the law can be attributed to product differentiation and restrictions to free markets, such as discriminating monopolies, tariffs, subsidies and other trade restrictions. Parsley and Wei [1996] and Engel and Rogers [2001] looked at price fluctuations within the United States, which allows them to control for trade barriers such as those found by Isard. They still found price dispersion that could not be accounted for by distance and preferences. Stigler [1961] posited that information was in effect a large culprit in the dispersion of prices for a homogeneous good. Stigler suggests that "Price dispersion is a manifestation–and, indeed, it is the measure– of ignorance in the market." Baye and Morgan [2004] found price dispersion on the Internet where there were no trade barriers, products were homogeneous and the cost of information was negligible. Rogoff et al. [1995]examine price dispersion over the past 700 years. The surprising result is that even with the advent of information technology, lower transportation costs, reduced trade restrictions, fewer plagues, and fewer wars price dispersion has not declined much in the past 700 years.

Meyer et al. [1992] note that if the law of one price is satisfied, then there is no pecuniary incentive to conform to the equilibrium. When it is violated, strategic uncertainty makes observed price differences an unreliable indicator of a profit opportunity because the violation does not indicate who should respond or by how much.

The optimization premium is the incentive a supplier has to best respond. It is usually impossible to compute the optimization premium using field data. This paper uses the experimental method to investigate whether ceteris paribus lowering the number of suppliers, that is, increasing market concentration, and thus increasing the optimization premium increases the frequency that the law of one price is satisfied.

It also investigates the possibility that transportation costs solve the allocation coordination problem. Transportation costs may answer the question of which supplier should respond to a violation of the one price law and so may help coordinate suppliers' behavior, but transportation costs introduce the possibility of inefficient cross-hauling. Cross-hauling is the bidirectional transporting of a homogeneous product between two locations, which decreases welfare when transportation is costly. As the optimization premium increases suppliers have a greater incentive to behave strategically. Brander [1981] showed that strategic suppliers will engage in inefficient cross-hauling.

2 Analytical Framework

To focus the analysis, consider an economy of two islands indexed by j, where $j \in J = \{A, B\}$.[1] On each island there is a Marshallian fish market.[2] In the

[1] The analytical framework in this paper differs from Meyer et al. [1992] in two ways. The allocation problem is continuous and transportation costs may not be zero. It is based on Van Huyck [1989] and was used in Wade [2006].

[2] Marshall [1930] writes, "...when a thing already made has to be sold, the price which people will be willing to pay for it will be governed by their desire to have it, together with

morning of each day, fishermen i sails to their fishing grounds, where their fleet of two boats catch x_i units of fish. The fishermen must decide how to divide up the catch, s_{ij}, amongst their two boats, which spend the afternoon delivering the catch to the two islands. Just before dinner, consumers on each island come down to the dock to purchase the catch of the day, which sells for price p_j on island j. Any fish not eaten at dinner that market day spoils. That evening fishermen i's fleet returns to their home island with their profits for the day, π_i.

In this economy, there are n suppliers indexed $i \in I = \{1, 2, \dots, n\}$. Each supplier is endowed with x_i units of a homogeneous good. The total units of the homogeneous good is $x = \sum_{i=1}^{n} x_i$. Supplier i delivers $q_{ij} = s_{ij} x_i$ units of the homogeneous good to location j.

A supplier must decide what share of the catch to deliver to each location, which can be represented by the vector $s_i = (s_{iA}, s_{iB})$. Supplier i's decision must satisfy the feasibility constraint that $\sum_{j \in J} s_{ij} = 1$ and $s_{ij} \geq 0$. Denote supplier i's set of feasible deliveries S_i and $s_i \in S_i$.

Let the $n \times 2$ matrix of supplier choices, $s = (s_1, \dots, s_n)^T$, denote an allocation and S is the set of feasible allocations. An allocation s determines the total quantity of the good supplied to each location j, denoted q_j^s, and defined $q_j^s = \sum_{i=1}^{n} q_{ij} = \sum_{i=1}^{n} s_{ij} x_i$. All units of the good delivered to location j are sold for price p_j.

Supplier i's marginal transportation cost to location j is denoted c_{ij} and is assumed to be a non-negative constant. The profit from a delivery of q_{ij} units is the prevailing price times the quantity delivered, $p_j q_{ij}$, less transportation costs, $c_{ij} q_{ij}$. Supplier i chooses the vector s_i to maximize the expected profit function, which is the sum of realized profits from deliveries to each location:

$$\pi_i = E(\sum_{j \in J} (p_j - c_{ij}) q_{ij}) = E(\sum_{j \in J} (p_j - c_{ij}) s_{ij} x_i) = x_i \sum_{j \in J} E(\bar{p}_{ij}) s_{ij}, \quad (1)$$

where $\bar{p}_{ij}$ is the prevailing price in market j net of supplier i's transportation costs.

2.1 Price taking suppliers

To provide a useful bench market, suppose suppliers are price takers. A *price taking* supplier takes p_j as given in equation 1.

Given a vector of net prices $\bar{p_i} = (\bar{p}_{iA}, \bar{p}_{iB})$, a price taking supplier i maximizes total profits when $s_i^\star$ satisfies:

$$\sum_{j \in \bar{J}^i} s_{ij}^\star = 1, \quad (2)$$

where $\bar{J}^i = \{j \in J : \bar{p}_{ij} = \bar{p}_i^\star = max(\bar{p}_{iA}, \bar{p}_{iB})\}$. $\bar{J}^i$ is the set of locations with the highest price net of supplier i's transportation costs. A price taking supplier

the amount they can afford to spend on it.... This, for instance, is the case with a fish market, in which the value of fish for the day is governed almost exclusively by the stock on the slabs in relation to demand..." A similar parable with indivisible market delivery was used in Meyer et al. [1992].

would not voluntarily choose positive deliveries to location k if $\bar{p}_{ik} < \bar{p}_i^\star$, which implies that $s_{ik}^\star = 0$ for $k \notin \bar{J}^i$. However, a price taking supplier is indifferent about the quantity delivered to locations contained in the set of highest price locations, $\bar{J}^i$. This indeterminacy will be called an allocation problem.

One reaction to the allocation problem is to argue that unformalized idiosyncratic characteristics of the suppliers solve the allocation problem. For example, suppose that locating operations at a specific location reduces a supplier's transportation costs associated with deliveries to that location. Then the suppliers' location decision results in suppliers having heterogeneous transportation costs. Assume that a supplier's location is predetermined by the condition that a fixed cost of entry is equal to the shadow price of the endowment, that is, there is no incentive for new suppliers to enter any local market.

Let a *home* supplier h to market k have a supplier specific cost c_{hk} equal to 0. Let I^j denote the set of suppliers local to market j, that is, $I^j = \{ i \in I \mid c_{ij} = 0\}$. A *foreign* supplier f to market j has marginal transportation costs c_{fj} greater than 0. Partition the set of suppliers, I, into two sets of local suppliers for market j, I^j, where $I = I^A \cup I^B$. Equilibrium entry makes it feasible for local demand to be served by local suppliers; specifically, let $\sum_{i \in I^j} x_i = q_j^d(p^\star)$.

Given the assumed distribution of local suppliers, then the equilibrium price vector $(p^\star, p^\star)$ not only clears all markets but also implies a unique allocation. When all markets have the same price $p^\star$, supplier i's price net of transportation costs $\bar{p}_{ij}$ is highest in his local market h and supplier i only delivers to h, that is, $\bar{J}^i = \{h\}$ for all h in I^j. Since $\bar{J}^i$ contains a single element, price taking suppliers who are local to market j maximizes total profits when they deliver everything to their home market, that is, $s_{ij} = 1$ for $j \in \bar{J}^i$ and $s_{ik} = 0$ for k not in $\bar{J}^i$. This individual behavior is consistent with general market clearing, because it is feasible for local suppliers to satisfy local demand at $p^\star$.

Heterogeneous transportation costs solve the allocation problem, but weakens the law of one price. Given supplier locations, there are now infinitely many price vectors that motivate suppliers to implement allocation $s^\star$. Specifically, the local price of the homogenous commodity can differ from $p^\star$ as long as this variation leaves the set of markets with maximal net prices unchanged for all suppliers.

The equilibrium with all suppliers serving their local market is a unique equilibrium allocation that is also efficient. The heterogeneous transportation costs solve the allocation problem, but are not actually incurred, and there is no social welfare loss due to transportation to foreign markets. In the experiment, subject behavior will be characterized as price taking when subjects only supply low cost markets. As shown below, strategic suppliers will deliver to high transportation cost markets if transportation costs are not prohibitive.

At each location there is demand for the good, which is represented by a demand function that determines quantity demanded q_j^d at location j given the prevailing price, p_j:

$$q_j^d = q(p_j, w_j),\ for\ j \in J; \tag{3}$$

where w_j is a parameter representing the influence of the number, wealth, and preferences of consumers at location j on market demand. Assume that the quantity demanded is decreasing in p_j and increasing in w_j.

Local market clearing requires that the quantity supplied equals the quantity demanded at location j, that is, $q_j^s = q_j^d = q_j$, where q_j is the quantity exchanged in location j. Suppose that each island has a spot market for the good, that is, each location has a Marshallian auctioneer who discovers the price at location j, p_j^*, that equates demand to supply. The price is determined after a supplier has delivered q_{ij} units of the good to location j. The good cannot be transported to a second local market, because it perishes if not consumed immediately. Hence, the decision is irreversible and the supplier sells q_{ij} at the prevailing price, p_j^*. Given the quantity supplied to market j, q_j^s, the local auctioneer announces a price p_j^* that clears the local market, that is, $q_j^s = q_j^d = q(p_j^*, w_j)$.

Inverting the demand function gives the local price p_j as a function of the total quantity supplied to market j, q_j^s:

$$p_j^* = p(q_j^s, w_j) = p(\sum_{i=1}^{n} s_{ij}x_i, w_j). \tag{4}$$

The inverse demand function $p(q_j^s, w_j)$ is assumed to be strictly positive on some bounded interval $(0, \bar{q}\,(w_j))$ on which it is twice continuously differentiable, decreasing in q_j^s, and increasing in w_j. The inverse demand function is assumed to be concave in q_j^s. For $q_j^s \geq \bar{q}\,(w_j)$, $p(q_j^s, w_j) = 0$. Since the locations are isolated it is natural to assume that p_j does not depend on deliveries to other locations.

Equation (4) maps a vector of quantities into a vector of prices, which is determined by an allocation s implemented by the n suppliers. Ex post the law of one price no longer holds as the local price is what ever is necessary to clear the market. This dispersion of realized prices does not provide conventional arbitrage opportunities for suppliers, because of the physical isolation of each local market.

2.2 Strategic Suppliers

Increasing the share s_{ij} supplier i delivers to location j lowers the price p_j^* by the assumption of a negatively sloped demand curve. Instead of price taking behavior, suppose that each supplier behaves strategically and takes account of their influence on prices. The strategic interdependence amongst the suppliers can be formalized as the following strategic market game Γ.

The n suppliers make up the set of "players", I. Each supplier chooses from the set of the feasible share vectors, $s_i \in S_i$. The experiment used a linear demand function,

$$P_j(s_{ij}, s_{-ij}) = w_j - b_j(x_i s_{ij} + \sum_{-i} x_{-i} s_{-ij}), \tag{5}$$

with two locations, $j \in \{A, B\}$. The transportation costs are heterogeneous such that each supplier had a designated home location, h, with a zero cost to supply, $c_{ih} = 0$, and a foreign location, f, that had a positive transportation cost, $c_{if} > 0$. From the assumption of two locations and the constraint that the shares have to sum to one note that $s_{if} = 1 - s_{ih}$. The strategic supplier i optimizes by choosing s_{ih}^* to maximize the following profit function:

$$\pi_i (s_{ih}, s_{-ih}) = x_i (s_{ih} P_h (s_{ih}, s_{-ih}) + (1 - s_{ih}) (P_f ((1 - s_{ih}), (1 - s_{-ih})) - c_{if})) \tag{6}$$

Solving the first order conditions from differentiating equation (6) gives

$$s_{ih} = \frac{(n+1)}{4} - \frac{\sum_{-i} s_{-ih}}{2} + \frac{c_{if}}{4 x_i b_j} \tag{7}$$

The market statistic, m_{-ih}, is the average allocation of the other suppliers to market h and is defined as follows:

$$m_{-ih} \equiv \left(\frac{1}{n-1}\right) \sum_{-i} s_{-ih}.$$

Substituting the market statistic into equation (7), gives the best response functions for all $i \in I$

$$s_{ih}^* = r_i(m_{-ih}) \equiv \frac{(n+1)}{4} - \frac{(n-1) m_{-ih}}{2} + \frac{c_{if}}{4 x_i b_j} \tag{8}$$

An assignment s^* is a pure strategy Nash equilibrium of allocation game Γ, that is, $s_i^* = r_i \left(s_{-i}^*\right)$ for all $i \in I$. When $c_{if} = 0$, equation (8) can be simplified to $s_{ih}^* = \frac{1}{2}$. A strategic supplier with zero transportation costs delivers to both locations equally regardless of the number of suppliers. When $c_{if} > 0$, the solution is not symmetric. As can be seen in equation (8), increasing the transportation cost to the foreign market, c_{if}, increases the share supplied to the home market.[3]

2.3 Inefficient Cross-hauling

The unique equilibrium allocation with positive transportation costs, $c_{if} > 0$, is not the efficient allocation. In an efficient allocation, each supplier should deliver only to their home market, which does not incur transportation costs. Instead, strategic suppliers engage in inefficient cross-hauling. A strategic supplier tries to influence market price to increase profits. As seen in Equation (8), a strategic supplier has an incentive to allocate to the foreign market.

The strategic equilibrium profit is

[3] A strategic supplier will no longer supply the costly location when $c_{ij} \geq x_i b_j (n+1)$.

$$\begin{aligned}\pi_i^* &= x_i s_{ih}^* P^* + x_i(1 - s_{ih}^*)(P^* - c_{ij}) \\ &= x_i P^* - x_i s_{ih}^* c_{ij} \\ &= x_i P^* - \mu_i \\ &= \hat{\pi}_i - \mu_i \end{aligned} \tag{9}$$

where $\hat{\pi}_i$ is the efficient profits that can be generated if all firms deliver solely to their home market and μ_i is the cross hauling loss created by a strategic supplier delivering to a location where transportation costs are incurred.

3 Experimental Design

We impose the ceteris paribus condition that the total size of the economy is fixed and vary the number of suppliers and their stock to investigate the accuracy of the one price law and the inefficient cross-hauling prediction, that is, we impose the following constraint on economy size:

$$x_i n = X \tag{10}$$

where x_i is the stock allocated by supplier i, n is the number of suppliers, and X is the total stock in the economy. Equation (10) allows for a clean ceteris paribus comparison of increased market participation. By holding the stock constant across treatments, the optimization premium is reduced for a small supplier. We investigate the effect of the optimization premium on the law of one price. A large supplier can have a greater effect on price, which provides a stronger incentive to conform to the law of one price and to engage in inefficient cross-hauling.

Tab. 1: Experimental design - 2 × 2 design

Treatment	Sessions	Suppliers per Session	Stock	Transport Costs	Periods	One Price	Home Share
1	5	2	3	$0.00	50	$0.35	0.50
2	5	6	1	$0.00	50	$0.35	0.50
3	5	2	3	$0.07	50	$0.35	0.60
4	5	6	1	$0.07	50	$0.35	0.80

The experiment uses a 2×2 design, which results in four treatments, see Table 1. The first blocking variable is the number of suppliers, n, either 2 or 6. We will refer to the first and third treatments, which have two suppliers, as large supplier treatments, and the second and forth treatments, which have six suppliers, as small supplier treatments. Large suppliers were endowed with three units each period, $x_i = 3$, and small suppliers were endowed with one unit, $x_i = 1$. The second blocking variable is transportation costs, which were either \$0.00 or \$0.07. The design used twenty cohorts. Five cohorts for each treatment.

The design tests the following hypotheses:

- H_0: Increasing n ceteris paribus decreases observed price dispersion.
- H_1: With transportation costs, increasing n ceteris paribus results in less inefficient cross-hauling.
- H_2: When $n = 6$ subjects behave as if they are price takers, that is, allocate their stock to their home market.
- H_3: When $n = 2$ subjects are more likely to use their unique equilibrium strategy.

The inverse demand function[4] at location j is given by

$$P_j = 0.70 - 0.11667 Q_j. \tag{11}$$

The equilibrium price for both market locations is \$0.35 in all treatments. In treatment 1 and 2, which have zero transportation costs all firms deliver half of their stock to their home market. Market concentration does not influence this result. However, in treatment 3 and 4, which have transportation costs of \$0.07, the large firms deliver 60 percent of their stock to their home market and the small firms, if they behave strategically, deliver 80 percent of their stock to their home market.

Suppliers without transportation costs lose nothing by transporting the good to both markets. In aggregate, the total cross-hauling loss is \$0.168 in treatment 3 and for the six small small suppliers in treatment 4, the loss is \$0.084, half the size of the large suppliers. Thus, the theoretical prediction for the suppliers is a reduction in cross-hauling loss with an increase in the number of suppliers.

The four treatments differ in the incentive to best respond, that is, the optimization premium. Let $\pi_G(r_i(s_{-i}), s_{-i})$ denote the expected payoff to a player in game G who plays $r_i(s_{-i})$. Let $\pi_G(s_i, s_{-i})$ be defined as the expected payoff to player i for playing s_i. Then the optimization premium for game G is the function $u_G(i) : [0, 1] \rightarrow \Re$ given by

$$u_G(s_i, s_{-i}) = \pi_G(r_i(s_{-i}), s_{-i}) - \pi_G(s_i, s_{-i}) \tag{12}$$

[4] The profit function was chosen because it follows from Meyer et al. [1992] where the linear demand function in this paper is tangent to the iso-elastic demand function in Meyer et al.

The intuition behind the optimization premium is that a larger optimization premium creates a larger incentive for the supplier to best respond to rivals. The optimization premium has been shown to influence the coordination of subjects and the speed of convergence to a stable equilibrium, see Battalio et al. (2001). The small suppliers have a smaller optimization premium thus penalizing the suppliers less for not having best responded. Figure 1 represents the optimization premia for the four treatments. Each contour line represents a \$0.05 penalty for not having best responded. Large suppliers have a much greater optimization premium than the small suppliers, see Figure 1.

Figure 1 diagrams the best response functions to the subjects. The vertical axis is the allocation, s_{ih}, of the supplier to their home location. The horizontal axis depicts the average allocation decisions of the suppliers, m_{-ij}. The dark line depicts the best response curve for a supplier as viewed from the home market allocation. Because the axes are denoted in share allocated to the home market, the relevant portion of the figure is from zero to one.

The equilibria are indicated on Figure 1 by the dotted lines. Without transportation costs all suppliers divide their stock equally between both locations and, hence, $m_{-ij} = \frac{1}{2}$ and tracing this to the red best response function shows that indeed $s_{ij} = \frac{1}{2}$ is a best response. The case with two suppliers and transportation costs is slightly more complicated. Here the other supplier delivers 0.4 percent of their stock to what is for them their foreign market and tracing this to the red best response function shows that indeed $s_{ij} = 0.6$ is a best response. Finally, with six suppliers and transportation costs two suppliers are in the same position as i and deliver 0.8 of their stock to i's home market and the other three suppliers deliver 0.2 to i's home market, which means that $m_{-ij} = 0.44$ and tracing this up to the red best response curve shows that indeed $s_{ij} = 0.8$.

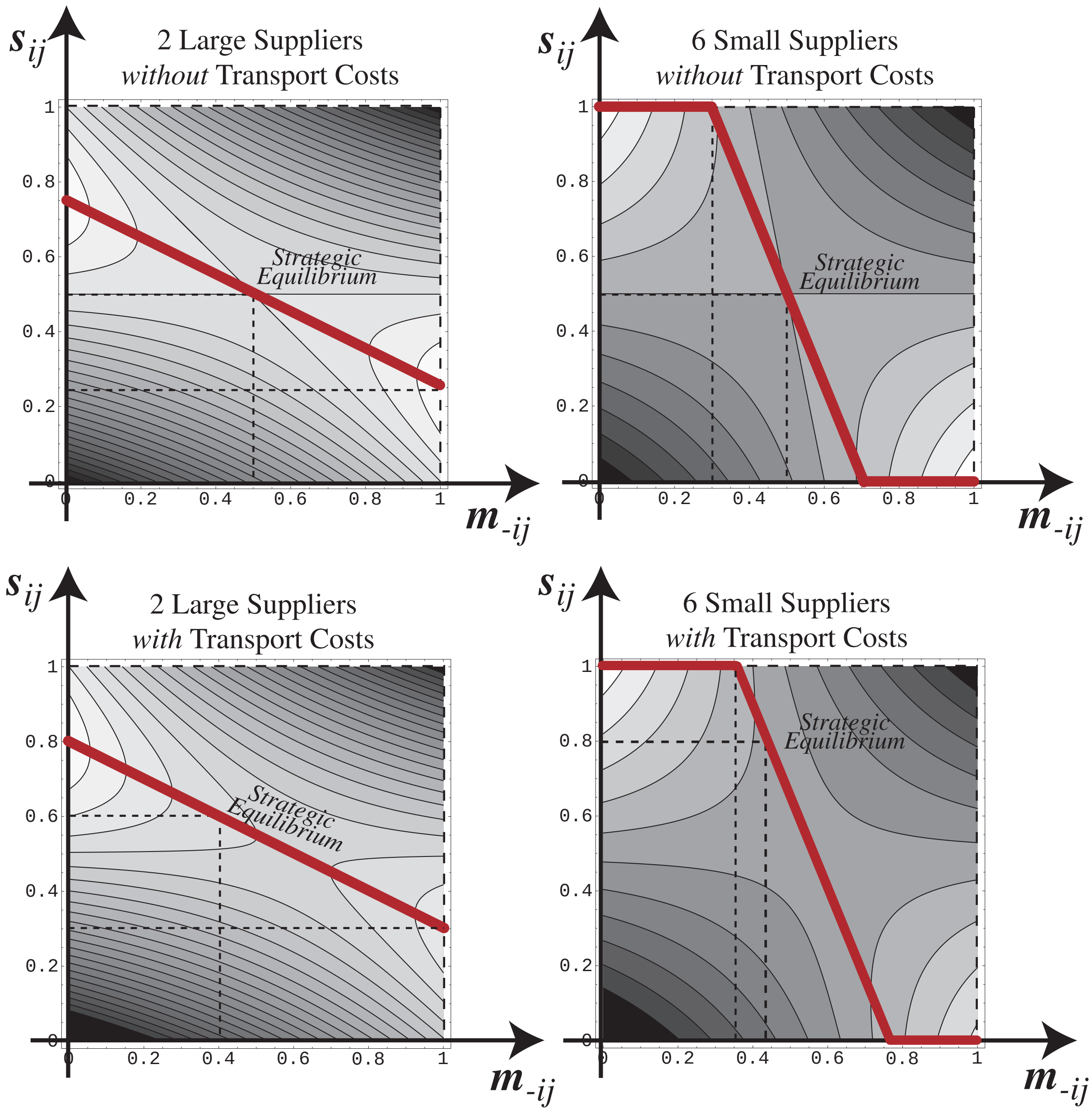

Fig. 1: Best response curves with contour (lighter shades represent higher payoffs)

The experiment uses the ERL (Economics Research Laboratory) Gray Box software (see Figure 2). The subjects participated in a two market design with a specified number of goods. The novelty of the Gray Box software is the clear depiction of the optimization premium to the subjects. The contour shading indicates a better and best response to all allocation choices by rival suppliers. The subject is not left to randomly search the grid for a better response to a response by other suppliers. The contour clearly demarcates the better and best responses to others allocation choices.

The subjects were not allowed to communicate one with another during the experiment. As each subject looked at the screen, they could determine what they thought the average of the other market players will supply to Market A, m_{-iA}. This is called the market statistic (MS). The market statistic is the average of the other player's choices. The market statistic excludes the choice made by the individual. This is the viewed by the subjects as a horizontal yellow line in Figure 2. They can slide the market statistic until they find what they think is the expected choice of other suppliers to Market A. They then can move the vertical green line, which is their own participation in market, up and down until they have found a best response to the market statistic.

The Gray Box Interface also displays a contour that reveals optimal allocations for areas of a lighter shade. They then confirm their choice and once all participants have made their choice, their own payoff is displayed along with the true market statistic. This is one period. The game was repeated for 50 periods. There was no time limit for the subjects to make a choice in any of the periods.

The subjects earned from \$14.37 to \$52.50 plus a \$5.00 fee for participating. After the experiment the subjects were all paid in cash and in private. The efficient allocation profits are \$17.50 for the small suppliers and \$52.50 for the large suppliers.

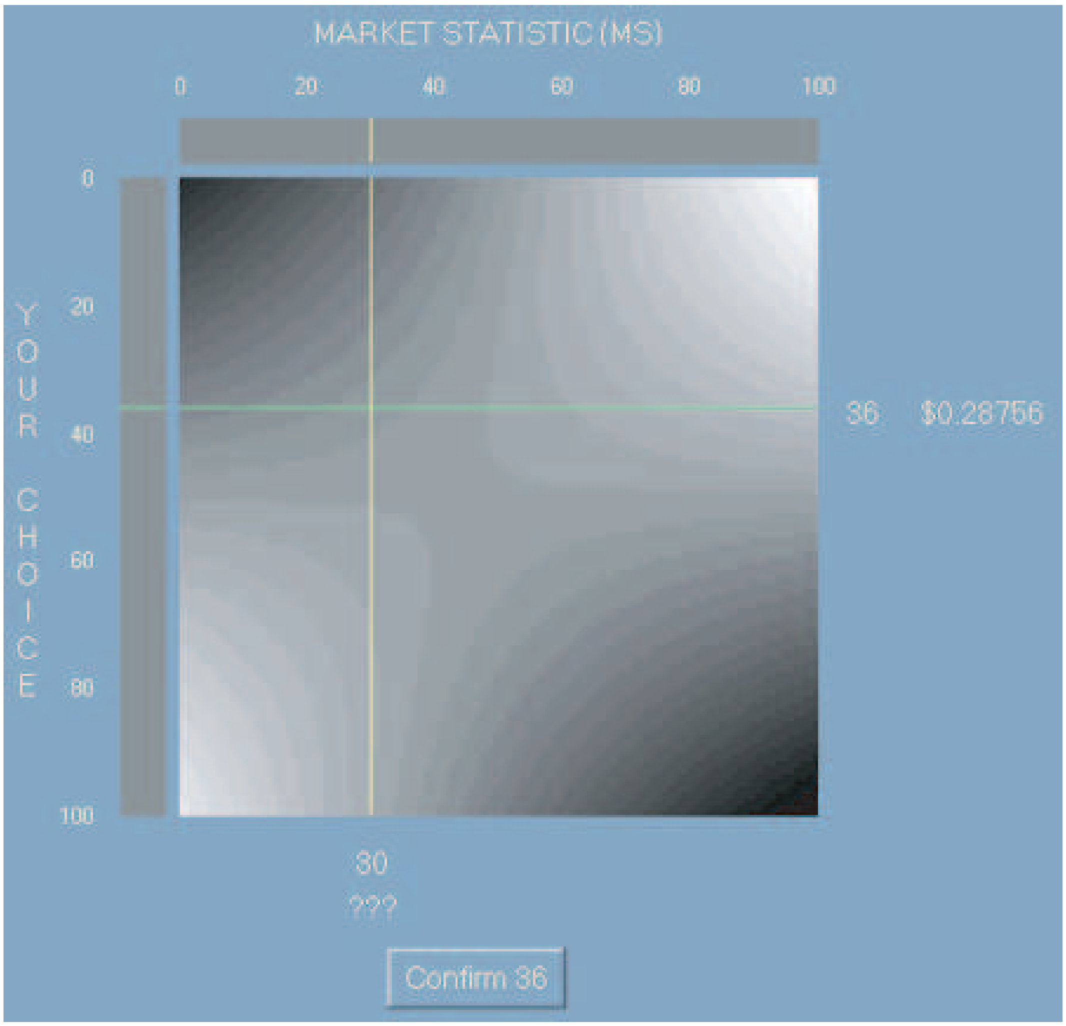

Fig. 2: Example of ERL Gray Box GUI (6 suppliers with transportation costs)

4 Experimental Results

Figure 3 through Figure 6 reports the allocation decisions of each supplier throughout the 50 periods. In treatment 1 where there are two large suppliers and no transportation costs the equilibrium prediction is very accurate. All of the subject most of the time divide their stock equally between both locations, see Figure 3. Introducing transportation costs, which introduces a tension between the equilibrium prediction and the efficient allocation, introduces a significant amount of noise but towards the end of the sessions we see that the equilibrium prediction is fairly accurate, see Figure 4. (Recall that in the two supplier with transportation costs treatment and with player 0 local to market A and player 1 local to market B, the solid line for player 0 is predicted to be at 60 and the solid line for player 1 is predicted to be at 40.) There is a clear separation of player 0 behavior from player 1 behavior in treatment 3.

Inspecting the six small supplier figures, 5 and 6, and comparing them with the two large supplier figures immediately reveals much noisier behavior. The equilibrium prediction of 50 percent delivery to Market A for the six small suppliers with no transportation costs is accurate for very few of the subjects, see figure 5. The equilibrium prediction of 80 percent delivery to one's home market for the six small suppliers with transportation costs is not accurate either. Although, a close inspect of figure 6 does reveal that the first three subjects in a cohort who are local to Market A deliver more on average to Market A than the last three subjects in a cohort who are local to Market B. The difference in behavior is not as striking as one would expect from the predicted 80 versus 20 difference.

4.1 Market Concentration and Price Dispersion

Figures 7 through 10 report the price that clears Market A in each period. The law of one price predicts a market clearing price of \$0.35 each period. Deviations from that price represent the inability of suppliers to solve the allocation coordinate problem. The observed price dispersion is a disequilibrium phenomena. The one price law makes accurate predictions in Treatment 1, see figure 7. For the other three treatments, the one price law predicts the central tendency of the market price but there is persistent price dispersion that is difficult to evaluate visually.

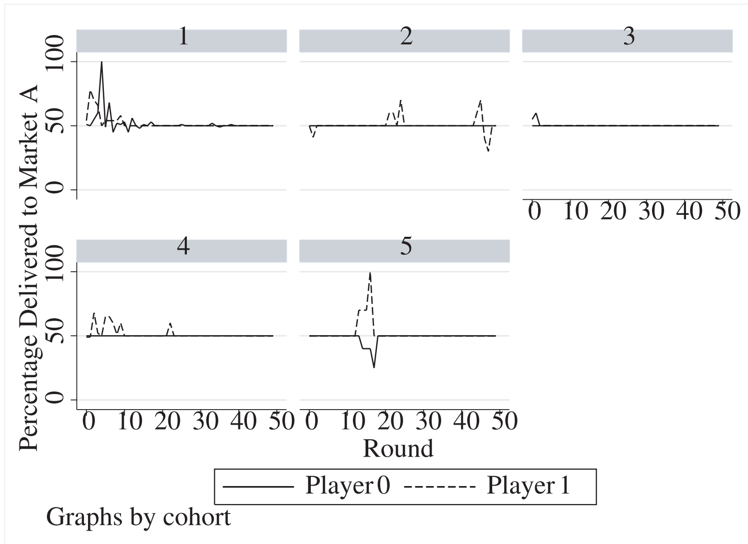

Fig. 3: Treatment 1 (2 suppliers no transport costs) - Allocation to Market A by subject

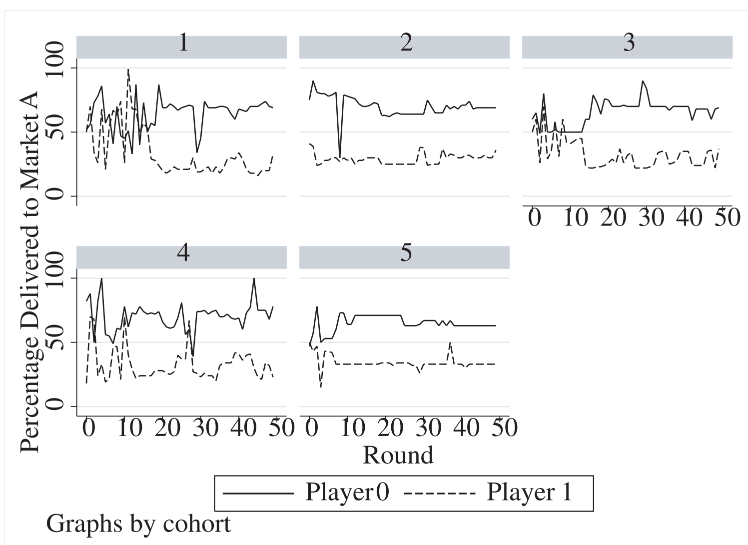

Fig. 4: Treatment 3 (2 suppliers with transport costs) - Allocation to Market A by subject

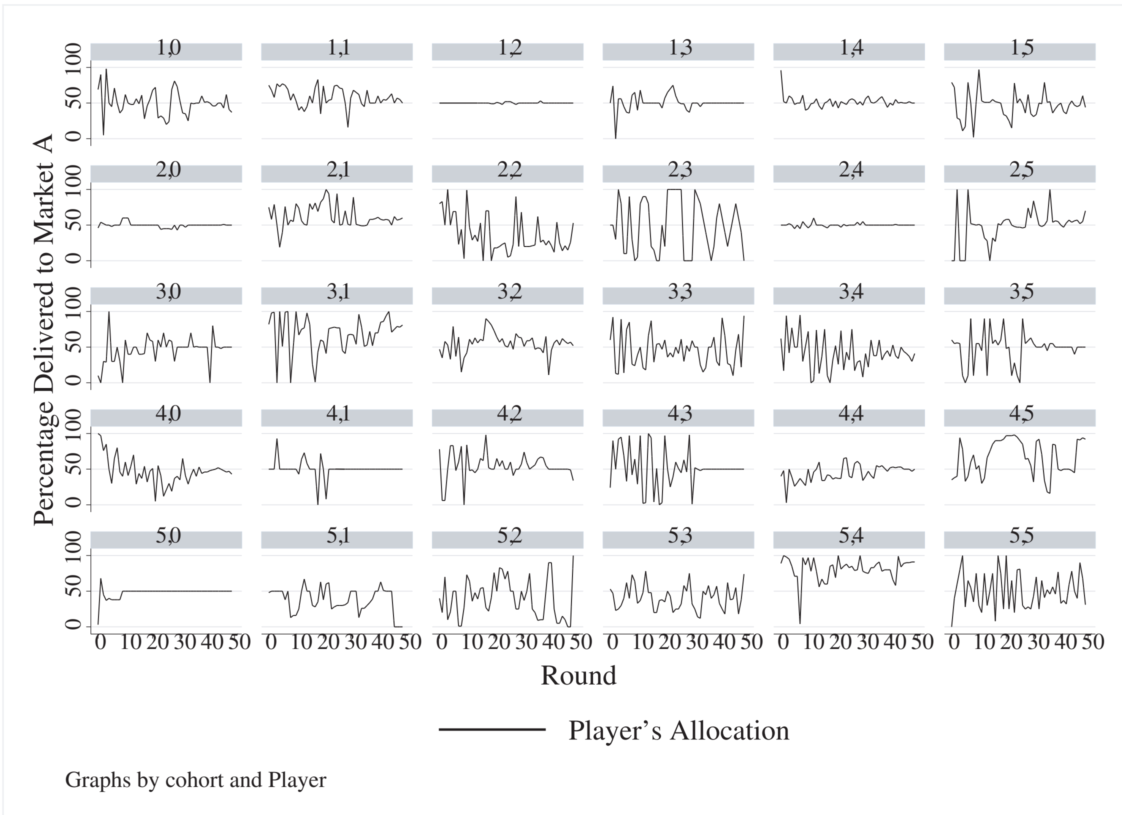

Fig. 5: Treatment 2 (6 suppliers no transport cost) - Allocation to Market A by subject

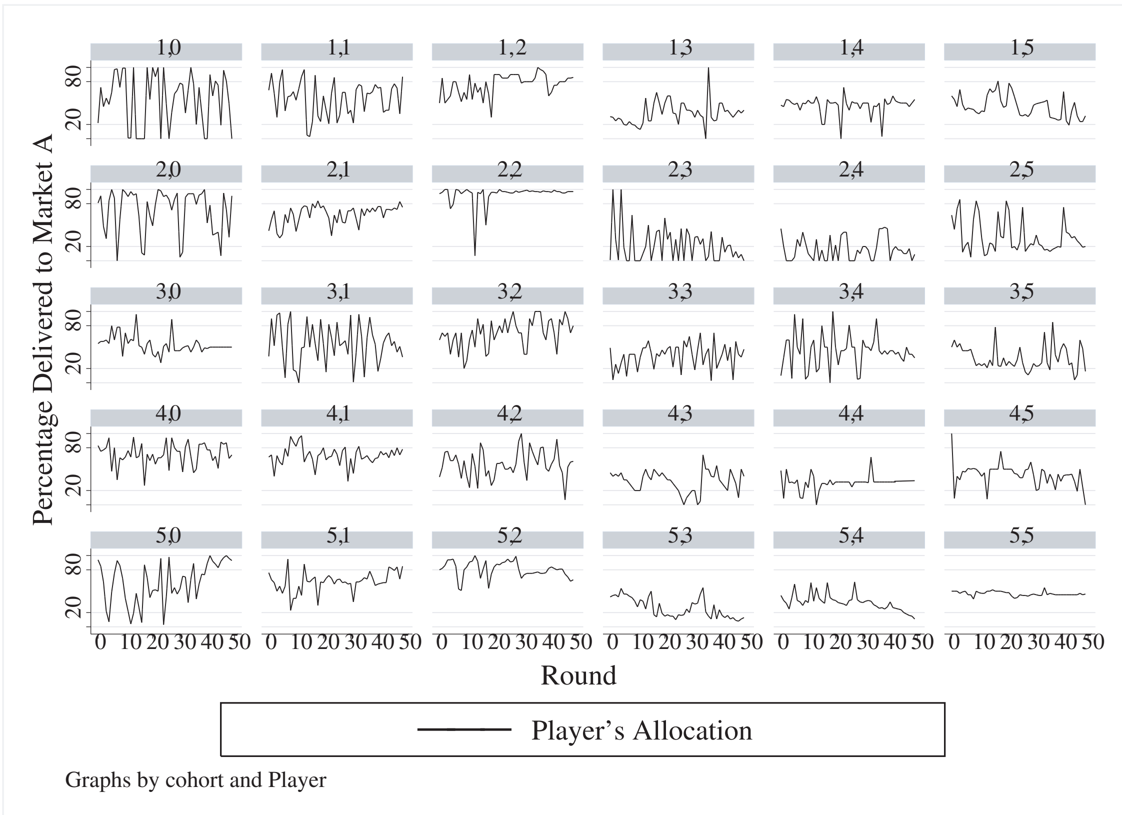

Fig. 6: Treatment 4 (6 suppliers with transport costs) - Allocation to Market A by subject

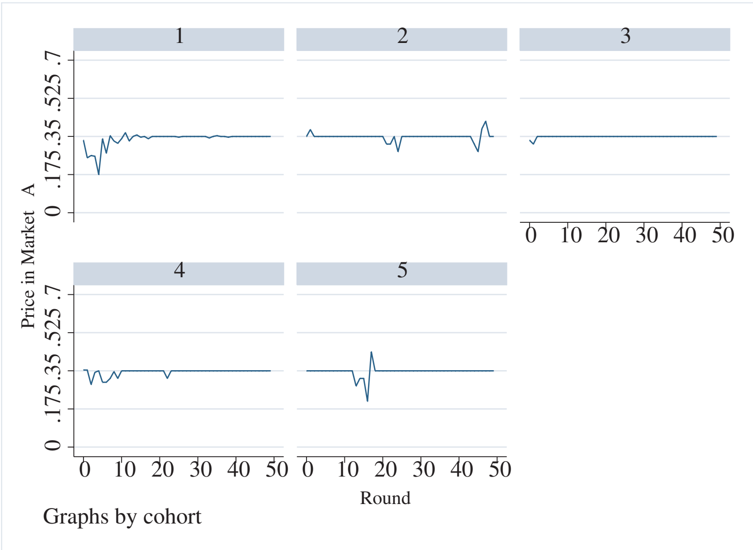

Fig. 7: Treatment 1 (2 suppliers no transport costs) - Market Price in Market A by round

Fig. 8: Treatment 2 (6 suppliers no transport cost) - Market price in Market A by round

Fig. 9: Treatment 3 (2 suppliers with transport costs) - Market price in Market A by round

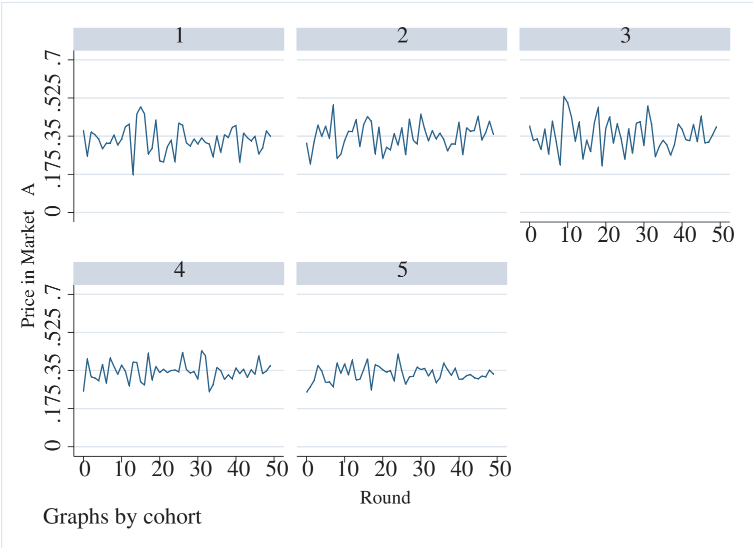

Fig. 10: Treatment 4 (6 suppliers with transport costs) - Market price in Market A by round

Measures of price dispersion that are unitless are helpful when comparing across treatments. Suppose the prices across markets is drawn from a distribution, F, with mean μ and variance σ^2. The coefficient of variation, $CV = \sigma/\mu$, has been used by Carlson and Pescatrice [1980], Sorensen [2000], Baye et al. [2004] and others, to measure price dispersion in retail markets. The coefficient of variation for treatment 1, two large suppliers without transportation costs, is 0.065 and for treatment 2, six small suppliers without transportation costs, the coefficient of variation is 0.155. A t-test indicates that the two coefficients are statistically different from one another with a p 0.000. The coefficient of variation for treatment 3, two large suppliers with transportation costs, is 0.140 and for treatment 4, six small suppliers with transportation costs, the coefficient of variation is 0.163. A t-test indicates that the two coefficients are also statistically different from one another with a p 0.000. Increasing market concentration reduces price dispersion significantly and, hence, we reject Hypothesis H_0.

4.2 Inefficient Cross-hauling

Testing hypothesis H_1 that with transportation costs increasing market concentration (ceteris paribus reducing n) results in more inefficient cross-hauling requires estimating an econometric model, because the amount of cross-hauling in treatments 3 and 4 are similar. Both treatments have subjects allocating about two-thirds of their stock to the home market, which contrasts with the equilibrium prediction of 60 percent in treatment 3 and 80 percent in treatment 4. The theoretical cross-hauling loss for the large suppliers is \$0.168 and for the six small small suppliers is \$0.084. In treatment 3 with two suppliers, the average spent per round on transportation costs is \$0.138 and in treatment 4, the average spent per round on transportation costs is \$0.1443. Somewhat surprisingly, there was more cross hauling with small suppliers than with large suppliers although the difference is very small.

Equation 13, tests if increasing n affected the loss to the suppliers. In equation 13 the indicator variable is for treatment 3 and 4, where treatment 3 was the ommited variable. The results are displayed in Table 4.2. At 6% level of significance we can reject the null that there is no effect on cross-hauling loss by increasing the number of suppliers. However, the sign is positive indicating that small suppliers produced statistically significantly more cross-hauling losses.

$$\text{Cross-Hauling Loss} = \beta_0 + \beta \text{ TREATMENT} + error \tag{13}$$

4.3 Do subjects in treatment 4 behave as price takers?

The data reject hypothesis H_2 that when $n = 6$ subjects behave as if they are price takers. If subjects were to behave as price takers then they would supply their entire stock to their home location. This is also the efficient allocation as no transportation costs are incurred.

In treatment 4, the six small suppliers behave strategically. Specifically, suppliers allocated 34 percent of their stock to the foreign location, which is greater

Tab. 2: Cross-hauling loss to economy

Cross-Haul	**Coef.**	**Std. Err.**	**t**	**P<t**	**[95% Conf.**	**Interval]**
Treatment 4	0.00655	0.00347	1.89000	0.06000	-0.00027	0.01337
Constant	0.13779	0.00245	56.16000	0.00000	0.13297	0.14261

than the price taking prediction of zero and even greater than the strategic equilibrium prediction of 20 percent. It is an open question why the six small suppliers behave like this in treatment 4.

5 Summary and Conclusions

This paper has considered the possibility that even in a complete information framework with no trade barriers or product differentiation, it is difficult for suppliers to eliminate persistent price dispersion. Market concentration was found to be a key to knowing whether subjects would solve the allocation coordination problem. As the optimization premium is increased, more subjects use their unique equilibrium strategy. In treatment 1, which has two large suppliers and no transportation costs, subjects played their strategy predicted by a strategic analysis (deliver exactly half their stock to the home market) 89 percent of the time. However, in treatment 2, which has six small suppliers and no transportation costs, subjects played their predicted strategy (deliver exactly half their stock to the home market) only 27 percent of the time. This resulted in persistent price dispersion in treatment 2, which was not observed in treatment 1. Increasing market concentration reduced price dispersion.

Subjects engaged in inefficient cross-hauling when transportation costs to the foreign market were strictly positive as predicted by a strategic analysis. Treatment 3, which has two large suppliers and transportation costs, saw market share fluctuate around the predicted equilibrium shares, but the inefficiency of the equilibrium seems to have prevented them from settling into an equilibrium allocation. At any rate, treatment 3 resulted in persistent price dispersion.

Treatment 4, which has six small suppliers and transportation costs, strongly rejects hypothesis H_2 that small suppliers will behave as price takers in this game. In fact, they behave very much like the large suppliers of treatment 3. They actually engage in more inefficient cross-hauling than the large suppliers. This remains a puzzle for future research.

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