The Navigation Economic Technologies Program

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A MODEL OF SPATIAL MARKET AREAS AND TRANSPORTATION DEMAND

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IWR Report 05-NETS-P-01

Navigation Economic Technologies

The purpose of the Navigation Economic Technologies (NETS) research program is to develop a standardized and defensible suite of economic tools for navigation improvement evaluation. NETS addresses specific navigation economic evaluation and modeling issues that have been raised inside and outside the Corps and is responsive to our commitment to develop and use peer-reviewed tools, techniques and procedures as expressed in the Civil Works strategic plan. The new tools and techniques developed by the NETS research program are to be based on 1) reviews of economic theory, 2) current practices across the Corps (and elsewhere), 3) data needs and availability, and 4) peer recommendations.

The NETS research program has two focus points: expansion of the body of knowledge about the economics underlying uses of the waterways; and creation of a toolbox of practical planning models, methods and techniques that can be applied to a variety of situations.

Expanding the Body of Knowledge

NETS will strive to expand the available body of knowledge about core concepts underlying navigation economic models through the development of scientific papers and reports. For example, NETS will explore how the economic benefits of building new navigation projects are affected by market conditions and/or changes in shipper behaviors, particularly decisions to switch to non-water modes of transportation. The results of such studies will help Corps planners determine whether their economic models are based on realistic premises.

Creating a Planning Toolbox

The NETS research program will develop a series of practical tools and techniques that can be used by Corps navigation planners. The centerpiece of these efforts will be a suite of simulation models. The suite will include models for forecasting international and domestic traffic flows and how they may change with project improvements. It will also include a regional traffic routing model that identifies the annual quantities from each origin and the routes used to satisfy the forecasted demand at each destination. Finally, the suite will include a microscopic event model that generates and routes individual shipments through a system from commodity origin to destination to evaluate non-structural and reliability based measures.

This suite of economic models will enable Corps planners across the country to develop consistent, accurate, useful and comparable analyses regarding the likely impact of changes to navigation infrastructure or systems.

NETS research has been accomplished by a team of academicians, contractors and Corps employees in consultation with other Federal agencies, including the US DOT and USDA; and the Corps Planning Centers of Expertise for Inland and Deep Draft Navigation.

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A MODEL OF SPATIAL MARKET AREAS AND TRANSPORTATION DEMAND

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ABSTRACT: In this paper, we derive a model of transportation demand and the interrelated supply decisions of agricultural shippers over a geographic space. These shippers use prices to both procure grain and to make output, mode, and market decisions. These decisions are each affected by the characteristics of the region and the level of spatial competition between the shipper and its rivals. We integrate each of these factors into our model of derived demand and spatial competition. The model is applied to data representing barge elevators on the Upper Mississippi and Illinois Rivers to estimate transportation demands and gathering areas. The results provide demand elasticity estimates for annual volumes between -1.3 to –1.9, estimates which are sizably larger than previous estimates of similar traffic. The results also indicate that inbound transportation rates to the barge shipper has a significant influence on annual volumes as does the distance to the nearest competitor. A second model, explaining the size of the market area of elevators is also estimated. We find that the rates of alternative modes that compete for barge traffic have a strong influence on market areas as does the distance to the nearest competitor. The results provide for a strong argument that transportation demands are elastic and that spatial market areas vary substantially with transportation rates.

1. INTRODUCTION

Current navigation planning models define demands in terms of originating and terminating pools for a specific commodity on an annual basis (ODC). These models differ with regard to assumptions on the behavior of demand in response to rate movements. The Tow Cost (TCM) and ORNIM models hold that demands are constant up to a threshold level (e.g., the least cost rail rate) at which point all traffic flows to the alternative mode. The ESSENCE model holds that these demands are not constant, but rather fall as price increases until that same threshold point is reached. The basis for this treatment is that demanders are distributed geographically over space and that as price increases, shippers that define the ODC triplicate demand less barge.

These OCD triples reflect the decisions of port elevators. Our approach is to examine the responsiveness of these elevators to barge rates. Specifically, barge rates are a determinant of the price that elevators offer to shippers located off of the river. As barge prices increase, the price increase is passed on to those shippers that use the elevator. To the extent that these shippers have alternatives or respond to price decreases, the river elevator ships less down the river.

We model these decisions using a spatial modeling approach. For the past century economists have been interested in the effects of space on economic competition. Clark and Clark (1912) were the first to examine how firms competed over customers in a spatial context. Many theories have followed most notably Hötelling (1929) and Lösch (1941). All of these theories, while theoretical in nature, agree that as transportation costs increase the size of the firm's market area decreases and that as the distance between firms increases the size of the firm's market area increases.

While numerous theories exist to explain how firms interact over space, very little work has been done on empirically estimating these relationships. This lack of research has stemmed from the lack of real world data available on firms in a spatial context. We add to this literature by theoretically and empirically analyzing the quantity shipped and market areas of agricultural elevators located along the Mississippi and Illinois Rivers taking into account the spatial relationships and characteristics of the elevators. We find that, controlling for location, the firm's market area decreases in size as the distance between the origin location and destination location decreases. We additionally find that demand elasticity estimates for annual volumes of between -1.3 to –1.9, estimates that are sizably larger than previous estimates of similar traffic.

In Section 2, we provide a more complete summary of the literature on firms in a spatial context paying particular attention to pricing over geographically dispersed customers. In Section 3, we present a theoretical model of spatial competition and market areas for agricultural elevators. Section 4, details the empirical model used to estimate the firm's market areas in a spatial context, while Section 5 outlines the data used for the analysis. Section 6 presents the results of this estimation technique, while in Section 7 provides concluding comments.

2. PREVIOUS LITERATURE

The spatial economics literature consists of two interconnected areas of focus: market areas and spatial pricing/competition. These areas aim to describe how a firm's set of customers changes as the firm changes its pricing policies, given the spatial distribution of customers. Related research examines the spatial location of firms given optimal pricing. Previous literature tends to address each of these issues individually rather than combining them. Following this tradition, we take locations as given and model the pricing behavior in conjunction with spatial characteristics to explain the prices paid to farmers, the volumes shipped by the elevator and, consequently the volume shipped via the river.

Clark and Clark (1912) is the first attempt to explain how firms located at different geographic points compete for customers. In this study, each firm's market share is determined by the location of the customer indifferent between the firm and its nearest competitor. This indifferent point is based on each firm's base price and the transportation costs of the customer to each location. Fetter (1924) follows the work of Clark and Clark (1912) by examining the shape of each firm's market area. Fetter (1924) surmises that it is unlikely that there is only one indifferent customer located between the firms, but rather there must be a band or series of such customers located at varying distances between the two firms. This series of customers thus constitutes the shape and extent of the firm's market area.

According to Fetter's "Law of Market Areas" the difference between each firm's base price and that of its nearest competitor determine both the size and the shape the firm's market area. An increase in freight rates acts to move the indifferent customer further away from the higher priced firm, increasing the market area of the lower priced firm. Alternatively, it will allow the lower priced firm to raise their prices while retaining the same market area. If the firms have identical base prices such an increase in the freight rates will not change the indifferent customer only the price that they face.

The most notable work done on spatial competition is Hötelling (1929). This work mathematically formalizes the models of both Clark and Clark (1912) and Fetter (1924). Hötelling (1929) assumes that buyers are distributed evenly on a line, that each buyer faces constant transportation costs, and that demand is inelastic. These buyers then must decide which firm of two firms to purchase from. Unlike previous work, Hötelling (1929) then allows firms to respond to their competitors through either price or location decisions. Using this approach, each competitor is found to adjust their prices, taking their competitor's price as given, to maximize profits. Proceeding in this fashion, each firm finds it profitable to locate closer to their competitor because they can attract more of the customers located between the two firms.

Much later, D'Aspremont, Gabszewicz and Thisse (1979) prove that the Hötelling (1929) model does not prove that firms will cluster in the middle of the market. With homogeneous products, as two firms move closer together they have to charge a price equal to that of their competitor plus transportation costs. Such a pricing system would drive price, and subsequently profit down as the firms move closer together because of the increased competition from their rivals. Indeed D'Aspremont, Gabszewicz and Thisse (1979) argue that duopolists should like to locate apart and divide the market, allowing each firm to gain some degree of market power.

Another line of work regarding firms in space focuses on the shape of firms' market areas. The most notable work in this area is Lösch (1954) who argues for the existence of hexagon shaped market areas so that the market is "full". Mills and Lav (1964) later show that under the assumption of linear demand both profits and market areas are maximized with circular market areas. They also examine other shapes and conclude that dodecagon shaped market areas are equilibrium market area shapes.

Later research, e.g., Eaton and Lipsey (1976) find that many market shapes satisfy the equilibrium conditions of their model including squares, rectangles, and hexagons. In fact, the only market shape that they could conclude would not satisfy their equilibrium conditions was an equilateral triangle market area. The reason that Eaton and Lipsey's (1976) result varies from that of Lösch (1954) is because they assume that all firms charge the same exogenously imposed mill price. Our model differs from much of this primary research by taking the location of the firms as fixed and focusing on effect of the spatial distribution of firms on pricing and the gathering area for port facilities. In particular, we consider the effects of pricing and the spatial distribution of firms (and other variables) on output and the size of the market area. Of course, the concepts of Clark and Clark (1912), Fetter (1924) and others are retained in the sense that the firms base price and the set of indifferent customers determines the geographic space titled "market area". We note that in our data, elevators tend to agglomerate in some areas and separate in others, leading to elevator competition between areas and within areas.

3. THEORETICAL MODEL

Our primary focus in this paper is the movement of agricultural products. Production of agricultural commodities occurs over space, and transportation of such commodities is a critical component of agricultural markets. At harvest, goods are transported from the farm to a storage facility, a gathering point, or to a final destination. The gathering points are transshipment points, represented by country elevators, rail sub-terminals, and/or barge loading facilities. From these points, there is further transportation to the final destination. By and large, commodities almost always pass through one or more of these gathering points for transshipment to another location. Ultimately, the commodities reach their final destination. The final destinations are numerous. Such final destinations include processing plants, feedlots, and export markets.[1] Our data, described in a later section, represent the transportation decisions of what we term transshipment locations. That is, they receive commodities from the farm or another gathering point, and ship to another location in the transportation infrastructure.

The model we develop in this section is a model of grain elevator competition that gives rise to a procurement function defining the relationship between an elevator's market area and characteristics of the firm, its rivals and the space that they are competing in. Since we are specifically looking at grain terminals located along both the Mississippi and Illinois rivers, we model elevators located in a linear geographic space. For simplicity and clarity, we assume that there are $n=1,2,\ldots,N$ elevators located $D=d_{12},d_{23},\ldots,d_{n-1n}$ miles apart from one another, and that grain per mile is evenly distributed between the elevators with parameter y.

We assume that farmers sell their grain to the elevator that yields them highest returns net of transportation costs $(w^e + \delta_e - \theta D^e)$ where w^e is elevator e's bid price, δ_e is the farmer's preferences for elevator e, θ

[1] Our focus is on US shipments. As such, we include export market as a "final" destination. Of course, once at the export elevator, there is another set of transportation and marketing decisions from which we abstract.

is the farmer's cost per unit distance, and D^e is the distance from the farmer's location to elevator *e*.[2] The farmer's problem then is treated quite simply. That is, once the decision to sell has been made, our model is simply a decision of where to sell to from a set of locations. We translate grain locations into distances, and assume that no one elevator offers a price high enough to price the other elevators out of the market.

Consider farmers producing grain. Further, suppose that these farmers are located between two elevators (A and B). The indifferent farmer is located such that

$$D^A = \frac{w^A - w^B}{2\theta} + \frac{\delta_A - \delta_B}{2\theta} + \frac{D}{2} \tag{1}$$

Note that the distance the indifferent farmer is from elevator A, D^A, is increasing in the price A offers, $\frac{\partial D^A}{\partial w^A} > 0$, decreasing in the price B offers, $\frac{\partial D^A}{\partial w^B} < 0$, increasing in farmer tastes for elevator A, $\frac{\partial D^A}{\partial \delta_A}$, decreasing in farmer tastes for elevator B, $\frac{\partial D^A}{\partial \delta_B}$, increasing in the distance between the two elevators, $\frac{\partial D^A}{\partial D} > 0$ and ambiguous in the farmer's transportation cost, θ.

For an elevator (A) that serves farmers located between elevators A and B and elevators A and C, total output is given by the total produced (*yD*), and its share of the distance between A and B and A and C, which we denote D^{A-B} and D^{A-C} as defined by (1). Total output for elevator A given prices is then:

$$\begin{aligned} Q^A &= Dy\left\{ \int_0^{D^{A-B}} \frac{1}{D} dt_1 + \int_0^{D^{A-C}} \frac{1}{D} dt_2 \right\} = Dy\left\{ \frac{D^{A-B}}{D} + \frac{D^{A-C}}{D} \right\} \\ &= \frac{y}{2\theta}\left\{ 2w^A - w^B - w^C + 2\delta_A - \delta_B - \delta_C \right\} + \frac{Dy}{2} \end{aligned} \tag{2}$$

Elevator A's output is increasing in the price it offers, but decreasing in the price of its rivals. Note that if prices and non-price characteristics are the same, the elevators simply split the market area. If prices are different, then there are a number of effects. First, greater distances between elevators increase total regional output and, hence, the quantity each elevator handles. Second, an increase in farmer transportation costs reduces the effectiveness of pricing differences on the market area, and therefore, the quantity of the higher priced elevator. Of course, since all goods are shipped, it has the effect of increasing the quantity of the lower priced elevator. Finally, as with increases in the distances between elevators, increases in the grain yield result in a larger total market with no change in market area resulting in an increase in production at each elevator. Third, and increase in farmer preferences for elevator A relative to elevators B and C, leads to an increase in elevator A's output.

We use this expression to define the output, i.e. market area, of a representative elevator that competes with others over geographic space. The expression given by (2) is a deterministic relationship in the model i.e.,

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[2] δ_e enters this equation to control for non-price differences across farmer's utility functions. For example, one farmer may like the options provided to it by using a large multi-plant companies elevators, while a different farmer may prefer his/her local cooperative elevator to the large corporative elevators.

there is a unique w^A for a corresponding output level (Q). However, for the purposes of this section, we invert the expression given by (2) such that Q can be the choice variable. The result is:[3]

$$w^A = \frac{1}{2}\left\{w^B + \delta_B + w^C + \delta_C\right\} + \frac{\theta}{y}\left\{Q^A - \frac{Dy}{2}\right\} - \delta_A \tag{3}$$

Given equation (3), the costs of procurement for the firm are simply:

$$C^{\text{Procurement}} = w^A Q^A = w^A(Q^A, w^B, w^C, D, y, \delta_A, \delta_B, \delta_C)Q^A = C^{\text{Procurement}}(Q^A, w^B, w^C, D, y, \delta_A, \delta_B, \delta_C)$$

with the properties that marginal costs are positive and increasing in Q.

In addition to procurement, there is the cost of the elevator company to operate over and above just the costs of procurement over a geographic space. On this matter, we simply assert that such costs are positively related to activity levels (Q), factor prices (w), and non-positively related to fixed asset levels (e.g., capacity, K). That is, $C^{Operations} = C^{Operations}(Q, w, K)$. With operations and procurement identified, the total cost function of the facility making transportation decisions, is given by:

$$\begin{aligned} C^{Elevator} &= C^{Operations}(Q^A, w, K) + C^{\text{Procurement}}(Q^A, w^B, w^C, D, y, \delta_A, \delta_B, \delta_C) \\ &= C(Q^A, w, K, w^B, w^C, D, y, \delta_A, \delta_B, \delta_C) \end{aligned} \tag{4}$$

There are a few notes of interest in regard to this cost function. First, we constructed this model for the specific purpose of solving an optimization program of shippers that must procure their product over space. While most shippers face this type of problem (i. e., the gathering of inputs over space and the dissemination of outputs over space), it is not a common treatment. Specifically, we note that the cost function depends on the input prices of rivals (The price paid by neighboring elevators). The more common treatment is simply to ignore the spatial procurement of inputs and specify costs as one of operations in our discussion above. So long as this cost function has increasing marginal costs, the remainder of the theory present applies.

Second, a necessary condition for the procurement cost function to be increasing in output, is that the neighboring shippers do not respond to the price changes of the elevator or that the response is less than a direct matching of prices. If there is a direct matching of price changes, quantities will not change. This can be seen by totally differentiating equation (2) and imposing the restriction that price changes are equivalent. This issue is overcome in our model where we allow elevators to offer differentiated services. There are, however, lots of differences among elevators in terms of yields, capacity levels, transportation attributes etc., that allow for a non-trivial result.

The firm then chooses Q^A, which implicitly determines w^A given the bid prices, and preferences for its rivals. The elevator must additionally decide where to ship the commodity to and what mode to ship with, so as to maximize their profits defined as:

$$Max\,\pi_{md} = (P_d - t_{md} - s_{md})Q_{md} - C(Q_{md}) \tag{5}$$

where P_d is the price that the elevator gets for the commodity at its destination, t is the transportation costs associated with shipping the commodity to that location from the elevator via shipment mode m, and s is the service characteristics of shipment mode m from the elevator to the destination. Assuming that larger shipment sizes are harder to obtain (e.g., the shipper must increase its bid price to increase its gathering area or to induce farmers to reach a reservation price or, alternatively, processing gets more costly with larger sizes), the solution yields how much the shipper will send to the terminal location by a given mode.

[3] As intuition, note that if all firms priced the same, then $Q - Dy$ must take a value of zero. For this to happen, each firm serves one-half of the distance to each of its neighboring rivals.

Theoretically, this quantity is a function of the price at the destination, the transportation rate, service induced costs, and procurement/processing costs determinants.

$$Q^*_{md} = Q^*_{md}(P_d, t_{md}, s_{md}, c, D, y) \tag{6}$$

where *c* is simply the set of parameters of the cost function that we derived previously.

Given the first-order condition to equation, we can see how changes in each of the determinants of equation (6) affect the profit maximizing quantity, market area, for an elevator. An increase in P_d, the price that the elevator gets when it ships the commodity, will not surprisingly increase the quantity, or market area, of the firm. In addition, as the distance between elevators increase, so do the prices offered farmers with the result that both output and market areas increase. Increases in t_{md}, s_{mn}, or *c* will decrease the quantity, or market area, of the firm. Examining the elements of *c*, the cost parameter closer, we see that increases in factor prices and the bid prices of rivals increase costs, thus reducing both profits and the firm's quantity, or market area. Meanwhile, increases in capacity (*K*), grain per mile (*y*) and distance between elevators (*D*) reduce costs therefore, increasing both profits and the firm's quantity, or market area.

These changes, however, may induce another effect. In particular, as prices, capacity, yields, distances between elevators, etc. change so do the profits attached to the elevator's discrete decision of where to ship (i.e., the terminal market) and the how to ship (i.e., the mode).

4. EMPIRICAL MODEL

From the theoretical model, we derived an equation, (6), which defined the quantity shipped by an elevator as a function of the price that the elevator gets when it ships the commodity, transportation costs of shipping the commodity, the service characteristics of the mode, the costs of operation, farmer preferences for non-price characteristics of the elevators, crop production, and the distance to competitors. In this section, we present an empirical framework to examine these relationships.

As noted previously, we notice some elevators agglomerating together while other elevators separate out. Because of this fact, we assume that the agglomerated groups of elevators compete across groups for business, and that once the farmer has decided to bring their crops to one area over the other areas, the firms within an area compete amongst each other for that business. Thus, to equation (6) we add several measures of area characteristics including the number of firms in the area, the capacity of elevators in the area, and a dummy variable for firms located at the same location. Additionally, while we have modeled the competition between river terminals, we recognize that off-river terminals also compete for business with the river terminals. We do not observe the output of these locations; however, we do observe the alternative transportation rate for the river terminals which we put into equation (6) to control for the share of the market the river terminal gets when competing with the off-river terminal. Finally, we note that there are two basic types of firms: large conglomerate firms with many locations and independent or cooperative local firms. We add a dummy variable to equation (6) to control for each of these types of firms. Empirically, based on equation (6), and the aforementioned observations, the model we estimate is given by:

$$\begin{gathered}\text{Annual Tons } = f(\text{barge rate, alternative rate, transportation rate from farmer to elevator,} \\ \text{distance to nearest competitor, dummy variable for elevators located at the same location,} \\ \text{firm capacity, \# of firms in area, capacity of firms in area,} \\ \text{dummy variable for large conglomerate firms, area production)}\end{gathered} \tag{7}$$

Where *barge rate* is the rate per ton-mile of the barge movement; *transportation rate from farmer to elevator* is the rate per ton-mile of trucking or rail to the rail loading facility (i.e., in the context of the model presented earlier, it is the farmer's transportation cost); *alternative rate* is the rate per ton-mile of the most common alternative to shipping down the river, an element of mode choice from our theoretical section; *distance to nearest competitor* is the distance to the nearest competitor; the *dummy variable for elevators located at the same location* is equal to one for firms located one mile or less from their nearest competitor and is designed to capture any agglomeration effects; *capacity* is the capacity in bushels of the firm; *number of firms in area* in the number of competing elevators in the same county and bordering counties; *capacity of firms in area* is the capacity of the firms in the same county and bordering counties; *area production* is the average production of the commodity in the county and bordering counties; and the *dummy variable for large conglomerate firms* is a dummy variable equal to 1 if the shipper is one of the six conglomerate firms in our sample.[4]

We expect the effect of the barge rate to be negative (the law of demand), the effect of the alternative rate should be positive because as the alternative rate increases, it should increase the river terminal's market area when competing with its off-river rival, and the transportation rate (θ in our theory) has a negative effect. We also expect the distance to competitor (D from our theory) to increase annual tonnages. Capacity should also increase production, the number of firms in the area has an ambiguous effect (it increases competition which should decrease quantity, but farmers from far distances are more likely to ship to an area where there are many choices and then choose which to use when they arrive), the capacity of the firms in the area has a negative effect because larger firms around you means stronger competition, and area production (y from our theory) has a positive effect.

We additionally estimate equation 7 with gathering area instead of annual ton-miles as the dependent variable. This is done to investigate how firm market areas change as each of the independent variables change. In particular, we investigate whether market areas indeed increase as the distance between competitors increases as previous theoretical work indicates.

5. DATA SOURCES AND VARIABLES

The majority of data used for this analysis came from the Tennessee Valley Authority (TVA). TVA collected these data during two sets of personal interviews of barge terminals located along America's inland waterways. For this study, we employ a subset of the data. In particular, we limit ourselves to the activities of the 103 grain elevators located on the Upper Mississippi and Illinois rivers.

As indicated Figure 1, the terminal locations of agricultural shippers are not uniformly distributed as many of the previous theories of spatial competition and market areas assume.[5] Instead, we observe clusters of observations and single observations at others. Since we are examining grain elevators, an obvious explanation for this clustering in some areas is the differences in crops across areas. As indicated in Figure 2, this is indeed the case. The darker areas represent increasing farm densities starting at 0 farms per square mile.[6] The majority of the elevator clusters fall within the areas of high farm density.

During the course of their interviews, the TVA collected information regarding each location's annual tons shipped, commodities shipped, barge charges, truck transfer charges, the termination of the shipments, their average gathering area of product to be shipped, and alternative routes that they could have sent that shipment if not by barge.

Figure 3 contains median gathering areas for some of the elevators. We calculated these gathering areas by grouping the elevators together according to their location along the river and then calculating the median gathering area of the elevators in each grouping. These median gathering areas were then graphed in the

[4] We used several distances to classify firms as being in the "same location", the results were robust across specifications of this distance; however, the r-squared was maximized by using 1 mile which is why we chose to use 1 mile as our "same location" criteria.
[5] We matched the TVA data with the USACE Port Series to obtain these terminal locations.
[6] We use the Environmental Systems Research Institute's (ESRI's) Farm Density measure for this figure which was taken from the number of reported farms in 1997.

center of the geographic group. Not surprisingly, we observe the largest median gathering areas where the farm densities are the highest.

We supplemented these data with crop yields per acre and harvest levels at the county level from USDA. Summary statistics are provided in Table 1. These statistics suggest there is considerable variation in annual ton-miles shipped. That barge rates per ton-mile are, as expected, much smaller than alternatives (rail and truck). Rates inbound to the shipping elevator are approximately 7 time higher than the barge rates, but much less than the alternative rate, owing to shorter distances. Firm capacity and area capacity vary quite a bit from elevator to elevator. The distance between elevators is about 1.75-6.5 miles, while the number of firms in the same area appears to be approximately 4-5.25. There also appears to be considerable variation in the area production of crops. Finally, the gathering area (the distance of inbound shipments) has a centile value of 60 miles and an average value of about 68.3. Further, a simple regression of gather and river mile indicates that gathering areas increase with river mile, and a 100 mile increase in river mile increases gathering areas about 4 miles. From the lower reaches of the river to the most northern areas, this suggests a difference in gathering area of about 33 miles.

6. RESULTS

Because of the groupings of firms as indicated in Figure 1, we estimate four different models on equation (7). First, we estimate equation (7) using annual ton-miles as our dependent variable and then we estimate equation (7) using gathering area as our dependent variable. When estimating these equations, we use both OLS and a fixed effects model by area (as defined above).[7] We use the fixed effects model to control for any unobservable characteristics of either the waterway or land located around each elevator. For example, several elevators might locate close together just downstream of a lock which is consistently congested.

The results of the four regressions using annual ton-miles as the dependent variable are reported in Table 2. While the four regressions using gathering area as the dependent variable are reported in Table 3. In all models, we use log forms for the continuous variables.

The first two columns in Table 2 are the OLS estimates of annual ton-mile regressions, while the last two columns reflect the fixed effects estimates of annual ton-miles. The second and forth columns include all of our spatial measures (i.e. number of firms in the area, capacity of the firms in the area, distance to nearest competitor, the dummy for same location, and area production), while the first and third column exclude them. We present the regressions in this way to assess the stability of the coefficients of interest with respect to the spatial characteristics of the elevators.

The two OLS models fit the data with R-squares of 36 and 40 percent. In both columns one and two the coefficient on the barge rate per ton-mile is about -1.5 (this is an estimate of the elasticity of demand for barge shippers). Inbound rates should and do affect annual tonnages, showing that as inbound rates increase by one percent, there is a corresponding decrease in annual tonnages by about 1.2 percent. The effect of alternative modes of transportation is not statistically significant. This may be explained by the observed fact that, in our data, we do not observe shipments being shipped by methods other than barge from the river terminal locations.. The firm's capacity is not statistically significant in any of the models. The results also indicate that elevators who primarily ship corn as opposed to wheat or soybeans ship a larger quantity annually. In both OLS specifications conglomerate firms ship more than non-conglomerate firms. Area production is found to be positive and significant, indicating that elevators in areas where more crops are produced ship more quantity annually.

The results presented in columns 3 and 4 of Table 2 reflect the same effects on the annual ton-miles of the shipper using fixed effects to control for unobserved differences in the areas where the elevators are located. These two specifications fit the data with R-squares of about 52 and 60 percent, a marked improvement from the straight OLS models. However, the F-test for the use of such fixed effects is

[7] An early reader noted our lack of destination price, which we do not observe. However, we do observe destination, and when we include dummy variables for each location, not only do our results not change, but none of the dummy variables are statistically significant.

statistically insignificant with a p value of .12 when controlling for all other spatial characteristics in column 4. In column three the coefficient on the barge rate per ton-mile is -1.33 while in column 4 it is -1.90, both being statistically significant. Inbound rates are found to only affect annual tonnages in the fixed effects model controlling for the observable spatial characteristics of the elevator, showing that as inbound rates increase by one percent, there is a corresponding decrease in annual tonnages of 1.1 percent. The effect of alternative modes of transportation is not statistically significant. The firm's capacity has an insignificant effect on annual ton-miles shipped. The results again indicate that elevators who primarily ship corn as opposed to wheat or soybeans ship a larger quantity annually. In both specifications conglomerate firms ship more than non-conglomerate firms, but the effects are statistically significant only when we control for the observed spatial characteristics. Column 4 shows that when controlling for both the observable spatial characteristics and the non-observable spatial characteristics (through fixed effects by area) many of the observable spatial characteristics are significant. The distance to nearest competitor variable is both positive and significant indicating that firms ship more the farther they are from their nearest competitor. Area capacity is negative and significant indicating that if you are located near firms capable of shipping large quantities you ship less output. Additionally, the number of firms in the area is positive and significant which coincides with our previous story that farmers may ship to areas where there are many firms and then make there decision of who to sell to when they get to that area. All of these area characteristic variables indicate that there is competition going on both between areas and between firms within areas as we suggested previously. Finally, area production is positive, but insignificant when using fixed effects.

In Table 3, we present the results for these same four specifications using gathering area as our dependent variable rather than annual ton-miles. In the OLS models, alternative rate is negative and statistically significant, indicating that as the alternative rate increases, elevators' gathering areas shrink. One interpretation of this result is that as the alternative rate increases farmers find shipping to the river elevators more appealing and thus the river elevators can reach their profit maximizing quantity with a smaller gathering area. Across all four specifications presented in Table 3 we find that elevators who ship more corn than soybeans and wheat tend to have smaller gathering areas, and that conglomerate firms have larger gathering areas. Examining column four where we control for the spatial characteristics, both observed and unobserved, we see that elevators' gathering areas increase as the distance from their nearest competitor increases, and that firms located at the same location have larger gathering areas. Both of these results coincide with our predicted theoretical outcome. Additionally, we find that controlling for the unobserved fixed effects in this model is warranted with an F-test.

All four annual ton-mile specifications show that demand for barge movements is elastic with estimated elasticities between -1.33 and -1.90. We also demonstrated that the spatial characteristics of the elevators affect their quantity shipped and that these characteristics need to be controlled for when estimating such demand models. Additionally, all of our results are stable and robust across all estimation specifications.

7. CONCLUSIONS

This paper develops and estimates a model of spatial competition with a direct link to transportation demands. Transportation demand emanates from the decision of elevators to supply markets. In order to supply markets, these elevators must procure grain from farmers and other elevators located off river. These elevators do it through a pricing mechanism (the bid price). This allows the procurement of grain over a spatial area. We develop a model that explains these pricing decisions and link the decisions directly to output decisions of the barge shipping elevator. Our empirical work suggests that using this approach, barge quantities are responsive to price levels. Our estimates suggests that demand is relatively elastic with an elasticity estimates between –1.33 to -1.90. In addition, we find strong evidence that the output of firms is affected by the spatial distribution and characteristics of firms in the marketplace. In particular, the distance of the nearest competitor has a positive influence on both firm output (and, therefore transportation demands) and elevator gathering areas. To our knowledge, this is the first study to integrate the spatial properties of market areas into an empirical framework. Additionally, aggregating this work by pool, this research fits directly into the existing U.S. Army Corps of Engineers planning models currently used.

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REFERENCES

Clark, John Bates and John Maurice Clark. *The Control of Trusts*. New York: The Macmillan Company, (1912).

D'Aspremont, C., J. Jaskold Gabszewicz, and J.F. Thisse. "On Hotelling's 'Stability in Competition." Econometrica 47, no. 5 (1979): 1145-1150.

Eaton, B. Curtis and Richard G. Lipsey. "The Non-Uniqueness of Equilibrium in the Loschian Location Model." *The American Economic Review* **66**, no. 1 (1976): 77-93.

Fetter, Frank A. "The Economic Law of Market Areas." *The Quarterly Journal of Economics* **38**, no. 3 (1924): 520-529.

Hotelling, Harold. "Stability in Competition." *The Economic Journal* **39**, no. 153 (1929): 41-57.

Lerner, A.P. and H.W. Singer. "Some Notes on Duopoly and Spatial Competition." *The Journal of Political Economy* **45**, no. 2 (1937): 145-186.

Lösch, August. *The Economics of Location*. New Haven: Yale University Press, 1954.

Mills, Edwin S. and Michael R. Lav. "A Model of Market Areas with Free Entry." *The Journal of Political Economy* **72**, no. 3 (1964): 278-288.

LIST OF TABLES AND FIGURES

Table 1. Descriptive Statistics

Variable	Centile	Average
Annual Ton-Miles (thousand)	13,900	56,900
Barge Rate	.012	.011
Transportation Rate to Elevator	.089	.094
Alternative Rate	.128	.125
Firm Capacity (thousand)	574	1,850
Distance to Nearest Competitor	1.75	6.58
Area Capacity (thousand)	2,500	7,900
Number of Area Firms	4	5.25
Area Production (thousand)	41,600	58,400
Gathering Area	60	68.30

Table 2. Annual Output Regression Estimates

	OLS *Log(Annual Ton-Miles)*	**OLS** *Log(Annual Ton-Miles)*	**Fixed Effects by Area** *Log(Annual Ton-Miles)*	**Fixed Effects by Area** *Log(Annual Ton-Miles)*
Log(Barge Rate)	-1.41**	-1.61***	-1.33**	-1.90***
	(0.583)	(0.608)	(0.661)	(0.697)
Log(Transportation Rate to Elevator)	-1.24**	-1.19**	-0.860	-1.10*
	(0.550)	(0.560)	(0.654)	(0.638)
Log(Alternative Rate)	-0.365	-0.126	-0.065	0.204
	(0.746)	(0.756)	(0.857)	(0.840)
Log(Capacity)	0.166	0.199	0.114	0.164
	(0.114)	(0.122)	(0.175)	(0.187)
% of Elevator Shipments that are Corn	1.86***	1.45***	1.62***	1.45***
	(0.409)	(0.461)	(0.466)	(.505)
Log(Distance to Nearest Competitor)		-0.068		0.787*
		(0.199)		(0.428)
Same Location Dummy		-0.144		0.709
		(0.508)		(0.768)
Log(Area Capacity)		-0.006		-0.147*
		(0.032)		(0.079)
Number of Firms in the Area		0.051		0.296*
		(0.063)		(0.164)
Dummy for Conglomerate Firms	0.969***	0.882***	0.646	0.752*
	(0.330)	(0.335)	(0.412)	(0.398)
Log(Area Production)		0.101*		0.088
		(0.054)		(0.070)
Constant	2.58	0.383	5.52	-0.128
	(2.943)	(3.385)	(3.582)	(4.678)
Observations	103	103	103	103
R-squared	0.3604	0.3963	0.5222	0.6022

A * indicates significance at the 10% level, a ** indicates significance at the 5% level, a *** indicates significance at the 1% level.

Table 3. Gathering Area Regression Estimates

	OLS *Log(Gathering Area)*	**OLS** *Log(Gathering Area)*	**Fixed Effects by Area** *Log(Gathering Area)*	**Fixed Effects by Area** *Log(Gathering Area)*
Log(Barge Rate)	0.118	0.185	0.370	0.398
	(0.230)	(0.232)	(0.235)	(0.262)
Log(Transportation Rate to Elevator)	-0.070	0.038	0.143	0.108
	(0.217)	(0.213)	(0.232)	(0.240)
Log(Alternative Rate)	-0.712**	-0.693**	-0.412	-0.382
	(0.294)	(0.288)	(0.304)	(0.316)
Log(Capacity)	-0.040	-0.027	-0.063	0.005
	(0.045)	(0.047)	(0.062)	(0.070)
% of Elevator Shipments that are Corn	-0.412**	-0.468***	-0.366**	-0.412**
	(0.161)	(0.176)	(0.166)	(.190)
Log(Distance to Nearest Competitor)		-0.085		0.280*
		(0.076)		(0.161)
Same Location Dummy		-0.095		0.529*
		(0.194)		(0.288)
Log(Area Capacity)		0.009		0.023
		(0.012)		(0.030)
Number of Firms in the Area		0.032		-0.055
		(0.024)		(0.062)
Dummy for Conglomerate Firms	0.357***	0.282**	0.375**	0.324**
	(0.130)	(0.128)	(0.146)	(0.150)
Log(Area Production)		0.007		0.008
		(0.020)		(0.026)
Constant	3.40***	3.66***	5.94***	4.51**
	(1.159)	(1.290)	(1.272)	(1.756)
Observations	103	103	103	103
R-squared	0.1977	0.2920	0.5131	0.5469

A * indicates significance at the 10% level, a ** indicates significance at the 5% level, a *** indicates significance at the 1% level.

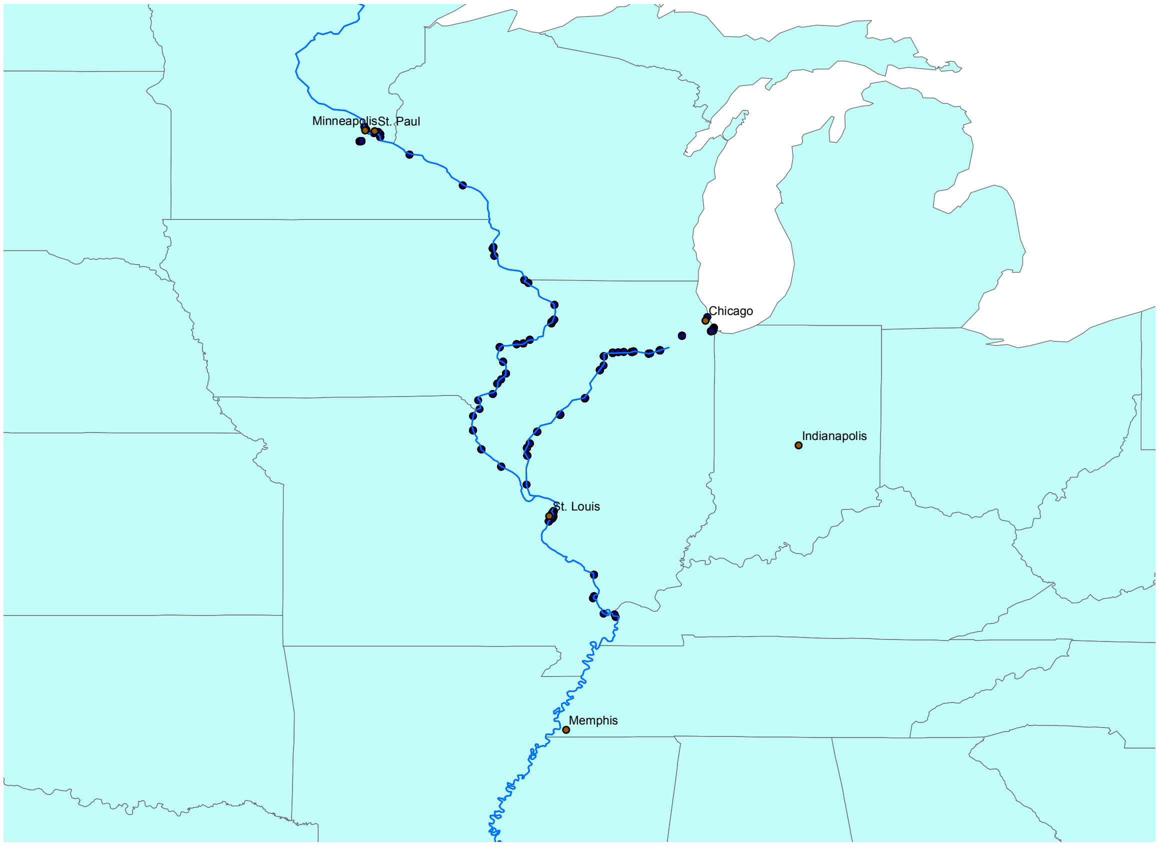

Figure 1: Barge Terminal Locations Shipping Grain

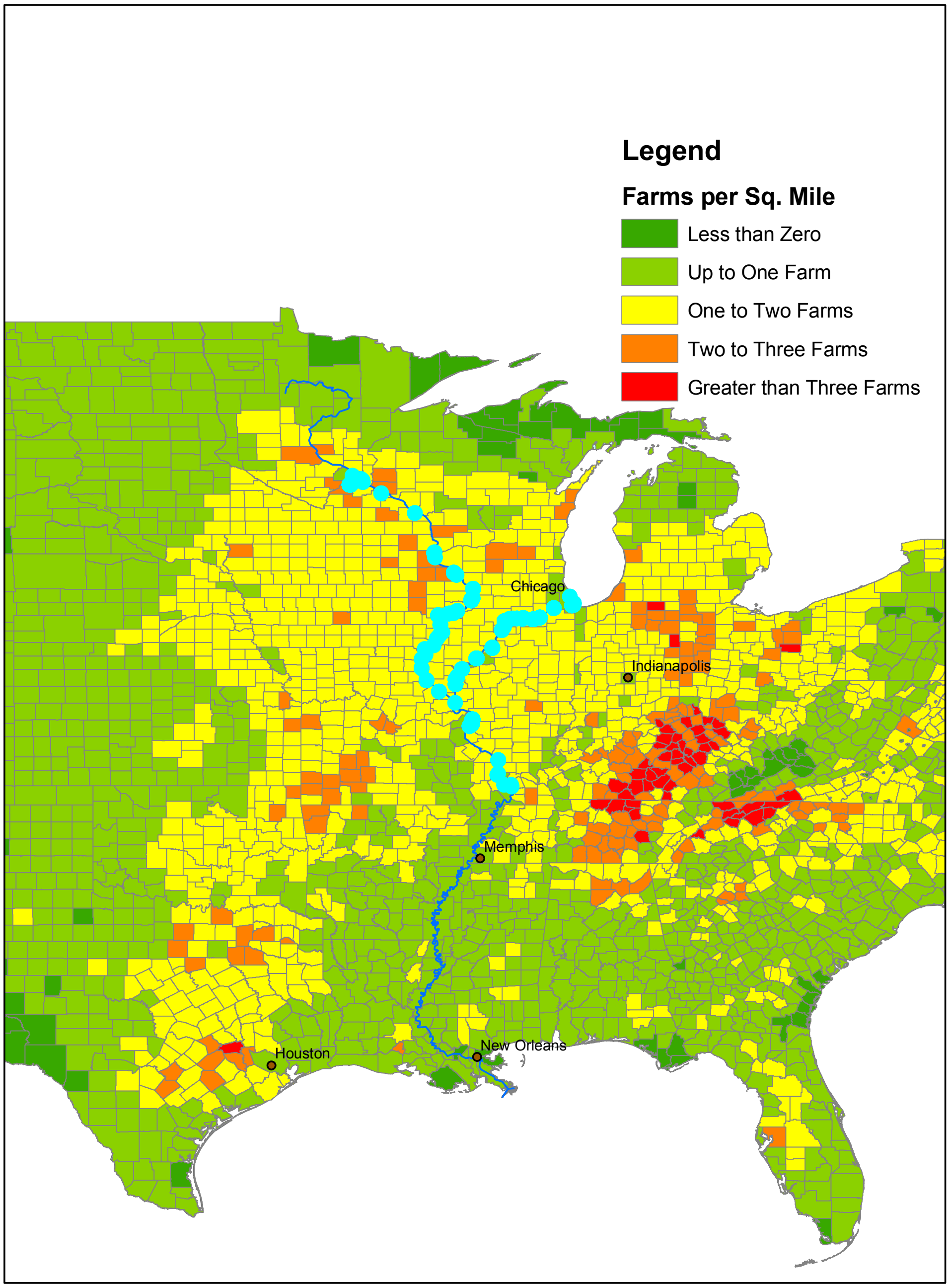

Figure 2: Farm Densities

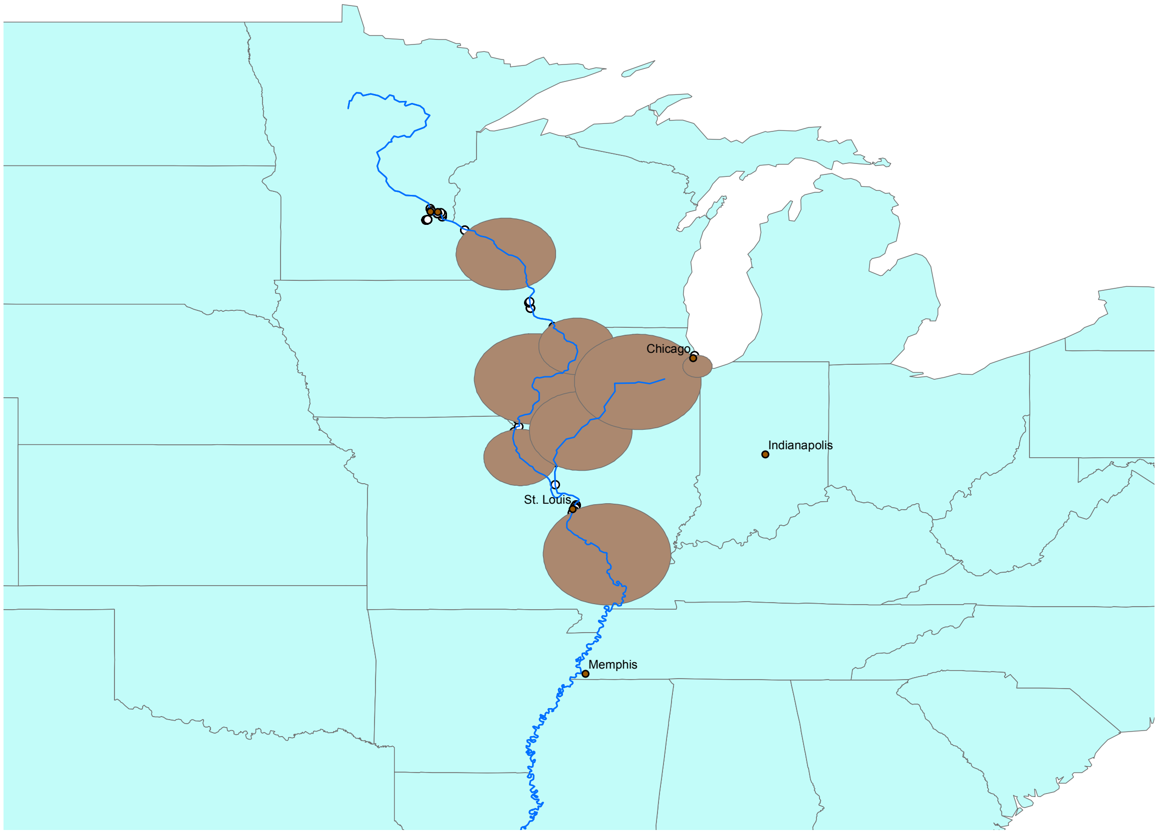

Figure 3: Median Gathering Areas

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The NETS research program is developing a series of practical tools and techniques that can be used by Corps navigation planners across the country to develop consistent, accurate, useful and comparable information regarding the likely impact of proposed changes to navigation infrastructure or systems.

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- A model for forecasting international and domestic traffic flows and how they may be affected by project improvements.
- A regional traffic routing model that will identify the annual quantities of commodities coming from various origin points and the routes used to satisfy forecasted demand at each destination.
- A microscopic event model that will generate routes for individual shipments from commodity origin to destination in order to evaluate non-structural and reliability measures.

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