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Can A Capsule Pipeline System Compete With Truck, Rail, and Barge in Shipping Agricultural Products?*

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ABSTRACT

Economic feasibility of transporting grain by a capsule pipeline is evaluated by comparing railroad's freight rate equation and the pipeline system's average total cost equation. These equations are estimated by using a multiple regression technique with 1985 cross section data obtained from industry sources.

The study found that the cost structure of railroads is different from that of a pipeline system; rail rates increase at a decreasing rate as distance increases while the average total cost of a pipeline system increase' at an increasing rate. This implies that a pipeline system has a comparative advantage over railroads in short distance routes and railroads have a comparative advantage in long distance routes. This study more precisely suggests that a pipeline system can compete with railroads under the following conditions; (1) the length of the system is less than 300 miles and (2) the system handles more than 80 million bushels of grain annually.

INTRODUCTION

The United States transportation industry has been changed due to two acts of legislation; the 4R Act (1976) and Staggers Act (1980), which provided railroads with more freedom in pricing their services by further restricting the Interstate Commerce Commission (ICC) jurisdiction. Rail rates have been differentiated on the basis of shipment sizes to compete with other modes of transportation. For example, railroads introduced 3- and 10-car rates to compete with trucks and introduced 75-, 100-, and 150-car rates to compete with barges. In addition, rail rates are also spatially differentiated, depending upon factors such as intermodal competition and/or shipment volume. The diversified pricing system in the U.S. railroad industry has affected the truck and barge industries. Trucks are mainly used for shipments of perishable processed food (e.g., meat, vegetable), while barges are used for long distance shipments of large volumes of grain.

The pipeline system used for this study is a pneumatic capsule pipeline developed by Tubepress System, Inc., of Houston, Texas (1). This sytem uses air pressure generated by a pumping system to move wheeled capsules in the pipeline. The capsule container is cylindrical with an open top for loading and unloading. Various sizes of the capsule pipeline can be built depending upon the amount of grain available in a region. A system of two pipelines is used in a route, one for sending loaded capsules with grain and the other for returning the capsules after unloading grains at the destination. Another pipeline system available for grain shipments is hydraulic capsule pipeline developed by the University of Missouri (8,9). The system uses fluid, most likely water, to move the capsules loaded with grain. A water pump is used to move the capsules floated in the the pipeline. The other operating system of a hydraulic capsule pipeline is similar to that of a pneumatic capsule pipeline. The technology is available to ship grain through a pipeline system but we are not sure if the technology is economically feasible to compete with other modes of transportation for grain shipments under the deregulated rail rate structure. Furthermore, it is important to know under what conditions the existing pipline technology is economically feasible or what changes should be made to compete with railroads for grain shipments.

Few studies have been made to evaluate the economic feasibility of grain transportation by pipeline (Koo 1982, Koo 1986). Koo concluded in his study (1982) that the economic feasibility of transporting grain by pipeline largely depends upon the volume of grain available for shipments through the pipeline system and the length of the system (1982). His study found that a 272-mile pipeline system originating in Montana and connected to the upper end of the Columbia-Snake River barge system can compete with railroads if it handles more than 66 million bushels of grain (1.8 million metric tons) annually. A more recent study by Koo (1986) suggested that a satellite system which connects several small elevators with the capsule pipelines in order to ship a large volume of grain is more economical than building new subterminals. No studies have been recently made to analyze economic feasibility of transporting grain by pipeline under the deregulated rail rate structure. In fact, the economics of a pipeline system for grain shipments have been virtually ignored in the literature of transportation economics.

The objective of this study is to analyze potential competition between railroads and a capsule pipeline in shipping agricultural products under the deregulated railroad pricing system.

Before examining the economics of a pneumatic capsule pipeline system, the theory of freight rate making is briefly reviewed and reconstructed with inclusion of the pipeline system. An empirical estimation of the model is made and rail and pipeline systems are compared in terms of their average total costs.

ANALYTICAL FRAMEWORK

Grain produced in the United States is generally moved from the farm to an elevator by truck and then moved from the elevator to final destination by rail and barge. Barges are the least expensive mode of transportation for long-distance shipments (over 1,000 miles) of large volumes of grain. Trucks are the most expensive mode for long-distance shipments but are the least expensive for short-distance shipments (150 miles). Rail is the least cost mode for distances between 150 and 1,000 miles. Market shares of these three modes of transportation are shown in Figure 1.

In Figure 1, TT′ is a hypothetical short-run average total cost curve for trucks, RR′ is for rail, and WW′ is for waterways. The shape of these curves reflects the concept of "rate taper"; that is, these rates increase at a decreasing rate as distance increases due to economics of long-haul. In addition, the slopes of the curves

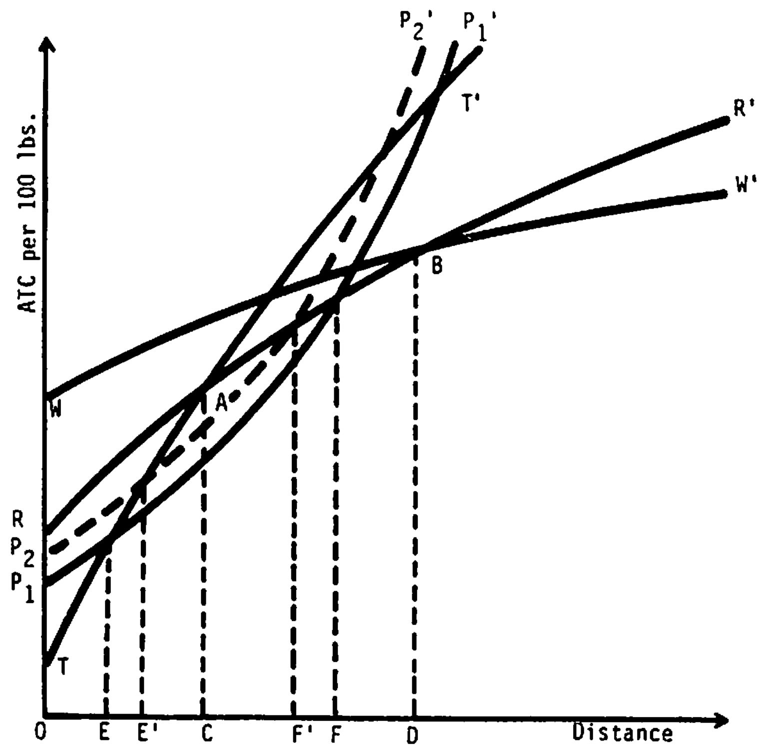

FIGURE 1. Hypothetical Average Total Cost Curves for Rail (RR'), Truck (TT'), Water (WW') and Pipeline (P_1P') for a Given Origin/Destination

represent the cost structure of the corresponding industry. TT' curve has a slope steeper than other curves and a lower intercept point on the Y-axis. This indicates that the trucking industry is characterized as a smaller fixed cost industry with higher marginal costs in the short run compared with other modes of transportation. In contrast WW' curve has the highest intercept point on the Y-axis with the flattest slope. This implies that the barge industry is characterized as a higher fixed cost industry with the lower marginal costs in the short run compared with other modes of transportation. As indicated by RR' curve, railroads are between truck and barge transportation in terms of cost structure. It is hypothesized that a capsule pipeline has higher fixed costs than the railroad, and its marginal costs increase at either an increasing or constant rate as distance increases because the system becomes less efficient as distance increases. PP′ is a hypothetical short-run average total cost curve in Figure 1 for a pipeline system.

If the freight rate is solely determined by the cost of providing service, the transport market will be divided between modes according to the hauling distance. The trucking industry traditionally will have a natural advantage in the 0C market, railroads in CD market, and water in the market segment whose distance is greater than D. When a capsule pipeline system is introduced in a region, the truck's market declines from 0C to 0E and the railroad's market from CD to FD. This implies that the pipeline system captures its market share from both trucks and railroads. Since trucks have a competitive disadvantage in large volume shipments over a pipeline system and railroads, railroads are a major potential competitor for a pipeline system in shipping grain to final destinations. As shown in Figure 1, the size of market declines from EF to E′F′ as average total cost curve shifts upward from P_1P_1' to P_2P_2' (decrease in shipment volume).

Railroads by nature, however, have an incentive to compete with other modes of transportation by engaging in price discrimination to penetrate markets where other modes have a competitive advantage. Where intermodal competition exists, railways may lower rates below their average total costs while charging higher rates elsewhere.

Railroads also differentiate their rates on the basis of the volume of traffic.

THE MODEL

Based on the characteristics associated with railroads, a general model of freight rates for U.S. grain movement is formulated as follows:

$$FR^{R}_{ij} = f_r\,(DT_{ij},\ DTS_{ij},\ V_{ij},\ FQ_{ij},\ OD,\ DD,\ e_{ij}) \qquad (1)$$

where,

FR^{R}_{ij}	=	freight rates in cents per hundredweight (lbs) between i^{th} origin and jth destination
DT_{ij}	=	rail distance in miles between origin and destination pairs
DTS_{ij}	=	distance squared
V_{ij}	=	shipment volume in tons
FQ_{ij}	=	shipment frequency, or a number of shipment moves per year
OD	=	a dummy variable representing characteristics of origin points
DD	=	a dummy variable representing characteristics of destination
e_{ij}	=	a random error term

A capsule pipeline system is assumed to have a similar cost structure to railroads as follows:

$$FR^{P}_{ij} = f_p(DT_{ij},\ DTS_{ij},\ V_{ij},\ OD,\ DD,\ e_{ij}) \qquad (2)$$

where,

FR^{P}_{ij}	=	capsule pipeline freight rates in cents per hundredweight (lbs.) between i^{th} origin and j^{th} destination

All other variables are defined as previously.

In the rail rate equation (Equation 1), it is hypothesized that distance (DT_{ij}) has a positive sign and distance squared (DTS_{ij}) has a negative sign under an assumption that freight rates increase at a decreasing rate as distance increases. It is also hypothesized that volume (V_{ij}) and shipment frequency C(FQ_{ij}) have a negative sign in Equation 1. In Equation 2, it is hypothesized that distance (DT_{ij}) has a negative sign and distance squared (DTS_{ij}) has a positive sign under an assumption that the average total costs increase at an increasing rate as distance increases.

Economic feasibility of transporting grain by a capsule pipeline is evaluated by comparing Equations 1 and 2. These two equations are estimated by using multiple regression with cross section data in 1985. Rail freight rate data were collected from industry sources including the Minneapolis Grain Exchange, Kansas City Board of Trade, and various grain merchandising firms. Rail mileage figures were obtained from the Princeton University Railroad Network model. The total number of observations used to estimate rail freight rate equations was 44 origin/destination routes.

Since freight rates for a capsule pipeline are not available, average total costs (average fixed and operating costs) are used to estimate Equation 2. The cost data were obtained from Tubexpress Systems Incorporated. The data obtained are capital investment and annual operating costs on the basis of the length of the system and throughput volume. The capital investment costs are amortized with a life expectancy of 30 years and an interest rate of 6 percent. The amortized capital investment and annual operating costs are then divided by the quantity of grain shipped annually to obtain average total costs.

RESULTS

The estimated parameters for grain movements by railroads are shown in Table 1. All variables are significantly different from zero at the 5 percent level. R^2 is 0.93 indicating that 93 percent of variations in rail rates are explained by the independent variables included in the model.

The coefficient on distance (DT) is positive, and the coefficient on distance squared (DTS) is negative as hypothesized. This indicates that rail rates increase at a decreasing rate with hauling distance. The coefficients in volume (V) and shipment frequency (FQ) are both negative, indicating that rail rates decline as volume and shipment and frequency increase. Dummy variables representing the Northeast region (OD1), Southeast region (OD2), and Southern region (OD3) are

TABLE 1. THE ESTIMATED RAILROAD'S FREIGHT RATE EQUATION

Variable	Coefficient	t-Value
Intercept	30.04	10.06
DT	0.12	11.36
DTS	-0.54×10^{-4}	-5.79
V	-0.30×10^{-2}	-16.71
FQ	-0.32×10^{-3}	-6.18
OD1	21.35	6.48
OD2	-8.97	-2.18
OD3	26.30	-2.49
OD1 x DT	0.36×10^{-1}	-6.57
OD3 x DT	0.12	4.38
OD3 x DTS	-0.75×10^{-4}	-4.32
DD1	20.93	2.32
DD1 x DT	-0.70×10^{-1}	-3.44
DD1 x DTS	0.56×10^{-4}	4.33
R^2	0.93	

all significantly different from zero at the 5 percent level. Also, the dummy variable interacting with distance (OD1 x DT, OD3 x DT, OD3 x OTS) is significant. Dummy variables representing destination (Gulf), and the dummy variable interacting with distance are also significantly different from zero at the 5 percent level. This implies that regional characteristics such as inter- and intra- modal competition play an important role in pricing rail services.

Table 2 shows the estimated average total cost equations for a capsule pipeline system. All cost equations have very high R^2; 0.97 for models 1 and 2 and 0.98 for model 3. This implies that average total cost of a capsule pipeline system is well explained by distance, distance squared and volume of grain shipped. The t-values for all estimated coefficients are very high, indicating that the coefficients are significantly different from zero at the 5 percent level.

Models 1 and 2 are statistically different from each other. This implies that average total cost for a short pipeline system is different from that of a long distance system.

The coefficient on distance (DT) in model 3 is negative, and the coefficient on distance squared (DTS) is positive as hypothesized. This indicates that the average total cost of the pipeline system increases at an increasing rate with hauling distance. The coefficient on volume is negative as expected.

Based on the estimated railroad's freight rate equation, region-specific equations (truncated) by route are derived by eliminating all independent variables other than intercept, distance (DT), and distance squared (DTS), and by adjusting origin and destination dummy

TABLE 2. THE ESTIMATED CAPSULE PIPELINE SYSTEM'S AVERAGE TOTAL COST EQUATIONS

Variable	Model 1[a]	Model 2[b]	Model 3[c]
Intercept	111.13 (10.73)	-57.23 (1.84)	124.91 (10.76)
DT	3.11 (9.16)	0.58 (13.46)	-0.14 (2.33)
DTS	--	--	0.68×10^{-4}
V	-1.59 (9.16)	-1.20 (3.26)	-1.32 (5.24)
R^2	0.969	0.974	0.98

[a]Average total cost equation for a short distance pipeline system (5-50 miles).
[b]Average total cost equation for a long distance pipeline system (200-700 miles).
[c]Average total cost equation for all distances (5-700 miles).

variables. These region-specific equations are shown in Table 3. These equations represent regional characteristics associated with the corresponding route. Since coefficients for the distance variables are all positive and those for distance squared variables are all negative as expected. This implies that rail rates have the same characteristics in all regions; increase at a decreasing rate with hauling distance. On the other hand, the magnitude of the intercept term of one region specific equation is different from others, indicating that rail rates are spatially differentiated even though the rate structure in one region is similar to that in other regions.

TABLE 3. TRUNCATED FREIGHT RATE EQUATIONS FOR RAILROADS AND A CAPSULE PIPELINE SYSTEM

Equation No.	Routes		Intercept	DT	DTS
	Origin	Destination			
Rail					
1	1	Gulf	40.49	0.087	-0.56×10^{-5}
2	2	Gulf	16.79	0.080	-0.2×10^{-6}
3	3	Gulf	30.06	0.162	-0.42×10^{-5}
Pipeline					
4	--	--	72.1	-0.139	0.67×10^{-4}
5	--	--	45.7	-0.139	0.67×10^{-4}
6	--	--	19.3	-0.139	0.67×10^{-4}

Equations 4, 5, and 6 are average total cost equations with an annual throughput capacity of 40 million bushels, 60 million bushels, and 80 millions bushels, respectively. These equations are derived by substituting the volume variable for the specific quantity (40, 60, or 80 million bushel) and adding it to the intercept term. The three equations have the same coefficient for distance and distance squared variables. The magnitude of the intercept term is the largest in Equation 4, the second largest in Equation 5, and the smallest in Equation 6. This implies that average total costs for a pipeline system decline as throughput volume increases. Coefficients for the distance variable are all negative and those for the distance squared variable are all positive. This implies that average total costs of a pipeline system increase at an increasing rate with hauling distance.

A comparison between region-specific rail rates and average total costs of a pipeline system are shown in Figure 2. Average total cost of a pipeline system with a throughput capability of 80 million bushels is lower than region specific rail rate Equation 2 when distances are less than 300 miles. This implies that a capsule pipeline system with a throughput capacity of 80 million bushels can compete with railroads if distances are less than 300 miles in the Southeast region (region 2). The pipeline system can compete with railroads for distances less than 440 miles in regions 1 and 3 if it handles more than 80 million bushels of grain. The pipeline system with a throughput capacity of 60 million bushels cannot compete with railroads in region 2 but can compete with railroads in regions 1 and 3. A pipeline system with a throughput capacity of 40 million bushels cannot compete with railroads in any of these regions. This means that the pipeline system is too expensive to compete with railroad if it handles only 40 million bushels of grain annually.

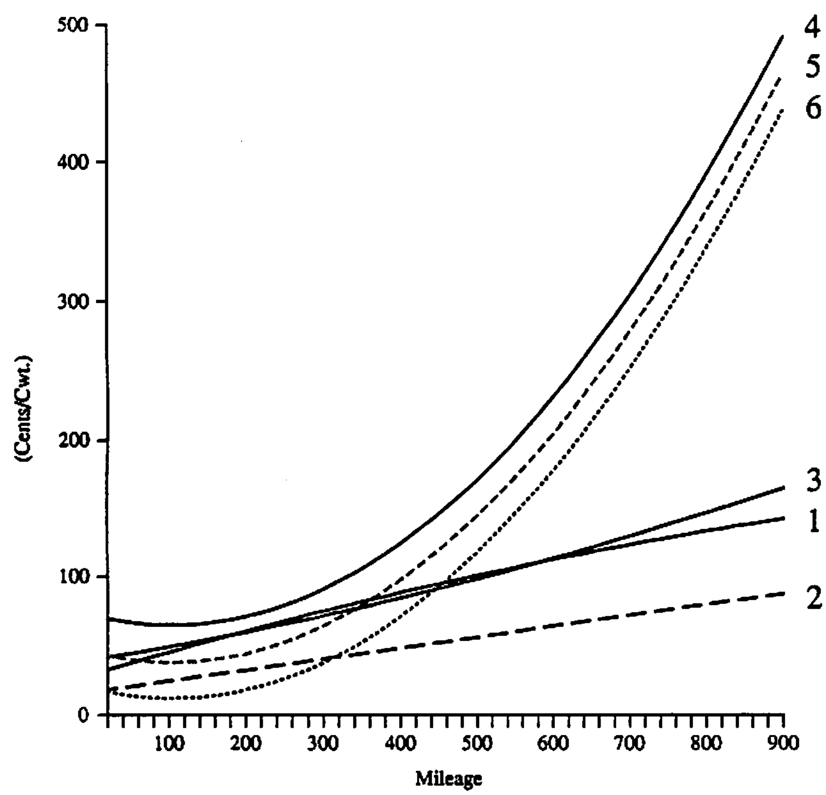

Figure 2. Freight Rail Rate Structure for Selected Routes and Cost Structure for a Pipeline System

CONCLUDING REMARKS

Economic feasibility of transporting grain by a capsule pipeline was evaluated by comparing average total costs of the pipeline system with rail rates. This study found that railroads' rate structure is quite different from the cost structure of a pipeline system; rail rates increase at a decreasing rate as distance increases while average total costs of a pipeline increase at an increasing rate. This implies that a pipeline system could have a competitive advantage in competing with railroads for short distance shipments and could lose its advantage as shipment distance increases.

This study also shows that a pipeline system can compete with railroads under the following conditions: (1) the length of a pipeline system is less than 300 miles and (2) the system handles more than 80 million bushels of grain annually. This implies that a capsule pipeline system is economically feasible in a route which satisfies the conditions mentioned above.

In reality, very limited numbers of routes satisfy the conditions mentioned above for grain shipments. Some routes may have annual throughput volume but are longer than 300 miles. On the other hand, some routes may be short (less than 300 miles) but not have enough annual throughput volume to economically justify the pipeline system. Some routes from inland subterminals to water access points in the Mississippi and Columbia-Snake river systems and between inland subterminals and ports are most likely candidates for the pipeline system.

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