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A Transportation Model of Interregional Competition in the Potato Industry

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Abstract

An interregional competition model was developed for fresh potatoes to assess the impact of alternative highway routes for optimum distribution of potatoes. For the purpose of this analysis, the continental U.S. was divided into twelve producing regions and seven consumption regions. Fixed supplies were used for producing regions and demand functions for consumption regions. Transportation costs were estimated between origins and destinations. Reactive programming provided the optimum distribution patterns of potatoes. The base model routed the shipment over U.S. and Interstate highways. The optimal solution obtained from this base model provided a measure to compare the impact of alternative highway routings on the distribution patterns of potatoes. The net revenue of the base model (Model 1) was 17,505 million dollars. When the transportation cost was by 10 per cent, the overall net revenue (of Model- 2) was 17,331 million dollars. When the transportation cost was decreased by 10 per cent the overall net revenue (of Model- 3) was 17,672 million dollars. Similarly when the income of the consumers was increased by 10 per cent the overall net revenue (of Model-4) was 18,448 million dollars.

Key Words: Reactive programming, Transportation cost, Optimum distribution, Alternative highway routes, Potatoes.

Introduction

Production and consumption patterns of agricultural commodities are continuously changing which require better transportation and marketing arrangements. Most agricultural commodities are not consumed at the place where they are produced; therefore, almost all agricultural commodities must be brought from farm to markets or warehouses. Then these products must be moved to retail stores and finally to consumers or final users. Therefore, transportation adds primarily place utility to goods.

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Transportation of agricultural products from one place to another is one of the most important components of interregional trade and competition. There are several factors that affect the transportation cost. An increase in the distance over which a commodity is to be transported may increase the total transportation cost. The transportation cost per unit of a commodity decreases with an increase in the volume. Transportation is an essential marketing function (Greig and Blakeslee, 1978). Transportation helps in widening of markets by bridging the gap between producers and consumers located in different areas. Transportation of goods from surplus areas to the places of scarcity helps in checking price rises in the scarcity areas and price decreases surplus areas; thus, this reduces the spatial differences in prices. Industrial growth is highly dependent on the transportation system that brings raw material from rural areas to industrialized urban areas. Transportation also plays a major role in the mobility of capital and labor from one area to another (Archarya and Agarwal, 1987).

One of the factors that affect the transportation commodities by highway are the routes which a carrier selects. By selecting a specific route, the highway carrier and/or its agent, at least in part is determining the cost per unit of shipment, the type of highway to be used, transit time, fuel and oil consumption. The shortest route, for example, may not be feasible route to move a commodity from an origin to a destination point due to bridge and highway weight limits and posted speed limits. The route that takes longer to transit may be the most feasible to move the product. The longer route may enable the trucker to move the product over better highways.

The general objective of this study was to estimate how the various highway routes affect the distribution of potatoes among regions in the United States with reference to the State of Mississippi. Specific objectives of this study are:

1. To estimate an optimum distribution of potato movements by regions and Mississippi from an origin to a destination point.

2. To estimate the impact of selected changes in transportation costs and income on the optimum distribution of potatoes found in objective 1.

Methods and Procedures

Supply Regions: Based on previous studies, (Ewald and Jones, 1980; Howard, 1984; Brewster, 1986; Fuller *et al*, 1990) and USDA publications, the potato producing states have been combined in a geographical basis into twelve regional supply centers. An origin city was selected in each region to enable transportation mileage and costs to be calculated. The selected supply regions and origin cities for the analysis are shown in Table 2.

Demand Regions: Seven demand points or consumption centers were selected for this analysis. The demand regions are based on the studies previously mentioned under the supply regions and Fruit and Vegetable Arrivals in Western Cities (USDA, 1989). The destination city within each region or state was chosen as the demand center because it was the most densely populated city of the region. The designated destination city centers allowed distances and costs to be estimated and assessed. In this analysis, the state of Mississippi served as a separate demand region to reflect the impact that selected routes, transportation costs and other factors might have on the cost of moving potatoes from an origin to the selected destination city in the state. The selected demand regions and destination cities are shown in Table 3. The Automap, a computer program allows an individual to select different highway routes. The Automap also provides a mileage matrix between each origin and destination points.

Demand

The demand equation was specified as a price dependent function in the form:

P = a + bQ.

In the demand equation P equals price and Q equals quantity. Price of substitute (Ps, rice) and personal income per capita was included in the intercept terms. The retail price in each consumption center was assumed to be dependent on: (i) quantity of potatoes in pounds received in given consumption center, (ii) the personal income per capita of the given consumption region, and (iii) price of the substitute. The expected function for a given consumption region is shown below:

P = f (Q, Ps, IN)

Where:

P = retail price per pound of fresh potatoes, Q = per capita quantity demanded in the given consumption centers at retail markets, Ps = price of the substitute in the given consumption region and IN = personal income per capita in the given consumption region.

The least squares multiple regression technique was used to estimate the equation. Time series data were collected and combined for seven regions, covering 1975 through 1992. The combined data provided 126 observations for regression analysis for this study.

A demand function was estimated using the OLS regression for seven demand regions. A linear model was set up to reflect the affect of seven consumption centers. This impact was incorporated by adding six dummy variables to the regression equation. The estimated demand equation is shown in Table 1.

The was significant at the 1 % level of significance. The Durbin-Watson Test value was 1.434, coefficient of determination (R-Square) was 0.451. All the coefficients were highly significant at 1 % level of significance and all variables had correct signs. Finally, the estimated single demand equation was segregated into seven demand equations, i.e; a separate equation for each region. The result was seven demand equations of the form:

P = a + bQ

The estimated demand equation for each region is given below:

Region 1. P=46.310 - .4560 Q,
Region 2. P = 47.046 - .4560 Q,
Region 3. P = 46.794 - .4560 Q,
Region 4. P = 45.792 - .4560 Q,
Region 5. P = 49.645 - .4560 Q,
Region 6. P = 48.841 - .4560 Q
Region 7. P = 47.590 - .4560 Q

Supply

Total supply of potatoes was considered fixed for each region. The quantity of potatoes sold in the market and potato stocks was taken as production in each state. Then an average of quantities sold and stocks was calculated from 1988 to 1992 for each state. The state's average quantities sold and stocks were then summed together to yield a total average regional production. Regional supplies were divided by the regional population to convert it into regional per capita supply, for each region. The supply regions and origin cities are shown in Table 2.

The distance matrix

To estimate the transportation costs between supply and demand points, a distance matrix was established. The distance matrix showed the distances between all the origin and destination cities. Three types of distances were developed for this study: (1) The distance matrix for the Shortest Distance routes (2) The distance matrix for the Quickest Time routes, and (3) The distance matrix for the Interstate and U.S. Highway routes.

Cost of transportation

The transportation distances were multiplied by the cost of transporting one pound of fresh potatoes one mile. This value was obtained from truck cost per vehicle per mile based on the 1989 annual report of USDA's publication "Fruit and Vegetable Truck Rate and Cost Summary".

Reactive programming

After estimating the demand function, fixed supplies and transfer costs the reactive programming model was used to determine optimum distribution pattern for potatoes. Transportation models of linear programming have been used in quantifying the locational advantages of different regions (Estrada, 1992). Reactive programming allows one to calculate equilibrium production and consumption levels as well as flows among regions simultaneously (Tramel and Seale, 1959).

Reactive programming distributed the supplies of the first production origin to the demand points which offered the highest net price (retail price less transportation cost) to that origin as if no other origin exists. Consequently, each origin maximized its net revenue. The price per unit in each production center was equal to the price in each demand center less the transportation costs per unit.

Results and Discussion

The results for objectives 1 and 2 were obtained using a reactive programming algorithm. The results indicate the market equilibrium solution of the least-cost flow of fresh potatoes (Maqsood and Allen, 2004). The optimal shipment solutions enabled net market prices and amounts of fresh potatoes to be distributed over all routes, which minimized the transportation costs.

Model solutions

Model 1: Routing transportation through U.S. and interstate Highways (Base model).

Model 2: A 10 percent increase in transportation cost was incorporated to estimate the effect on the distribution pattern and net revenue.

Model 3: A 10 percent decrease in transportation cost was incorporated to estimate the effect on the distribution pattern and net revenue.

Model 4: A 10 percent increase in the income was incorporated to estimate the effect on the distribution pattern and net revenue.

The speed of travel in models 1, 2 and 3 was 72.66, 72.85 and 53.33 miles per hour. The fixed supplies, transportation costs, and estimated demand functions were used as an input in the reactive programming models. The solution of these models provided optimal shipping patterns from each supply center to each consumption center.

Results for base Model (model 1)

The base model used the transfer costs by routing the shipment over U.S. and Interstate highways. The optimal industry wide solution obtained from this base model provided a measure (estimate) to compare the impact of alternative highway routings on the distribution patterns of potatoes.

The results of the reactive programming indicated the market equilibrium is a solution to the least-cost distribution patterns of potatoes. The estimated equilibrium distribution patterns of the base model are shown in Table 5. The shipments were made from all shipping points to all destination points. The total transfer cost of this model was about 1,907 million dollars. The net revenue of the base model was 17,505 million dollars. Transit time of model 1 was less as compared to model 2 and model 3.

Table 1: The estimated demand equation

Dependent Variable		Independent Variables								
	Intercept	Q	INC	Ps	D1	D2	D3	D4	D5	D6
Price/Lb. (S. Error)	28.715 7.208	-0.456 0.145	1.548 0.0003	0.715 0.086	-7.112 1.346	-2.543 0.990	-4.849 1.138	-11.218 1.709	-6.178 1.346	-2.929 1.026

Where:

D1 = 1 if the consumption center is Kansas City, zero otherwise; D2 = 1 if the consumption center is New Orleans, zero otherwise; D3 = 1 if the consumption center is Chicago, zero otherwise; D4 = 1 if the consumption center is Las Vegas, zero otherwise; D5 = 1 if the consumption center is Manchester, zero otherwise; D6 = 1 if the consumption center is Atlanta, zero otherwise; D7 = 1 if the consumption center is Jackson, zero otherwise;

Table 2: Supply regions and origin cities

Region	Origin City	States
1	Seattle (WA)	Washington, Oregon.
2	Los Angeles (CA	California.
3	Boise City (ID)	Montana, Idaho, Wyoming.
4	Denver (CO)	Utah, Colorado, Arizona.
5	Dallas (TX)	Texas, New Mexico.
6	Raleigh (NC)	North Carolina, Virginia.
7	Miami (FL)	Florida, Alabama.
8	New York (NY)	Pennsylvania, New York, New Jersey, Delaware.
9	Presque Isle (ME)	Maine, Rhode Island, Massachusetts, Connecticut.
10	Bismarck (ND)	South Dakota, Nebraska, North Dakota.
11	Detroit (MI)	Michigan, Indiana, Ohio.
12	Milwaukee (WI)	Minnesota, Iowa, Wisconsin.

Table 3: Demand regions and destination cities

Region	Destination City	States
1	Kansas City (MO)	Kansas, Missouri.
2	New Orleans (LA)	Louisiana, Arkansas, Oklahoma, Tennessee.
3	Chicago (IL)	Illinois, Kentucky, West.
4	Virginia, (MD)	Nevada.
5	Manchester (NH)	Vermont, New Hampshire.
6	Atlanta (GA)	Georgia, South Carolina.
7	Jackson (MS)	Mississippi.

Table 4: The regional per capita supply of fresh potatoes, 1989.

Region	Quantity (Lbs/capita)	Region	Quantity (Lbs/capita)
1	1675.98	7	1.95
2	18.56	8	30.35
3	8147.07	9	296.47
4	316.86	10	1246.89
5	23.90	11	18.50
6	1.14	12	444.24

Table 5: Equilibrium quantities, total revenue, transfer costs, and net revenue of the base model.

Origin	Destination	Total Quantity (100,000 Lbs.)	Total Revenue (100,000 US$)	Transfer Cost (100,000 US$)	Net Revenue (100,000 US$)
1	3	3398.40	1321.30	174.71	1146.59
1	4	12838.70	4695.01	363.33	4331.68
1	5	110334.70	45689.60	8462.67	37226.93
2	4	5551.42	2030.15	37.42	1992.74
3	1	39229.84	15052.48	1350.29	13702.19
3	2	25019.72	10140.49	1403.11	8737.39
3	4	41301.68	15104.02	677.76	14426.26
3	6	41864.68	16896.58	2274.10	14622.49
3	7	36054.52	14486.70	1894.67	12592.04
4	2	27274.68	11054.42	979.43	10074.99
5	7	4394.64	1765.77	44.47	1721.29
6	5	126.85	52.53	2.42	50.11
7	6	333.36	134.54	5.68	128.86
8	5	11469.90	4749.69	80.17	4669.51
9	5	34099.20	14120.47	331.44	13789.03
10	3	36387.46	14147.44	763.05	13384.39
11	5	4865.14	2014.65	97.30	1917.35
12	3	53129.04	20656.57	124.32	20532.24
	Total	487,673.60	194,112.40	19,066.33	175,046.10

Results for Model 2

The results of objective 2 are presented in this subsection. In this model a 10 percent increase in transportation cost was incorporated to estimate the effect on the distribution pattern and net revenue. The demand region 5 (Manchester) received about 15,765 million pounds of potatoes. The next largest amount totaling 9,390 million pounds of potatoes were shipped to demand region 3 (Chicago). The rest of the regions 4 (Las Vegas), 2 (New Orleans), 6 (Atlanta), 7 (Jackson) and 1 (Kansas City) received about 4,764; 5,178; 4,175; and 4,009 and 3,977 million pounds, respectively. The total transfer cost of this model was almost 2,074 million dollars. The total net revenue of this model was about 17,331 million dollars. Due to a 10 percent increase in transfer costs, the net revenue decreased by 0.99 percent as compared to the base model.

Results for Model 3

The 10 percent decrease in transportation costs was used. The amounts received in regions 1 (Kansas city), 2 (New Orleans), 3 (Chicago), 4 (Las Vegas), 5 (Manchester), 6 (Atlanta) and 7 (Jackson) were about 3,869; 5,283; 9,193; 5,666; 16,407; 4,263 and 4,081 million pounds, respectively. The total revenue of this model was almost 17,672 million dollars. Due to a 10 percent decrease in transportation costs, the total net revenue increased by 0.96 percent.

Results for Model 4

The 10 percent increase in income was included in this model. The affect of a 10 percent increase in income of the population in demanding regions was reflected by the optimal solution of this model. The shipments received in regions 1 (Kansas City), 2 (New Orleans), 3 (Chicago), 4 (Las Vegas), 5 (Manchester), 6 (Atlanta) and 7 (Jackson) were almost 3,975; 5,092; 9,171; 5,881; 16,656; 4,175 and 3,811 million pounds, respectively. The total net revenue of this model was about 18,448 million dollars. Due to a 10 percent increase in income, the net revenue increased by 5.39 percent. The transportation costs increased by 0.51 percent.

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