

An Economic Evaluation of Alternative Highway Routings on the 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 shipments 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 was 17,505 million dollars. The overall net revenue of model 2 was 17,502 million dollars. Model 3 provided the greatest net revenue of 17563 million dollars. Transit time of model 3 was also greater than model 1 and model 2. On the basis of transit time model 1 and 2 are best while on the basis of maximum net revenue model 3 is the best.

Key Words: Reactive Programming; Transportation cost; Optimum distribution; Alternative highway routes; Potatoes

INTRODUCTION

Transportation or movement of agricultural products from one place to another is one of the most important components of interregional trade and competition. 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.

Transportation costs may account for a considerable percent of the total cost of marketing. 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 & 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 & Agarwal, 1987).

One of the factors that affects the movements of agricultural 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 were:

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 using alternative highway routes on the optimum distribution of potatoes

MATERIALS AND METHODS

The development of supply and demand regions, estimation of fixed supplies, cost of transportation, and demand equation are explained.

Supply regions. Based on previous studies (Ewald & 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 city was selected on the assumption that it was the best representative of potato production in that region. Most of the selected cities within each region are the major shipping centers. The selected supply regions and origin cities for the analysis are shown in Table II.

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, 1989a). 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 III.

For accomplishing Objectives of this study time series data were collected by state and region for the years 1975 through 1992. United States Department of Agriculture sources provided most of the data on production of potatoes and potato stocks by states and retail prices. The other sources of the data were the Statistical Abstract of the United States and the Automap, a computer program. The Automap (Anonymous, 1992) allows an individual to select different highway routes. The Automap also provides a mileage matrix between each origin and destination point, and alternative highway routes.

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

$$P = a + bQ.$$

The demand function was specified in this way because the computer algorithm that was used for this analysis requires this form. In the demand equation P equals price and Q equals quantity. Price of substitute (P_s) (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 mathematical form of the expected function for a given consumption region is shown below:

$$P = f(Q, P_s, IN)$$

Where:

P = retail price per pound of fresh potatoes.

Q = per capita quantity demanded in the given consumption centers at retail markets.

P_s = price of the substitute in the given consumption region.

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 least-square multiple regression model 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 dummy variables were used as intercept shifters, therefore each demand region had the same slope but different intercept values. The results of this model provided seven demand functions. The estimated demand equation is shown in Table I.

Where:

$D1 = 1$ if the consumption center is Kansas City, zero otherwise;

Table I. The estimated demand equation

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

$D2 = 1$ 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;

The computed F-value of the model was 10.578, which was significant at the 1 % level of significance. This indicates that a definite statistical relationship exists between the dependent variable and the set of independent variables. The Durbin-Watson Test value was 1.434, coefficient of determination (R-Square) was 0.451 and adjusted R-Square was 0.408. In this model all the coefficients were highly significant at 1% level of significance and all variables had correct signs. Therefore, this was the best model in predicting prices, and hence used in all subsequent analysis.

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. $P = 47.590 - .4560 Q$

Table II. 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 III. 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 IV. 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 V. Time, distance, equilibrium quantities, revenue and transfer costs of the models

Models	Transit Time Hours	Total Distance Miles	Total Quantity 100,000Lbs	Total Revenue \$100,000	Transfer Cost \$100,000	Net Revenue \$100,000
1	288	20927	487673.60	194112.40	19066.33	175046.10
2	323	23533	487673.60	192987.40	17970.26	175017.10
3	375	19998	487673.60	193411.10	17781.48	175,625.66

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 were 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. The potato consumption for producing regions was deducted from the total supply of each region. The rest of the potato production was considered as regional total

supply for distribution.

The regional total supply was divided by the total regional population to convert it into regional per capita supply for each region. These per capita amounts were considered fixed supplies. The supply regions and origin cities are shown in Table II.

The distance matrix. To estimate the transportation costs between supply and demand points, a distance matrix was established by using Automap. 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. The shortest distance route means a route in which a minimum distance is involved from an origin to a destination. The quickest route means a route over which a carrier can travel at maximum legally allowed speed to reach a destination within a minimum time.

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 1989b, annual report of USDA's publication "Fruit and Vegetable Truck Rate and Cost Summary". The truck cost per vehicle per mile was quoted as 123.40 cents. This value was then divided by the average pounds of fresh potatoes in a truck load which is equal to 40,000 pounds. The result was 0.003085 cents or 0.00003085 dollars, i.e; the cost to ship one pound of fresh potatoes one mile. This value of transportation cost was then deflated using the consumer's price index (1.24) (U.S. Bureau of Census 1989c); (1982-84 = 100 constant dollars) the resulting value was 0.00002487.

Finally, this value was multiplied by the distance matrix to calculate the cost of transporting one pound of fresh potatoes between each origin and destination cities.

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. The spatial equilibrium model is a complex model when several regions are involved. The question of which supply region should supply which consumption region was difficult to answer. The reactive programming model has the capability to find the solution to such complex problems.

Transportation models of linear programming have been used in quantifying the locational advantages of different regions (Estrada, 1992). This was accomplished by calculating the least-cost flows of goods among regions based on predetermined supplies and requirements. Reactive programming allows one to calculate equilibrium production and consumption levels as well as flows among regions simultaneously (Tramel & 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. The investigation for the other profitable distribution continued until the supply of the first production center was exhausted. The second production center also distributed its supplies in the same manner, making compensations for the actions of the first. This process continued until the supplies of all the production origins were used up. The whole iteration was repeated until no production origin could increase its net revenue by moving one unit of commodity to another demand center. At this point an equilibrium was obtained which determined least transportation costs, new equilibrium quantities and prices for each demand point. 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. 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: Routing transportation through Quickest Time Highways as an alternative route.

Model 3: Routing transportation through Shortest Distance Highways as an alternative route.

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 V and Appendix A1. 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.

Results for model 2. The model 2 used the transfer costs by routing shipment of potatoes using the Quickest Time Route as an alternative highway route. The optimal distribution pattern

of fresh potato shipments is shown in Table V and Appendix A2. The shipments were made from all shipping points and arrivals were received in all destination points of the model. The total transfer cost of this model was 1,797 million dollars. The overall net revenue of this model was 17,502 million dollars.

By changing the route from U.S. and Interstate highways to the quickest time route the transportation cost was decreased by 5.75%. Moreover, distribution patterns were also changed to some extent, and there was an increase of 0.017% in the net revenue of this model. Transit time was greater than model 1 but less than model 3.

Results for model 3. In the model 3 transfer cost were incorporated by routing the shipments of potatoes through shortest distance routes. The optimal distribution patterns of this scenario are shown in Table V and Appendix A3. This

Appendix A1. Equilibrium quantities, total revenue, transfer costs, and net revenue of the base model

Origin	Destination	Total Quantity Lbs.	Total Revenue US\$	Transfer Cost US\$	Net Revenue US\$
		100,000	100,000	100,000	100,000
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	1503.29	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

Appendix A3. Equilibrium quantities, total revenue, transfer costs, and net revenue of the model 3

Origin	Destination	Total Quantity Lbs.	Total Revenue US\$	Transfer Cost US\$	Net Revenue US\$
		100,000	100,000	100,000	100,000
1	1	9515.52	3663.48	435.91	3227.57
1	3	117056.00	45651.84	5947.62	39704.22
2	4	5551.42	2039.04	37.42	2001.62
3	1	35761.76	13768.27	1218.40	12549.87
3	2	32924.24	13294.80	1741.69	11553.11
3	4	44319.36	16278.50	727.28	15551.22
3	6	41279.16	16705.67	2219.58	14486.09
3	7	29185.92	11705.39	1469.22	10236.17
4	7	27274.68	10942.60	834.33	10108.26
5	7	4394.64	1763.13	44.47	1718.66
6	6	126.85	51.34	1.21	50.12
7	6	333.36	134.91	5.60	129.31
8	5	11469.90	4712.98	70.20	4642.79
9	5	34099.20	14011.36	330.76	13680.59
10	3	4668.80	1820.83	96.83	1724.00
10	5	31718.66	13033.19	1289.68	11743.51
11	5	4865.14	1999.09	87.72	1911.37
12	5	53129.04	21830.72	1223.56	20607.16
	Total	487,673.60	193,407.10	17,781.48	175,625.66

model was another alternative route option to the base model (model 1).

The total transfer cost of this model was approximately 1,778 million dollars. By changing the route from U.S. and Interstate highways (base model) to the shortest distance route, the total transportation costs decreased by 6.74%. Some changes in the distribution pattern also took place and there was an overall 0.33% increase in the net revenue. Model 3 provided the greatest net revenue of 17563 million dollars. Transit time of model 3 was also greater than model 1 and model 2. On the basis of transit time model 1 and 2 are best while on the basis of maximum net revenue model 3 is the best.

CONCLUSION AND SUGGESTIONS

The base model (model 1) results were generated using reactive programming. This method provided an optimal least cost distribution pattern of potatoes within the United States. In this model, the Interstate and U.S. highway system was used for transportation of potatoes. The net revenue of the base model was 17,505 million dollars. Two alternative highway routes were used to estimate the impact on transportation costs and net revenue on the base model. The first alternative used for this purpose was the quickest time route. The optimal least-cost results of this model revealed that the transportation costs decreased by 5.75% when compared to the base model. The net revenue increased by 0.017%. The second alternative route used was the shortest distance route. The optimal least-cost solution of this model showed that the transportation costs were decreased by 6.74% when compared to the base model. The net revenue increased by 0.33%.

The optimal distribution patterns determined in this study were for potatoes as a general vegetable crop. However, there are many processed potato products. Research on the optimum distribution patterns of processed potato products is needed. Findings from this research may increase farmers' choices.

REFERENCES

- Acharya, S.S. and N.L. Agarwal, 1987. *Agricultural Marketing in India* Sukhadia University, Campus at Udaipur and Jobner, Oxford and IBH Publishing Co. New Delhi, India
- Anonymous, 1992. Automap Inc., Automap version 2.0. 9831 South, 51th, street. Building C-113 Phoenix, Arizona 85044
- Brewster, K., 1986. An Interregional Competitive Model for Fresh Apples in the United States. *M.Sc. Thesis*, Department of Agricultural Economics, Rutgers, the State University of New Jersey
- Estrada, J.K., 1992. A Transportation Model to Analysis Interregional and International Competition in the Corn Industry. *Ph.D. Thesis*, Mississippi State University
- Ewald, M. and J.R. Jones, 1980. *U.S. Potato Marketing the Origins and destinations of Potato Products*. Department of Agricultural Economics and Applied Statistics, University of Idaho
- Fuller, S.H., L. Goodwin and J. Schmitz, 1990. Potato Production in Texas: *Marketing Trends and Opportunities*. The Texas Agricultural Experiment Station, The Texas A&M University System. College Station, Texas
- Greig, W.S. and L. Blakeslee, 1978. *Potato: Optimum Use and Distribution With Comparative Costs by Major Regions of the U.S.* College of Agriculture Research Center, Washington State University
- Howard, E.A., 1984. An Analysis of Interregional Competition in the U.S. Summer Potato Market. *M.Sc. Thesis* Agricultural Economics Department Texas Tech University, Texas
- Tramel, T.E. and A.D. Seale, Jr., 1959. Reacting Programming of Supply and Demand Relations—Applications to Fresh Vegetables. *J. Farm Econ.* XLI: 1012–22
- U.S., Bureau of Census, 1989c. *Statistical Abstract of United States*. Washington D.C.
- U.S., Department of Agriculture, 1989. *Office of Transportation*
- U.S., Department of Agriculture, 1981. Office of Transportation. *Shipping Maine Potatoes to Eastern Markets*. Market Research Report–1119
- U.S., Department of Agriculture, 1991. *Economic Research Service, U.S. Potato Statistics, 1949–89*. Statistical Bulletin Number 829
- U.S., Department of Agriculture, 1989. Fruit and Vegetable Division *Fresh Fruit and Vegetable Arrivals in Eastern Cities*
- U.S., Department of Agriculture, 1989a. Fruit and Vegetable Division *Fresh Fruit and Vegetable Arrivals in Western Cities*
- U.S., Department of Agriculture, 1989b. Market News Branch, Fruit and Vegetable Division, *Fruit and Vegetable Truck Rate and Cost Summary*
- U.S., Department of Commerce, Economics and Statistics Administration, 1993. *Statistical Abstract of the United States*. Bureau of the Census

(Received 15 January 2004; Accepted 20 March 2004)