An Analysis of Milk Assembly Costs

In the Greater Ohio Area:

A Multi-output Approach

by

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ABSTRACT

A non-traditional multi-output cost function for milk haulers is estimated. Hauling firm outputs are (i) assembly miles, (ii) transport miles, and (iii) volume of milk hauled. Data were provided by 40 firms. The estimated cost function is shown to exhibit substantial economies of scale for all three joint outputs.

Introduction

Transporting milk from farms to milk processing plants is an integral part of a complex milk marketing system. Independent milk haulers negotiate with farmers to procure enough milk to fill their tanks to capacity. Milk assembly costs and reimbursement methods vary between farm-to-plant milk hauling firms. Costs vary among regions and haulers due to proximity of inputs and factors influencing input usage (Kerchner; Lough).

Past analyses of milk hauling cost functions have typically relied on engineering and accounting data and have imposed a linear short-run total cost function (Jacobson and Fairchild; Karpoff et.al.; Lee, Wasserman, et.al.). These a priori specifications have restricted the estimated average and marginal costs to be constant for all route miles and load weights. As a result these analyses are not able to determine the extent of the economies of scale with respect to cost or output embodied in the milk assembly process. Also, by not separating the productive output of the milk hauling process into the joint products of volume hauled and miles driven, past analysis has not been able to investigate issues of relative economies of scale for assembly routes comprised of alternative combinations of volume and miles. As a result milk hauling schedules derived from these past studies have produced rate schedules which treat the economic cost to dairy producers as identical regardless of location on the route and volume hauled. This no doubt has resulted in some large scale producers subsidizing smaller scale producers in the assembly and transport of their raw milk to the local processing plant.

In the greater Ohio area, farm-to-plant transportation is accomplished by a large number of privately owned hauling firms. For the most part, these firms procure accounts with the dairy farmers they service. Negotiations between farmers, milk haulers, and milk marketers determine procurement practices and hauling charges. Reasonableness of negotiated charges, or hauling rates, is of concern to dairy farmers, milk haulers, milk marketers, and dairy processors. Whether or not negotiated hauling rates are reasonable depends on whether they adequately reflect the costs of hauling milk.

Methods Used to Study Milk Hauling Costs

The principle objectives of this study were to estimate the total, average, and marginal costs of assembly of raw milk in the greater Ohio milkshed area in order to provide current rate information to haulers, handlers, and dairy producers. Estimation of the cost structure will provide insight into the degree of scale economies embodied in the process of raw milk assembly and allow the comparison of these possible economies with respect to the costs involved in transportation as distinct from volume hauled.

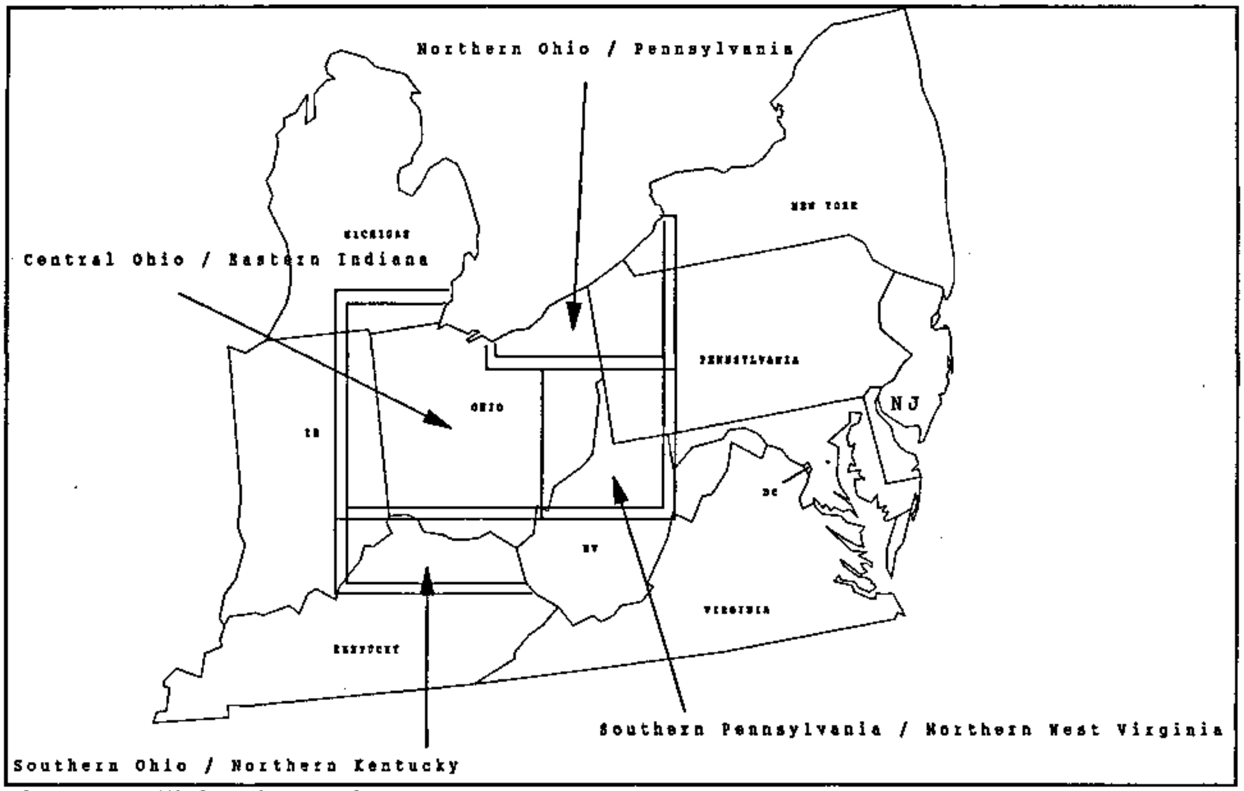


Figure 1. Milk hauling study area.

The Survey Area

Forty milk hauling firms were surveyed in the greater Ohio area (Figure 1). Because differences in terrain and dairy farm density may affect milk hauling costs, the area was divided into three study regions:

1. Greater Ohio Milkshed -- all four regions, figure 1.
2. Central Ohio -- Eastern Indiana (C.Oh.-E.In.),
3. Eastern Ohio -- Southern Pennsylvania -- Northern West Virginia (E.O.,-S.P,-N.WV.),

The greater Ohio milkshed area includes dairy areas that are relatively flat in the west and northwest as well as hilly areas in the south, east, and northeast. The C.Oh.-E.In. region is relatively flat allowing for use of larger trucks. This region has relatively few, large dairy farms. The E.O.-S.Pa-N.WV. is comparatively hilly and contains relatively small dairy farms spread over a large area.

Data Collection

Data were collected from 40 firms representing 131 loads hauled during December 1988 through April 1989. A load was defined as the itinerary a milk hauler followed to collect a tank or trailer of milk, deliver the milk to a processing plant, and return to the point of origin. Most milk hauling firms collected one load of milk a day and had two load itineraries, run on alternate days. Selected hauling firms assembled milk for Milk Marketing, Incorporated (MMI). Data were collected using a survey developed by the authors and directly administered by MMI fieldmen. The survey recorded fixed and variable costs for all loads of milk collected by each hauling firm.

Costs Included in the Study

All costs incurred by milk hauling firms were collected. These included cash, opportunity, and overhead costs. An example of opportunity cost was a charge for owner labor. While this was not a cash cost, it was a real cost to the firm because the owner could find employment elsewhere. Another opportunity cost was a charge for capital invested in trucks and equipment (Smith). This is a real cost to the firm because capital could be invested elsewhere. Overhead costs included depreciation and maintenance on trucks.

Total load costs were divided into three categories:

1. Labor cost. This cost included the labor expense associated with those who drove the milk truck.
2. Fuel cost. Fuel cost was exclusively the cost of the fuel used to collect a load of milk
3. Vehicle costs. Vehicle costs basically were overhead costs. They included preventive and repair maintenance, tire, insurance, highway taxes, tolls, license and registration, truck and route ownership, spare vehicle, non-truck driver labor, and other company overhead costs.

Milk assembly outputs

Hundredweights of raw milk and truck miles driven are the major variables which effect input usage levels and the total cost of load of milk. Past studies typically used hundredweights per mile as the assumed output variable. However this definition overlooks the fact that milk haulers are marketing both a distance hauled as well as a volume hauled product. In this analysis, the output of a hauling firm is defined as the following joint products:

1. Assembly miles. Assembly miles is the miles from the load's origin, typically the milk hauler's garage, to the last farm serviced on a load.
2. Transport miles. Transport miles is the miles from the last farm service to the delivery plant plus the miles to the load's origin or the first stop on the next load.
3. Hundredweights (Cwts.) of milk hauled. This amount equals the amount of milk delivered to the plant.

General Model Specification

Estimation of the cost function for each region is based on the assumption that the firms involved in assembly and hauling of raw milk in the study area are output constrained cost minimizing firms with a well behaved production technology. Assuming that this cost function meets well prescribed regularity conditions a specific functional form can be defined. For this study the well known translog cost function (TLCF) was selected (Brown, et.al.). The use of TLCF in modeling transportation cost functions has provided insight in other areas of transportation research (Harris; Griliches). The TLCF can be regarded as a local, second-order approximation to an arbitrary cost function. The translog functional form is flexible in that no a priori restrictions are placed on it regarding scale economies, or input substitution. The model specification for m outputs and n inputs is:

$$\begin{aligned}(1)\qquad \ln C = {} & \ln K + \Sigma_m A_i \ln Y_i + \Sigma_n B_j \ln P_j \\ & + 1/2\, \Sigma_m \Sigma_m A_{ij} \ln Y_i \ln Y_j \\ & + 1/2\, \Sigma_n \Sigma_n B_{ij} \ln P_i \ln P_j \\ & + \Sigma_m \Sigma_n G_{ij} \ln Y_i \ln P_j,\end{aligned}$$

where C is the long run total cost of a load of milk, Y_i is the quantity of the ith output, P_j is the price of the jth input, ln denotes natural logarithm, and A_{ij}, B_{ij}, and G_{ji} are function parameters. The output and price cross-effects are assumed to be equal ($A_{ij} = A_{ji}$, and $B_{ij} = B_{ji}$). The expression (1) has one neutral scale parameter (K), m + n first order parameters (A_i,B_i), and (m+1)(m/2)+(n+1)(n/2)+m*n second order parameters. The only restriction imposed is that the cost function be homogenous of degree 1 in input prices. This requires the following m+n+1 linear restrictions on the model parameters:

(2.a) $$\sum_{j=1}^{n} B_j = 1 \qquad (j=1,2,\cdots,n)$$

(2.b) $$\sum_{j=1}^{n} B_{ij} = 0 \qquad (j=1,2,\cdots,n)$$

(2.c) $$\sum_{j=1}^{n} G_{ij} = 0 \qquad (j=1,2,\cdots,n)$$

The inclusion of the above restrictions resulted in (m+n+1)(m+n)/2 free parameters.
The use of Sheppard's lemma:

(3) $$\frac{\partial \ln C}{\partial \ln P_j} = \frac{P_j X_j}{C} = S_j,$$

where S_j is the share of the jth input in total cost, provides a set of factor input share equations from the cost function. With the translog function this yields the following n equations:

(4) $$S_j = B_j + \Sigma_m G_{ij} \ln Y_i + \Sigma_n B_{ij} \ln P_i \qquad (j=1,2,\cdots,n).$$

Since the sum of the factor share equations add to 1 (due to restrictions (2)), only n-1 of the equations needed to be estimated. Additionally, no new parameters are introduced as the parameters in the share equations are the same as those in the cost function. The cost function and the n-1 share equations are estimated as a constrained seemingly unrelated regression.

Scale Cost Economies

Of central interest in this analysis is the degree of scale cost (dis)economies (SCE) embodied in the raw milk assembly cost structure. From the estimated parameters of the TLCF both the aggregate scale elasticity and the output specific elasticities can be calculated. For a proportional increase in all three outputs, ceterus paribus, the logarithmic differential of cost:

(5) $$d \ln C = \sum_{i}^{m} \partial \frac{\ln C}{\partial \ln Y_i} \, d \ln Y_i$$

provides a scale measure of the response of costs to a change in all outputs (Akridge and Hertel). If the summation of the first order output parameters (A_i) is less than one then the cost function exhibits overall economies of scale. Proportional increases in all outputs, ceterus paribus, results in less than proportional increase in total cost. Individual output scale elasticities are measured by the magnitude of the individual output parameters directly.

Estimated Regional Costs and Scale Elasticities

The study area and regional cost function estimates and aggregate scale elasticities for the two regions are presented in Table 1. By scaling the data at the geometric mean of each series the second-order terms of the translog cost function become identically zero whenever the cost function is evaluated at the logaritmic means of the outputs and input prices. Therefore these terms are not presented in Table 1. The estimated standard error of the study area equation was tested for heteroskedasticity which might have been induced by combining dissimilar topographical areas into one function. The null hypothesis of homoskedasticity could was not rejected.

In the overall study region and across regions 1 and 2, the first order output coefficients are positive and less than 1 indicating increasing economies of scale for each output, ceterus paribus. Clearly there exist significant total and individual scale cost economies across the loads and milk routes reflected in this milkshed area. Averge and marginal costs fall substantially for each of the outputs. This suggests that basing hauling rate schedules on a fixed stop charge and a constant price per hundredweight of milk hauled results in some producers subsidizing others on the route.

Figures 2 through 4 illustrate average costs for each output at deviations from the geometric means. As each output increases, average costs decline. This occurred for all ranges of data, for all outputs, and in each region and the study area.

Figure 5 depicts the relationship between average hauling cost per hundredweight and the capacity of the truck tank being used. The tank capacities listed are representative of those actually used on routes in the study area. The declining average cost structure indicates that substantial economies can be gained by consolidating small loads into large capacity truck tanks.

Implications of the Cost Relationships

The data presented emphasize the marked divergence from previous farm-to-plant milk hauling studies. Average (and marginal) costs were not constrained to be constant but instead where determine to be declining over the relevant output range for all outputs. Costs relationships described above hold several implications for the structure of the milk hauling industry. Hauling large loads of milk results in lower average cwt. costs. This suggests that, on average, firms with larger loads are more cost efficient than smaller firms. Thus, there is likely to be a continued move towards larger trucks, and fewer firms, within the milk hauling industry.

The average load in each region was produced in a manner which fully utilized the existing vehicle capacity. However, this capacity was far from the cost minimizing level which could be used in the milkshed regions. In the study area the average load could have been hauled in a truck with a 4000 gallon tank. In region 1 and 2 a 4500 and 3500 gallon tank would handle the average load respectively. In all regions, the maximum technological capacity was 6500 gallon tandem tractor. If the topography was not suitable to a tractor-trailer setup, at least a 5500 gallon tri-axle setup could be utilized quite effectively.

For example, two firms operating in the study area would incur an average cost per hundredweight of $0.85 and total cost of $439.00 hauling two separate 3000 gallon loads. If this were rationalized into one 6000 gallon load the average cost per hundredweight would decline to $0.506 and the estimated total cost would be $261.00. A saving in resources of $178.00 would be gained combining loads.

Summary

In the greater Ohio area, there has not been a recent cost of milk assembly study. In addition past studies have imposed constant average and marginal costs at the outset. The information from this study suggests that significant cost economies exist in the collection and transportation of raw milk. Average per unit costs fall as the all of the output levels increase. Specifically, for cost per hundredweight, the larger the load the lower the average cost of assembly. If hauling rates are set to approximate the average cost of assembling a load, milk hauling companies operating relatively larger loads will be able to offer their customers lower hauling rates than companies that operate relatively smaller loads. Eventually, competitive pressure from milk hauling companies and pricing pressure from dairy farmers will result in the utilization of larger capacity vehicles.

Finally, the average cost of servicing relatively larger production size farms is less than the cost of servicing the relatively smaller farms. Therefore, to charge farms the approximate cost of service, a system of variable volume or stop charges should be incorporated. The use of such a system would result in larger production size shippers paying a lower average cost but a higher total cost than relatively smaller shippers.

This information will help dairy farmers, milk haulers, cooperatives, plants, and Federal marketing orders make better decisions. Additionally, information that results in the proper alignment of cost and rates will help assure that the farm-to-plant milk hauling function will not be the cause of a disruption of the milk marketing system. Such a disruption could result in an inadequate supply of milk to meet the consumers' demands, or be the cause of an unnecessary high retail price.

Table 1. Geometric means and first-order coefficients for the milk hauling cost functions.#

Variable Definition	Study Region		Region 1		Region 2	
	Mean	Coefficient (std. error)	Mean	Coefficient (std. error)	Mean	Coefficient (std. error)
Constant		-0.1012		-0.133		-0.05
		0.006		0.006		0.005
Assembly Miles	74.68	0.347	68.2	0.314	89.3	0.275
		0.009		0.12		0.005
Transport Miles	98.30	0.449	86.4	0.43	144.8	0.439
		0.006		0.005		0.006
Cwt. Hauled	347.75	0.032	391.7	0.16	299.8	0.075
		0.016		0.26		0.014
Labor ($/hour)	8.13	0.345	8.11	0.34	7.92	0.335
		0.003		0.004		0.005
Fuel (cts/gal.)	94.46	0.138	95.2	0.135	97.9	0.164
		0.002		0.002		0.005
Vehicle (cts/gal)	65.36	0.512	69.5	0.523	54.0	0.50
		0.003		0.003		0.004
Total Cost ($/CWT.)	246.83		237.9		285.5	
Adj. R-Square		0.95		0.94		0.90
Estimated Measures of Cost Economies of Scale*						
Overall Scale Economies		0.825		0.90		0.78
Assembly Mile SCE		0.347		0.31		0.27
Transport SCE		0.446		0.43		0.43
Volume SCE		0.032		0.16		0.07

#: Second order coefficients are not presented. The data is scaled to the geometric mean so that second order terms are all zero for purposes of economic evaluation.

*: Cost increases less than proportional to output when the scale parameter is less than 1.0. Individual cost scale elasticities are directly the coefficients.

Figure 2.
Estimated Average Cost Curves
by Region
Hundredweights Hauled

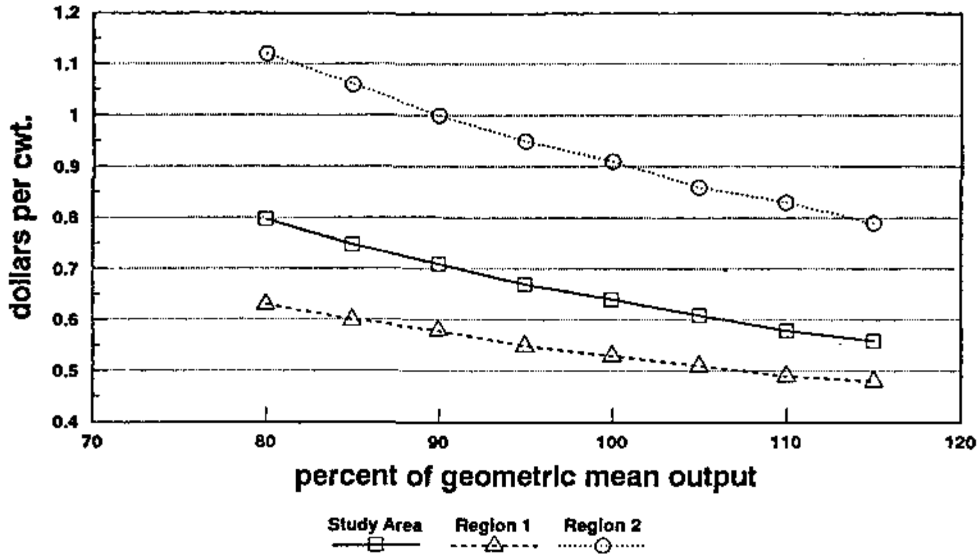


Figure 3.
Estimated Average Cost Curves
by Region
Assembly miles

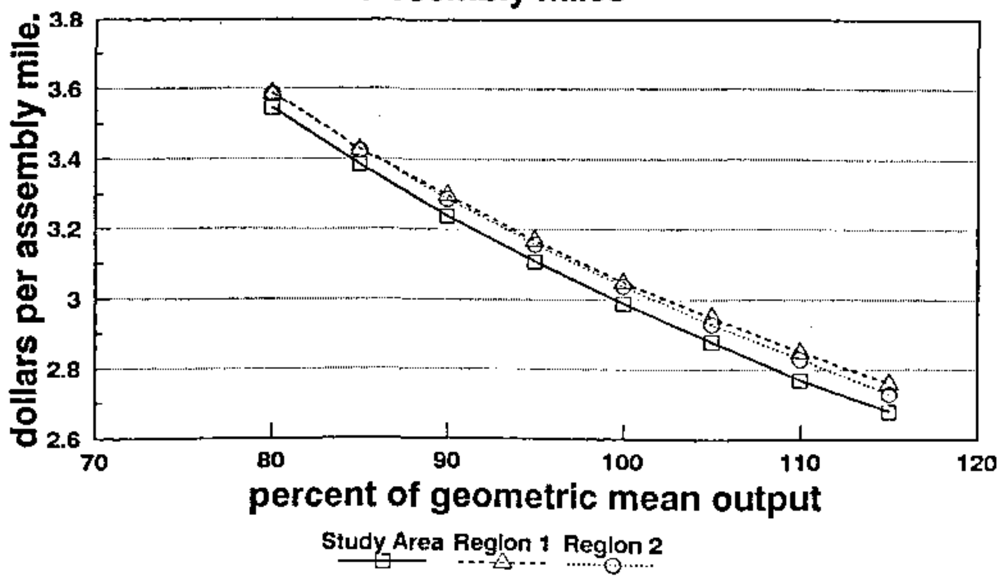


Figure 4.
Estimated Average Cost Curves
by Region
Transport mile

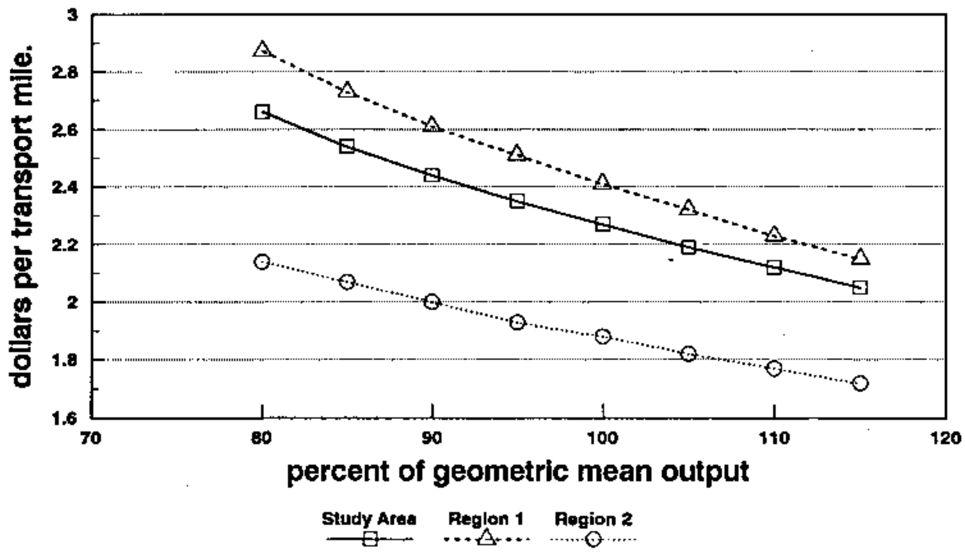
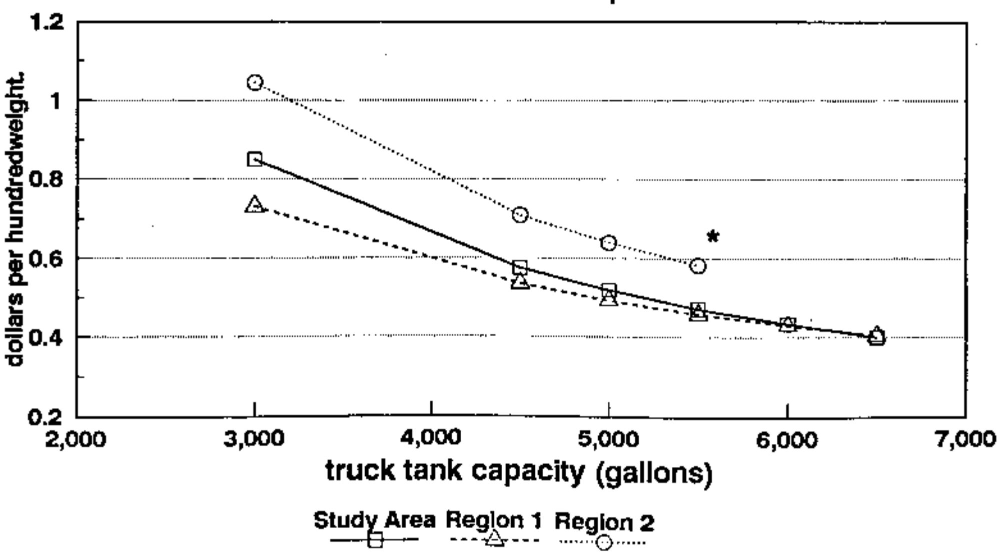


Figure 5.
Estimated Average Cost Curves
by Region
Alternative Truck Tank Capacities



*: no reported tank capacities over 5500 gal.

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TABLE 1. DESCRIPTIVE STATISTICS, MILK HAULING ANALYSIS, GREATER OHIO, 1989.

	Region 1		Region 2	
Variable	Mean	Coefficient	Mean	Coefficient
Constant	N.A.	-0.1334	N.A.	-0.0503
		(-19.887)		(-8.386)
Assembly Miles	68.2	0.3141	89.3	0.2745
		(24.699)		(49.637)
Transport Miles	86.4	0.4326	144.8	0.4388
		(76.542)		(71.035)
Cwts. Hauled	391.7	0.1602	299.8	0.0751
		(5.958)		(5.408)
Labor ($/hr)	8.11	0.3420	7.92	0.3355
		(80.379)		(58.999)
Fuel (cts/gal)	95.2	0.1348	97.9	0.1640
		(50.304)		(32.694)
Vehcile (cts/gal)	69.5	0.5232	54.0	0.5005
		(146.563)		(120.229)
Adj R Square	N.A.	0.94	N.A.	0.90
Deg. of Freedom	N.A.	18	N.A.	7
Total Cost($/ld)	237.9	208.2	285.5	271.5

TABLE 2. HUNDREDWEIGHTS HAULED OUTPUT, COMPARATIVE STATISTICS, MILK HAULING ANALYSIS, GREATER OHIO, 1989.*

Region 1				Region 2			
Prcnt.		$/Cwt.		Prcnt.		$/Cwt.	
Geom. Mean	Cwts.	Avg. Cost	Marg. Cost**	Geom. Mean	Cwts.	Avg. Cost	Marg. Cost
85	332.9	0.60	0.141	85	254.9	1.06	0.040
90	352.5	0.58	0.135	90	269.9	1.00	0.042
95	372.1	0.55	0.130	95	284.9	0.95	0.039
100	391.7	0.53	0.125	100	299.8	0.91	0.038
105	411.2	0.51	0.120	105	314.8	0.86	0.036
110	430.8	0.49	0.117	110	329.8	0.83	0.034
115	450.4	0.48	0.113	110	344.8	0.79	0.033

* Hundredweights output is evaluated at the geometric means of all other outputs and inputs.

** Incremental cost associated with the production of one more hundredwieght of milk hauled.

TABLE 3. ASSEMBLY MILES OUTPUT, COMPARATIVE STATISTICS, MILK HAULING ANALYSIS, GREATER OHIO, 1989.*

Region 1				Region 2			
Prcnt.		$/Mile		Prcnt.		$/Mile	
Geom. Mean	Miles	Avg. Cost	Marg. Cost**	Geom. Mean	Miles	Avg. Cost	Marg. Cost
85	57.9	3.43	0.940	85	75.9	3.43	0.873
90	61.4	3.30	0.904	90	80.4	3.29	0.833
95	64.8	3.17	0.871	95	84.8	3.16	0.804
100	68.2	3.05	0.841	100	89.3	3.04	0.770
105	71.6	2.95	0.813	105	93.8	2.93	0.754
110	75.0	2.85	0.787	110	98.2	2.83	0.718
115	78.4	2.76	0.764	115	102.7	2.73	0.698

* Assembly miles output is evaluated at the geometric means of all other outputs and inputs.

** Incremental cost associated with the production of one more transport mile.

TABLE 4. TRANSPORT MILES OUTPUT, COMPARATIVE STATISTICS, MILK HAULING ANALYSIS, GREATER OHIO, 1989.*

Region 1				Region 2			
Prcnt.		$/Mile		Prcnt.		$/Mile	
Geom. Mean	Miles	Avg. Cost	Marg. Cost**	Geom. Mean	Miles	Avg. Cost	Marg. Cost
85	73.5	2.73	0.581	85	123.1	2.07	0.821
90	77.8	2.61	0.555	90	130.3	2.00	0.793
95	82.1	2.51	0.532	95	137.6	1.93	0.768
100	86.4	2.41	0.510	100	144.8	1.88	0.746
105	90.7	2.32	0.491	105	152.0	1.82	0.724
110	95.1	2.23	0.473	110	159.3	1.77	0.704
115	99.4	2.15	0.456	115	166.5	1.72	0.687

* Transport miles output is evaluated at the geometric means of all other outputs and inputs.

** Incremental cost associated with the production of one more transport mile.

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