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Regional Barge Service Demand Elasticities

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ABSTRACT

An analysis of the elasticity of demand for barge services on a regional basis is presented. The Mississippi River drawing area is divided into 18 regions and elasticity coefficients are computed. These elasticity coefficients range from 0.0 (i.e., perfect inelasticity) to a -18.4 (i.e., highly elastic). The magnitude of the coefficient, which indicates the responsiveness in the quantity demanded of barge services to a change in barge rates, is related to regional specific factors such as distance to river elevators and the rail-barge rate differential.

I. INTRODUCTION

The implications of inland waterway user charges on the cost of transporting grain and upon grain flows have been reported previously [1, 2, 3, 6]. Subsequently, the linear programming model was used by Hauser et al. [5] to estimate the implication of model results for expansion of multiple-car rail loading facilities. A second extension of this model concerns the appropriate estimation of demand elasticities for barge transportation. The word "appropriate" is inserted because previous to this contribution, elasticities have been computed in the aggregate or by river segment. As suggested by this paper, the computation of elasticity at river terminals is insufficient because substitution between different transport modes occurs not at the river terminal, but at inland elevators. Section 1 offers a brief review of the model and data employed in this analysis. Section 2 discusses the implications of model results for the computations of demand elasticities for barge transportation. Section 3 discusses the relationship between region specific market factors and estimated regional elasticities of demand for barge service.

II. MODEL REVIEW

The objective of the model employed to estimate the impact of inland waterway user charges is to minimize the total transportation and handling cost of transporting corn, soybeans and wheat from domestic surplus regions to domestic and foreign demand regions.[1] To estimate the impact of user charges, a base solution, i.e., no user charges, is obtained. This computer solution is based upon projected 1989 production levels, projected 1989-1990 domestic and foreign demands and 1980 transportation alternatives and costs. The criteria used to evaluate this solution consisted mainly in the judgment that flows by crop on particular river segments, flows by crop through individual export facilities, and flows by crop to domestic and foreign demand regions represented reasonable approximations of the current shipping pattern. The impact of inland waterway user charges is then estimated by increasing origin specific barge rates by the amount of the user tax from that origin, resubmitting the model to the computer and comparing the results of the tax solution to the base and alternative tax solutions.

In total, there are 218 corn, 200 soybean and 156 wheat-originating regions specified in the model. Sixty-seven regions serve as domestic demand destinations; grain is transported to these destinations to satisfy livestock feed or processing deficits. Six foreign import demand regions are specified. Grain transported within origin regions for local feed consumption and processing are accounted for by deducting these local demands from local supplies. In this way, all demands are satisfied either explicitly as in the case of endogenous foreign or domestic demands, or implicitly as a reduction in the grain surplus in grain originating regions.

Transport activities are defined as single, three to five, 25, 30, 50 to 54, 60 to 65, 75 to 100, and 125 car rail shipments; single, three, five, 25 and 50 car rail-barge combination shipments; truck; truck-barge; and ocean-going vessels. The cost coefficients for the transport activities are based upon the transport rates faced by shippers in 1980. Rail rates were obtained from 62 railroad freight tariffs published by 26 railroad companies, grain cooperatives or grain exchanges. Rate selection for individual origin-destination pairs is based primarily on consultation with shippers and railroad executives. Truck rates are based upon estimated truck cost [9] plus a two percent profit margin, as suggested by grain trucking firm executives. Ocean-going vessel rates are estimated by calculating the average ocean grain rates weighted by ship payload capacity, published by the *Journal of Commerce and Commercial* (10) for the period October 1979-September 1980.

Thirty-five river origins on eight river segments are specified. The river segments are the Upper, Middle and Lower Mississippi, Illinois, Ohio, Missouri, Arkansas and Columbia-Snake Rivers. Activities which utilize barges are given a barge contract and a spot rate. One level of contract rates was assumed for each river segment over the entire period under study and is based upon consultation with barge company executives.[2] Spot rates are computed as a quarterly average, weighted by the number of barges traded during September, 1979 to August,

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1980 on the daily barge freight call session at the Merchants Exchange of St. Louis (ll). In the case of Upper Mississippi River origins, the barge alternative is not available during the winter period.

An interesting feature of this model is the incorporation of regional constraints upon the usage of transportation equipment. Rail car capacity is based upon a projected rail car fleet of 251,655 covered hopper cars in 1990. Of this total 65,531 were allotted to grain export shipments. Barge capacity is based upon a projected covered hopper dry cargo barge supply equal to 14,886 barges in 1990. Rail car usage by supply region and barge usage is based upon estimated turnaround time (TAT) and bushels of grain shipped by mode. Rail TATs are based upon the actual experience of two central Iowa grain shipping firms. Barge TAT are based on industry estimates of average river speeds, loading, unloading and fleeting times at the origin and exporting ports. A shipment by multiple-car rail reduces the allotted regional rail capacity. Barge usage reduces the allotted barge capacity.

The two types of user taxes specified in the model and used to calculate elasticity coefficients are fuel and segment-specific ton-mile taxes.[3] A fuel tax is simply a tax levied on each gallon of propulsion fuel consumed on the inland waterways and is similar to federal and state highway fuel taxes imposed on fuel consumed by automobiles and trucks. The fuel tax is designed to recover total river system expenditures for operation, repair, maintenance and construction. A segment tax is similar to the taxes collected on toll highways and is designed to recover segment specific expenditures.

III. ELASTICITY OF DEMAND FOR BARGE SERVICE

Elasticity of demand is an important concept indicating the responsiveness in quantity demanded of a product to a change in the price of the product all else held constant. In this case the product of concern is barge services and the price is the barge rate. The change occurring in the barge rate is the increase in the rate due to user charges. The general formula for calculating elasticity coefficients is:

$$E = \frac{\Delta Q}{\Delta P} \frac{P}{Q} \qquad (1)$$

where

E = own price elasticity of quantity demanded for the product
Q = quantity demanded of the product
P = price of the product
Δ Q, Δ P = changes in quantity and price from initial situation

The magnitude of the computed elasticity coefficient is significant in a number of ways. Consider the importance to barge owners and operators. If the elasticity coefficient is less than a minus one, demand is defined to be elastic. A price (rate) increase will reduce total revenue received by the barge operator because the gain in total revenue associated with the increase in rate is less than the loss in revenue associated with the decline in the quantity of barge services demanded. If the elasticity coefficient is between zero and a minus one demand is inelastic. A rate increase will increase total revenue

Koo [7] and Hauser [6] have estimated the elasticity of demand for barge services. Koo estimates a system-wide elasticity of demand given a proportional change in all barge rates. As estimated by Koo the elasticity of demand for barge services is equal to 3.52, 2.43 and 2.27 when barge rates are increased by 10, 20 and 30 percent respectively. As indicated in Table 1 however, the imposition of user charges will not increase barge rates by a constant percentage at all grain origins. In 1990, the fuel tax ranges from 23.1 percent of the barge rate at Lewiston, Idaho to 6.3 percent at Greeneville, Mississippi. The segment tax as a percent of the barge rate ranges from 30.4 to 3.6 percent at Lewiston, Idaho and Greeneville, Mississippi, respectively. Hauser determines elasticities given the differential percentage increase in rates due to the fuel and segment taxes projected for 1985. The elasticity coefficient represents an average-elasticity weighted by quantity shipped through particular origins on a given river segment. Utilizing this weighting scheme, elasticity coefficients were calculated by river segment given the increase in barge rates due to the imposition of 1990 user charges. The calculated elasticities are presented by river segment in Table 2.

As indicated in Table 2, the demand for barge services is elastic in total and on the Upper Mississippi, Missouri and Arkansas Rivers. The demand for barge services is inelastic on the Lower Mississippi, Illinois and Columbia-Snake. The results for the Ohio River indicate that elasticities are only valid over a particular range of prices. For a relatively small increase in rates, the demand for Ohio River barge traffic is perfectly inelastic. Given the relationship between revenue generated and the magnitude of the elasticity coefficient, barge owner revenue would increase upon the Lower Mississippi, Illinois and Columbia-Snake rivers. On the Upper Mississippi, Arkansas, and Missouri barge revenue would decline. The effect on the revenue generated from Ohio River shipments is dependent upon type of tax implemented.

A major determinant of the magnitude of the elasticity coefficient is the availability of substitutes. In the context of the user charge study substitution may occur between modes and between origin-destination pairs. The ability of inland shippers to substitute direct rail service for combination rail-barge or truck-barge service will influence the elasticity for barge services. Similarly, the ability of inland shippers to substitute shipments to processing locations for export shipments or between exporting ports will affect the magnitude of the elasticity coefficient. Substitution between transport modes and destinations, however, does not occur at the river origin. Substitution would occur at the inland grain origin elevator. The grain shipper substitutes the combined truck-barge or rail-barge movement with a direct rail or truck shipment to inland processing or exporting ports. Therefore, estimation of elasticity coefficients at the grain origin elevator would seem more appropriate.

Table 3 presents elasticity coefficients estimated at the grain origin elevator for the regions depicted by Map 1. The method of calculation may be represented as follows:

$$E_r = \sum_a \frac{\Delta Q_{ia}}{\Delta P_{ia}} \frac{P_{ia}}{Q_{ia}} \frac{Q_{ia}}{Q_r} \qquad (2)$$

Table 1.
User charges as a percent of barge rates by type of tax, origin, and river, 1990

River	Origin	Fuel tax	Segment tax
Mississippi	Minneapolis, MN	10.6	14.8
	Clinton, IA	10.2	12.5
	St. Louis, MO	10.2	9.2
	Memphis, TN	7.4	4.2
	Greenville, MS	6.3	3.6
Illinois	Seneca, IL	10.5	11.2
	Peoria, IL	10.4	10.7
	Naples, IL	9.6	9.6
Ohio	Cincinnati, OH	10.8	5.3
	Mt. Vernon, IN	9.2	5.0
Missouri	Sioux City, IA	11.5	12.8
	Kansas City, MO	9.7	11.2
Arkansas	Catoosa, OK	12.8	25.5
Columbia/Snake	Lewiston, ID	23.1	30.4
	Windust, WA	16.4	22.4
	Biggs, OR	14.0	16.0

Table 2.
Elasticity estimates resulting from imposition of 1990 user charges and average tax per bushel of corn by river segment

	Fuel tax		Segment tax	
River segment	Elasticity[a]	Average tax per bushel (cents/bushel)	Elasticity[a]	Average tax per bushel (cents/bushel)
Upper Mississippi	2.41	3.72	2.06	4.69
Lower Mississippi	0.72	1.37	0.80	0.88
Ohio	1.62	2.54	0.00	1.30
Illinois	0.35	3.12	0.43	3.37
Missouri	5.61	6.41	4.84	7.25
Arkansas	6.46	4.23	3.25	8.43
Columbia-Snake	0.46	1.48	0.35	1.70
Total	1.94		1.37	

[a] Signs have been charged from negative to positive.

Table 3.
Easticities of demand for barge transportation computed from 1990 user charges by decisionpoint regions

		Elasticity of demand for barge transportation	
Region	State	Fuel tax	Segment tax
A	SD,MN	5.2	12.1
B	MN	12.4	10.0
C	MN,WI	0.0	0.0
D	IA	18.4	14.5
E	IA	5.8	4.8
F	IA	1.2	1.0
G	IA	0.0	0.0
H	IA	6.4	5.4
I	IL	1.6	1.8
J	IL	0.0	0.0
K	IL,IN	10.1	7.1
L	IN,OH	0.0	0.0
M	KS	16.9	14.4
N	NE	5.7	5.0
O	MO	0.0	0.0
P	KY	6.7	0.0
Q	OK	10.3	5.2
R	AR,MI,LA	0.0	0.0

where

Er = own price elasticity of barge services demanded at region r.

Q_{ia} = quantity demanded, at origin elevator a in region r, of a combined mode i—barge movement in the base solution; i truck, single or multiple car rail.

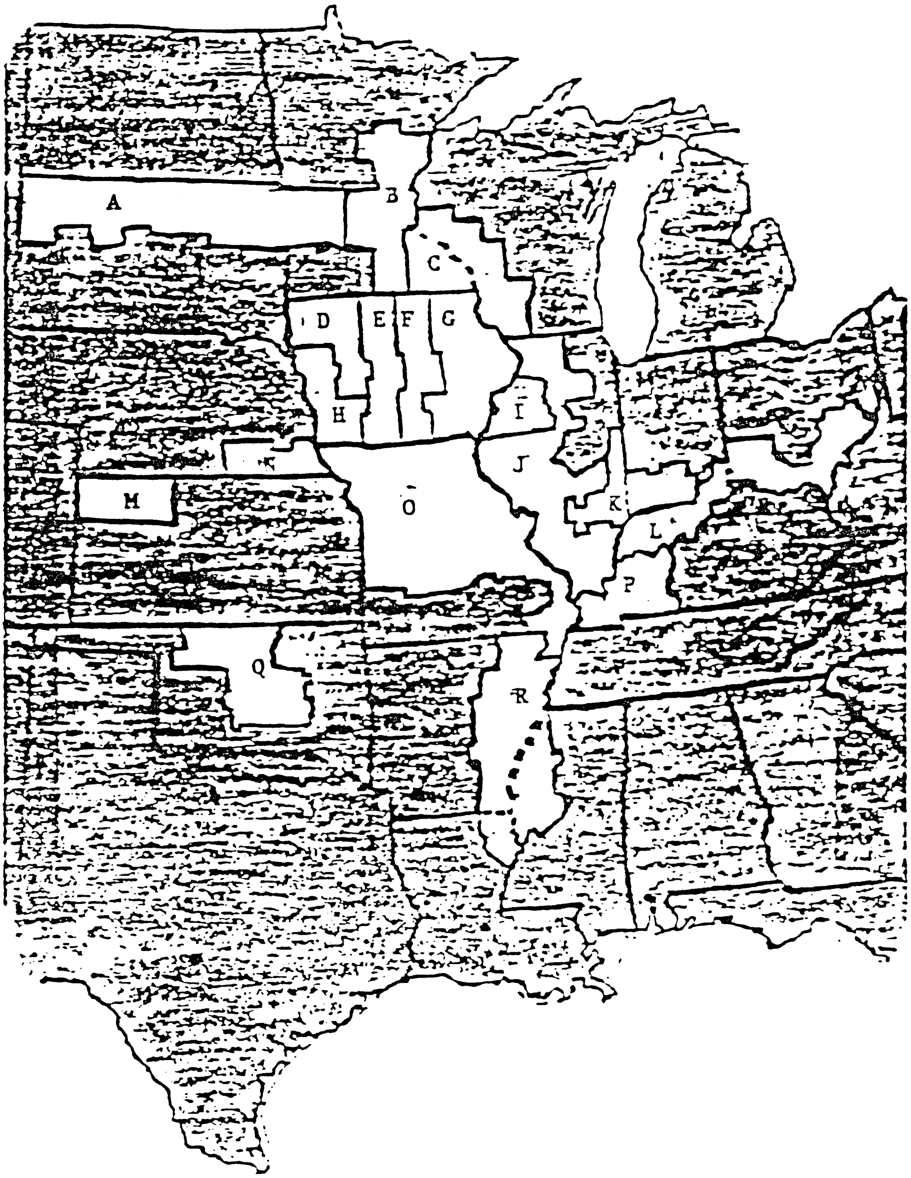
P_{ia} = the price (rate) of a combined mode i—barge movement to Gulf ports originating at elevator a.

Qr = total quantity of barge services demanded by shipments originating at region r.

The estimated elasticity coefficients—with signs changed from negative to positive—range from 0.0 in regions C, G, J, L, O and R to 18.4 in region D; northwestern Iowa. Perfect inelasticity of demand for combined truck- or rail-barge movements would indicate that user charges at the level specified in this analysis are insufficient to cause diversions to direct truck or rail movements. The regions characterized by a perfectly inelastic demand are, in general, located in very close proximity to the river. In these regions, the combined truck- or rail-barge rates remain cheaper than the next-best alternative after user charges are imposed. The exceptions to this close proximity-perfect inelasticity rule are the entire state of Missouri, region I (Illinois) and region P (western Kentucky). In Missouri, the absence of water-competitive rail rates favors the continued use of barge transportation after user charges are imposed. Regions I and P, although in close proximity to the river, are characterized by an elastic demand for barges. User charges divert grain from export shipment to regional processing locations.

In the remaining regions the distance to barge loading points, availability of alternative means of transportation, and other factors to be discussed in the next section become crucial to the determination of the elasticity coefficient. Iowa is an excellent example. Region G is characterized by perfect inelasticity of demand for barge services. This region is in close proximity to the river and the rate on substitute transportation, i.e., rail rates, does not become competitive even after user charges are imposed. Region F shows a slightly elastic demand for barge services. Region E is characterized by an even greater elasticity of demand for barge services. In both regions E and F multiple-car rates to the Gulf become competitive with rail-barge and truck-barge rates after user charges are imposed. In addition, these regions are located at a greater distance from the river making the total rate to export larger. Regions D and H are located in close proximity to the

Map 1.
Water competitive regions in the Mississippi River basin[1]



[1]No barge shipments originate in shaded areas

Missouri River. Per bushel user charges on the Missouri River, however, are relatively larger than on other river segments. The large increases in barge transportation rates readily cause grain to divert from barge shipment to truck or rail shipment.

IV. FACTORS INFLUENCING REGIONAL ELASTICITIES

Table 4 presents the mean values and range of selected market factors which could influence the magnitude of the regional elasticity coefficients. In general, the demand for a specific product (or service) will be more elastic the greater the number of substitutes for the product, the larger the percentage expenditures on the product in relation to total expenditures and the more the product is considered dispensible [8]. Also included in Table 4 is the simple correlation coefficient between the listed market factors and the regional elasticity coefficients. The magnitude and sign of the correlation coefficient indicates the strength and direction of the relationship between the factors and the computed elasticities.[4] The market factors may be divided into three distinct categories. These categories are regional grain usage, barge related factors and rail related factors.

A. Regional Grain Usage.

Included in this category is the grain surplus—defined as regional production minus seed, feed and local processing—as a percentage of production (%SUR) and total processing demand, as a percentage of production (%PROC). Total processing demands are equivalent to local processing plus the grain shipped to processing deficit locations.

The first factor (%SUR) measures the grain available to be shipped from the region. On average 63% of the grain produced in water-competitive regions is available for shipment. The range of surplus percentage values, however, suggests that the grain available for shipment differs widely between regions. The Mississippi delta states of Arkansas, Louisiana and Mississippi, although characterized by intensive soybean production, have relatively small corn production in relation to heavy feed usage. Hence, the small percentage surplus. On the other hand, Region M (Kansas) has particularly high levels of wheat production in relation to total usage. The magnitude of the correlation coefficient between %SUR and the elasticity coefficients, although not particularly high, suggests that the elasticity of demand for barge services will increase the greater the availability of surplus grain in relation to production. Alternatively, the positive relationship implies that given a change in the rate relationship between rail and barge, the larger will be the quantity of grain that may shift to another transportation mode or from export shipment to processing. The availability of processing relative to barge (or export) shipment is considered in the second factor (%PROC). The sign of the correlation coefficient suggests that as the processing alternative

Table 4.
Mean and range values and simple correlation coefficients between market factors and regional elasticity coefficients

Factor	Mean	Range Low	Range High	Correlation Coefficient Fuel	Correlation Coefficient Segment
1) Regional Usage					
%SUR	0.63	0.27(R)[a]	0.88(M)	0.32	0.31
%PROC	0.09	0.00(C)	0.63(R)	-0.31	-0.35
2) Barge Related					
TM	104.5	2.20(P)	346.00(M)	0.67	0.82
MBR[b]	97.5	42.80(R)	173.40(M)	0.67	0.76
%B	0.66	0.27(H)	1.00(C)	-0.30	-0.27
3) Rail Related					
R-B[b]	28.90	4.00(N)	72.00(L)	-0.51	-0.56
%U	0.39	0.19(G)	1.00(F,N)	0.47	0.46
%R	0.11	0.00()[c]	0.59(H)	0.36	0.27

[a]Region(s) in parenthesis.

[b]Measured in cents per hundredweight.

[c]Regions A, C, G, J, L, M, O, P, R.

increases in importance relative to export shipment the demand for barge services becomes more inelastic. Since the model requires that all processing demands be satisfied at least cost in the base solution, the relationship between %PROC and the regional elasticities implies that the increase in barge rates have a minimal impact on flows to processing points. Hence, %PROC may also be viewed as a measure of grain availability, that is, processing shipments and local processing demands are locked-in to a region's grain usage in the base solution. The availability of grain, therefore, that may be shipped by barge and subsequently shift to other outlets as barge rates increase is diminished.

B. Barge Related Factors.

Included in this category are total mileage, averaged over the region, to river terminals (TM), the average barge rate for shipments originating in the region (MBR), and the percent of all grain flows originating in the region and traveling by barge in the base solution of the model (%B). The correlation between the factors TM and MBR and the elasticity coefficients suggests a relatively stronger and positive relationship. A relatively larger total mileage to river elevators or a relatively larger barge rate to the Gulf in comparison to other regions would increase the total rate on the barge movement (truck or rail-barge) and, therefore, increase the attractiveness of alternative outlets after barge rates increase. The third factor (%B) is negatively related to the regional elasticity. A larger percentage of grain shipments dedicated to barge shipment in the base solution would be indicative of the indispensibility of the barge mode to the region.

C. Rail Related Factors.

Included in this category is the difference between the minimum export rail rate and total barge rate (truck or rail-barge) in cents per hundredweight (R-B), the regional percentage utilization of multiple-car train loading facilities (%U) and the percentage of all export grain flows traveling by rail in the base solution (%R). Table 4 indicates that as the rail-barge rate differential decreases, the demand for barge services becomes more elastic. A smaller increase in barge rates is, therefore, necessary for grain shippers to shift from barge to rail shipment. The sign of relationship between the elasticity coefficients and the percentage utilization of regional multiple-car rail capacity (%U) is misleading. It would be expected that if rail capacity is fully utilized the alternatives to barge transportation would be limited and barge demand would be more inelastic. However, the average utilization of rail capacity—40 percent—would suggest that the availability of rail transportation in water competitive regions is, on the whole, of limited importance in shipper decision making. The decision to substitute from barge to rail is based primarily on rate considerations. The correlation between the third factor (%R) and the elasticity coefficients may be interpreted in a similar manner as the %B factor. A larger percentage of rail shipments in the base solution would indicate the indispensibility of rail to the region. Hence, the less competitive the barge mode before barge rates increase and the greater the substitution away from barge after rates escalate.

V. SUMMARY

A linear programming model developed to estimate the impact of inland waterway user charges on corn, wheat and soybean flows is utilized to consider the appropriate estimation of demand elasticities for barge services. Although elasticities computed on a river segment and systemwide basis indicate that for the majority of barge traffic the demand for barge services is elastic, there are additional factors to consider.

1. Empirically estimated elasticities are valid only for the range of rate increases under analysis. The elasticity coefficients estimated for the Ohio River origins are an excellent example. The elasticity coefficient computed on the basis of the segment tax would suggest a perfectly inelastic demand for barge services. However, this conclusion would not be supported if rate increases of the magnitude caused by the fuel tax were imposed. Given the fuel tax, the demand for Ohio River barge services is elastic.
2. Elasticity coefficients computed at river origins, although indicative of the directional change in barge owner revenues given a change in barge rates, do not fully approximate the responsiveness of barge traffic to a change in barge rates. Barged grain originates at an inland grain elevator. It is at the inland grain elevator that the decision to utilize barges or ship direct by rail or truck is made. Factors such as grain availability, distance from river elevators, and the rail-barge rate differential are important considerations for the decision maker. These results strongly suggest that the elasticity of demand for barge transportation varies considerably depending upon the origin of the grain shipped.

ENDNOTES

1. A comprehensive mathematical documentation of the linear programming model used to estimate the impact of inland waterway user charges is available in references #1, 2, and 6.
2. Barge rates are quoted at a premium or discount to Bargeload Bulk Grain Tariff #7. Even though one level of contract rates is utilized this does not mean that all river elevators on a particular river face the same rates. For example, according to the tariff the benchmark rate (100% of tariff) at

Peoria is $4.81 per ton. At Seneca, also on the Illinois River, the bench mark is $5.24 per ton.

3. The 1990 fuel tax is equal to 38.1 cents per gallon. The 1990 segment specific ton-mile taxes are equal to 0.23, 0.05, 0.17, 0.03, 0.31, 0.62 and 0.38 cents per ton-mile for the Upper Mississippi, Lower Mississippi, Illinois, Ohio, Missouri, Arkansas and Columbia-Snake Rivers, respectively. These levels were developed in a user charge study completed by Data Resources Inc. [4]. See reference #2 for the procedures utilized to determine origin-specific rates.
4. The simple correlation coefficient ranges between -1 and 1. At either extreme a perfect linear correlation is suggested.

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