

## Reliability of Programming Software: Comparison of SHAZAM and SAS.

Oluwarotimi Odeh  
Department of Agricultural Economics,  
Kansas State University,  
Manhattan, KS 66506-4011  
Phone: (785)-532-4438  
Fax: (785)-523-6925  
Email: [odeh@agecon.ksu.edu](mailto:odeh@agecon.ksu.edu)

Allen M. Featherstone  
Department of Agricultural Economics,  
Kansas State University,  
Manhattan, KS 66506-4011  
Phone: (785)-532-4441  
Fax: (785)-523-6925  
Email: [afeather@agecon.ksu.edu](mailto:afeather@agecon.ksu.edu)

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### Introduction

The ability to combine quantitative methods, econometric techniques, theory and data to analyze societal problems has become one of the major strengths of agricultural economics. The inability of agricultural economists to perform this task perfectly in some cases has been linked to the fragility of econometric results (Learner, 1983; Tomek, 1993). While small changes in model specification may result in considerable impact and changes in empirical results, Hendry and Richard (1982) have shown that two models of the same relationship may result in contradicting result. Results like these weaken the value of applied econometrics (Tomek, 1993).

Since the study by Tice and Kletke (1984) computer programming software have undergone tremendous improvements. However, experience in recent times has shown that available software packages are not foolproof and may not be as efficient and consistent as researchers often assume. Compounding errors, convergence, error due to how software read, interpret and process data impact the values of analytical results (see Tomek, 1993; Dewald, Thursby and Anderson, 1986). It is obvious that wrong parameter estimates, when used for the desired purpose (policy, analytical or predictive) deviate from reality, which the researcher intends to capture. The danger in this is when researchers take programming results as foolproof, without rigorous cross-program tests and validation, parameter estimates and the implications drawn from them are flawed (Tomek, 1993). More often, replication of results become difficult and even in some cases suggests lack of thoroughness and therefore leads the later researcher to question the credibility of the prior study. While in some cases the programming software used in

a study is stated, details of the software such as version, options used and even code used are often not provided.

In his study, Tomek (1993) underscores the importance of confirmation research and replication to confirm published results. More importantly, the author identifies the use of alternative estimators (computer codes) as one of the major causes of divergent econometric results. Dewald, Thursby and Anderson (1986) reported errors in privately written computer codes. An earlier version of SAS was once reported to compute the Durbin-Watson statistic incorrectly (Tomek, 1993), while the incorrect computation of the marginal effects of dummy variable in version 7 of Limdep is known to have been rectified in the more latest version 8. As a result of these econometric and computer problems, Tomek (1993) joined Dewald, Thursby and Anderson (1986) in urging that professional journals should require that authors “submit programs and data” and give details on data transformations, model restrictions and estimators.

This paper therefore addresses two key objectives. First, we examine the reliability of some selected programming software packages researchers use in data analyses. This is addressed in terms of the consistency of results, irrespective of how variables are arranged. The key question is, does the way a research problem is coded in a given software package impact the results of the analysis? The aim is to examine whether independent estimation procedures by different researchers using the same software package, dataset and empirical model yield the same results. Second, we examine the statistical and economic effects of the results of these selected software packages on research analysis and their implications.

The remaining part of the paper is presented as follows. The following section features some previous studies on software reliability. A section on the econometric problem is next. This is followed by a section on Procedures, then another on Data, after which the preliminary results and discussion are presented. The section on summary and conclusion are presented at the end.

### Previous Studies

A search of existing agricultural economics literature revealed that the most recent study on examining the reliability of most of the software packages used in the profession is by Tice and Kletke (1984). Earlier studies on the efficiency of various mathematical programming algorithms documented include Crowder et al. (1978), Benichou et al. (1977), Ibaraki (1976), and Land and Powell (1973). In their study, Tice and Kletke (1984) examined the reliability of three versions of IBM linear programming software by solving a linear programming problem. They reported that repeated estimations of the problem yielded different objective functions. In fact, they stated that “..it has been generally assumed by researchers that widely used computer software packages written and supported by reputable firms give reliable, consistent, and accurate solutions” and raised questions about the reliability of the widely used commercial linear programming package. They further recommended that users of the version found to be inconsistent (IBM MPSX linear programming package) should consider using other alternatives). In consonance with this, Crowder, Dembo and Mulvey (1978) also reported that differences in solution outcomes could occur and may cause changes in computational sequences. According to them, this irregularity may lead to inconsistencies in the estimated results due to rounding error.

While one could say that impressive developments have been made in computer technology in recent years, there is the crucial need to examine the reliability of programming software packages and determine whether researchers are really getting reliable and consistent estimates. The importance of this lies, among other things, in the fact that considerable value (predictive, policy, analytical etc) is placed on the estimates derived from research results and if these results vary with the procedure adopted in analysis, software used, the order of variable arrangement in programming code etc., the credibility of these results would be questioned.

Another aspect of interest is the need to quantify the impact of some of the observed inconsistencies in estimated results in terms of statistical significance of parameters and the effects of these attendant errors on reported economic indicators (elasticities).

### Programming Problem

Two test problems are examined. The first is specified as a Quadratic profit function with three outputs and five inputs thus as;

$$\Pi^* = b_0 + \sum_{i=1}^m b_i P_i' + \sum_{i=m+1}^{n-1} b_i W_i' + \frac{1}{2} \left( \sum_{i=1}^m \sum_{j=1}^m b_{ij} P_i' P_j' + \sum_{i=m+1}^{n-1} \sum_{j=m+1}^{n-1} b_{ij} W_i' W_j' \right) + \sum_{i=1}^m \sum_{j=m+1}^{n-1} b_{ij} P_i' W_j'$$

where :  $\Pi^* = \Pi^* / W_n$  (1)

$$W_i' = W_i / W_n \quad \text{and} \quad P_i' = P_i / W_n$$

By Hotelling's lemma, we get three outputs and five inputs, where the bi's are parameters to be estimated,  $P_i'$ s and  $W_i'$ s are normalized output and input prices respectively. That is, normalizing with the n<sup>th</sup> input to ensure homogeneity leaves us with the normalized profit function, three outputs and four inputs to estimate. The normalized quadratic function is chosen because of its wide use in many production analyses (Lusk et al.,

2002; Lau, 1976) the ease of estimation and since it represents a class of flexible functional forms commonly used in most empirical studies. It specifically enables us to impose the regularity restrictions and examine the effect of nonlinearity of most functional forms used. Symmetry restrictions are imposed by setting  $b_{ij} = b_{ji}$  for all  $i$  and  $j$ .

Elasticities for the profit function are calculated using

$$\varepsilon_{ii} = \frac{\partial Y_i}{\partial P_i} \frac{\bar{P}_i}{pY_i} \quad \text{and} \quad \xi_{ii} = \frac{\partial X_i}{\partial W_i} \frac{\bar{W}_i}{pX_i} \quad \text{for own output and input elasticities while}$$

$$\varepsilon_{ij} = \frac{\partial Y_i}{\partial P_j} \frac{\bar{P}_j}{pY_i} \quad \text{and} \quad \xi_{ij} = \frac{\partial X_i}{\partial W_j} \frac{\bar{W}_j}{pX_i} \quad \text{for cross output and input elasticities respectively;}$$

where  $pY_i$  and  $pX_i$  are the predicted output and input (at the respective means),  $\bar{P}_i$  and  $\bar{P}_j$  are mean output prices, and  $\bar{W}_i$  and  $\bar{W}_j$  are the mean input prices.

A second test problem involves simple estimation of the profit function as a system of linear equations (OLS). This is attempted to see if nonlinearity plays any role in the reliability of the analytical results.

### Procedures

Regular economic restrictions were imposed on the functions (in equations 1 and 2 above). Estimation is carried out in two parts (with and without curvature imposed): The first part involves estimation of the profit function without curvature imposed, but with homogeneity and symmetry imposed. Repeated estimation is done by changing the arrangement of the equations in the computer code (i.e swapping the order of the equations). For example in the first scenario, the first problem (profit function) is explicitly stated as;

$$\begin{aligned} \pi = & b_0 + b_1 * p_1 + b_2 * p_2 + b_3 * p_3 + b_4 * W_4 + b_6 * W_6 + b_7 * W_7 + b_8 * W_8 + \\ & 0.5 * (b_{11} * (P_1 * P_1) + b_{22} * (P_2 * P_2) + b_{33} * (P_3 * P_3) + b_{44} * (W_4 * W_4) + 66 * (W_6 * W_6) + b_{77} * (W_7 * W_7) + \\ & b_{88} * (W_8 * W_8)) + \\ & b_{12} * P_1 * P_2 + b_{13} * P_1 * P_3 + b_{23} * P_2 * P_3 + b_{46} * W_4 * W_6 + b_{47} * W_4 * W_7 + b_{48} * W_4 * W_8 + b_{67} * W_6 * W_7 + \\ & b_{68} * W_6 * W_8 + \\ & b_{78} * W_7 * W_8 + b_{14} * P_1 * W_4 + b_{16} * P_1 * W_6 + b_{17} * P_1 * W_7 + b_{18} * P_1 * W_8 + b_{24} * P_2 * W_4 + b_{26} * P_2 * W_6 + \\ & b_{27} * P_2 * W_7 + b_{28} * P_2 * W_8 + \\ & b_{34} * P_3 * W_4 + b_{36} * P_3 * W_6 + b_{37} * P_3 * W_7 + b_{38} * P_3 * W_8 \end{aligned}$$

$$(3) \quad y_1 = b_1 + b_{11} * P_1 + b_{12} * P_2 + b_{13} * P_3 + b_{14} * W_4 + b_{16} * W_6 + b_{17} * W_7 + b_{18} * W_8 \quad (4a)$$

$$y_3 = b_3 + b_{13} * P_1 + b_{23} * P_2 + b_{33} * P_3 + b_{34} * W_4 + b_{36} * W_6 + b_{37} * W_7 + b_{38} * W_8 \quad (4c)$$

$$x_4 = b_4 + b_{14} * P_1 + b_{24} * P_2 + b_{34} * P_3 + b_{44} * W_4 + b_{46} * W_6 + b_{47} * W_7 + b_{48} * W_8 \quad (5a)$$

$$x_8 = b_8 + b_{18} * P_1 + b_{28} * P_2 + b_{38} * P_3 + b_{48} * W_4 + b_{68} * W_6 + b_{78} * W_7 + b_{88} * W_8 \quad (5d)$$

where Prof is the profit function,  $Y_n$  (where  $n=1,..,3$ ) denoting the three output equations and  $X_{n+m}$  (where  $m=1,2..4$ ) are the input equations.

In the second scenario, the order of the input and output equations are swapped thus;

$$x_4 = b_4 + b_{14} * P_1 + b_{24} * P_2 + b_{34} * P_3 + b_{44} * W_4 + b_{46} * W_6 + b_{47} * W_7 + b_{48} * W_8 \quad (5 a')$$

$$x_8 = b_8 + b_{18} * P_1 + b_{28} * P_2 + b_{38} * P_3 + b_{48} * W_4 + b_{68} * W_6 + b_{78} * W_7 + b_{88} * W_8 \quad (5 d')$$

$$y_1 = b_1 + b_{11} * P_1 + b_{12} * P_2 + b_{13} * P_3 + b_{14} * W_4 + b_{16} * W_6 + b_{17} * W_7 + b_{18} * W_8 \quad (4 a')$$

$$y_3 = b_3 + b_{13} * P_1 + b_{23} * P_2 + b_{33} * P_3 + b_{34} * W_4 + b_{36} * W_6 + b_{37} * W_7 + b_{38} * W_8 \quad (4 c')$$

The two scenarios are estimated separately and their estimates compared. From the parameter estimates from both functions, parameters from the same  $n^{\text{th}}$  equation were recovered using the imposed conditions and the statistical properties are noted. To examine the economic effects, elasticity estimates based on these are also computed.

Only software packages with significant differences in the estimated parameters from the first scenario are subjected to the second part of the analyses. In the second part, the above exercises are also repeated for each of the scenarios with curvature imposed using the Cholesky factorization method. This approach is adopted because of its

simplicity and wide usage in research analysis. Symmetry and homogeneity conditions are also imposed.

It must be noted that for the first part of the estimation procedure, the same set of re-arrangements and reordering of functional forms using the available dataset were done in the estimation procedure for each software package. The effects of order of arrangement of equations within models and the consistency of computation are also investigated to identify their respective effects on parameter estimates.

The second problem involves simple linear, estimation of the functions in the software packages to see whether (non)linearity of the function impacts the reliability of estimated parameters from each of the packages.

#### Data and Methods:

Data on 26 firms enrolled in the Custom Harvester Analysis and Management program from 1998-2002 were used. Contained in this are three output variables and five input variables on each of the firms. Price data on each of the variables for the sample time period are from the United States Department of Agriculture (USDA) databank.

The latest versions of programming software (SHAZAM - version 9, and SAS - version 8), were chosen based on wide usage. In SHAZAM, the NL command is used so that the estimation is the non-linear iterative seemingly unrelated regression (SUR). The GENRVAR command is also used so that the default starting values of one are used for all the thirty-six (36) parameters estimated, while the convergence criterion is set at 0.1E-5. To ensure consistency, the problems were similarly specified in SAS. There the ITSUR command was used with the same convergence criterion was maintained to enhance comparability of results consistency with SHAZAM.



For the third problem, all the necessary computations regarding the squared terms were done before estimation and all the equations were specified thereafter as a system of linear equations and the SYSTEM command was used for estimation in SHAZAM. This aspect of the estimation was carried not carried out in SAS for reasons that would be stated in the next section.

### Results and Discussion

Table 1 shows a summary statistics of the data used. Result from the profit function (scenario 1) show that order of arrangement of the equations has no effect on the parameter estimates from the SAS software and they were quite consistent irrespective of whether the output equations are arranged before or after the input equations. With SHAZAM however, parameter estimates varied in magnitude between the two scenarios. As shown in Table 2, the numbers of statistically significant parameters differ between the two scenarios, though the signs of the parameters remained unchanged.

Various elasticity estimates from the analysis were computed to show the economic impacts of the observed inconsistency on results. The elasticity estimates from SAS are presented in Table 3 are the same between all the scenarios based on the fact that their parameter estimates are identical. As shown in Table 4, the elasticity estimates from SHAZAM differ between the two scenarios. A paired t-test between the elasticities from two scenarios were conducted. This was specified as;

$H_0: D = 0$  (the difference between elasticities from scenarios 1 and 2= is 0)

$H_a: D \neq 0$  (the difference is not 0)

We reject the null in three out the eight cases (three outputs and five inputs sets of elasticities). These estimated elasticity differences also give an idea of the magnitude of

potential between two orders of arrangement of the equations in using SHAZAM. Also, further examination shows that this anomaly is not limited to non-linear function.

A simple OLS estimation of the entire system (as eight sets of linear equations) also gave different parameter estimates and elasticities from the two scenarios (Table 4). Unlike the profit function, the cost function was invariant to the order of arrangement of the equations in both software packages.

With curvature imposed, parameter estimates from SHAZAM estimation in both scenarios still differ from each other. As shown in Table 5 the number of statistically significant parameters differ depending on the order of arrangement. Table 6 also shows that the elasticity estimates differ significantly between the two scenarios based on the paired t-test.

### Conclusion

This paper examines the reliability of some selected programming software packages; namely, SHAZAM and SAS. Using the latest versions of both packages, the statistical and economic implications of the observed inconsistency in terms of analytical results were also computed and examined.

Our results show that the order of arrangement of output and input equations impact estimated parameter values in SHAZAM and but has no effect on results from SAS. Based on the study results, statistical and economic impacts also reveal that the inconsistency in the SHAZAM software package can alter statistical and economic results from research analysis. On the other hand, parameter estimates obtained when the problem is specified as a normalized quadratic cost function were invariant to the order of arrangement of the input equations. This suggests that SHAZAM handles the negative

signs in the mathematical operations in this context of these specified problem differently depending on whichever operator (+ or -) comes first.

It must be stated that the aim of this study is purely academic and is therefore not geared towards endorsing any particular programming software package or software producing company. It therefore should not be seen as such. Rather, it is expected that the study result would underscore the need for cross-testing or cross-validation of research results (in line with Tomek, 1993), particularly when there exist any reason to suspect inconsistency in results obtained from the analysis. Most often, the results and implications drawn from research results have far reaching implications that they should not be allowed to be vitiated by the flaw of any analytical tool.

An important and often ignored issue in some published papers is the need to provide information on the programming software package used, version and other relevant information that may be useful in case the study is to be replicated. It must also be emphasized that more rigorous reliability test might need to be conducted on these software packages to verify our results. Perhaps a deeper look need to be taken at some of the software packages researchers use, to ensure that estimation results are truly what the results of the data generating process and behavior exhibit, rather than a computer computational error.

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SAS manual.

**Table 1**                      **SUMMARY STATISTIC**

Variable	N	Mean	Std	Minimum	Maximum
Wages	88	14.965	0.58565	0.34298	14.12
Cost of Trav and other	88	107.15	2.9917	8.95	103.03
Cost of Fuel and Lube	88	0.87118	0.15161	2.30E-02	0.67
Cost of Repair and Maint	88	23.765	9.136	83.466	8.949
Cost of Dep and Int.	88	0.19991	4.61E-02	2.13E-03	0.1034
Price of S/Grains	88	14.968	1.9029	3.6212	10.129
Price of O/Grains	88	21.906	5.4754	29.98	8.8562
Price of Trucking	88	0.12147	3.32E-02	1.10E-03	5.83E-02
Labor	88	7725.94	7213.74	549	44051
Travel and Other	88	1031.55	1076.91	80.45	7193.78
Fuel and Lube	88	64744.08	62574.55	5612	360150
Repair and Maint	88	2273.72	1963.58	361	10844
Depr and Int.	88	1008308.86	918476	148500	5922914
Small Grains	88	16161.43	13470.29	941	69631
Other Grains	88	7127.23	7301.62	944	38783
Trucking	88	1143470.82	1161809	45444	6525927

Table 2.

Nonlinear	ITSUR	SAS
Para	Estimate	t Value
A0	-2820.98*	-1.88
A1	7207.763	0.37
A3	-116109***	-3.25
A4	-1444.7*	-1.99
A5	-1830261***	-7.15
A6	30967.03***	7.43
A7	8327.424***	4.24
A8	1719390***	4.41
W11	-125045	-0.9
W13	-176716	-0.91
W14	-5360.22*	-1.7
W15	-901924	-0.8
W33	2001843	1.62
W34	-72523.4***	-3
W35	-1.16E+07	-1.2
W44	-701.321	-0.83
W45	-531863*	-1.82
W55	-158328	0
W66	-83616.6***	-2.67
W67	-30329.6**	-2.07
w68	-5487966**	-2.42
W77	-36638.6***	-4.02
w78	-425205	-0.37
w88	-8.21E+08***	-3.55
W16	5671.746	0.31
W36	336602.6**	2.32
W46	3587.579	0.79
W56	2097153	1.09
W17	21727.47**	2.53
W37	181306.3**	2.45
W47	5177.216**	2.2
W57	2568965**	2.42
W18	1906389	1.49
W38	16118062	1.55
W48	223514.5	0.66
W58	3.62E+08**	2.46

\*\*\*, \*\* and \* indicate statistical significant at 1, 5 and 10 percent respectively.

SHAZAM	OUTPUT/INPUT		INPUT/OUTPUT	
	COEFFICIENT	T-RATIO	COEFFICIENT	T-RATIO
A0	-2667.9	-1.7594	-2929.7	-2.0022
A1	9889.3	0.46628	12537	0.60163
A3	-1.15E+05	-3.6112	-1.10E+05	-3.567
A4	-1010.2	-1.56	-1038.7	-1.6114
A5	-1.18E+06	-7.9024	-1.17E+06	-7.8239
A6	24836	7.9321	25688	9.1115
A7	6629.4	3.8445	6427.8	3.7296
A8	9.28E+05	7.7609	9.40E+05	7.9264
W11	-1.15E+05	-0.75165	-1.31E+05	-0.86756
W13	-55164	-0.29417	-62825	-0.33501
W14	-2024.6	-0.8029	-1981.2	-0.78218
W15	81339	0.19051	1.68E+05	0.41691
W33	3.41E+06	2.9876	3.05E+06	3.0936
W34	-42745	-2.2849	-41939	-2.2571
W35	-6.20E+05	-2.1354	-4.97E+05	-2.3314
W44	174.31	0.25397	192.16	0.27893
W45	-1.23E+05	-0.98051	-97643	-0.82045
W55	58379	1.6771	38807	2.5616
W66	-34731	-1.8199	-35514	-1.8716
W67	-9973.4	-1.2044	-8932.1	-1.1078
W68	2.83E+05	0.71635	41748	0.51497
W77	-27545	-4.299	-26984	-4.1921
W78	1.58E+06	2.8855	1.79E+06	4.1732
W88	-42458	-1.7815	-29427	-2.5565
W16	-16514	-1.3199	-18199	-1.4991
W36	1.63E+05	1.8253	1.57E+05	1.7667
W46	-2893.3	-0.95954	-2968.9	-0.98667
W56	-4.68E+05	-1.2324	-6.49E+05	-2.6329
W17	11789	1.5233	2256.5	1.4465
W57	1.37E+06	2.5991	1.31E+06	2.518
W18	-6.57E+05	-1.9939	-7.91E+05	-3.1579
W38	-4.56E+05	-1.6006	-2.94E+05	-2.4637
W48	-4.11E+05	-2.5689	-4.16E+05	-2.5997
W58	68196	1.9753	49975	2.7062

Table 3	Number of Coeff.	Number of		
		10%	5%	1%
Output/Input	36	22	16	8
Input/Output	36	24	21	11
Difference	None	2	5	3

**Table 4**

<b><u>Elasticities</u></b>	<b><u>(SAS)</u></b>							
<b><u>Output/Input</u></b>	<b><u>Outputs</u></b>		<b><u>Inputs</u></b>					<b>Dep. &amp; Int.</b>
	S_Grains	O_Grains	Trucking	Labor	Travel/Oth	Fuel & Lube	Rep and Maint	Dep. & Int.
S_Grains	-0.77528	-0.41189	-0.41342	0.05253	1.05442	0.18100	0.05280	0.25983
O_Grains	-0.64664	-1.14415	-0.07366	0.46276	0.27037	0.22418	0.17523	0.73190
Trucking	-0.72662	-0.08246	-0.88320	0.25215	0.62891	0.12377	0.04698	0.64048
Labor	-0.11084	-0.62195	-0.30271	2.44129	-2.00791	0.20029	0.16630	0.23554
Travel/Oth	-1.95520	-0.31935	-0.66352	-1.76460	2.96618	0.40137	-0.13086	1.46597
Fuel & Lube	-0.78600	-0.62011	-0.30580	0.41223	0.93998	-0.27110	0.26884	0.36196
Rep and Maint	-0.23709	-0.50114	-0.12002	0.35387	-0.31685	0.27796	0.07358	0.46969
Dep. & Int.	-0.31231	-0.56035	-0.43801	0.13418	0.95025	0.10018	0.12574	0.00032



**Table 5**

**Elasticities - SHAZAM**

<u>a) Output/Input</u>	<u>Outputs</u>			<u>Inputs</u>				
	S_Grains	O_Grains	Trucking	Labor	Travel/Oth	Fuel & Lube	Rep and Maint	Dep. & Int.
S_Grains	-0.3080314	-0.1295596	2.04E-02	-0.14632	0.576078	8.36E-02	-4.07E-02	-5.55E-02
O_Grains	-0.2014964	-0.8150986	0.258727	0.237927	-4.16E-02	0.1157305	7.67E-02	0.369198
Trucking	3.59E-02	0.2923796	-4.37E-05	-8.31E-02	-0.15918	-3.35E-03	-8.27E-02	1.15E-04
Labor	0.3064227	-0.3203874	9.90E-02	2.129103	-2.31297	5.94E-02	5.96E-02	-2.02E-02
Travel/Oth	-1.054029	4.90E-02	0.165712	-2.02074	2.433084	0.3482015	-0.2217467	0.300522
Fuel & Lube	-0.3603401	-0.3206853	8.21E-03	0.122155	0.82014	-0.4382682	0.150415	1.84E-02
Rep and Maint	0.182699	-0.2210779	0.211092	0.127717	-0.54356	0.1565388	-1.75E-02	0.104062
Dep. & Int.	6.61E-02	-0.2828006	-7.82E-05	-1.15E-02	0.195669	5.08E-03	2.76E-02	-1.10E-04
<b><u>b) Input/Output</u></b>								
S_Grains	-0.3140446	-0.1156891	3.00E-03	-0.16077	0.625367	8.05E-02	-4.17E-02	-7.67E-02
O_Grains	-0.1797963	-0.7955705	0.292504	0.223343	-7.42E-02	0.1094541	7.21E-02	0.352168
Trucking	5.27E-03	0.3307202	-3.02E-05	-9.97E-02	-0.15087	-2.16E-03	-8.33E-02	8.43E-05
Labor	0.3365682	-0.3008588	0.118795	2.420597	-2.65902	6.74E-02	5.82E-02	-4.16E-02
Travel/Oth	-1.146492	8.75E-02	0.157404	-2.32851	2.863203	0.3126524	-0.2175286	0.271735
Fuel & Lube	-0.3465329	-0.3033154	5.28E-03	0.138618	0.734474	-0.3902449	0.1470485	1.47E-02
Rep and Maint	0.1869009	-0.2080644	0.212622	0.124596	-0.53211	0.15312	-1.92E-02	8.21E-02
Dep. & Int.	9.13E-02	-0.2697917	-5.71E-05	-2.37E-02	0.176472	4.05E-03	2.18E-02	-7.30E-05

**Elasticities Differences**

	<u>Output</u>			<u>Input</u>				
	S_Grains	O_Grains	Trucking	Labor	Travel/Oth	Fuel & Lube	Rep and Maint	Dep. & Int.
S_Grains	0.0060	-0.0139	0.0174	0.0145	-0.0493	0.0032	0.0009	0.0212
O_Grains	-0.0217	-0.0195	-0.0338	0.0146	0.0326	0.0063	0.0046	0.0170
Trucking	0.0306	-0.0383	0.0000	0.0166	-0.0083	-0.0012	0.0006	0.0000
Labor	-0.0301	-0.0195	-0.0198	-0.2915	0.3461	-0.0080	0.0015	0.0215
Travel/Oth	0.0925	-0.0385	0.0083	0.3078	-0.4301	0.0355	-0.0042	0.0288
Fuel & Lube	-0.0138	-0.0174	0.0029	-0.0165	0.0857	-0.0480	0.0034	0.0037
Rep and Maint	-0.0042	-0.0130	-0.0015	0.0031	-0.0114	0.0034	0.0017	0.0219
Dep. & Int.	-0.0252	-0.0130	0.0000	0.0122	0.0192	0.0010	0.0058	0.0000
Mean difference	0.0043	-0.0216**	-0.0033	0.0076	-0.002	-0.001	0.0018*	0.0143**

Note: \*\*\* Indicates statistical significance at 1% level while \* indicates statistical significance at 10% level based on paired t-test.

<b>Table 6</b>	Number of Coeff.	Number of Significant Coefficients		
		10%	5%	1%
Output/Input	36	13	11	8
Input/Output	36	15	10	9
Difference	None	2	1	1

Table 7

***Elasticities with Curvature imposed***

<u>Output/Input</u>	<u>Output</u>			<u>Input</u>				
	S_Grains	O_Grains	Trucking	Labor	Travel/Oth	Fuel & Lube	Rep and Maint	Dep. & Int.
S_Grains	-3.07E-02	-8.77E-03	-1.77E-03	2.99E-02	-3.17E-02	-2.63E-04	1.01E-02	3.33E-02
O_Grains	-0.4652015	-0.349384	-0.1955114	5.64E-03	0.318449	0.2155735	0.2535654	0.2168686
Trucking	-1.60E-02	-3.32E-02	-4.14E-02	-1.71E-02	0.185228	-9.41E-03	2.67E-02	-9.48E-02
Labor	-0.1131653	-4.02E-04	7.18E-03	0.319382	-0.33475	-8.32E-03	1.56E-02	0.1145269
Travel/Oth	-0.3690987	6.98E-02	0.2388808	1.02778	-2.29097	0.2662673	-6.02E-02	1.117558
Fuel & Lube	1.00E-02	-0.1543886	3.97E-02	-8.35E-02	-0.87048	0.6856468	-4.54E-02	0.4184849
Rep and Maint	-8.38E-04	-3.98E-04	-2.47E-04	3.42E-04	4.31E-04	-9.96E-05	4.05E-04	4.04E-04
Dep. & Int.	-0.3543719	-4.35E-02	0.1118873	0.321661	-1.02232	0.1170991	5.15E-02	0.8179545

Input/Output

	S_Grains	O_Grains	Trucking	Labor	Travel/Oth	Fuel & Lube	Rep and Maint	Dep. & Int.
	-3.01E-02	-8.40E-03	-1.74E-03	2.94E-02	-3.11E-02	-5.52E-04	9.77E-03	3.27E-02
	-0.4528753	-0.3429726	-0.1975389	-3.09E-03	0.330251	0.2135145	0.2464885	0.2062277
	-1.58E-02	-3.32E-02	-4.27E-02	-1.80E-02	0.19057	-1.00E-02	2.66E-02	-9.74E-02
	-0.1122018	2.19E-04	7.57E-03	0.316508	-0.33324	-8.50E-03	1.53E-02	0.1143245
	-0.3738093	7.38E-02	0.2530451	1.049944	-2.37568	0.2772944	-6.32E-02	1.158623
	2.09E-02	-0.1498938	4.19E-02	-8.42E-02	-0.87167	0.6811176	-4.93E-02	0.4111485
	-8.24E-04	-3.86E-04	-2.48E-04	3.39E-04	4.43E-04	-1.10E-04	3.95E-04	3.92E-04
	-0.3471867	-4.06E-02	0.1141301	0.317755	-1.02209	0.1153805	4.93E-02	0.8133487

**Elasticities Differences - with Curvature imposed**

	<u>Output</u>			<u>Input</u>					
	S_Grains	O_Grains	Trucking	Labor	Travel/Oth	Fuel & Lube	Rep and Maint	Dep. & Int.	
S_Grains	-6.20E-04	-3.62E-04	-2.75E-05	5.11E-04	-6.87E-04	2.89E-04	2.78E-04	6.18E-04	
O_Grains	-1.23E-02	-6.41E-03	2.03E-03	8.74E-03	-1.18E-02	2.06E-03	7.08E-03	1.06E-02	
Trucking	-1.63E-04	1.38E-05	1.32E-03	8.72E-04	-5.34E-03	6.37E-04	7.24E-05	2.59E-03	
Labor	-9.63E-04	-6.22E-04	-3.91E-04	2.87E-03	-1.51E-03	1.86E-04	2.27E-04	2.02E-04	
Travel/Oth	4.71E-03	-3.99E-03	-1.42E-02	-2.22E-02	8.47E-02	-1.10E-02	3.00E-03	-4.11E-02	
Fuel & Lube	-1.09E-02	-4.49E-03	-2.26E-03	7.34E-04	1.19E-03	4.53E-03	3.86E-03	7.34E-03	
Rep and Maint	-1.32E-05	-1.23E-05	1.01E-06	3.81E-06	-1.15E-05	1.03E-05	9.56E-06	1.23E-05	
Dep. & Int.	-7.19E-03	-2.83E-03	-2.24E-03	3.91E-03	-2.34E-04	1.72E-03	2.26E-03	4.61E-03	
Mean difference	-0.0034*	-0.0023**	-1.97E-03	-5.66E-04	8.29E-03	-2.00E-04	0.0021**	-1.88E-03	

Note: \*\*\* Indicates statistical significance at 1% level while \*\* and \* indicate statistical significance at 5% and 10% levels respectively, based on paired t-test.