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by

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Traditionally the role of separability in system of demand functions has been the subject of numerous analyses, with few directed toward systems of supply functions. Separability an important property of production, confirms the existence of aggregation in variables and the decentralization of decision making. Separability implies that marginal rates of substitution between pair of inputs (outputs) in the separated group are independent of the levels of inputs (outputs) outside the group.

Weak separability in the estimation of a systems of demand functions was first explored by Sono(1961) and Leontief(1947) to deal with aggregation problems in consumer and producer theory respectively. Berndt and Christensen(1973) employed the cost function to test the existence of capital aggregate assuming a labor aggregate in US manufacturing industry. In another study, they test the existence of a labor aggregate assuming a capital aggregate. Woodland(1976) employed a variable profit function and retested the hypothesis employing a translog production function to investigate the permissibility of aggregation(separability) of inputs. Recent work has been carried out in regards to the separability aspect but no aggregation (separability) test has been performed for both inputs and outputs in the primal approach.

To capture technological advances in the production of different outputs and improved input usage an inputs/output separability assumption is used. This general assumption is very rarely tested leading to potential bias in the estimates. To overcome this, weak separability needs to be estimated and tested by a system of demand (supply) functions generated by output maximization (input minimization) subject to an expenditure constraint.

Traditionally the iterative seemingly unrelated regression (ITSUR) estimation of input demand functions eliminates the aggregation problem in inputs for given output production. Similarly estimation of output supply functions in the framework of demand functions is expected to eliminate the aggregation problem in outputs. The separability conditions summarized by this restriction can be tested by any one of three demand systems: Almost Ideal demand system (AIDS), the Translog demand system and the Rotterdam demand system.

The major objective of the analysis is to test for separability in multiple-input, multiple-output production technology (input requirement technology) using a primal approach. The time series properties of the null hypothesis of unit roots versus a null hypothesis of stationarity is carried out prior to the estimation. In the second section models describing unit roots and separability are presented. Brief description of construction of the output and input data is presented in the third section. An empirical application to the Nebraska agriculture sector is used to estimate and test for unit roots and separability property. The results and conclusion are presented in the final section.

Separability and Unit Root Econometric Models

Production (Input requirement) function and Separability:

One way of specifying a multi-output, multi-input production technology is to assume that inputs and outputs are non-allocable. One observes only total quantities of input index vector $X = (X_1.......X_N) \in \mathbb{R}^N_+$ used in the production of output index vector $Y= (Y_1.......Y_M) \in \mathbb{R}^M_+$. An explicit production technology assuming input-output separability can be represented as:

$$P(X) - L(Y) = 0 \qquad (1)$$

The other assumptions like positive[1], linear homogenous function[2] with neutral technical change and profit maximization, convexity[3] of the input requirement set and concavity[4] of the production function is assumed. Output(input) separability can be represented by an output(input) set in terms of a single-output(input) index and multi-input(output) index as:

$$\begin{aligned} \boldsymbol{P(X)} &= \boldsymbol{Y : X \text{ can produce } Y,\ X} \ \ \mathbb{R}_{+}^{N} \\ \boldsymbol{L(Y)} &= \boldsymbol{X : Y \text{ produced by } X,\ Y} \ \ \mathbb{R}_{+}^{M} \end{aligned} \qquad \textbf{(2)}$$

The main reason for the distinction of input/output representation is to test for aggregation in input and output indexes. A translog function approximation is represented for the output and input set along with time capturing the technological change as:

$$\begin{aligned} \ln Y &= \ln {}_0 + \ln {}_t\, t + \sum_{i=1}^{n} {}_i \ln X_i + \frac{1}{2}\ {}_t t^2 + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} {}_{ij} \ln X_i \ln X_j + \sum_{i=1}^{n} {}_{it} \ln X_i\, t + {}_i \\ \ln X &= \ln {}_0 + \ln {}_t\, t + \sum_{i=1}^{n} {}_i \ln Y_i + \frac{1}{2}\ {}_t t^2 + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} {}_{ij} \ln Y_i \ln Y_j + \sum_{i=1}^{n} {}_{it} \ln Y_i\, t + {}_i \end{aligned} \qquad \textbf{(3)}$$

The assumptions of constant returns to scale, homogeneity, symmetry impose the following restrictions in both cases:

$${}_i = \mathbf{1} \ , \qquad {}_{ij} = \mathbf{0} \ , \qquad {}_{ij} = {}_{ji} \qquad \textbf{(4)}$$

The logarithmic marginal productivity (input requirement condition) is

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1 $P(X) > 0$ for $X \gg 0_J$; $L(Y) > 0$ for $Y \gg 0_{G,B}$;

2 $P(\theta X) = \theta P(X)$ for $\theta \geq 0$, $X \geq 0$; $L(\lambda Y) = \lambda L(Y)$ for $\lambda \geq 0$, $Y \geq 0$;

3 $L[\lambda Y^1 + ({}^1\text{-}\lambda) Y^2\ ] \leq \lambda\ L(Y^1) + ({}^1\text{-}\lambda)\ L(Y^2)$

4 $P[\theta X^1 + (1\text{-}\theta) X^2] \geq \theta\ P(X^1) + (1\text{-}\theta)\ P(X^2)$

$$\frac{\ln Y}{\ln X_i} = \frac{Y}{X_i}\frac{X_i}{Y} = \frac{W_i X_i}{Y} = CS_i = {}_i + \sum_{i=1}^{n} {}_{ij} \ln X_j + \sum_{i=1}^{n} {}_i t + {}_i$$

$$\frac{\ln X}{\ln Y_i} = \frac{X}{Y_i}\frac{Y_i}{X} = \frac{P_i Y_i}{X} = RS_i = {}_i + \sum_{i=1}^{n} {}_{ij} \ln Y_j + \sum_{i=1}^{n} {}_i t + {}_i \qquad (5)$$

The conditions for inputs {i&j} to be functionally separable from input k is that the first and second derivatives of Y (X) should satisfy the following condition:

$$Y_i \; Y_{jk} - Y_j \; Y_{ik} = 0 \qquad (6)$$

Testing for Unit roots:

The classical methods used to test economic data for time series properties have not been able to draw standard conclusions. This requires the need to perform and compare the null hypothesis of stationary [Kwiatkowski, Phillips, Schmidt and Shin(KPSS)] as well as null hypothesis of a unit root [augmented Dickey Fuller(ADF) and Phillips-Perron(PP) tests]. The time series property of unit roots and stationarity was tested for output and input variables before estimating the model since it has implication for economic theory and modeling. The ADF test statistic is based on two forms of OLS regression estimation results from suitably specified regression equations:

$$(A) \qquad Y_t = {}_0 + {}_1 Y_{t-1} + \sum_{J=1}^{P} {}_j \; Y_{t-j} + {}_t$$

$$(B) \qquad Y_t = {}_0 + {}_1 Y_{t-1} + {}_2 t + \sum_{J=1}^{P} {}_j \; Y_{t-j} + {}_t \qquad (7)$$

where (A) is with constant, no-trend and (B) is with constant, trend. P is the number of lagged terms to ensure the errors are uncorrelated. The null hypothesis to be tested is $_1 = 0$.

PP (1988) developed a generalization to the DF procedure, which is nonparametric with respect to nuisance parameters allowing for a wide class of weakly depended and possibly heterogeneously distribution data. The PP test is based on OLS regressions:

$$\begin{aligned} &(A) \quad Y_t = {}_0 + {}_1 Y_{t-1} + {}_t \\ &(B) \quad Y_t = {}_0 + {}_1 Y_{t-1} + {}_2 t + {}_t \end{aligned} \qquad \textbf{(8)}$$

with (A) and (B) definition similar to equation (7). The null hypothesis to be tested is ${}_1$=1. The ADF and PP test take the presence of a unit root(a stochastic trend) in the time series as the null hypothesis. In contrast, the approach of KPSS(1992) is to take the presence of a deterministic trend(absence of a unit root or stochastic trend) as the null hypothesis. For the time series Y_t two forms of stationarity can be tested from the regression equation:

$$\begin{aligned} Y_t &= \ t + r_t + e_t \\ r_t &= r_{t-1} + u_t \end{aligned} \qquad \textbf{(9)}$$

where r_t is stochastic and follows random walk, error terms u_t are white noise with mean 0, variance ${}_u^2$ and the initial value r_0. The null hypothesis to be tested is H_o: ${}_u^2 = 0$.

Nebraska Input and Output Data

The input and output quantity indexes have been constructed by accounting for quantity and quality changes, the details of which are present in Shaik(1998). The input and output data for Nebraska agriculture sector spans the period 1936-94. The five aggregated, output quantity indexes are constructed from 22 commodities including 10 livestock commodities, 7 field crops and 5 oils and vegetable crops. Similarly five aggregated input quantity indexes were also constructed from 25 variables including 4 farm equipments, 4 farm real estate including building and structures, 4 breeding livestock, 2 types of farm labor and 11 intermediate inputs in the computation of productivity measures representing the differential technological changes occurring in crop and livestock sectors.

Outputs

The outputs were regrouped into food grains(FOG), feed crops(FEC), vegetable and oil crops(VO), meat animals(MA), poultry and other livestock including milk, honey and wool production(PO). Annual data on crop production [yield per acre times total harvested acres for each crop] and prices received by the farmers were used in the construction of an output Theil-Tornquist quantity index. Similarly for livestock commodities the quantity estimates [pounds of meat produced] and average prices per pound were used in the construction of livestock quantity indexes.

Inputs

Particular emphasis was given in the construction of farm equipment(FE), breeding livestock(BLS), farm real estate(FRE), farm labor(FL) and intermediate inputs(INT) with different methods needed in the construction of indexes for each group to account for quantity and quality changes. In the case of farm equipment, a perpetual inventory method was used in the construction of capital stock for four assets to account quantity changes, aggregated by rental value reflecting their marginal products in the construction of a quantity index. In the case of breeding livestock, the number of breeding livestock on January 1 was used as a measure of capital stock. The rental value was used as shares, with zero depreciation [as the value of the calf is approximately the same as that of the cull cow sent for slaughter at the end of the life period, so depreciation is assumed zero since the farmer has neither gained nor lost] in the construction of breeding livestock quantity index. In the case of farm real estate, three types of land[non-irrigated, irrigated and pastures] and value of building and structures are included. The acres of land and value of the structures, used as quantity was aggregated by state-level cash rents and rental value respectively to obtain a farm real estate quantity index.

An implicit quantity index [logarithmic difference between the rate of change in expenditures and price index] was calculated as the differences between the rate of change in expenditures and producer price index, share weighted by the expenditures.

To account for quantity changes in agriculture labor's contribution to agriculture production, data was compiled on hours worked for hired labor and unpaid and family labor along with the wage rate for hired labor was used. Wage compensation was used as shares in the aggregation of the farm labor quantity index.

Empirical Application to Nebraska Agriculture Sector

The empirical results are based on time series data for shares and quantity indexes of 5 outputs (meat animals, poultry, food grains, feed crops and vegetable & oils) and 5 inputs (farm equipment, breeding livestock, farm real estate, farm labor and intermediate inputs) for Nebraska agriculture sector. The results of unit roots and stationarity analysis are presented in table 1.

Results from table 1 indicate the breeding livestock quantity index to be stationary, since we can reject the unit root and cannot reject the level stationarity. Six times series data appear to be nonstationary, since we cannot reject the unit root but can reject the level stationarity (farm real estate index and meat animal share) and trend stationarity(farm labor, vegetable and oils index and farm labor and vegetable and oils share). Two series (meat animals quantity index and meat animal share) appear to be stationary since we can reject the PP unit roots. The feed crops quantity index appear to be nonstationary. Three series(food grain index, farm real estate and poultry share) appear to be stationary, since we can reject the ADF unit roots and cannot reject the level stationarity(food grains index and farm real estate share) and trend stationarity(poultry). The rest of the series seem ambagious since we cannot reject either unit roots or the level and trend stationarity. We conclude that the data are not sufficiently informative to distinguish between these hypothesis.

Overall except for the breeding livestock quantity index all other indexes and shares have unit roots, but with first difference all the variables were stationary except for the farm equipment index and the vegetable and oils share. On second difference even these were stationary.

Given the homogeneity and symmetry restrictions, 18 unknown parameters need to be estimated in a system of equations based on iterative seemingly unrelated regression(ITSUR). Unlike the traditional separability condition, here we impose separability between two (i & j) variables from the other(k) variables. Estimates of 15 unknown nonlinear parameters for 10 combinations of separability are presented in table 2 for inputs and table 3 for outputs.

Under the null hypothesis, with degrees of freedom equal to number of nonlinear restrictions, separability in outputs/inputs are tested by the likelihood ratio test statistic LR = 2 (unrestricted model - restricted model). The LR test statistics are also presented in table 2 for outputs and table 3 for inputs. The separability restrictions tested at the point of approximation cannot be rejected in both output and input variables so the data appear to support aggregation in output and inputs.

In the case of inputs, the group (farm equipment and breeding livestock) is explicitly separable from farm real estate, farm labor and intermediate inputs. Similarly other input and output separability restrictions can be explained. Given this startling result of separability, extended research needs to be done with hypothesis testing of separability between specific input and output variables. An extension would be to test for separability between specific outputs and inputs.

Conclusions

This paper examines two issues. The first issue, test for time series properties of unit roots for input, output shares and quantity indexes. Here a comparison is drawn between the null hypothesis of unit roots and null hypothesis of stationarity, with seven of the twenty variables acknowledging both hypothesis. With regard to the issue of separability, our findings support the aggregation of input/output quantity indexes.

Further possible extensions to this study, would be to examine individual separability analysis, compute the Morishima elasticity of substitution to explain the same. In another extension, one could estimate the bias in the output and input technologies. From the econometric point of view, Monte Carlo simulations can be performed to generate a confidence interval for time series properties.

Table 1. Unit Root and Stationary Test for Output and Input Quatity Index and Shares.

		DF	PP	KPSS			DF	PP	KPSS
Quantity Index					**Shares**				
Farm Equipment	T	-1.9293	0.2864	0.1064	Farm Equipment	NT	-2.4876	-1.7285	0.1526
Breeding Livestock	NT	-2.5708	-2.7948	0.3795	Breeding Livestock	T	-7.2677	-3.9629	0.2113
Farm Real Estate	NT	-1.2314	-1.9057	0.8469	Farm Real Estate	NT	-3.6093	-2.4698	0.1598
Labor	T	-2.1465	-2.2498	0.2093	Labor	T	-2.6859	-2.5527	0.1803
Intermediate	T	-0.7691	-0.9453	0.1335	Intermediate	T	-1.9550	-2.5420	0.1138
Meat Animals	T	-2.4123	-4.3767	0.0943	Meat Animals	NT	-1.4373	-1.4683	0.8650
Poultry	NT	-1.8381	-1.1838	1.0034	Poultry	T	-3.3224	-1.7623	0.1404
Food Grains	NT	-2.3806	-4.3505	0.3307	Food Grains	T	-2.4385	-3.0320	0.1041
Feed Crops	T	-3.0020	-4.9570	0.2123	Feed Crops	NT	-4.1911	-2.4742	0.1093
Veg & Oil	T	-1.5819	-1.3009	0.3040	Veg & Oil	T	-1.0549	-0.5600	0.2598
	No Trend	Trend	Level S (NT)	Trend S (T)		No Trend	Trend	Level S (NT)	Trend S (T)
Critical Values	-2.5700	-3.1300	0.4630	0.1460	Critical Values	-2.5700	-3.1300	0.4630	0.1460
Critical Level			0.05	0.05	Critical Level			0.05	0.05

Table 2. Nonlinear Parameter Estimates of Translog Function Imposing Homogeneity, Symmetry, and Separability in Inputs.

Parameters	Unrestricted	(FE & BLS) FRE, FL, INT **1**	(FE & FRE) BLS, FL, INT **2**	(FE & FL) BLS, FRE, INT **3**	(FE & INT) BLS, FRE, FL **4**	(BLS & FRE) FE, FL, INT **5**	(BLS & FL) FE, FRE, INT **6**	(BLS & INT) FE, FRE, FL **7**	(FRE & FL) FE, BLS, INT **8**	(FRE & INT) FE, BLS, FL **9**	(FL & INT) FE, BLS, FRE **10**
a1	-2.155899	-0.258230	0.087526	-0.441455	-2.239054	0.103394	0.158214	0.181179	0.143545	0.098434	0.103848
b11	-0.001841	0.000055	0.000172	-0.000357	-0.000663	-0.000022	-0.000013	-0.000016	0.000014	0.000018	-0.000022
b12	0.000026	0.000013	0.000013	0.000031	0.000022	0.000010	0.982678	0.0000530	0.000037	0.000040	0.000015
b13	0.000341	0.000292	0.000190	0.000398	0.000399	0.000029	0.000052	0.000000	0.000068	0.0000007	0.000101
b14	0.001751	-0.000277	-0.000245	-0.000171	0.000123	0.000004	-0.982681	-0.000002	-0.000078	-0.000065	-0.000073
b15	-0.000276	-0.000083	-0.000130	0.000099	0.000119	-0.000022	-0.000036	-0.000035	-0.000041	0.000000	-0.000020
a2	0.036701	-0.023827	-0.031593	-0.015773	0.039711	0.033194	-1.473399	-2.234050	-0.004672	-0.048186	-0.041720
b12	0.000026	0.000013	0.000013	0.000031	0.000022	0.000010	0.982678	0.0000530	0.-000037	0.000040	0.000015
b22	0.000003	0.000002	0.000003	0.000001	0.000010	0.000656	-3.929267	-0.0009599	-0.000001	0.000000	0.000001
b23	0.000015	0.000018	0.000019	0.000011	0.000016	-0.000228	-0.001003	0.0004547	0.0000727	0.000030	0.000058
b24	-0.000029	-0.000026	-0.000028	-0.000029	-0.000033	-0.000370	1.964568	0.0001931	-0.000084	-0.000073	-0.000058
b25	-0.000015	-0.000008	-0.000007	-0.000014	-0.000015	-0.000069	0.983024	0.000259	-0.000025	0.000002	-0.000016
a3	0.881138	0.264121	0.127040	0.328333	0.913312	0.094009	0.566112	0.857867	-0.431638	0.650243	0.116289
b13	0.000341	0.000292	0.000190	0.000398	0.000399	0.000029	0.000052	0.000000	0.000068	0.000007	0.000101
b23	-0.000025	-0.000083	0.000019	0.000011	0.000016	-0.000228	-0.001003	0.0004547	0.0000727	0.000030	0.000058
b33	0.000318	0.000337	0.000335	0.000240	0.000328	0.000708	0.000883	0.000333	-0.000416	0.000568	0.001094
b34	-0.000356	-0.000340	-0.000355	-0.000380	-0.000471	-0.000315	0.000401	-0.000488	0.000130	-0.000121	-0.000984
b35	-0.000278	-0.000207	-0.000188	-0.000269	-0.000273	-0.000195	-0.000333	-0.000299	0.000145	-0.000484	-0.000269
a4	0.731611	0.380697	0.318860	0.421729	0.754075	0.311347	0.589518	0.724987	0.496487	0.255667	0.645411
b14	0.001751	-0.000277	-0.000245	-0.000171	0.000123	0.000004	-0.982681	-0.000002	-0.000078	-0.000065	-0.000073
b24	0.000039	-0.000026	-0.000028	-0.000029	-0.000033	-0.000370	1.964568	0.0001931	-0.000084	-0.000073	-0.000058
b34	-0.002376	-0.000340	-0.000355	-0.000380	-0.000471	-0.000056	0.000401	-0.000488	0.000130	-0.000121	-0.000984
b44	0.000687	0.000702	0.000680	0.000675	0.000465	0.000490	0.000530	0.000424	0.000198	-0.000265	0.001029
b45	-0.000100	-0.000059	-0.000052	-0.000095	-0.000084	-0.000068	-0.982819	-0.000127	-0.000167	-0.000006	0.000086
a5	1.506449	0.637239	0.498167	0.707166	1.531956	0.458056	1.15955	1.470017	0.796278	0.043842	0.176172
b15	-0.000276	-0.000083	-0.000130	0.000099	0.000119	-0.000022	-0.000036	-0.000035	-0.000041	0.000000	-0.000020
b25	0.000004	-0.000008	-0.000007	-0.000014	-0.000015	-0.000069	0.983024	0.000259	-0.000025	0.000002	-0.000016
b35	-0.000057	-0.000207	-0.000188	-0.000269	-0.000273	-0.000195	-0.000333	-0.000299	0.000145	-0.000484	-0.000269
b45	0.000076	-0.000059	-0.000052	-0.000095	-0.000084	-0.000068	-0.982819	-0.000127	-0.000167	-0.000006	0.000086
b55	0.000254	0.000357	0.000376	0.000278	0.000253	0.000353	0.000164	0.000202	0.000088	0.000487	0.000218
at1	0.001597	0.000632	0.000456	0.000725	0.001640	-0.000052	-0.000080	-0.000092	-0.000073	-0.000050	-0.000053
at2	-0.000019	0.000012	0.000016	0.000008	-0.000020	0.000484	0.001249	0.001636	0.000002	0.000025	0.000021
at3	-0.000446	-0.000132	-0.000063	-0.000165	-0.000463	-0.000046	-0.000286	-0.000434	0.000721	0.000173	-0.000057
at4	-0.000371	-0.000192	-0.000161	-0.000213	-0.000382	-0.000157	-0.000299	-0.000367	-0.000251	-0.000129	0.000173
at5	-0.000762	-0.000320	-0.000249	-0.000355	-0.000775	-0.000228	-0.000585	-0.000743	-0.000400	-0.000018	-0.000084
LLF	218.000	221.345	221.182	221.128	221.129	221.158	221.059	221.067	221.126	221.144	221.140
LR Test		6.6904	6.3640	6.2556	6.2586	6.3166	6.1182	6.1330	6.2526	6.2872	6.2796
Restrictions		3	3	3	3	3	3	3	3	3	3

Chi-sq for 3 df with 0.05 probability is 7.815

Table 3. Nonlinear Parameter Estimates of Translog Function Imposing Homogeneity, Symmetry, and Separability in Outputs.

Parameters	Unrestricted	(MA & PO) FOG,FEC,VO **1**	(MA & FOG) PO, FEC, VO **2**	(MA & FEC) PO, FOG, VO **3**	(MA & VO) PO, FOG, FEC **4**	(PO & FOG) MA, FEC, VO **5**	(PO & FEC) MA, FOG, VO **6**	(PO & VO) MA, FOG, FEC **7**	(FOG & FEC) MA, PO, VO **8**	(FOG & VO) MA, PO, FEC **9**	(FL & INT) FE, BLS, FRE **10**
a1	-1.099965	0.086836	0.179426	-0.074811	0.477784	0.474972	1.476241	0.340740	0.577516	0.417405	1.255777
b11	0.000252	0.000190	0.000198	0.000002	0.000035	0.000395	0.000143	0.000324	0.000259	0.000256	0.000355
b12	-0.000161	-0.000151	-0.000126	0.000002	0.000005	-0.000361	2.672874	-0.000149	-0.000226	-0.000219	-0.000209
b13	-0.000066	-0.000029	-0.000057	0.000001	0.000004	0.000003	-0.000101	-0.000122	0.000020	-0.000009	-0.000108
b14	-0.000019	-0.000013	-0.000018	-0.000009	-0.000026	0.000036	-2.672867	0.000024	-0.000037	-0.000028	-0.000041
b15	-0.000006	0.000002	0.000002	0.000003	-0.000019	-0.000073	-0.000049	-0.000078	-0.000016	-0.000000	0.0000004
a2	0.451256	0.101340	0.103089	0.180828	0.020269	-0.245287	-2.200737	-0.063046	0.101898	0.030728	0.326743
b12	-0.000161	-0.000151	-0.000126	0.000002	0.000005	-0.000361	2.672874	-0.000149	-0.000226	-0.000219	0.000209
b22	0.000228	0.000226	0.000200	0.000101	0.000102	0.000533	-10.691320	0.000124	0.000230	0.000234	0.000256
b23	-0.000059	-0.000063	-0.000064	-0.000090	-0.000090	-0.000170	-0.000103	-0.000009	0.000013	-0.000003	-0.000032
b24	-0.000015	-0.000015	-0.000014	-0.000015	-0.000018	-0.000084	5.345632	-0.000059	-0.000024	-0.000020	-0.000016
b25	0.000007	0.000002	0.000003	0.000003	0.000001	0.000082	2.672917	0.000092	0.000008	0.000008	0.000001
a3	0.420680	0.170812	0.090735	0.203587	0.075316	0.001995	0.453572	0.116629	-0.374102	0.008121	0.318857
b13	-0.000066	-0.000029	-0.000057	0.000001	0.000004	0.000003	-0.000101	-0.000122	0.000020	-0.000009	-0.000108
b23	-0.000059	-0.000089	-0.000064	-0.000090	-0.000090	-0.000170	-0.000103	-0.000009	0.000013	-0.000003	-0.000032
b33	0.000130	0.000126	0.000128	0.000099	0.000100	0.000167	0.000148	0.000140	-0.000078	0.000047	0.000151
b34	-0.000011	-0.000011	-0.000009	-0.000012	-0.000015	0.000001	0.000056	-0.000005	0.000030	-0.000019	-0.000011
b35	0.000006	0.000003	0.000001	0.000002	0.000001	-0.000001	0.000000	-0.000005	0.000016	-0.000016	-0.000001
a4	1.173156	0.646797	0.633541	0.690711	0.326417	0.773028	1.206977	0.638580	0.702304	0.565149	-0.989035
b14	-0.000019	-0.000013	-0.000018	-0.000009	-0.000026	0.000036	-2.672867	0.000024	-0.000037	-0.000028	-0.000041
b24	-0.000015	-0.000015	-0.000014	-0.000015	-0.000018	-0.000084	5.345632	-0.000059	-0.000024	-0.000020	-0.000016
b34	-0.000011	-0.000011	-0.000009	-0.000012	-0.000015	0.000000	0.000056	-0.000005	0.000030	-0.000019	-0.000011
b44	0.000073	0.000068	0.000070	0.000066	0.000064	0.000078	0.000069	0.000071	0.000061	0.000067	0.000100
b45	-0.000029	-0.000029	-0.000029	-0.000030	-0.000005	-0.000030	-2.672891	-0.000031	-0.000030	0.000001	-0.000031
a5	0.054873	-0.005786	-0.006791	-0.000315	0.100214	-0.004708	0.063947	-0.032903	-0.007616	-0.021403	0.087658
b15	-0.000006	0.000002	0.000002	0.000003	-0.000019	-0.000073	-0.000049	-0.000078	-0.000016	-0.000015	0.000004
b25	0.000007	0.000002	0.000003	0.000003	0.000001	0.000082	2.672917	0.000092	0.000008	0.000008	0.000001
b35	0.000006	0.000003	0.000001	0.000002	0.000001	-0.000001	0.000000	-0.000005	0.000016	-0.000016	0.000001
b45	-0.000029	-0.000029	-0.000029	-0.000030	-0.000005	-0.000030	-2.672891	-0.000031	-0.000030	0.000001	-0.000031
b55	0.000022	0.000022	0.000022	0.000022	0.000022	0.000021	0.000022	0.000021	0.000022	0.000022	0.000025
at1	0.001065	0.000461	0.000414	0.000544	0.000506	-0.000237	-0.000746	-0.000168	-0.000289	-0.000208	-0.000635
at2	-0.000229	-0.000051	-0.000052	-0.000092	-0.000083	0.000626	0.001620	0.000532	-0.000051	-0.000015	-0.000165
at3	-0.000214	-0.000087	-0.000046	-0.000103	-0.000099	-0.000001	-0.000230	-0.000059	0.000691	0.000497	-0.000162
at4	-0.000595	-0.000327	-0.000320	-0.000349	-0.000328	-0.000391	-0.000612	-0.000323	-0.000355	-0.000285	0.001006
at5	-0.000027	0.000003	0.000004	0.000001	0.000005	0.000003	-0.000032	0.000017	0.000004	0.000011	-0.000044
LLF	218.000	221.0628	221.0281	221.0357	221.0091	221.0235`	221.0145	221.0094	221.0398	221.0090	221.0069
LR Test		6.1256	6.0562	6.0714	6.0182	6.0470	6.0290	6.0188	6.0796	6.0180	6.0138
Restrictions		3	3	3	3	3	3	3	3	3	3

Chi-sq for 3 df with 0.05 probability is 7.815

References:

Berndt, E. R., and L. R. Christensen. "The Translog Function and the Substitution of Equipment, Structures and Labor in U.S. Manufacturing 1929-1968." *Journal of Econometrics*. 1(1973): 81-114.

Berndt, E. R., and L. R. Christensen. "Testing for the Existence of a Consistent Aggregate Index of Labor Inputs." *American Economic Review*. 64(1974): 391-404.

Kwiatkowski, D., P. C. B. Phillips, P. Schmidt and Y.Shin. "Testing the Null Hypothesis o f Stationarity Against the Alternative of a Unit root." *Journal of Econometrics*. 54(1992):159-178.

Leontief, W, 1947, Introduction to a Theory of the Internal Structure of Functional Relationships, *Econometrica*, 15, 361-373.

Phillips, P. C. B., and P. Perron. "Testing for a Unit Root in Time Series Regression." *Biometrika*. 75(1988): 335-46.

Shaik, Saleem. "*Unpublished Dissertation*, Dept. of Agriculture Economics, University of Nebraska-Lincoln, May 1998.

Sono, M, 1961, The Effect of price changes on the demand and supply of separable goods, *International Economic Review*, 2, 239-271.

Woodland, A.D, 1978, On Testing Weak Separability, *Journal of Econometrics*, 8, 383-398.