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Autocorrelation effects of seemingly unrelated regression (sur) model on some estimators

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ABSTRACT

The seemingly unrelated regression (SUR) proposed by Zellner consists of L regression equations each of which satisfies the assumptions of the standard regression model. These assumptions are not always satisfied mostly in Economics, Social Sciences and Agricultural Economics which may lead to adverse consequences on the estimator parameters properties. Literature has revealed that multicollinearity often affects the efficiency of SUR estimators and the efficiency in the SUR formulation increases, the more the correlations between error vector differ from zero and the closer the explanatory variables for each response being uncorrelated. This study therefore examined the effect of correlation between the error terms and autocorrelation on seven methods of parameter estimation in SUR model using Monte Carlo approach.

A two equation model was considered in which the first equation has the presence of autocorrelation and correlation between the error terms exists between the two equations. The levels of correlation between the error terms were specified as CR = -0.99, -0.9, -0.8, -0.6, -0.4, -0.2, 0, +0.2, +0.4, +0.6, +0.8, +0.9 and +0.99 and autocorrelation levels RE= -0.99, -0.9, -0.8, -0.6, -0.4, -0.2, 0, +0.2, +0.4, +0.6, +0.8, +0.9 and +0.99 A Monte Carlo experiment of 1000 trials was carried out at five sample sizes 20, 30, 50, 100 and 250. The seven estimation methods; Ordinary Least Squares (OLS), Cochran – Orcut (GLS2), Maximum Likelihood Estimator (MLE), Multivariate Regression, Full Information Maximum Likelihood (FIML), Seemingly Unrelated Regression (SUR) Model and Three Stage Least Squares (3SLS) were used and their performances were critically examined. Finite properties of estimators' criteria such as bias, absolute bias, variance and mean squared error were used for methods comparison.

The results show that the performances of the estimators cannot be solely determined by the evaluation given by bias criterion because it always behaves differently from other criteria. For the eight different cases considered in this study, it was observed that when the sample size is small (i.e 20 or 30) there is high variability among the estimators but as the sample size increases the variance of the estimator decreases and the performances of the estimators become asymptotically the same.

In the presence of correlation between the error terms and autocorrelation, the estimator of MLE is preferred to estimate all the parameters of the model at all the level of sample sizes.

KEYWORDS: *SUR, Autocorrelation, Error terms, mean square error, Bias, Absolute Bias, Variance.*

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I. INTRODUCTION

The seemingly unrelated regression (SUR) model is well known in the Econometric literature (Zellner, 1962, Srivastava and Giles, (1987), Greene (1993) but is less known elsewhere, its benefits have been explored by several authors and more recently the SUR model is being applied in Agricultural Economics (O' Dorell et al 1999), Wilde et al (1999). Its application in the natural and medical sciences is likely to increase once scientists in the disciplines are exposed to its potential.

The SUR estimation procedures which enable anefficient joint estimation of all the regression parameters was first reported byZellner (1962) which involves the application of Aitken's GeneralisedLeastsquares(AGLS), (Powell 1965) to the whole system of equations.Zellner (1962 & 1963), Zellner&Theil (1962) submitted that the joint estimationprocedure of SUR is more efficient than the equation-by-equation estimationprocedure of the Ordinary Least Square (OLS) and the gain in efficiency would bemagnified if the contemporaneous correlation between each pair of thedisturbances in the SUR system of equations is very high and explanatoryvariables (covariates) in different equations are uncorrelated. In other words, theefficiency in the SUR formulation increases the more the correlation betweenerror vector differs from zero and the closer the explanatory variables for eachresponse are to being uncorrelated.

After the much celebrated Zellner's joint generalized least squares estimator, several other estimators for different SUR systems were developed by manyscholars to address different situations being investigated. For instance, Jackson(2002) developed an estimator for SUR system that could be used to modelelection returns in a multiparty election. Sparks (2004) developed a SURprocedure that is applicable to environmental situations especially when missingand censored data are inevitable. In share equation systems with randomcoefficients, Mandy & Martins-Filho (1993) proposed a consistent andasymptotically efficient estimator for SUR systems that have additiveheteroscedastic contemporaneous correlation. They followed Amemiya (1977) byusing Generalized Least Squares (GLS) to estimate the parameters of the covariance matrix. Furthermore, Lang, Adebayo &Fahrmeir (2002), Adebayo(2003), and Lang *et al* (2003) in their works also extended the usual parametricSUR model to Semiparametric SUR (SSUR) and Geoadditive SUR models withina Bayesian context. Also O'Donnell *et al* (1999) and Wilde *et al* (1999) developedSUR estimators that are applicable in Agricultural Economics. More recently,Foschi (2004) provided some new numerical procedures that could successively and efficientlysolve a large scale of SUR model..In all the estimation procedures developed for different SUR situations asreported above, Zellner's basic recommendation for high contemporaneouscorrelation between the error vectors with uncorrelated explanatory variableswithin each response equations was also maintained. However, in most practical situations, the explanatoryvariables across the different equations in SUR systems are often correlated.Also, it may be necessary to jointly regress the demand for two or morecomplementary products like automobiles and gasoline on peoples' income andexpenditures on other products within the SUR framework. While the twodemands (responses) would obviously correlate through their error, satisfying thefirst basic requirement of SUR estimation, people's income and their expenditureon other products should not be expected to be uncorrelated thereby, violatingthe second important condition. Therefore, the existence of this kind ofrelationship needed to be recognized and accorded proper management withinthe SUR context such that the efficiency of SUR estimator would not becompromised.It is now obvious, due to several instances of SUR highlighted above, that theindependent variables are often correlated (collinear).

The seemingly unrelated regression proposed by Zellner (Zellner; 1962) consists of L regression equations each of which satisfies the assumptions of the standard regression model:

$$\begin{aligned} y_1 &= X_1\beta_1 + u_1 \\ y_2 &= X_2\beta_2 + u_2 \\ &\;\;. \quad . \quad . \\ &\;\;. \quad . \quad . \\ y_L &= X_L\beta_L + u_L \end{aligned} \qquad (1.1)$$

Wherey_i and u_i are Nx1 vectors and X_i is aNxK matrix. Notice that by stacking all equations together we can write this system as

$$\begin{pmatrix} y_1 \\ . \\ . \\ . \\ y_L \end{pmatrix} = \begin{pmatrix} X_1 \ldots\ldots\ldots\ldots 0 \\ . \quad . \\ . \qquad . \\ . \qquad\quad . \quad 0 \\ 0 \ldots\ldots\ldots\ldots X_L \end{pmatrix} \begin{pmatrix} \beta_1 \\ . \\ . \\ . \\ \beta_L \end{pmatrix} = \begin{pmatrix} u_1 \\ . \\ . \\ . \\ u_L \end{pmatrix} \qquad (1.2)$$

LNx1 $\quad$ LNx$\sum_i k_i$ $\quad$ $\sum_i k_i$x1 $\quad$ LNx1

$$Y = X\beta + U \qquad (1.3)$$

So we stack all the equations together into a system of the OLS form in (1.3). This suggests as an estimation procedure to run OLS on this system, i.e to consider

$$\hat{\beta} = \left(X^{\prime} X\right)^{-1} X^{\prime} Y$$

1.2 Efficiency of SUR model for estimating regression coefficients.

Note that if either $\sigma_{ij} = 0$ for all $j \neq i$ or $X_i = X_j$ for all $j \neq i$, then, the two model formulations produce estimator identical to

$$\beta_j = (X_j^{/} X_j)^{-1} X_j^{/} Y_j \text{ for j=1,2,…,p}$$

The efficiency in the SUR formulation increases, the more the correlations between error vector differ from zero and the closer the explanatory variables for each response being uncorrelated (e.g. see Sparks (1987)) discussed how to select variables and parameter estimators for the SUR model. The standard errors for the set of the regression parameter estimates in the SUR formulation are given by the diagonal elements of $(X^{/}\sum^{-1}X)^{-1}$ while for the unrelated formulation they are the appropriate diagonal elements of $(X_j^{/} X)^{-1}$ for j=1,2…,p. These can be used to gain an idea of the relative merits of the SUR model formulation for estimating the regression parameters of the model.

Generally when $\sigma_{ij} = 0$ and the covariances are known, it can be shown that the diagonal elements of $(X_j^{/} X)^{-1}$ are larger than the corresponding diagonal elements of $(X^{/}\sum^{-1}X)^{-1}$ for each j. The mean square error of prediction using the generalized least squares estimate is smaller. This is not generally true when the covariances are unknown but depend on the sample size n (Zellner, 1963; Kmenta and Gilbert, 1968; Revankar, 1974 ; Mehta and Swamy ,1976; and Maeshiro ,1980). When fitting regression models with small sample sizes, is unlikely that the seemingly unrelated regression formulation and related generalized least squares estimates are going to add much value.

However, the larger the sample size, the more reliable the estimate of σ_{ij} and hence the more likely an advantage is gained from the seemingly unrelated regression formulation of the model.

Consequently, this study examines the performances of some estimation methods in Seemingly Unrelated Regression model in the presence of autocorrelation with the intention of studying their effects on the estimators and identifying the preferred estimator(s) of the model parameters.

Very specifically, the study aims at the following:

(i) Examine the effect of sample size on the performance of the estimators
(ii) Examine the effect of autocorrelation (RE) and correlation between the error terms (CR) on the performance of seven estimators.
(iii) Identify the estimator that yields the most preferred estimates under separate or joint influence of the three correlation effects under consideration.

II. THE MODEL FORMULATION

The Seemingly Unrelated regression (SUR) Model used in this research work is given as

$$y_{1t} = \beta_{01} + \beta_{11}x_{1t} + \beta_{12}x_{2t} + u_{1t} \quad (3.1)$$

where $u_{1t} = \rho u_{1(t-1)} + e_{1t}$, $e_{1t} \approx (0, \sigma^2)$.

$$y_{2t} = \beta_{02} + \beta_{21}x_{1t} + \beta_{22}x_{3t} + u_{2t} \ , \ u_{2t} \approx N(0, \sigma^2) \quad (3.2)$$

NOTE: (1) Autocorrelation exists in equations (3.1)
(2) There is correlation between U_1 and U_2 of the two equations
(3) There is no correlation between X_1 and X_3 in equation (3.2), thus, equation (3.2) appears as control equation.

III. EQUATION USED FOR GENERATING VALUES IN SIMULATION

The equation used for generating values of the variables in the simulation study as proposed by Ayinde K.(2007) is given below

Suppose $W_i \sim N(\mu, \sigma_i^2) \quad i = 1,2$. If these variables are correlated, then, W_1 and W_2 can be generated with the equations

$$W_1 = \mu_1 + \sigma_1 z_1$$
$$W_2 = \mu_2 + \rho\sigma_2 z_1 + \sigma_2 z_2 \sqrt{1-\rho^2} \qquad (3.3)$$

whereZ_i~N(0,1) i = 1,2 and $|\rho| < 1$ is the value of the correlation between the two variables.

3.1 Other Specifications

1. Sample Size(n) of 20, 30, 50, 100 and 250 were used in the simulation
2. The following levels were used for the correlations studied:
   a. Autocorrelation(RE) : -0.99, -0.9,-0.8, -0.6, -0.4, -0.2, 0, 0.2, 0.4, 0.6, 0.8,0.9, 0.99
   b. Correlation between error term (CR) : -0.99, -0.9,-0.8, -0.6, -0.4, -0.2, 0, 0.2, 0.4, 0.6, 0.8, 0.9, 0.99
   c. Replication (RR) : we make use of 1000 replications
   d. Two RUNS were done for the simulations which were averaged at analysis stage.

3.2 Criteria for comparism

Evaluation and comparison of the seven (7) estimators were examined using the finite sampling properties of estimators which include Bias (BB), Absolute Bias (AB), Variance (VB) and the Mean Square Error (MB) criteria.

Mathematically, for any estimator $\hat{\beta}_i \; of \; \beta_i$ of model (3.1) & (3.2)

(i) $\bar{\hat{\beta}}_i = \frac{1}{R}\sum_{j=1}^{R}\hat{\beta}_{ij}$ $\qquad$ $(ii)\, Bias\left(\hat{\beta}_i\right) = \frac{1}{R}\sum_{j=1}^{R}\left(\hat{\beta}_{ij} - \beta_j\right) = \bar{\hat{\beta}}_i - \beta_i$

$(iii)\, AB\left(\hat{\beta}_i\right) = \frac{1}{R}\sum_{j=1}^{R}\left|\hat{\beta}_{ij} - \beta_j\right|$ $\quad (iv) Var\left(\hat{\beta}_i\right) = \frac{1}{R}\sum_{j=1}^{R}\left(\hat{\beta}_{ij} - \bar{\hat{\beta}}_i\right)^2$

$(v)\, MSE\left(\hat{\beta}_i\right) = \frac{1}{R}\sum_{j=1}^{R}\left(\hat{\beta}_{ij} - \beta_i\right)^2$, for i = 0, 1, 2 and j = 1,2,… , R.

Using a computer program which was written with TSP software package to estimate all the model parameters and the criteria, the performances of seven estimation methods; Ordinary Least Squares (OLS), Cochran – Orcut (COCR), Maximum Likelihood Estimator (MLE), Multivariate Regression, Full Information Maximum Likelihood (FIML), Seemingly Unrelated Regression (SUR) and Three Stage Least Squares (3SLS) were examined by subjecting the results obtained from each finite properties of the estimators into a multi factor analysis of variance model. Consequently, the highest order significant interaction effect which has "method" as a factor is further examined using the Least Significance Difference (LSD) test. The estimated marginal mean of the factor was investigated out at a particular combination of levels of the correlations in which estimators were preferred. An estimator is most preferred at a particular combination of levels of the correlation if the marginal means is the smallest. All estimators whose estimated marginal means are not significantly different from the most preferred are also preferred.

IV. RESULTS

The summary of results from the Analysis of variance tables of the criteria showing the effect of the estimators, correlation between the error term sand autocorrelation on β_i are presented in Table 4.5.1 below.

TABLE 4.5.1: ANOVA for sample size of 20

n	SOV	EQN	β_i	df	TYPE III SUM OF SQUARES			
					Bias	**Absolute Bias**	**Variance**	**Mean Square**
20	RE	1	β01	12	892.446***	115926.509***	2445822.237***	3951716.298***
			β11	12	.029***	32.515***	95.927***	96.084***
			β21	12	.012	24.373***	23.509***	87.017***
		2	β02	12	.112	103.206***	122116.658***	128548.527***
			β12	12	.063	.628***	.093***	.091***
			β22	12	.132***	.605***	.113***	.125***
	CR	1	β01	12	.670	.003	.003	.005
			β11	12	.001	6.016E-5	8.532E-5	8.897E-5
			β21	12	7.468***	3.807***	3.176***	5.004***
		2	β02	12	3.519	45.130***	113879.706***	119769.347***
			β12	12	.513***	.032	.224***	.032***
			β22	12	3.006***	.404***	.139***	.011***
	M	1	β01	6	315.786***	83483.317***	4080093.223***	6466311.896***
			β11	6	.000	4.612***	5.977***	5.990***
			β21	6	.007	5.564***	2.320***	9.779***
		2	β02	6	.042	45.091***	232859.705***	243905.100***
			β12	6	.476***	.141***	.002***	.006***
			β22	6	.086***	2.096***	.361***	.391***
	RE*CR		β01	144	.458	.026	.021	.037
			β11	144	.001	.000	.001	.001
			β21	144	5.046	1.759	7.126***	19.761**
			β02	144	5.506	195.745***	360069.375***	378405.077***
			β12	144	.048	.423***	.054***	.052***
			β22	144	.019	.256***	.053***	.052***
	RE*M	1	β01	72	5540.631***	454326.369***	1.038E7***	1.557E7***
			β11	72	.011	15.816***	40.207***	40.276***
			β21	72	.014	15.506***	13.080***	56.497***
		2	β02	72	.675	199.404***	716966.573***	755012.778***
			β12	72	.201	.078	.007**	.007
			β22	72	.116***	.529***	.131***	.134***
	CR*M	1	β01	72	.515	.002	.002	.004
			β11	72	.001	4.520E-5	6.406E-5	6.680E-5
			β21	72	5.943	2.889***	2.473**	3.902
		2	β02	72	3.940	196.384***	683436.471***	721549.650***
			β12	72	.243	.407***	.004	.022***
			β22	72	.148***	1.340***	.289***	.246***
	RE*CR*M	1	β01	864	.348	.020	.017	.030
			β11	864	.001	.000	.000	.000
			β21	864	3.917	1.358	5.731	15.895
		2	β02	864	33.150	884.547***	2141981.317***	2251208.104***
			β12	864	.072	.059	.006	.005
			β22	864	.082	.433	.102	.103
	ERROR	1	β01	1183	3595.810	8759.488	8834975.252	8871627.167
			β11	1183	.245	11.841	50.548	50.564
			β21	1183	84.299	23.465	28.185	128.394
		2	β02	1183	214.134	135.089	1384793.426	1438377.807
			β12	1183	16.754	2.534	.089	.150
			β22	1183	.659	1.140	.197	.256
	TOTAL	1	β01	2365	10346.814	662542.071	2.575E7	3.487E7
			β11	2365	.288	64.783	192.657	192.913
			β21	2365	106.707	78.742	85.610	326.275
		2	β02	2365	261.126	1804.890	5756781.519	6037516.906
			β12	2365	18.374	4.302	.480	.365
			β22	2365	4.259	6.818	1.387	1.320

***** Significant at 0.05 level of significance**

**** Significant at 0.1 level of significance**

4.5.1 EFFECT ON β_0

Consequently in equation 1, it can be inferred that the performances of the estimators are affected by autocorrelation under all criteria. The results of the LSD further test visa- vice their estimated marginal means revealed that all estimatorsexceptGLS2 are preferred to estimate β_0 at all the levels of autocorrelation.

In equation 2, the estimators are affected by autocorrelation and correlation between the error terms under all the criteria except in bias criterion. The results of the LSD further test visa- vice their estimated marginal means as shown in revealed that all estimatorsexceptGLS2 are preferred to estimate β_0 at all levels of autocorrelation and correlation between the error terms.

EFFECT ON β_1

Consequently in equation 1, it can be inferred that the performances of the estimators are affected by autocorrelation under all criteria except for bias. The results of the LSD further test visa- vice their estimated marginal means revealed that GLS2 and MLE estimators are preferred to estimate β_1 at all the levels of autocorrelation.

In equation 2, the estimators are affected by autocorrelation and correlation between the error terms under all the criteria except in bias criterion. The results of the LSD further test visa- vice their estimated marginal means revealed that all estimators are preferred to estimate β_1 at all levels of autocorrelation and correlation between the error terms.

EFFECT ON β_2

Consequently in equation 1, it can be inferred that the performances of the estimators are affected by autocorrelation and correlation between the error terms. The results of the LSD further test visa- vice their estimated marginal means revealed that GLS2 and MLE estimators are preferred to estimate β_2 at all the levels of autocorrelation.

In equation 2, the estimators are affected by autocorrelation and correlation between the error terms under all the criteria. The results of the LSD further test visa- vice their estimated marginal means revealed that SUR and 3SLS estimators are preferred to estimate β_2 at all levels of autocorrelation and correlation between the error terms EXCEPT for -0.9 and -0.8 levels of correlation between the error terms under bias that is significantly different.

Summarily, GLS2, MLE, SUR and 3SLS are preferred to estimate the model at sample size of 20

TABLE4.5.2: ANOVA for the sample size of 30

n	SOV	EQN	β_i	df	TYPE III SUM OF SQUARES			
					Bias	**Absolute Bias**	**Variance**	**Mean Square**
30	RE	1	β01	12	1368.073***	165272.612***	1.008E12***	1.009E12***
			β11	12	.029***	37.228***	125.437***	127.031***
			β21	12	.075	29.385***	69.897***	83.604***
		2	β02	12	.095	51.854***	6251392.175***	6258276.131***
			β12	12	.005	.334***	.025***	.025***
			β22	12	.011	.175***	.008***	.043***
	CR	1	β01	12	.147	10.954	1.102E8	1.102E8
			β11	12	.271***	.043	.144	.137
			β21	12	1.980***	5.721***	5.706***	5.296***
		2	β02	12	.200	13.613***	5187309.671***	5192414.391***
			β12	12	2.338***	.012	.096***	.001
			β22	12	.695	15.467***	.018***	2.358***
	M	1	β01	6	187.891***	82932.248***	6.302E11	6.312E11***
			β11	6	.013**	5.296***	7.289***	7.403***
			β21	6	.009	4.316***	8.386***	8.620***
		2	β02	6	.007	9.955***	5467535.629***	5474905.799***
			β12	6	.029	.034	.004***	.004
			β22	6	.001	.114***	.052***	.040***
	RE*CR		β01	144	1.846	131.775	1.362E9	1.363E9
			β11	144	.143**	.163	1.140	1.113
			β21	144	1.132	2.945***	20.161***	18.791***
			β02	144	1.196	70.924***	3.657E7***	3.661E7***
			β12	144	.024	.222	.016***	.016
			β22	144	.034	.108	.005***	.016

	RE*M	1	β01 β11 β21	72 72 72	7396.149*** .012 .045	696530.165*** 17.083*** 15.567***	6.041E12*** 51.754*** 46.940***	6.050E12*** 52.348*** 48.988***
		2	β02 β12 β22	72 72 72	583 .002 .028	43.075*** .034 .105	3.735E7*** .003** .016***	3.739E7*** .004 .026
	CR*M	1	β01 β11 β21	72 72 72	.988 .203*** 1.491***	45.595 .032 4.279***	6.622E8 .108 4.281	6.623E8 .103 3.968
		2	β02 β12 β22	72 72 72	.863 .012 .009	40.424*** .085 .414***	3.189E7*** .004*** .035***	3.193E7*** .005 .065
	RE*CR*M	1	β01 β11 β21	864 864 864	10.321 .107 .853	546.890 .121 2.202	8.173E9 .855 15.134	8.174E9 .835 14.102
		2	β02 β12 β22	864 864 864	7.135 .001 .014	249.877*** .041 .174	2.190E8*** .003 .013***	2.192E8*** .003 .030
	ERROR	1	β01 β11 β21	1183 1183 1183	3150.131 .916 13.579	4943.259 19.633 13.356	4.933E10 110.203 69.548	5.003E10 112.032 66.923
		2	β02 β12 β22	1183 1183 1183	44.274 7.545 123.484	32.901 6.245 4.942	2.213E7 .041 .011	2.212E7 .357 1.476
	TOTAL	1	β01 β11 β21	2365 2365 2365	12115.647 1.693 19.164	950459.247 79.598 77.788	7.739E12 296.927 240.059	7.751E12 301.002 250.302
		2	β02 β12 β22	2365 2365 2365	54.357 9.965 124.277	512.744 7.003 21.562	3.639E8 .192 .158	3.642E8 .413 4.059

4.5.2 EFFECT ON β_0

Consequently in equation 1, it can be inferred that the performances of the estimators are affected by autocorrelation under all criteria. The results of the LSD further test visa- vice their estimated marginal means revealed that all estimators are preferred to estimate β_0 at all the levels of autocorrelation exceptfor GLS2 which differed significantly at 0.8, 0.9 and 0.99 autocorrelation levels.

In equation 2, the estimators are affected by autocorrelation and correlation between the error terms under all the criteria except in bias criterion. The results of the LSD further test visa- vice their estimated marginal means revealed that all estimators are preferred to estimate β_0 at all levels of autocorrelation and correlation between the error terms exceptfor GLS2 which differed significantly at autocorrelation level of 0.9 and correlation between the error terms of 0.99 under bias criterion.

EFFECT ON β_1

Consequently in equation 1, it can be inferred that the performances of the estimators are affected by autocorrelation and correlation between the error terms under all criteria. The results of the LSD further test visa- vice their estimated marginal means revealed that GLS2 and MLE estimators are preferred to estimate β_1 at all the levels of autocorrelation and correlation between the error terms.

In equation 2, the estimators are affected by autocorrelation and correlation between the error terms under variance criterion. The results of the LSD further test visa- vice their estimated marginal means revealed that GLS2 and MLE estimators are preferred to estimate β_1 at all levels of autocorrelation and correlation between the error terms.

EFFECT ON β_2

Consequently in equation 1, it can be inferred that the performances of the estimators are affected by autocorrelation and correlation between the error terms under all criteria. The results of the LSD further test visa- vice their estimated marginal means revealed that GLS2 and MLE estimators are preferred to estimate β_1 at all the levels of autocorrelation and correlation between the error terms except that we have to be cautious when using them at some levels of autocorrelation.

In equation 2, the estimators are affected by autocorrelation and correlation between the error terms under variance criterion. The results of the LSD further test visa- vice their estimated marginal means revealed that all estimators except OLS, GLS2 and MLE estimators are preferred to estimate β_2 at all levels of autocorrelation and correlation between the error terms.

Summarily, GLS2 and MLE estimators are preferred to estimate the model at sample size of 30

TABLE4.5.3: ANOVA for sample size of 50

n	SOV	β_i	df	TYPE III SUM OF SQUARES			
				Bias	**Abs.Bias**	**Var**	**MSE**
50	RE	β01	12	452.571***	74575.669***	1.764E11***	1.770E11***
		β11	12	.050***	18.709***	24.791***	24.976***
		β21	12	1.014***	6.985***	1.255***	2.662***
		β02	12	.515***	35.964***	251158.322***	252591.912***
		β12	12	.417***	.167***	.004***	.007***
		β22	12	.129**	.174***	.001***	.003***
	CR	β01	12	1.992	234.178	1.404E9	1.406E9
		β11	12	.022***	.972***	1.780***	1.786***
		β21	12	5.131***	.177**	.052	.030
		β02	12	1.353***	6.205***	161713.711***	162539.579***
		β12	12	3.505***	1.093***	.026***	.024***
		β22	12	.221***	.373***	.003***	.003***
	M	β01	6	227.569***	24107.884***	8.971E10***	9.003E10***
		β11	6	.001	3.527***	2.193***	2.209***
		β21	6	.085	2.311***	.619***	.709***
		β02	6	.105***	1.285***	178487.825***	179459.300***
		β12	6	.021***	.003	.002***	8.218E-5
		β22	6	.023	.307***	.010***	.012***
	RE*CR	β01	144	23.036	2764.733	1.713E10	1.714E10
		β11	144	.019	4.251***	12.667***	12.699***
		β21	144	1.698	1.158	.538***	1.049***
		β02	144	2.520***	28.684***	1365792.064***	1373566.001***
		β12	144	.136***	.165***	.005***	.009
		β22	144	.058	.055	.001	.001
	RE*M	β01	72	3285.331***	280727.544***	1.056E12***	1.060E12***
		β11	72	.021	8.107***	10.064***	10.139***
		β21	72	.847	3.449***	1.724***	1.696***
		β02	72	2.363***	10.635***	1480512.907***	1488990.865***
		β12	72	.132***	.218***	.003***	.008***
		β22	72	.009	.064	.002***	.003
	CR*M	β01	72	11.459	1223.011	8.561E9	8.571E9
		β11	72	.016	.241	.671	.673
		β21	72	3.879***	.469	.307***	.207
		β02	72	1.161***	6.135***	982226.051***	987452.884***
		β12	72	.012	.092***	.002**	.007***
		β22	72	.010	.276***	.006***	.007***
	RE*CR*M	β01	864	137.160	14657.361	1.026E11	1.027E11
		β11	864	.013	1.423	4.996	5.009
		β21	864	1.263	.490	1.123	.968
		β02	864	13.881***	59.010***	8150369.132***	8196863.794***
		β12	864	.048	.067	.002	.003
		β22	864	.008	.050	.002	.002
	ERROR	β01	1183	6296.390	82375.378	8.427E11	8.460E11
		β11	1183	.278	8.667	23.218	23.233
		β21	1183	12.234	8.004	2.939	4.219
		β02	1183	4.175	9.073	1571334.088	1580748.512
		β12	1183	.661	.922	.026	.070
		β22	1183	6.136	1.510	.012	.043
	TOTAL	β01	2365	10435.662	480676.871	2.295E12	2.303E12
		β11	2365	.420	45.888	80.372	80.717
		β21	2365	26.153	23.042	8.557	11.540
		β02	2365	26.079	157.021	1.414E7	1.422E7
		β12	2365	4.946	2.729	.070	.128
		β22	2365	6.593	2.811	.038	.073

4.5.3.1 EFFECT ON β_0

Consequently in equation 1, it can be inferred that the performances of the estimators are affected by autocorrelation under all criteria. The results of the LSD further test visa- vice their estimated marginal means revealed that all estimators are preferred to estimate β_0 at all the levels of autocorrelation exceptfor GLS2 which differed significantly at 0.99 autocorrelation levels.

In equation 2, the estimators are affected by autocorrelation and correlation between the error terms under all the criteria. The results of the LSD further test visa- vice their estimated marginal means revealed that all estimators are preferred to estimate β_0 at all levels of autocorrelation and correlation between the error terms exceptfor GLS2 which differed significantly at autocorrelation level of 0.9 & 0.99 and correlation between the error terms of 0.99 under all criteria.

4.5.3.2 EFFECT ON β_1

Consequently in equation 1, it can be inferred that the performances of the estimators are affected by autocorrelation and correlation between the error terms under all criteria. The results of the LSD further test visa- vice their estimated marginal means revealed that GLS2 and MLE estimators are preferred to estimate β_1 at all the levels of autocorrelation and correlation between the error terms.

In equation 2, the estimators are affected by autocorrelation and correlation between the error terms under variance criterion. The results of the LSD further test visa- vice their estimated marginal means revealed that GLS2 and MLE estimators are preferred to estimate β_1 at all levels of autocorrelation and correlation between the error terms.

4.5.3.3 EFFECT ON β_2

Consequently in equation 1, it can be inferred that the performances of the estimators are affected by autocorrelation and correlation between the error terms. The results of the LSD further test visa- vice their estimated marginal means revealed that GLS2 and MLE estimators are preferred to estimate β_2 at all the levels of autocorrelation and correlation between the error terms.

In equation 2, the estimators are affected by autocorrelation and correlation between the error terms under all the criteria. The results of the LSD further test visa- vice their estimated marginal means revealed that all estimators except OLS,GLS2 and MLE estimators are preferred to estimate β_2 at all levels of autocorrelation and correlation between the error terms.

Summarily, GLS2 and MLE estimator are preferred to estimate the model at sample size of 50

TABLE 4.5.4: ANOVA for sample size of 100

n	SOV	β_i	df	TYPE III SUM OF SQUARES			
				Bias	**Abs.Bias**	**Var**	**MSE**
100	RE	β01	12	47.699	48743.394***	7.898E9***	7.945E9***
		β11	12	.022***	21.108***	33.739***	33.776***
		β21	12	.014	7.287***	3.435***	4.171***
		β02	12	.031	23.608***	27762.719***	27802.782***
		β12	12	.004	.122***	.002***	.002***
		β22	12	.007	.019***	.001***	.001***
	CR	β01	12	.001	.001	.000	.000
		β11	12	.011***	.002	.006	.006
		β21	12	1.366***	1.539***	.352***	.320***
		β02	12	.486	.139***	12228.857***	12185.714***
		β12	12	.047***	.692***	.018***	.016***
		β22	12	.057	1.315***	.002***	.019***
	M	β01	6	12.616	13036.510***	3.909E9***	3.932E9***
		β11	6	.005***	3.739***	2.145***	2.151***
		β21	6	.000	1.601***	.568***	.585***
		β02	6	.044	.218***	13231.759***	13252.284***
		β12	6	.003	.058***	.002***	.002***
		β22	6	.002	.095***	.004***	.005***
	RE*CR	β01	144	.001	.008	.002	.002
		β11	144	.022***	.026	.077	.077
		β21	144	.810***	.784***	1.083***	.978***
		β02	144	.204	15.466***	147798.362***	148004.003***
		β12	144	.011	.053***	.002***	.002***
		β22	144	.002	.021	.000***	.000
	RE*M	β01	72	151.558	156345.485***	4.691E10***	4.719E10***
		β11	72	.015***	9.522***	13.766***	13.781***

		β21	72	.005	4.081***	2.357***	2.457***
		β02	72	.167	2.498***	158513.192***	158738.340***
		β12	72	.011	.044***	.001***	.001***
		β22	72	.009	.029***	.001***	.001***
	CR*M	β01	72	.001	7.294E-6	5.759E-5	6.569E-5
		β11	72	.009***	.001	.004	.004
		β21	72	1.024***	1.158***	.264***	.240***
		β02	72	.063	1.170***	73197.801***	73298.063***
		β12	72	.001	.052***	.001***	.001***
		β22	72	.002	.123***	.002***	.002***
	RE*CR*M	β01	864	.001	.000	.001	.001
		β11	864	.018	.016	.058	.057
		β21	864	.610	.587	.813	.734
		β02	864	.899	13.854***	877548.891***	878767.713***
		β12	864	.011	.029	.001	.001
		β22	864	.005	.038	.001***	.001
	ERROR	β01	1183	3458.358	1982.236	5.755E10	5.739E10
		β11	1183	.034	8.157	27.089	27.121
		β21	1183	1.548	1.645	1.959	2.328
		β02	1183	28.879	4.729	142202.156	142616.134
		β12	1183	.422	.148	.005	.005
		β22	1183	13.178	.257	.000	.009
	TOTAL	β01	2365	3670.242	220115.863	1.163E11	1.165E11
		β11	2365	.137	42.568	76.883	76.972
		β21	2365	5.378	18.685	10.833	11.814
		β02	2365	30.774	61.678	1452558.902	1454739.728
		β12	2365	.510	1.199	.031	.030
		β22	2365	13.260	1.905	.012	.039

4.5.4.1 EFFECT ON β_0

Consequently in equation 1, it can be inferred that the performances of the estimators areaffected by autocorrelation under absolute bias, variance and mean square error criteria. The results of the LSD further test visa- vice their estimated marginal means revealed that all estimators are preferred to estimate β_0 at all the levels of autocorrelation exceptfor GLS2 which differed significantly at 0.99 autocorrelation levels.

In equation 2, the estimators are affected by autocorrelation and correlation between the error terms under all the criteria. The results of the LSD further test visa- vice their estimated marginal means revealed that all estimators are preferred to estimate β_0 at all levels of autocorrelation and correlation between the error terms exceptfor GLS2 which differed significantly at autocorrelation level of 0.99 and correlation between the error terms of -0.99 and +0.99 under all criteria considered.

4.5.4.2 EFFECT ON β_1

Consequently in equation 1, it can be inferred that the performances of the estimators areaffected by autocorrelation and correlation between the error terms under all criteria. The results of the LSD further test visa- vice their estimated marginal means revealed that GLS2 and MLE estimators are preferred to estimate β_1 at all the levels of autocorrelation and correlation between the error terms.

In equation 2, the estimators are affected by autocorrelation and correlation between the error terms under all the criteria. The results of the LSD further test visa- vice their estimated marginal means revealed that GLS2 and MLE estimators are preferred to estimate β_1 at all levels of autocorrelation and correlation between the error terms.

4.5.4.3 EFFECT ON β_2

Consequently in equation 1, it can be inferred that the performances of the estimators are affected by autocorrelation and correlation between the error terms under all criteria. The results of the LSD further test visa- vice their estimated marginal means revealed that GLS2 and MLE estimators are preferred to estimate β_2 at all the levels of autocorrelation and correlation between the error terms, although they too are significantly different at some limited levels of autocorrelation.

In equation 2, the estimators are affected by autocorrelation and correlation between the error terms under variance criterion. The results of the LSD further test visa- vice their estimated marginal means as shown in Table EB4.8 of appendix 5 revealed that all estimators except OLS, GLS2 and MLE estimators are preferred to estimate β_2 at all levels of autocorrelation and correlation between the error terms.

Summarily, GLS2, SUR and MLE estimator are preferred to estimate the model at sample size of 100

TABLE4.5.5: ANOVA for sample size of 250

n	SOV	β_i	df	TYPE III SUM OF SQUARES			
				Bias	**Abs.Bias**	**Var**	**MSE**
250	RE	β01	12	1.478***	4632.931***	1.059E8***	1.059E8***
		β11	12	.030***	6.158***	2.703***	2.730***
		β21	12	.001	2.812***	.540***	.658***
		β02	12	.003	6.709***	83.297***	83.466***
		β12	12	.319	.035***	17.412	.001**
		β22	12	.002	.021***	8.986E-5***	.000***
	CR	β01	12	.008	6.104E-5	8.877E-5	8.761E-5
		β11	12	.001	5.698E-5	3.105E-5	3.798E-5
		β21	12	.205***	.627***	.062***	.058***
		β02	12	.338***	.295***	30.040	29.626
		β12	12	.778**	.356***	17.229	.006***
		β22	12	.036	.303***	.000***	.001***
	M	β01	6	.190***	873.346***	5.133E7***	5.133E7***
		β11	6	7.732E-5	1.168***	.229***	.230***
		β21	6	.001	.583***	.102***	.105***
		β02	6	.001	.021	28.674	28.775
		β12	6	.182	.007	8.763	.000
		β22	6	.001	.073***	.001***	.001***
	RE*CR	β01	144	.005	.000	.001	.001
		β11	144	.012	9.808E-5	.000	.000
		β21	144	.176	.311**	.155***	.148***
		β02	144	.027	2.815***	352.222	353.150
		β12	144	3.609	.015	209.071	.000
		β22	144	.005	.012	6.516E-5***	.000
	RE*M	β01	72	2.434	10508.921***	6.160E8***	6.161E8***
		β11	72	.011***	2.858***	1.109***	1.120***
		β21	72	.001***	1.528***	.355***	.376***
		β02	72	.003	.195	344.710***	345.580***
		β12	72	1.811	.071	104.517	.001
		β22	72	.002	.042***	.000***	.000***
	CR*M	β01	72	.006	4.581E-5	6.662E-5	6.574E-5
		β11	72	.001	3.947E-5	2.313E-5	2.817E-5
		β21	72	.152**	.469***	.046	.044
		β02	72	.005	.090	162.122	162.533
		β12	72	1.763	.013	104.616	.000
		β22	72	.006	.075***	.001***	.001***
	RE*CR*M	β01	864	.004	.000	.001	.001
		β11	864	.009	8.591E-5	.000	.000
		β21	864	.131	.233	.116	.111
		β02	864	.055	1.121	1945.383	1950.633
		β12	864	21.396	.030	1254.431	.001
		β22	864	.004	.021	.000***	.000
	ERROR	β01	1183	3.854	16061.289	7.821E8	7.822E8
		β11	1183	.082	3.122	2.240	2.268
		β21	1183	1.781	2.054	.749	.792
		β02	1183	3.320	7.305	2945.654	2953.427
		β12	1183	37.560	1.475	1717.611	.034
		β22	1183	3.873	.314	6.234E-5	.003
	TOTAL	β01	2365	7.981	32077.122	1.555E9	1.556E9
		β11	2365	.146	13.305	6.281	6.348
		β21	2365	2.449	8.618	2.125	2.292
		β02	2365	3.756	18.552	5892.407	5907.490
		β12	2365	67.419	2.003	3433.660	.042
		β22	2365	3.929	.863	.003	.007

4.5.5.1 EFFECT ON β_0

Consequently in equation 1, it can be inferred that the performances of the estimators areaffected by autocorrelation under all criteria. The results of the LSD further test visa- vice their estimated marginal means revealed that all estimators are preferred to estimate β_0 at all the levels of autocorrelation exceptfor GLS2 which differed significantly at 0.99 autocorrelation levels.

In equation 2, the estimators are affected by autocorrelation under variance and mean square error criteria. The results of the LSD further test visa- vice their estimated marginal means revealed that all estimators are preferred to estimate β_0 at all levels of autocorrelation exceptfor GLS2 which differed significantly at autocorrelation level of 0.99 in both criteria considered.

Summarily, we can infer that all the estimators are preferred to estimate β_0 except GLS2 at all five sample sizes under consideration.

4.5.5.2 EFFECT ON β_1

Consequently in equation 1, it can be inferred that the performances of the estimators areaffected by autocorrelation under all criteria. The results of the LSD further test visa- vice their estimated marginal means revealed that GLS2 and MLE estimators are preferred to estimate β_1 at all the levels of autocorrelation.

In equation 2, the estimators are neither affected by autocorrelation nor correlation between the error terms under all criteria.

Summarily, we can infer that GLS2 and MLE estimators are preferred to estimate β_1 at all five sample sizes under consideration and at all levels of autocorrelation and correlation between the error terms.

4.5.5.3 EFFECT ON β_2

Consequently in equation 1, it can be inferred that the performances of the estimators areaffected by autocorrelation and correlation between the error terms under all criteria. The results of the LSD further test visa- vice their estimated marginal means revealed that GLS2 and MLE estimators are preferred to estimate β_2 at all the levels except at -0.99 and +0.99 correlation between the error terms under absolute bias.

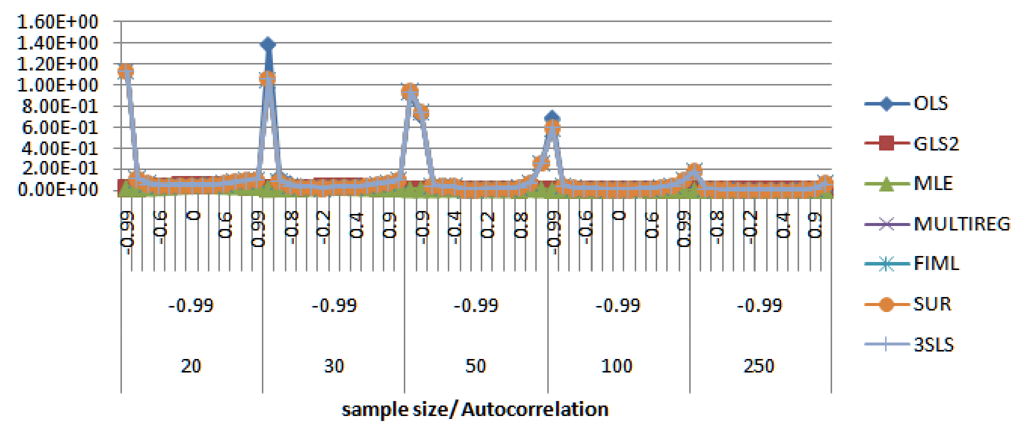
In equation 2, the estimators are affected by autocorrelation and correlation between the error terms under variance criterion. The results of the LSD further test visa- vice their estimated marginal means as shown in revealed that all estimators except OLS, GLS2 and MLE estimators are preferred to estimate β_2 at all levels of autocorrelation and correlation between the error terms.

Summarily, we can infer that GLS2 and MLE estimators are preferred to estimate β_2.

Summarily, MLE estimator is preferred to estimate the model at sample size of 250

Conclusively, the estimator of MLE is preferred to estimate all the parameters of the model in the presence of correlation between the error terms and autocorrelation at all the sample sizes.

Figure 7: Performaces of the estimators using MSE(B_{11}) at different levels of sanple size, correlation bet the error term and autocorrelation at CR = -0.99



In fig.7, the plot of MSE values against different sample sizes for all the estimators revealed appreciable increase in efficiency (lower MSE) of the estimators as sample size increases with MLE estimator showing a better performance over GLS2.

V. SUMMARY OF THE FINDINGS

5.1.5 When there is correlation between the error terms and Autocorrelation

The summary of results from the Analysis of variance tables of the criteria showing the performances of the estimators and sample sizes on parameters of the two equation model when there is presence of correlation between the error terms and autocorrelation are presented in Table 5.1.5

Table 5.1.5: Summary of results when there is presence of correlationbetweenthe error terms and autocorrelation

n	EQN	PARAMETERS	PREFERRED	OVERALL ASSESSMENT	MOST PREFERRED
20	1	β_{01}	All except CORC	CORC, MLE	MLE
		β_{11}	CORC, MLE		
		β_{21}	CORC, MLE		
	2	β_{02}	All except CORC	All except CORC	
		β_{12}	All		
		β_{22}	SUR, 3SLS		
30	1	β_{01}	All except CORC	CORC, MLE	MLE
		β_{11}	CORC, MLE		
		β_{21}	CORC, MLE		
	2	β_{02}	All except CORC	MLE.SUR,3SLS	
		β_{12}	CORC, MLE		
		β_{22}	MulReg,FIML,SUR,3SLS		
50	1	β_{01}	All	CORC, MLE	CORC, MLE
		β_{11}	CORC, MLE		
		β_{21}	CORC, MLE		
	2	β_{02}	All	CORC,MLE.SUR,3SLS	
		β_{12}	CORC, MLE		
		β_{22}	MulReg,FIML,SUR,3SLS		
100	1	β_{01}	All except CORC	CORC, MLE	MLE
		β_{11}	CORC, MLE		
		β_{21}	CORC, MLE		
	2	β_{02}	All except CORC	MLE,MulReg,FIML,SUR,3SLS	
		β_{12}	CORC, MLE		
		β_{22}	MulReg,FIML,SUR,3SLS		
250	1	β_{01}	All except CORC	CORC, MLE	MLE
		β_{11}	CORC, MLE		
		β_{21}	CORC, MLE		
	2	β_{02}	All except CORC	All except CORC	
		β_{12}	All		
		β_{22}	MulReg,FIML,SUR,3SLS		

From table 5.1.5 when there is presence of correlation between the error terms and autocorrelation in the model under the equation 1 in all the five sample sizes, all the estimating methods except CORC are equally good in estimating the parameters β_{01}, meanwhile, for parameters β_{11}andβ_{21} CORC and MLE estimators are good for their estimation thus it can be concluded that MLE estimating method is preferred in estimating all the model parameters in equation 1.

Under equation 2, it was observed that all estimation methods except CORC are good in estimating all the parameters of the model at all level of the sample sizes.

However, observing the two equations together, we can conclude that MLE is the most preferred in estimating all the parameters of the two equations among all the estimation methods used.

5.2. RECOMMENDATION

The research work has revealed that MLE method of estimation is the most preferred estimator in estimating all the parameters of the model based on the four criteria used namely; Bias, Absolute Bias, Variance and Mean Square Error under the five level of sample sizes considered. It can therefore be recommended that when the validity of other correlation assumptions cannot be authenticated in seemingly unrelated regression model, the most preferred estimator to use is MLE. Meanwhile, for any SUR model without any form of correlation, SUR estimation method is most preferred.

5.3. SUGESTION FOR FURTHER STUDY

This study considered two- equation model with two depended variables in each equation, a future research may consider situation in which more than two equations and as many depended variables as possible.

One may still consider a Bayesian estimation approach as one of the estimation methods in order to test its own potential.

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