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# APPLICATION OF OKUN'S LAW ON NIGERIAN ECONOMY: EVIDENCE FROM SPATIAL ECONOMETRICS ANALYSIS

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**ABSTRACT**
Spatial econometrics should be viewed in a wide sense involving developments of models and statistical tools for the analysis of externalities, spillovers, interactions etc., in various areas including economics, geography and regional science, etc. This study examined application of Okun's law on the Nigerian Economy using 2018 cross-sectional data of Gross Domestic product (GDP) and unemployment rate data sourced from the National Bureau of Statistics (NBS), Nigeria and from an economics website. In economics, Okun's law is an empirically observed relationship between unemployment rate and GDP of any country. Results from the Ordinary Least Squares (OLS) reveal that there is positive relationship between unemployment rate and GDP in Nigeria though not significant while autocorrelation is present in the estimated model at 5% level of significance. The Moran I statistic for spatial autocorrelation test is significant at 5% while the Monte-Carlo simulation of Moran I statistic at 10,000 simulations revealed the presence of spatial autocorrelation at 5% level of significant. The following spatial models namely: Spatial Lag Model (SLM), Spatial Error Model (SEM) and Spatial Autoregressive with autoregressive error structure (SARAR) were applied in this study. In addition, result from Spatial Lag Model shows a unit increase in GDP leads to an increase of 0.0497 with increase in Unemployment rate in Nigeria. In addition, a unit increase of GDP in one state of Nigeria produces a total impact of increment of 0.1306 in Unemployment rate. The findings contradict Okun's Law but the relationship is not significant in the case of the Nigerian Economy.

**Keywords:** Okun's Law, Cross-sectional, GDP, Unemployment, OLS, SLM, SEM, SARAR, Models.

## INTRODUCTION
The first law of geography states that "everything is usually related to all else but those which are near to each other are more related when compared to those that are farther away as stated by Waldo Tobler in 1970 (Dempsey, 2014). In addition, Tobler's first law of geography is one of the key reasons while "spatial is special" (Li et al., 2014). This first law bring to play the concept of spatial autocorrelation and spatial econometrics.

Spatial econometrics is a subfield of econometrics that deals with spatial interaction (spatial autocorrelation) and spatial structure (spatial heterogeneity) in regression models for cross-sectional and panel data (Baltagi, 2001; Arbia, 2014; Okoro-Ugochukwu & Adenomon (2021A, 2021B).

In economics, Okun's law is empirically observed as the connection between unemployment and country's losses in production. Some researchers have studied Okun's law in developing and developed economies. Moosa, (2008) studied the validity of Okun's law in four Arab countries: Algeria, Egypt, Morocco and Tunisia. He found that output growth does not translate into employment gains for the four countries, which means that Okun's coefficient turn out to be statistically insignificant. Mitchell and Pearce (2010) also have found that unemployment rate and GDP growth move in opposite direction but the change in unemployment rate causes less influenced in GDP growth as compared to Okun's coefficient benchmark. Abraham (2014) examined the effect of output on unemployment rate in Nigeria between 1985 and 2013 using Autoregressive Distributed Lag (ARDL) bounds-test. The study discovered that output (GDP) variations have no significant impact on unemployment. The study concluded that Okun's law is not validated in Nigeria Economy. In Spain, Loría and Salas (2014) using the quadratic version of the first-difference of Okun's law model for the period between 1995Q1 and 2012Q2. The study disagreed that Okun's law is not stable over time and observed that 7.38% growth rate reduces changes in unemployment.
Kargi (2014) in a study of 23 Organization for Economic and Cooperation Development (OECD) countries found that unemployment and growth do not move in the same direction.
Similarly, Dixon, Lim and van Ours (2016) found that increase in economic growth would reduce unemployment rate as well as have a distributional effect of reducing unemployment among youths in 20 OECD countries. Adenomon and Tela (2017) studies two version of the
Okun's law with Nigeria data using simple regression models. The results revealed that the models are stable and no autocorrelation exist. The result also revealed that the parameters of the models are not statistically significant. The implication of the result revealed that as GDP increase, there will be a corresponding increase in the unemployment rate in the country. This further implies that the Okun's law is not practicable in the Nigerian economy.

Other studies have followed investigating empirically the relationship between output and unemployment (Sogner, 2001; Noor et al., 2007; Dritsaki & Dritsaki, 2009; Sogner and Stiassny, 2002). These studies mostly revealed the validity of the relation between output and unemployment rate. However, the estimates of Okun's coefficient vary substantially across countries and regions.

From the forgoing, most studies have not pay much attention of the study application of Okun's Law on developing economy such as Nigerian Economy using spatial regression model. Hence the needs for this present study.

This study examined the application of Okun's law on the Nigerian Economy using Spatial Regression models (Spatial Lag Model (SLM); Spatial Error Model (SEM) and Spatial Auto-regressive with additional Auto-regressive error structure (SARAR).

## MATERIALS AND METHODS

In this study, we used data from the National Bureau of Statistics Bulletin (NBS) 2017 and from https://stateofstates.kingmakers.com.ng

### Model Specification

Spatial models such as Spatial Lag Model, Spatial Error Model and Spatial Autoregressive with additional Auto-regressive error structure were employed in this study

The following models such as Spatial Lag Model, Spatial Error Model and Spatial Autoregressive with additional Auto-regressive error structure are employed to account for spatial auto-correlation error that is inherent in cross-sectional data.

We would discuss different specifications of linear Spatial Econometric models which can be considered once the hypothesis of no Spatial autocorrelation in the disturbances is violated.

The general condition for the applicability of Ordinary Least Square is given by the equation below:

$$y = \lambda W u + X\beta_{(1)} + WX\beta_{(2)} + u \qquad |\lambda| < 1 \qquad 1$$

$$\upsilon = \rho W u + \varepsilon \qquad |\rho| < 1 \qquad 2$$

with the $X$ known to be a matrix of non-stochastic regressors, $W$ is the weighted matrix exogenously given, $e\,|X \approx i.i.d.N(0, \delta^2_{\varepsilon n} l_n)$ and $\beta_{(1)}$ , $\beta_{(2)}$ , $\lambda$ *and* $\rho$ are the parameters to be estimated. The restrictions on the parameters, $\lambda$ *and* $\rho$ hold if $W$ is row-standardized.

The first equation here considers the spatially lagged variable of the dependent variable $y$ as one of the regressors which may also contain spatially lagged variables of some or all of the exogenous variables (the term $WX$). While the second equation considers a spatial model for the stochastic disturbances. In principle, there is no need that the three weight matrices in Equations (1) and (2) are the same, however in practical cases it may difficult to justify a different choice.

The Equation (1) can also be written as:

$$y = \lambda W\gamma + Z\beta + \upsilon \qquad |\lambda| < 1 \qquad 3$$

having defined the matrix of all regressors, current and spatially lagged, as $Z = [X, WX]$ and the vector of regression parameters as $\beta = [\beta_{(1)}, \beta_{(2)}]$

This model was termed SARAR (1) (acronym for Spatial Auto Regressive with additional Auto Regressive error structure) by Kelejian and Prucha (1998) and encompasses several spatial econometric models. In particular we have five remarkable cases:

(i) $\beta = 0$ and either, $\lambda$ *or* $\rho = 0$, known as the pure spatial autoregressive model
(ii) $\lambda = \rho = 0$, known as the Lagged independent variable model
(iii) $\lambda = 0$, $\rho \neq 0$ known as Spatial Lag Model (SLM)
(iv) $\lambda \neq 0$, $\rho = 0$ known as Spatial Error Model (SEM)
(v) $\lambda \neq 0$, $\rho \neq 0$ the complete model (SARAR)

We will review these five cases in the following sections. Before doing this, however, let us consider a general condition on the model's parameters.

First of all notice that Equation 1 can also be written as:

$(I - IW)y = X\beta\,(1) + WX\beta\,(2) + u$

$$y = (I - IW)-1\,[X\beta + WX\beta + u] \qquad 4$$

and Equation 2 as:

$$u = (I - \rho W)^{-1}_{\varepsilon} \qquad 5$$

provided that the two inverse matrices exist. Using the Gerschgorin (1931) theorem Kelejian and Prucha (1998) proved that, when the W matrix is row-standardized, both inverse matrices exist if $|\lambda| < 1$ and $|\rho| < 1$, hence the parameters' restriction reported in Equations 1 and 2.

### Pure Spatial Autoregression

When $\beta = 0$ and either $\lambda$ or $\rho = 0$, and further assuming $e\,X \approx$ *i.i.d.N*(0,*s* 2 *enln* ) and W non-stochastic, then the model reduces to a simple spatial autoregression that can be estimated via the ML procedure (Whittle, 1954).

In this case we have

$$y = \lambda W y + \varepsilon \qquad |\lambda| < 1 \qquad 6$$

when ρ = 0 or

$$y = \rho W y + \varepsilon \qquad |\rho| < 1 \qquad 7$$

when $\lambda = 0$ since, in this instance, $y = u$. In this case we can derive the likelihood in the following way. First of all from Equation 6 or 7 we have that:

$(I - \rho W)\, y = \varepsilon$

Hence

$y = (I - \rho W) - 1\, \varepsilon$

so that

$$E(y) = 0 \qquad 8$$

And

$$E(yyT) = \delta^2_{\varepsilon}(I - \rho W) - 1(I - \rho WT) - 1 = \delta^2_{\varepsilon}\,\Omega \qquad 9$$

Having assumed normality of the innovations, the likelihood function can therefore be expressed as:

$$L(\rho, \sigma^2_{\varepsilon}) = const(\sigma^2_{\varepsilon})|\Omega| -^{\frac{1}{2}} \exp\{-\frac{1}{2\sigma^2_{\varepsilon}}\gamma^T \Omega^{-1}\gamma\} \qquad 10$$

Substituting the explicit expression for the matrix Ω reported in Equation 9, we can write:

$$L(\rho, \sigma^2_{\varepsilon}) = const(\sigma^2_{\varepsilon})^{-\frac{1}{2}}|1 - \rho W)^{-1}(1 - \rho W)^{-T}|^{-\frac{1}{2}} \times \exp\{-\frac{1}{2\sigma^2_{\varepsilon}}\gamma^T[(1 - \rho W)^{-1}(1 - \rho W)^{-T}]^{-1}\gamma\} \qquad 11$$

and, finally, the log-likelihood can be expressed as

$$l(\rho, \sigma^2_{\varepsilon}) = const\,\frac{n}{2}\ln(\sigma^2_{\varepsilon}) - \frac{1}{2}\ln|(1 - \rho W)^{-1}(I - \rho W)^{-T}| - \frac{1}{2\sigma^2_{\varepsilon}}\gamma^T[I - \rho W)^{-1}(1 - \rho W)^{-T}]^{-1}\gamma \qquad 12$$

### The classical model with spatially lagged non-stochastic regressors

When $\lambda = \rho = 0$, if we further assume that $\mathcal{E}\,|\,X \approx$ *i.i.d.N*$(0, \delta^2_n I_n)$, that both $X$ and $W$ are non-stochastic and that the matrix of all regressors $Z = [X, WX]$ is full rank then the model only possibly contains a spatial lag of some or all the independent variables. In this situation no particular estimation problem emerges and the model can be simply estimated using the OLS procedure.

### The Spatial Error Model (SEM)

When $\lambda = 0$ and $\rho \neq 0$ , the Model becomes

$$y = Z\beta + u \qquad 13$$

$$u = \rho W u + \mathcal{E} \qquad /\rho/ < 1 \qquad 14$$

with the regressors $Z$ and the weights $W$ non-stochastic. This

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model is referred to in the literature as the Spatial Error Model (SEM) (Anselin, 1988; Arbia, 2006; LeSage and Pace, 2009)
If $\mathcal{E} \mid X \approx i.i.d.N(0,\delta_{\varepsilon}{}^{2}{}_{n}I_{n})$, then we have that $u=(I-\rho W)^{-1}\mathcal{E}$ as in equation 3.5 so we can write:

$E(u) = 0$
$E(uu^{T}) = \sigma_{\mathcal{E}}^{2}(I-\rho W)^{-1}(I-\rho WT)^{-1} = \sigma_{\mathcal{E}}^{2}\Omega$ 15

a formulation that considers both heteroscedastic and autocorrelated error terms. In these circumstances the *GLS* procedure may be applied only if the value of the parameter *r* is known *a priori*, a circumstance which happens only very rarely in empirical cases. Notice that from Equation (14) we have

$(I-\rho W)u = \mathcal{E}$ 16

and models (13) (14) can thus also be written as:
$(I-\rho W)y = (I-\rho W)Z\beta + (I-\rho W)u$
$y = \rho Wy + Z\beta - WZ\rho\beta + \mathcal{E}$

$y = \rho Wy + Z\beta - WZy + \mathcal{E}$ 17

**A Primer for Spatial Econometrics**
With $\lambda = \rho\beta$ and one may think of estimating model (16) directly. However, two problems emerge. First of all, Equation (17) is over parameterized due to the restriction $\gamma = \rho\beta$. Secondly, the term *Wy* is correlated with the error term, thus producing endogeneity. To convince ourselves of this let us consider that, from Equation (17):
$(I - rW)y = Z\beta - WZg + \mathcal{E}$
and so,
$E[(Wy)\mathcal{E}T] = E[W(I-\rho W)-1(Z\beta - WZy) + W(I-\rho W)$
$-1\mathcal{E}\ ]\mathcal{E}T = W(I-\rho W)-1(Z\beta - WZy)E(\mathcal{E}T)$ 18
$+W(I-\rho W)-1E[\mathcal{E}\mathcal{E}T] = \sigma 2W(I-rW)-1I \neq 0$

So the error is endogeneous, in that it is correlated with the spatially lagged variable *Wy*. As a consequence of the endogeneity of the errors, the OLS procedure loses its optimal properties.
In principle, an instrumental variable procedure could have been adopted to accommodate endogeneity. However, Kelejian and Prucha (1998) proved that such a procedure is not consistent due to the fact that it is not possible to identify instruments for *Wy* which are linearly independent of the other two regressors, *Z* and *WZ*.

**The general SARAR (1,1) Model**
To start with, let us consider the case where, in Equations 1and 2, we set β = 0. We have:
$y = \lambda Wy + u \quad |\lambda| < 1$ 19
$u = \rho Wu + \mathcal{E} \quad |\rho| < 1$ 20

we thus have:
$(I - \lambda W)y = u \qquad y = (I-\lambda W)^{-1}u$ 21
And
$(I-\rho W)u = \mathcal{E} \qquad u = (I-\rho W)-1\mathcal{E}$ 22

Combining (3.21) and (3.22) we have:
$y = (I-\lambda W)(I-\rho W)^{-1}\mathcal{E}$ 23

$E(yyT) = E[(I-\lambda W)-1(I-\rho W)^{-1}\mathcal{E}\mathcal{E}^{T}(I-\lambda W)-T\ (I-\rho W)-T]$

$= \sigma_{\mathcal{E}}^{2}(I-\lambda W)-1(I-\rho W)-1(1-\lambda W)-T(I-\rho W)-T$ 24
$= \sigma_{\mathcal{E}}^{2}$

so that the inverse of Ω is now:
$\Omega-1 = (I-\lambda WT)(I-\rho WT)(I-\rho W)(I-\lambda W)$ 25
$= [I-(\lambda+\rho)WT + \lambda\rho WTWT]$
$X[I-(\lambda+\rho)WT + \lambda\rho WTWT]T$

where the two parameters $\lambda$and $\rho$are present in the form of a sum and of a product and so they cannot be identified univocally. This fact has been considered in the literature to suggest that a complete model of the kind reported in Equations (19) and (20) is not feasible in practice. However, Kelejian and Prucha (1998) proved that this only happens when β = 0 and it is not the case conversely when β ≠0, which is what usually happens in the generality of cases of interests in spatial econometrics. In this case we can define a more general spatial model which encompasses the Spatial Lag and the Spatial Error models previously discussed above. This model, as already said, was termed a SARAR(1,1) model by Kelejian and Prucha (1998), but is also referred to in the literature as the *General Spatial Model* by Anselin (1988) or as an *SAC* model by LeSage and Kelly (2009).
If we consider the general SARAR model we thus have
$y = Zb + \lambda Wy + u \qquad |\lambda| < 1$ 26

$u = \rho Wu + \mathcal{E} \qquad |\rho| < 1$ 27

$\mathcal{E} \mid X \approx i.i.d.N(0,\delta_{\varepsilon}{}^{2}{}_{n}I_{n})$,

**DATA ANALYSIS AND DISCUSSION OF RESULTS**

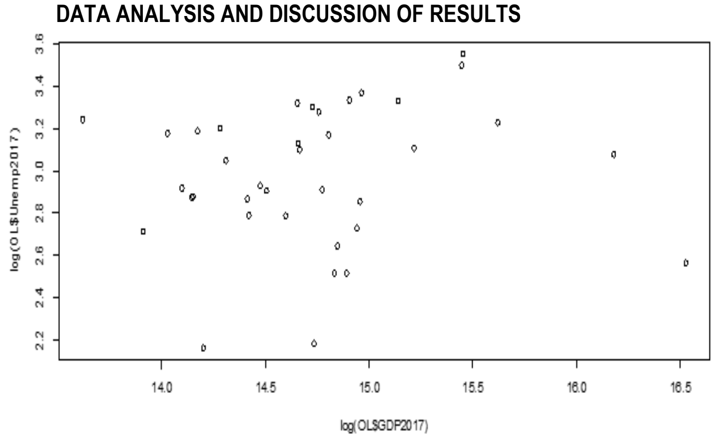


**Fig 1**: Scattered plot between GDP and Unemployment in all the states in Nigeria in 2017

From Fig 1 above represents the relationship between unemployment and GDP among the states in Nigeria including Federal Capital Territory. The fig 1 is truly scattered in natures.

**Table 1:** Global Moran I for regression residuals

```
data:
model: lm(formula = log(Unemp2017) ~ log(GDP2017), data = OL)
weights: W1

Moran I statistic standard deviate = 4.6039, p-value = 2.073e-06
alternative hypothesis: greater
sample estimates:
        Observed Moran I     Expectation       Variance
        0.44565764          -0.03507805       0.01090336
```

Table 1 above shows that there is evidence of spatial autocorrelation in the OLS residuals (p<0.05).

**Table 2:** Moran Test Monte-Carlo simulation

```
                 Monte-Carlo simulation of Moran I

data:  log(OL$GDP2017)
weights: W1
number of simulations + 1: 10001

statistic = 0.22773, observed rank = 9867, p-value = 0.0134

alternative hypothesis: greater
```

Some previous studies in spatial econometrics recommend Moran Test Monte-Carlo simulation over the Moran I test. Table 2 above shows that there is evidence of spatial autocorrelation in the OLS residuals (p<0.05).

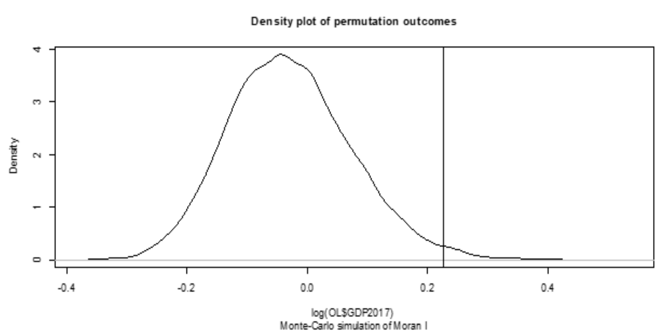


**Fig 2:** Density Plot for the Monte-Carlo simulation of Moran 1

The Moran test from the Monte-Carlo simulation at 10,000 times show evidence of spatial autocorrelation at 5% level of significance (evidence in fig. 2 above).

**Table 3**: Lagrange multiplier diagnostics for spatial dependence data

```
statistic   parameter    p.value
LMerr       15.41884     1 8.613e-05 ***
LMlag       15.89945     1 6.680e-05 ***
RLMerr      0.41512      1 0.5193809
RLMlag      0.89574      1 0.3439271
SARMA       16.31458     2 0.0002866 ***
```

**Table 4**: Result on Okun's Law in Nigeria using OLS and Spatial Models

| Parameters | OLS | Spatial Lag Model | Spatial Lag (Mixed) | Spatial Error Model (ML) | Spatial Error Model (GLS) | SARAR 2SLS | SARAR GS2SLS |
|---|---|---|---|---|---|---|---|
| Intercept | 2.08211 | 0.3531 | 0.6525 | 2.6077 | 2.5814 | -1.6584 | 0.3531 |
| GDP | 0.06123 | 0.0426 | 0.0221 | 0.0269 | 0.0285 | 0.0285 | 0.0426 |
| Lag (GDP) | | | 0.0909 | | | | |
| ADI | | 0.0497 | 0.0478 | | | | 0.0497 |
| AII | | 0.0809 | 0.02898 | | | | 0.0809 |
| ATI | | 0.1306 | 0.3375 | | | | 0.1306 |

In Table 4 above, the result from OLS shows that there is a positive relation between unemployment and GDP in Nigeria. One unit increase in GDP leads to increase of 0.06123 unit increase in Unemployment rate in Nigeria which contradicts Okun's Law. The intercepts and the GDP are not significant ($p > 0.05$) . In addition, the OLS has a weak R-squared of 1.195%. The implication of this result shows that the Okun's Law does not hold in Nigeria. This result agrees with the following works Adenomon & Tela (2017); Okoro-ugochukwu and Adenomon (2021B). However, our result contradicts other works from other countries especially developed countries (Dritsaki & Dritsaki, 2009). The Moran test revealed the Presence of Spatial Autocorrelation ($p < 0.05$). In addition, the Monte-Carlo simulation of Moran I reveal the Presence of Spatial autocorrelation ($p < 0.05$). Furthermore, the Lagrange Multiplier diagnostics test for spatial dependence such as LMerr, LMlag, SARMA, reveal that all are significant as ($p < 0.05$) while RLMerr and RLMlag are not significant ($p > 0.05$). The implication of this result provides the basis for Spatial regression Models.

For the Spatial Lag Model, the coefficient reveals positive relationship but the coefficient is not significant ($p > 0.05$). Furthermore, the LM test for Residual autocorrelation revealed the absence of spatial autocorrelation ($p > 0.05$). The implication is that the spatial lag Model has taken care of the effect of spatial autocorrelation. In addition, result from Spatial Lag Model shows a unit increase in GDP leads to an increase of 0.0497 increases in Unemployment rate in Nigeria. In addition, a unit increase of GDP in one state of Nigeria produces a total impact of increment of 0.1306 in Unemployment rate. This result agrees with the following works Adenomon & Tela (2017); Okoro-ugochukwu and Adenomon (2021B). However, our result contradicts other works from other countries especially developed countries (Dritsaki & Dritsaki, 2009).

For the Spatial Lag (Mixed) Model, the coefficient reveals positive relationship but the coefficient is not significant ($p > 0.05$). Furthermore, the LM test for Residual autocorrelation revealed the absence of spatial autocorrelation as ($p > 0.05$). The implication is that the spatial lag (Mixed) Model has taken care of the effect of spatial autocorrelation. In addition, result from Spatial Lag (Mixed) Model shows a unit increase in GDP leads to an increase of 0.0478 increases in Unemployment rate in Nigeria. In addition, a unit increase of GDP in one state of Nigeria produces a total impact of increment of 0.3375 in Unemployment rate. This result agrees with the following works (Adenomon & Tela (2017) ; Okoro-ugochukwu and Adenomon (2021B)). However, our result contradicts other works from other countries especially developed countries (Dritsaki & Dritsaki, 2009).

For the Spatial Error Model, the coefficient reveals positive relationship but the coefficient is not significant (p >0.05). For the Spatial Error (GLS) Model, the coefficient reveals positive relationship but the coefficient is not significant (p >0.05). This result agrees with the following works of Adenomon & Tela (2017) and Okoro-ugochukwu and Adenomon (2021B). However, our result contradicts other works from other countries especially developed countries (Dritsaki & Dritsaki, 2009).

For the SARAR (2SLS) Model, the coefficient reveals positive relationship but the coefficient is not significant (p >0.05). For the SARAR (GS2SLS) Model, the coefficient reveals positive relationship but the coefficients are not significant (p >0.05). In addition, result from SARAR (GS2SLS) shows a unit increase in GDP leads to an increase of 0.0497 increases in Unemployment rate in Nigeria. In addition, a unit increase of GDP in one state of Nigeria produces a total impact of increment of 0.1306 in Unemployment rate. This result agrees with the following works (Adenomon & Tela (2017) and Okoro-ugochukwu and Adenomon (2021B)) However, our result contradicts other works from other countries especially developed countries (Dritsaki & Dritsaki, 2009).

**Conclusion**

This study examined application of Okun's law on the Nigerian Economy using 2017 cross-sectional data of Gross Domestic product (GDP) and unemployment rate data sourced from the National Bureau of Statistics (NBS), Nigeria and from an economics website. In economics, Okun's law is empirically observed as the relationship between unemployment rate and GDP of any country. Results from the Ordinary Least Squares (OLS) reveal that there is positive relationship between unemployment rate and GDP in Nigeria though not significant but spatial autocorrelation was present in the estimated model at 5% level of significance. The Moran I statistic for spatial autocorrelation test is significant at 5% while the Monte-Carlo simulation of Moran I statistic at 10,000 simulations revealed the presence of spatial autocorrelation at 5% level of significant. The following spatial models namely: Spatial Lag Model (SLM), Spatial Error Model (SEM) and Spatial Autoregressive with autoregressive error structure (SARAR) were applied in this study.

Lastly, result from Spatial Lag Model shows a unit increase in GDP leads to an increase of 0.0497 increase in Unemployment rate in Nigeria. In addition, a unit increase of GDP in one state of Nigeria produces a total impact of increment of 0.1306 in Unemployment rate. This result contradicts Okun's Law.

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