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Application of Panel Data to the Effect of Five (5) World Development Indicators (WDI) on GDP Per Capita of Twenty (20) African Union (AU) Countries (1981-2011)

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Abstract
In this paper, we employ Fixed Effect of Panel Data Model to formulate a Panal Data Linear Regression model of Gross Domestic Product Per Capita of 20 African Union (AU) Countries using 5 World Development Indicator (WDI) as explanatory variables. Data were collected from 1981 to 2011. The 5 WDI are OER-Official Exchange Rate (LCU Per US$, Period Average), BM-Broad Money (% of GDP), INF-Inflation, GDP deflator (Annual %), TNR-Total Natural Resources Rents (% of GDP) and FDI-Foreign Direct Investment, Net Inflows (% of GDP).
Keywords: Econometrics, Cross section, Time series, Panel data, Fixed effect, Random effect.

1.0 INTRODUCTION

Econometrics is a rapidly developing branch of economics which, broadly speaking, aims to give empirical content to economic relations. The term 'econometrics' appears to have been first used by Pawel Ciompa as early as 1910; although it is Ragnar Frisch, one of the founders of the Econometric Society, who should be given the credit for coining the term, and for establishing it as a subject in the sense in which it is known today (see Frisch, 1936, p. 95). Econometrics can be defined generally as 'the application of mathematics and statistical methods to the analysis of economic data', or more precisely in the words of Samuelson, Koopmans and Stone (1954), as the quantitative analysis of actual economic phenomena based on the concurrent development of theory and observation, related by appropriate methods of inference

Chow (1983) in a more recent textbook succinctly defines econometrics 'as the art and science of using statistical methods for the measurement of economic relations'.

Panel data are data where the same observation is followed over time (like in time series) and where there are many observations (like in cross-sectional data). In this sense, panel data combine the features of both time-series and cross-sectional data and methods.

2.0 PANEL DATA MODEL

Different types of data are generally available for empirical analysis, namely, time series, cross section, and panel. A data set containing observations on a single phenomenon observed over multiple time periods is called time series (e.g GDP per capita for several years). In time series data, both the values and the ordering of the data points have meaning. In cross-section data, values of one or more variables are collected for several sample units, or entities, at the same point in time (e.g., GDP per capita for 20 African Union (AU) countries for a given year). Panel data sets refer to sets that consist of both time series and cross section data. This has the effect of expanding the number of observations available, for instance if we have 31 years of data across 20 countries, we have 620 observations. So although there would not be enough to estimate the model as a time series or a cross section, there would be enough to estimate it as a panel.

Looking at the model below

$$y_{it} = \beta_0 + \sum_{w=1}^{k} \beta_w X_{wit} + U_{it} \qquad 2.1$$

In matrix form

$$y_{it} = \beta_0 + X'_{it}\beta + U_{it} \qquad 2.2$$

In ***time series*** data, t = 1, 2, …,T and n = 1; while in ***cross-sectional*** data, i = 1, 2, …, n and T = 1. However, in ***panel data***, t = 1, 2… T and i = 1, 2 … n.

2.1 TYPES OF PANEL DATA

Generally speaking, there exist two types of panel datasets. ***Macro panels*** are characterized by having a relatively large T and a relatively small n. A typical example is a panel of countries where the variables are macro data like the one we are working on i.e GDP per capita. ***Micro panels***, instead, usually cover a large set of units "n" for a relatively short number of periods T.

Another important classification is between ***balanced*** and ***unbalanced*** panels. A ***balanced dataset*** is one in which all the n observations are followed for the same number of periods T. In an ***unbalanced dataset*** each observation might be available for a different number of periods so that the time dimension is potentially different for different observations.

2.2 USES OF PANEL DATA

Panel data possess some advantages over cross-sectional or time series data.
Panel data can address issues that cannot be addressed by cross-sectional or time-series data alone. Baltagi (2002) highlighted the following advantages of panel data over cross sectional or time-series data:

(i) Panel data control for heterogeneity, they give more informative data, more variability, less collinearity among the variables, more degrees of freedom and more efficiency
(ii) They study better, the dynamics of adjustment.
(iii) They are able to identify and measure effects that are simply not detectable in pure cross-sectional or pure time series data.
(iv) Panel data models allow us to construct and test more complicated behavioural models than purely cross-sectional or time-series data.

2.3 ESTIMATION OF PANEL DATA MODELS

As earlier discussed, panel data has two dimensions viz: the individual dimension and time dimension. A panel data model differs from a cross-section or time series in that it has double subscript on its variables. That is, it's of the form:

$$y_{it} = \beta_0 + \sum_{w=1}^{k} \beta_w X_{wit} + U_{it} = \beta_0 + X'_{it}\beta + U_{it} \qquad 2.3$$

$i = 1, 2 \ldots n; \quad t = 1, 2 \ldots T$

i could denote individuals, households, firms, countries etc. for the purpose of this paper, i denotes countries while t denotes time, y_{it} hence denotes the value of the dependent variable y for country i at time t. β_0 is a scalar, β is k × 1 matrix (a column vector) and X_{it} is the ith observation on the k explanatory variables. Although (2.3) postulates common intercept (β_0) for all i and t and common vector of slope coefficients for all i and t, variants of the model exist.
The variants include:

$$y_{it} = \beta_{0i} + \sum_{w=1}^{k} \beta_w X_{wit} + U_{it} = \beta_{0i} + X'_{it}\beta + U_{it} \qquad 2.4$$

(2.4) postulates constant slope coefficients and intercept that varies over countries.

$$y_{it} = \beta_{0it} + \sum_{w=1}^{k} \beta_w X_{wit} + U_{it} = \beta_{0it} + X'_{it}\beta + U_{it} \qquad 2.5$$

(2.5) postulates constant slope coefficients and intercept that varies over countries and time.

$$y_{it} = \beta_{0i} + \sum_{w=1}^{k} \beta_{wi} X_{wit} + U_{it} = \beta_{0i} + X'_{it}\beta_i + U_{it} \qquad 2.6$$

(2.6) postulates intercept and slopes that vary over countries.

$$y_{it} = \beta_{0it} + \sum_{w=1}^{k} \beta_{wit} X_{wit} + U_{it} = \beta_{0it} + X'_{it}\beta_{it} + U_{it} \qquad 2.7$$

(2.7) postulates intercept and slopes that vary over time and countries.
However, (2.3) suffices for most applications involving ***static*** (non dynamic) panel data models and shall hence form the basis of our further discussions on panel data.

3.0 METHODOLOGY

Basically, the static panel data models can be estimated using:
1. Ordinary Least Square (OLS)
2. Fixed Effects (FE) and
3. Random Effects (RE)
4. Seemily Unrelated (SUR)

Each of these methods has its underlying assumptions which must necessary be satisfied to obtain unbiased and efficient estimates. We consider only the Fixed Effects model.

3.1 ONE-WAY ERROR COMPONENT REGRESSION MODEL

Recall (2.3)

$$y_{it} = \beta_0 + \sum_{w=1}^{k} \beta_w X_{wit} + U_{it} = \beta_0 + X'_{it}\beta + U_{it}$$

$i = 1, 2 \ldots n; \quad t = 1, 2 \ldots T$

Where U_{it} denotes the effect of all omitted variables.

If U_{it} is decomposed as

$$U_{it} = \mu_i + v_{it} \qquad 3.1$$

We have

$$y_{it} = \beta_0 + X'_{it}\beta + \mu_i + v_{it} \qquad 3.2$$

(3.2) is called the one-way error component model where μ_i denotes the unobservable country specific (time invariant) effect and v_{it} (which varies with individual and time), the remainder disturbance in regression.

3.2 THE FIXED EFFECTS MODEL

As earlier emphasized, one of the approaches used to capture specific effects in a panel data model is the fixed effects (FE) regression. The FE approach is based on the assumption that the effects are fixed parameters that can be estimated.

In this case, the omitted country specific term μ_i are assumed to be fixed parameters to be estimated and v_{it} normal, independent and identically distributed i.e $NIID(0, \sigma_v^2)$. The X_{it} are assumed to be independent of v_{it} for all i and t. The fixed effects model is appropriate if inference is to be drawn on the countries that constitute the sample only and not for generalization for the entire population.

In vector form (3.2) can be written as:

$$y = \beta_0 J_{nT} + X\beta + U = Z\delta + U \qquad 3.3$$

where

y is nT χ 1; X is nT χ k; $Z = (J_{nT}, X)$; $\delta' = (\beta_0', \beta')$

J_{nT} is a vector of ones of dimension nT.

Note that (3.1) can be written as

$$U = Z_\mu \mu + v \qquad 3.4$$

Where

$$U' = (U_{11}, U_{12} \ldots U_{1T} \quad U_{21}, U_{22} \ldots U_{2T} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad U_{n1}, U_{n2} \ldots U_{nT})$$

$$Z_\mu = I_n \otimes J_T$$

Where I_n is identity matrix of dimension n, J_T is a vector of ones of dimension T and $\otimes$ denotes kronecker product;

$$\mu' = (\mu_1, \mu_2 \ldots \mu_n); v' = (v_{11}, v_{12} \ldots v_{1T} \quad v_{21}, v_{22} \ldots v_{2T} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad v_{n1}, v_{n2} \ldots v_{nT}).$$

Z_μ is a matrix of ones and zeros, that is, a matrix of individual dummies that are included in the regression to estimate μ_i which are assumed fixed.

At this juncture, we should note the following:

* $\quad Z_\mu Z_\mu' = I_n \otimes J_T \quad (where\ J_T\ is\ a\ square\ matrix\ of\ 1's\ of\ dimension\ T)$

** $\quad P = Z_\mu \left(Z_\mu^{'Z_\mu}\right)^{-1} Z_\mu'$

$$= I_n \otimes \bar{J}_T \quad \left(\bar{J}_T = \frac{J_T}{T}\right)$$

{P is a projection matrix on Z_μ. P averages the observations across time for each country.}

*** $\quad Q = I_{nT} - P$

{Q is a matrix which obtains deviations from individual mean.}

**** P and Q are symmetric idempotent matrices (P’ = P and P^2 = P)

P and Q are orthogonal i.e PQ = 0

P + Q = I_{nT}

Model Estimation

If we substitute (3.4) into (3.3), we shall have:

$$y = \alpha J_{nT} + X\beta + Z_{\mu}\mu + v = Z\delta + Z_{\mu}\mu + v \qquad 3.5$$

Where Z is nT × (K+1) and Z_{μ}, the matrix of country dummies is nT × n, if n is large, (3.5) will include too many dummies and the matrix to be inverted will be dimension (N+K)!. Apart from the herculean task of having to invert such a large matrix, the matrix will also fall into dummy variable trap.

Rather than attempt OLS on (3.5), we can obtain Least Squares Dummy Variables (LSDV) Estimators of α and β by pre multiplying (3.5) by Q and performing OLS on the transformed model:

$$Qy = QX\beta + Qv = Z\delta + Z_{\mu}\mu + v \qquad 3.6$$

Since $QZ_{\mu} = QJ_{nT} = 0$

$$QZ_{\mu} = \left[I_{nT} - Z_{\mu}(Z'_{\mu}Z_{\mu})^{-1}Z'_{\mu}\right]Z_{\mu} = Z_{\mu} - Z_{\mu}(Z'_{\mu}Z_{\mu})^{-1}Z'_{\mu}Z_{\mu} = Z_{\mu} - Z_{\mu} = 0$$

As follows:

$$Qy = QX\beta + Qv$$
$$Qv = Qy - QX\beta$$
$$S = (Qv)'(Qv) = (Qy - QX\beta)'(Qy - QX\beta)$$
$$S = y'Q'Qy - y'Q'X\beta - \beta'X'Q'Qy + \beta'X'Q'QX\beta$$
$$S = y'Q'y - y'Q'X\beta - \beta'X'Q'y + \beta'X'Q'X\beta$$
$$S = y'Qy - 2\beta'X'Qy + \beta'X'QX\beta$$
$$\frac{dS}{d\beta} = -2X'Qy + 2X'QX\beta$$
$$0 = -2X'Qy + 2X'QX\beta$$
$$2X'QX\beta = 2X'Qy$$
$$\hat{\beta} = (X'QX)^{-1}X'Qy$$

Mean of $\boldsymbol{\beta}$

$$\hat{\beta} = (X'QX)^{-1}X'Qy$$
$$\hat{\beta} = (X'QX)^{-1}X'(QX\beta + Qv)$$
$$\hat{\beta} = (X'QX)^{-1}X'QX\beta + (X'QX)^{-1}X'Qv$$
$$\hat{\beta} = \beta + (X'QX)^{-1}X'Qv$$
$$E(\hat{\beta}) = \beta + (X'QX)^{-1}X'QE(v)$$

Since

$$E(v) = 0$$

Then

$$E(\hat{\beta}) = \beta$$

Variance of β

$$\hat{\beta} - \beta = (X'QX)^{-1}X'Qv \qquad 3.7$$

$$V(\hat{\beta}) = E(\hat{\beta} - \beta)(\hat{\beta} - \beta) \qquad 3.8$$

On substituting (3.7) into (3.8), we have

$$V(\hat{\beta}) = E\left[[(X'QX)^{-1}X'Qv][(X'QX)^{-1}X'Qv]\right]$$
$$V(\hat{\beta}) = E[(X'QX)^{-1}X'Qvv'Q'X(X'QX)^{-1}]$$

Since

$$QQ' = Q$$

We have

$$V(\hat{\beta}) = [(X'QX)^{-1}X'Q[E(vv')]Q'X(X'QX)^{-1}]$$
$$E(vv') = \sigma_v^2 I_{nT}$$

Then

$$V(\hat{\beta}) = \sigma_v^2 I_{nT}[(X'QX)^{-1}X'QX(X'QX)^{-1}]$$
$$V(\hat{\beta}) = \sigma_v^2 I_{nT}(X'QX)^{-1}$$

Note: The OLS $\hat{\beta} = \beta + (X^{'}QX)^{-1}X^{'}Qv$ is sometimes called the Least Square Dummy Variable (LSDV).

4.0 RESULT OF ANALYSIS

The proposed Econometric model is given by

$$Y_{it} = \beta_0 + \beta_1 OER_{it} + \beta_2 BM_{it} + \beta_3 INF_{it} + \beta_4 TNR_{it} + \beta_5 FDI_{it} + \varepsilon_{it}$$

For i = 1, 2, …, n and t = 1, 2, … , T where n = 20; T = 31

Note: The independent variables are carefully selected so that they are correlated with the dependent variable but are not correlated with other independents variables. Hence, the independent variables are not correlated with one another (no multicollinearity).

In this section, we present the result of the model using the following specifications below.

Model Specification

Estimation of equation

Methods: Least Squares (LS)

Sample: 1981-2011

Panel Options

Effects specification: Cross Section is fixed, Period is none

Weights: *GLS weight: Cross-section SUR*

Coefficient covariance method: Ordinary.

Table 1: Panel Data Format

CCode	Cnid	t	I	YEAR	RGDP	OER	BM	INF	TNR	FDI
NGA	1	1	1	1981	772.10	0.62	30.03	16.21	30.18	0.91
NGA	1	2	2	1982	624.98	0.67	32.13	2.61	29.19	0.87
NGA	1	3	3	1983	428.13	0.72	33.31	16.14	35.71	1.04
NGA	1	4	4	1984	336.74	0.77	33.40	16.95	47.46	0.67
NGA	1	5	5	1985	330.98	0.89	32.00	3.69	47.04	1.71
NGA	1	6	6	1986	229.52	1.75	32.31	-1.50	31.82	0.96
NGA	1	7	7	1987	259.41	4.02	26.54	50.08	33.39	2.60
NGA	1	8	8	1988	246.39	4.54	26.44	21.38	29.16	1.66
NGA	1	9	9	1989	250.63	7.36	19.29	44.38	40.54	7.90
NGA	1	10	10	1990	291.87	8.04	22.08	7.16	47.48	2.06
NGA	1	11	11	1991	273.17	9.91	24.10	20.17	42.22	2.61
NGA	1	12	12	1992	319.30	17.30	20.82	83.62	35.70	2.74
NGA	1	13	13	1993	203.49	22.07	20.52	52.64	48.51	6.30
NGA	1	14	14	1994	220.22	22.00	21.58	27.77	41.14	8.28
NGA	1	15	15	1995	255.50	21.90	16.12	55.97	38.01	3.84
NGA	1	16	16	1996	313.44	21.88	13.11	36.90	40.11	4.51
NGA	1	17	17	1997	314.30	21.89	14.62	1.36	39.38	4.25
NGA	1	18	18	1998	272.44	21.89	18.58	-5.55	25.98	3.27
NGA	1	19	19	1999	287.92	92.34	21.79	12.29	32.60	2.89
NGA	1	20	20	2000	371.77	101.70	22.16	38.17	46.91	2.48
NGA	1	21	1	2001	378.83	111.23	24.52	10.74	39.87	2.48
NGA	1	22	2	2002	455.33	120.58	21.83	31.47	27.98	3.17
NGA	1	23	3	2003	508.43	129.22	20.20	11.20	34.40	2.96
NGA	1	24	4	2004	644.03	132.89	18.26	20.73	37.36	2.13
NGA	1	25	5	2005	802.79	131.27	17.73	19.76	43.15	4.44
NGA	1	26	6	2006	1,014.58	128.65	19.04	19.56	38.12	3.34
NGA	1	27	7	2007	1,129.09	125.81	28.03	4.81	34.84	3.64
NGA	1	28	8	2008	1,374.67	118.55	36.35	10.98	37.00	3.96
NGA	1	29	9	2009	1,091.26	148.90	40.68	-4.41	25.46	5.07
NGA	1	30	10	2010	1,443.21	150.30	32.48	26.78	32.56	2.65
NGA	1	31	11	2011	1,501.72	154.74	33.58	2.34	42.00	3.62
CIV	2	1	12	1981	948.99	271.73	27.92	2.98	3.84	0.39
CIV	2	2	13	1982	815.28	328.61	26.56	8.30	4.64	0.63
CIV	2	3	14	1983	706.10	381.07	26.55	9.05	5.50	0.55
CIV	2	4	15	1984	678.06	436.96	27.63	17.91	5.05	0.32
CIV	2	5	16	1985	664.87	449.26	29.97	0.34	4.70	0.42
CIV	2	6	17	1986	840.50	346.31	30.42	-2.02	2.76	0.77

OUTPUT FROM EVIEWS 7

TABLE 2: DESCRIPTIVE STATISTICS OF VARIABLES USED.

	RGDP	OER	BM	INF	TNR	FDI
Mean	1160.794	197.7944	37.83302	12.69653	7.640170	1.274752
Median	583.1229	8.803060	32.16974	7.774248	4.042073	0.373410
Maximum	8532.617	2522.746	151.5489	189.9751	48.50557	10.05164
Minimum	102.4829	0.000275	7.287787	-27.04865	0.145038	-2.069713
Std. Dev.	1325.736	357.1241	21.99282	21.04700	9.652967	1.892576
Skewness	2.254689	2.852006	1.194571	4.347025	2.344576	1.926401
Kurtosis	8.838048	13.04535	4.468418	27.94831	8.064135	7.063302
Jarque-Bera	1405.780	3447.326	203.1598	18031.79	1230.535	809.9913
Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Sum	719692.1	122632.5	23456.47	7871.850	4736.905	790.3462
Sum Sq. Dev.	1.09E+09	78945766	299400.4	274202.3	57678.28	2217.162
Observations	620	620	620	620	620	620

Source: *Eviews 7 Output*

It can be seen from Table 2 that the average RGDP per capita is $1,160.79, the average Official Exchange Rate (in local currency) is 197.79, the average board money is 37.83, the average inflation rate (GDP deflator) is 12.70, the total natural resources % of GDP is 7.64 and the foreign direct investment % of GDP is 1.27.

It is also evident that the GDP per capita minimum ever attained is $102.48 and the maximum ever attained is $8532.62. The standard deviation for the 620 dataset for RGDP is 1325.736 with skewness and kurtosis of 2.25 and 8.84 respectively.

Empirical Results

This section presents the empirical results of our model with the objective to assess the impact of some world development indicators (OER, BM, INF, TNR, FDI) on variables on gross domestic product per capita Africa Union countries. Estimates are made using the ordinary least squares static panel of cross sectional fixed effect. The choice of this model is justified by the fact that the dynamic panel data and random effect have not yielded robust estimators. Table 3 shows the results of estimating the Fixed Effect panel model in one stage on 20 African Union countries for the period 1981-2011

Table 3: Estimates of the Cross Section Fixed Effect panel model of one-error component on 20 African Union countries for the period 1981-2011

Dependent Variable: RGDP				
Method: Panel EGLS (Cross-section SUR)				
Sample: 1981 2011				
Periods included: 31				
Cross-sections included: 20				
Total panel (balanced) observations: 620				
Linear estimation after one-step weighting matrix				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	193.2930	19.02488	10.16001	0.0000
OER	-0.233136	0.011616	-20.06969	0.0000
BM	24.50454	0.444517	55.12621	0.0000
INF	-1.108138	0.136813	-8.099676	0.0000
TNR	3.649029	0.710298	5.137320	0.0000
FDI	57.04904	1.733163	32.91614	0.0000
Effects Specification				
Cross-section fixed (dummy variables)				
Weighted Statistics				
R-squared	0.971509	Mean dependent var		3.679436
Adjusted R-squared	0.970360	S.D. dependent var		6.465174
S.E. of regression	0.989187	Sum squared resid		582.2025
F-statistic	845.3767	Durbin-Watson stat		1.569984
Prob(F-statistic)	0.000000			
Unweighted Statistics				
R-squared	0.747038	Mean dependent var		1160.794
Sum squared resid	2.75E+08	Durbin-Watson stat		0.201782

Interpretation of Regression Results

The model to be fitted is

$$RGDP_{it} = \beta_0 + \beta_1 OER_{it} + \beta_2 BM_{it} + \beta_3 INF_{it} + \beta_4 TNR_{it} + \beta_5 FDI_{it} + \varepsilon_{it}$$

The model fitted is

$$\widehat{RGDP}_{it} = 193.29 - 0.23 OER_{it} + 24.50 BM_{it} - 1.1175 INF_{it} + 3.65 TNR_{it} + 57.05 FDI_{it}$$

Base on the probability values, OER, BM, INF, TNR and FDI are all statically significant. Note that all the regressions are not in the same unit. The average estimated GDP per capita of the selected AU countries when the effect of OER, BM, INF, TNR and FDI are zero is $193.29. 1.00 unit increase in OER-Official Exchange Rate (LCU Per US$, Period Average) will lead to a significant reduction in GDP per capita by $0.23 (0.23USD); if BM-Broad Money (% of GDP) increases by 1.00% then GDP per capita will increase by $24.50; if INF-Inflation, GDP deflator (Annual %) increases by 1.00% then GDP per capita will decrease by $1.11; if TNR-Total Natural Resources Rents (% of GDP) increases by 1.00% then GDP per capita will increase by $3.65 and if FDI-Foreign Direct Investment, Net Inflows (% of GDP) increases by 1.00% then GDP per capita will increase by $57.05. (Note: All the estimated parameters are significant at 5% without exception)

Table 3 also shows that 97.2% of the total variation in GDP per capita of the selected AU countries can be explained by the variations in OER-Official Exchange Rate (LCU Per US$, Period Average), BM-Broad Money (% of GDP), INF-Inflation, GDP deflator (Annual %), TNR-Total Natural Resources Rents (% of GDP) and FDI-Foreign Direct Investment, Net Inflows (% of GDP) while the remaining 2.8% could be explained by other variables other than the ones used in this model (Note: this is for the weighted statistics). While the unweighted statistics shows that 74.7% of the total variation in GDP per capita of the selected AU countries can be explained by the variations in OER-Official Exchange Rate (LCU Per US$, Period Average), BM-Broad Money (% of GDP), INF-Inflation, GDP deflator (Annual %), TNR-Total Natural Resources Rents (% of GDP) and FDI-Foreign Direct Investment, Net Inflows (% of GDP) while the remaining 25.3% could be explained by other variables other than the ones used in this model.

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