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 Panel 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 USS, 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

\[ y_{it} = \beta_0 + \sum_{i=1}^{n} \beta_i X_{wit} + U_{it} \]  
\[ y_{it} = \beta_0 + \beta_i X_{it} + U_{it} \]  

In time series data, \( t = 1, 2, \ldots, T \) and \( n = 1 \); while in cross-sectional data, \( i = 1, 2, \ldots, n \) and \( T = 1 \). However, in panel data, \( t = 1, 2, \ldots, T \) and \( i = 1, 2 \ldots, n \).

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:

\[ y_{it} = \beta_0 + \sum_{k=1}^{k} \beta_k x_{it} + u_{it} \quad (2.2) \]

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 \( t \). \( \beta_0 \) is a scalar, \( \beta \) is \( k \times 1 \) matrix (a column vector) and \( X_{it} \) is the \( i \)th observation on the \( k \) explanatory variables.

Although (2.3) postulates common intercept \( (\beta_0) \) for all \( i \) and \( t \) and common vector of slope coefficients for all \( i \) and \( t \), variants of the model exist.

The variants include:

\[ y_{it} = \beta_0 + \sum_{k=1}^{k} \beta_k x_{it} + u_{it} \quad (2.3) \]

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

\[ y_{it} = \beta_{0i} + \sum_{k=1}^{k} \beta_k x_{it} + u_{it} = \beta_{0i} + X'_{it} \beta + u_{it} \quad (2.4) \]

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

\[ y_{it} = \beta_{0i} + \sum_{k=1}^{k} \beta_k x_{it} + u_{it} = \beta_{0i} + X'_{it} \beta_i + u_{it} \quad (2.5) \]

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

\[ y_{it} = \beta_{0it} + \sum_{k=1}^{k} \beta_k x_{it} + u_{it} = \beta_{0it} + X'_{it} \beta_{it} + u_{it} \quad (2.6) \]

(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. Seemingly Unrelated (SUR)
Each of these methods has its underlying assumptions which must necessarily 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)

\[ y_{it} = \beta_0 + \sum_{\omega=1}^{k} \beta_{\omega} X_{\omega, it} + \varepsilon_{it} = \beta_0 + \varepsilon_{it} + \varepsilon_{it}, \]

\[ i = 1, 2, \ldots, n \]
\[ t = 1, 2, \ldots, T \]

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

If \( U_{it} \) is decomposed as

\[ U_{it} = \mu_i + \nu_{it} \]

We have

\[ y_{it} = \beta_0 + X'_{it} \beta + \mu_i + \nu_{it} \]  \hspace{1cm} 3.1

(3.2) is called the one-way error component model where \( \mu_i \) denotes the unobservable country specific (time invariant) effect and \( \nu_{it} \) (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 \( \mu_i \) are assumed to be fixed parameters to be estimated and \( \nu_{it} \) normal, independent and identically distributed i.e. \( NID(0, \sigma^2) \). The \( X_{it} \) are assumed to be independent of \( \nu_{it} \) 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:

\[ \mathbf{y} = \beta \mathbf{v}_{it} + \mathbf{X} \beta + \mathbf{U} = \mathbf{Z} \beta + \mathbf{U} \]  \hspace{1cm} 3.3

where

\[ \mathbf{y} \text{ is nT \times 1; } \mathbf{X} \text{ is nT \times k; } \mathbf{Z} = (\mathbf{J}_{nT}, \mathbf{X}); \beta' = (\beta_0', \beta') \]

\( \mathbf{J}_{nT} \) is a vector of ones of dimension nT.

Note that (3.1) can be written as

\[ \mathbf{U} = \mathbf{Z}_\mu \mu + \nu \]  \hspace{1cm} 3.4

Where

\[ \mathbf{U} = (u_{11}, u_{12}, \ldots, u_{1T}, u_{21}, u_{22}, \ldots, u_{2T}, \ldots, u_{n1}, u_{n2}, \ldots, u_{nT}) \]

\[ \mathbf{Z}_\mu = \mathbf{I}_n \otimes \mathbf{J}_T \]

Where \( \mathbf{I}_n \) is identity matrix of dimension n, \( \mathbf{J}_T \) is a vector of ones of dimension T and \( \otimes \) denotes kronecker product;

\[ \mu' = (\mu_1, \mu_2, \ldots, \mu_n) \]

\[ \nu' = (\nu_{11}, \nu_{12}, \ldots, \nu_{1T}, \nu_{21}, \nu_{22}, \ldots, \nu_{2T}, \ldots, \nu_{n1}, \nu_{n2}, \ldots, \nu_{nT}) \]

\( \mathbf{Z}_\mu \) is a matrix of ones and zeros, that is, a matrix of individual dummies that are included in the regression to estimate \( \mu_i \) which are assumed fixed.

At this juncture, we should note the following:

\[ \mathbf{Z}_\mu \mathbf{Z}_\mu = \mathbf{I}_n \otimes \mathbf{J}_T \]  \hspace{1cm} (where \( \mathbf{J}_T \) is a square matrix of 1’s of dimension T)

\[ \mathbf{P} = \mathbf{Z}_\mu (\mathbf{Z}_\mu')^{-1} \mathbf{Z}_\mu \]

\[ = \mathbf{I}_n \otimes \mathbf{J}_T \left( \mathbf{I}_T = \frac{\mathbf{J}_T}{T} \right) \]

\{\mathbf{P} \text{ is a projection matrix on } \mathbf{Z}_\mu \text{, } \mathbf{P} \text{ averages the observations across time for each country.}\}

\[ \mathbf{Q} = \mathbf{I}_{nT} - \mathbf{P} \]

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

\{\mathbf{P} \text{ and } \mathbf{Q} \text{ are symmetric idempotent matrices (} \mathbf{P}^2 = \mathbf{P} \text{, } \mathbf{P}^2 = \mathbf{P} \text{)}\}

\[ \mathbf{P} \text{ and } \mathbf{Q} \text{ are orthogonal i.e. } \mathbf{PQ} = \mathbf{0} \]

\[ \mathbf{P} + \mathbf{Q} = \mathbf{I}_{nT} \]
Model Estimation

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

\[ y = \beta + X\beta + Z_\mu \mu + \nu = Z_\beta + Z_\mu \mu + \nu \]  

Where \( Z \) is \( nT \times (K+1) \) and \( Z_\mu \), the matrix of country dummies is \( nT \times n \), 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 \( \alpha \) and \( \beta \) by pre multiplying (3.5) by \( Q \) and performing OLS on the transformed model:

\[ Qy = QX\beta + Qv = Z_\beta + Z_\mu \mu + \nu \]  

Since \( QZ_\mu = Q \) \[ nT \times (K+1) \] \( QQz = 0 \)

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

As follows:

\[ Qy = QX\beta + Qv \]
\[ Qv = -Qy - QX\beta \]

\[ S = (Qy)'(Qy) = (Qy - QX\beta)'(Qy - QX\beta) \]
\[ S = y'Qy - y'XQ\beta - \beta'X'Qy + \beta'X'QX\beta \]
\[ S = y'Qy - y'XQ\beta - \beta'X'Qy + \beta'X'QX\beta \]
\[ \frac{dS}{d\beta} = -2XQy + 2X'QX\beta \]
\[ 0 = -2XQy + 2X'QX\beta \]
\[ 2X'QX\beta = 2X'Qy \]
\[ \hat{\beta} = (X'QX)^{-1}X'Qy \]

Mean of \( \hat{\beta} \)

\[ \beta = (X'QX)^{-1}X'Qy \]
\[ \hat{\beta} = (X'QX)^{-1}X'QX\beta \]
\[ \beta = (X'QX)^{-1}X'QX\beta + (X'QX)^{-1}X'Qv \]
\[ \beta = \beta + (X'QX)^{-1}X'Qv \]

\[ E(\hat{\beta}) = \beta + (X'QX)^{-1}X'QE(\nu) \]

Since

\[ E(\nu) = 0 \]

Then

\[ E(\hat{\beta}) = \beta \]

Variance of \( \beta \)

\[ \beta - \beta = (X'QX)^{-1}X'Qv \]

\[ \hat{\beta} = E(\beta - \beta)(\beta - \beta) \]

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

\[ \hat{\nu} = E[(X'QX)^{-1}X'Qv][E(\nu)']Q'X(X'QX)^{-1} \]

Since

\[ QQ = Q \]

We have

\[ \hat{\nu} = (X'QX)^{-1}X'Q[QE(\nu')]Q'X(X'QX)^{-1} \]

\[ E(\nu') = \sigma_v^2 1_{nT} \]

Then

\[ \hat{\nu} = \sigma_v^2 1_{nT} [(X'QX)^{-1}X'QX(X'QX)^{-1} \]

\[ \hat{\nu} = \sigma_v^2 1_{nT}(X'QX)^{-1} \]

\[ \hat{\nu} = \sigma_v^2 1_{nT}(X'QX)^{-1} \]

\[ \hat{\nu} = \sigma_v^2 1_{nT}(X'QX)^{-1} \]
Note: The OLS $\hat{\beta} = \beta + (X'QX)^{-1}X'Qy$ is sometimes called the Least Square Dummy Variable (LSDV).

4.0 RESULT OF ANALYSIS

The proposed Econometric model is given by

$$Y_{it} = \beta_0 + \beta_{1}OER_{it} + \beta_{2}BM_{it} + \beta_{3}INF_{it} + \beta_{4}TNR_{it} + \beta_{5}FDI_{it} + \epsilon_{it}$$

For $i = 1, 2, \ldots, n$ and $t = 1, 2, \ldots, T$ 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 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

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<td>271.73</td>
<td>27.92</td>
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<td>1982</td>
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<td>1986</td>
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<td>30.42</td>
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</tbody>
</table>

OUTPUT FROM EVIEW 7

TABLE 2: DESCRIPTIVE STATISTICS OF VARIABLES USED.
Developing Country Studies
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Vol.4, No.21, 2014

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>193.2930</td>
<td>19.02488</td>
<td>10.16001</td>
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<td>OER</td>
<td>-0.233136</td>
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<td>BM</td>
<td>24.50454</td>
<td>0.444517</td>
<td>55.12621</td>
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<td>FDI</td>
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<td>1.733163</td>
<td>32.91614</td>
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</table>

Effects Specification

Cross-section fixed (dummy variables)

Weighted Statistics

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<th>R-squared</th>
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<td>Adjusted R-squared</td>
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<tr>
<td>S.E. of regression</td>
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<tr>
<td>F-statistic</td>
<td>845.3767</td>
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<tr>
<td>Prob(F-statistic)</td>
<td>0.000000</td>
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</table>

Unweighted Statistics

<table>
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<th>R-squared</th>
<th>0.747038</th>
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</thead>
<tbody>
<tr>
<td>Sum squared resid</td>
<td>2.75E+08</td>
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</table>

Interpretation of Regression Results

The model to be fitted is

\[
RGDP_{it} = \beta_0 + \beta_1OER_{it} + \beta_2BM_{it} + \beta_3INF_{it} + \beta_4TNR_{it} + \beta_5FDI_{it} + \varepsilon_{it}
\]

The model fitted is

\[
RGDP_{it} = 193.29 - 0.23OER_{it} + 24.50BM_{it} - 1.11INF_{it} + 3.65TNR_{it} + 57.05FDI_{it}
\]

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.
Reference


[4] Badi H. Baltagi “PANEL DATA METHODS- Prepared for the Handbook of Applied Economic Statistics” Department of Economics, Texas A&M University, College Station, TX 77843-4228, Office: (409) 845-7380, Fax: 409) 847-8757, E-mail: E304bb@tamvm1.tamu.edu.


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