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# Total Factor Productivity and the Widespread Cross-country Growth Disparities in Africa

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**Abstract:** Given the concern of the widespread cross-country rates and patterns of income growth in Africa, the objective of this paper is to investigate the contribution of country-specific variations in Total Factor Productivity (TFP) in explaining the sources of these enormous growth differentials. A panel of 10 "fast growing" and 10 "slow growing" African countries are studied over the period 2001-2012. The study adopts non-parametric growth accounting methodology and estimates TFP as a measure of technical change using the Solow residual. The Divisia Index weighting system is used to calculate the factor elasticities from the estimated coefficients of the translog production functions. Two types of estimators are used to estimate each country-group regression equation: the OLS estimator — applied on a set of stacked data, and the preferred fixed-effects estimator — applied on a set of unstacked (panel) data. The estimates of the translog production functions show that the relative share of capital per worker in total output per worker is approximately 83 percent for the "fast growing" and approximately 69 percent for the "slow growing" African economies. Results from the regression models show that for both country groups, TFP growth per worker is an important predictor of growth in output per worker. The marginal causal effect of TFP per worker on output per worker is however larger and stronger for the "fast growing economies" than for "slow growing African economies" — a result that provides a partial, but not a sufficient explanation for the sources of existing widespread growth differences in Africa. The study results provide an empirical support on the prominence of TFP in influencing African countries' potential to create more of their economic wealth, and add on existing empirical literature on growth in African with focus on the role of variations in TFP. Our study results further highlight the importance of technical changes associated with production input usage and shade light for the need by governments to nurture the country-specific determinants of TFP for enhanced wealth creation.

**Key words:** total factor productivity; Solow residual; growth disparities; Africa
**JEL codes:** O4, O11, O47

## 1. Introduction

Cross-country differences in income per worker are widely known to be enormous (Caselli, 2003; Alfaro, Charlton & Kanczuk, 2009). Yet, increasing and stable economic growth is a fundamental policy objective in nearly all modern societies. In support of this view, Malmaeus (2010) notes that most other goals in society will be

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more effectively achieved if the economy gets bigger. For instance income distribution raises, poverty reduces and welfare increases when an economy is growing. This argument is based on a hypothesis originally sketched out by Kuznets (1955) that income distribution tends to worsen at early stages of development, and only later improves as incomes rise. The Kuznets hypothesis means that high income growth improves income distribution. Empirical studies in support of this relationship include, among others; Sacks, Stevenson and Wolfers (2010) who showed that richer individuals in a given country are more satisfied with their lives than are poorer individuals; Roemer and Gugerty (1997) who found that economic growth is positively associated with reductions in poverty. Persistence of cross-country growth disparities perpetuates inequalities between countries and puts the low income economies at risk of insurmountable impoverishment and miserable welfare standards.

On the African continent, indeed African economies continue to record mixed rates and patterns of income growth. The so called the "lion economies" of Africa have outpaced the rest of the countries on the continent in building their economic wealth. By the year 2012, the stunning economic growth of the "lion economies" of Africa (*Angola, Nigeria, Ethiopia, Chad, Mozambique, Uganda, Tanzania, Liberia, Sierra Leone and Rwanda*) earned them a spot next to "Asia's tigers" of the 1980s and 1990s. Over the study period (2001-2012), the "lion economies" of Africa recorded an average annual growth rate of about 8.4 percent, well above the Asia's 7.9 percent and far above Latin America's 3.3 percent. Over the same period, Angola herself recorded a fabulous average growth rate of 11.3 percent, an annual average growth rate higher than any of the fast growing East Asian economies over the same period.

**Table 1 Average Annual Growth Rates (2001-2012) of Selected African Countries by Country Group**

| "Fast growing economies" | | "Slow growing economies" | |
|---|---|---|---|
| Country | Average annual growth in GDP | Country | Average annual growth in GDP |
| Angola | 11.3 | C. African Rep. | 1.0 |
| Chad | 9.8 | Guinea-Bissau | 1.3 |
| Sierra Leone | 9.7 | Comoros | 2.1 |
| Liberia | 8.6 | Gabon | 2.3 |
| Ethiopia | 8.5 | Seychelles | 2.3 |
| Rwanda | 8.0 | Swaziland | 2.3 |
| Mozambique | 7.8 | Guinea | 2.6 |
| Uganda | 7.5 | Cameron | 3.3 |
| Tanzania | 7.0 | Burundi | 3.3 |
| Nigeria | 6.5 | Djibouti | 3.6 |
| Country group average annual growth: 8.5 | | Country group average annual growth: 2.4 | |

Source: Based on World Bank data on development indicators (last updated December 2014).

As indicated in Table1 above, the difference in the rates of income growth between the "fast growing" and the "slow growing economies" is indeed pronounced. Over the study period, the "fast growing economies" of Africa recorded a monumental average annual growth rate of over 8 percent, while the "slow growing economies" registered a dismal average annual growth rate of only less than one half of the "fast growing economies"; the lowest not only on the African continent but also relative to the rest of the world.

Until recently, there has been a debate on the drivers of the impressive growth recorded by the "fast growing economies" on the African continent (Radelet, 2007; McKinsey & Company, 2010; AfDB, OECD, UNDP &

UNECA, 2011, 2012; Aryeetey, Devarajan, Kanbur & Kasekende, 2012). Although a number of growth drivers have been identified as sources of rapid economic growth in a handful of countries in Africa, the empirical growth literature largely misses the recognition of the role of variations in TFP in explaining the sources of growth differences existing on the continent, and yet TFP has gained credible importance in explaining cross country growth differences (Abramowitz, 1956; De Long, 1991; Romer, 1990; Kim & Lau, 1994; Harrigan, 1995; Comin & Hobijn, 2004; Hafiz, Mohammad & Mohammad, 2010). A number of empirical studies have actually indicated that a substantial portion of growth variation across countries is productivity-driven (e.g., Isaksson, 2007; Comin & Mark, 2006; Caselli, 2005; Michael, Enrique & Bazoumana, 2012; Hafiz, Mohammad & Mohammad, 2010). Higher TFP indicates better level of technology, higher per worker capital, larger returns and enhances an economy's ability to produce more output from a given stock of inputs.

Given the concern of the widespread cross-country growth differences existing on the African continent, and the lack of empirical literature on the role of TFP in explaining these growth differentials, the objective of this paper is to apply the operational research techniques, namely statistical and econometric analytical techniques, in order to further understand the sources of the existing widespread growth differences in Africa by utilizing theoretical insights advanced by Mankiw, Romer and Weil (1992) to estimate TFP, and then assess the contribution of this variable, i.e., TFP in explaining the sources of these growth differences. The paper also aims at adding on the existing empirical literature on the sources of rapid growth in some countries in African focusing on the role of country-specific variations in TFP.

## 2. Brief Literature Review on the Relationship between TFP and Growth

Total Factor Productivity (TFP) has been documented as a crucial measure of both input productivity and efficiency and thus an important indicator for policymakers. The view that TFP plays a pivotal role in explaining overall economic growth could be traced back to the work of Abramowitz (1956) and Solow (1956). It was Solow (1956) who initiated a new debate by identifying that economic growth involves technical change-which became to be known as Total Factor Productivity Growth (TFPG) in economic literature. Later his thesis became popular because certain economies attained a very high growth rate as compared to others. This fact attracted many researchers to look beyond the mere accumulation of factors of production. Thus TFP captures all effects that raise the productivity of physical factors including technical change, human capital, vintage capital, development expenditures, economies of scale, government policies, international trade policies and remittances. Federica and Murat (2011) have pointed out that since the seminal work of Solow (1956, 1957), TFP has been considered as the major factor in generating growth. In the neoclassical growth model of Solow (1956), factor accumulation can only explain about half the variations in the growth rate. What remains, known as the Solow residual, is attributed to the growth in technical progress or TFP.

Solow (1957) argued that cross-country differences in this exogenous residual (i.e., in TFP) might generate important cross-country differences in income per capita. Solow's (1957) seminal paper during the 20th century concluded that technical change was found to be the main source of economic growth in the United States during the 20th century. In the neoclassical growth models (for example, Solow, 1956, 1957), technological progress is seen as manna from heaven and determined outside the model (in other words, it is exogenous). Subsequent theoretical studies (e.g., Romer, 1990) provide alternative rationales for how TFP can endogenously explain economic growth.

### 2.1 Measurement of Productivity Growth

Common approaches to empirically measure TFPG at the country level can be divided into two main categories: growth accounting and frontier analysis. Growth accounting uses non-parametric procedures and is based on the estimation of aggregate production functions to produce a measure that approximates technological progress. This approach calculates TFP growth as the part of output growth not explained by accumulation of factor inputs (i.e., the residual of the production function). Empirically, this measure is provided by the Solow residual. The objective of this method is to determine how much economic growth is due to accumulation of inputs and how much can be attributed to technical progress; or, put in different terms, how much of growth can be explained by movements along a production function, and how much should be attributed to advances in technological and organizational competence, the shift in the production function.

On the other hand, the basics of frontier analysis are based on the estimation of a frontier production function (this can be parametric or non-parametric) and the measurement of the distance of the observations to the estimated frontier, which is labeled as inefficiency. The stochastic frontier and Data Envelopment (DEA) methods are used to estimate inefficiency. The Malmquist Index (Malmquist, 1953) and the Törnqvist t index (Törnqvist, 1936) are the commonly used procedures in empirical literature to estimate inefficiency. According to this definition, a rise in production can be attributed to a rise in efficiency. A firm is fully technically efficient if it is operating on the production frontier, the production frontier being defined for a reference time period with reference to a particular set of firms. A rise in efficiency implies either more output is produced with the same amount of inputs or that less inputs are required to produce the same level of output. Equally, the outward shift of a production frontier implies productivity growth.

## 3. Methodology

### 3.1 Sample and Data

The study considers a panel 10 “fast growing” and 10 “slow growing” African countries over the period 2001-2012. Secondary data on different variables are obtained from the World Bank data bank on development indicators (last updated December 2012), while data on TFP are computed.

### 3.2 Sample Selection

The study considers all the 10 countries listed by “*The Economist*” as “lion economies” of Africa by the year 2012 (*The Economist*, 2012) and groups these countries as the “fast growing” economies. The “slow growing economies” considered by the study are determined as the bottom 10 countries with the lowest average growth rate over the period of study.

### 3.3 Empirical Estimation of TFP

The study uses growth accounting and estimates TFP as “Solow residual” as a measure technical change. Growth accounting is useful because it breaks growth into components that can be attributed to the growth of factor accumulation and TFP. As Solow (1956) notes, this “residual” measures not only technological change but also the ignorance of both measurable and non-measurable factors with expected positive effects on production. Most empirical studies have used only two factor inputs: labour and capital to estimate TFP (e.g., Gollop & Jorgenson; 1980; Christensen, Cummings & Jorgenson; 1980; Hall & Jones, 1999; Limam & Miller, 2004). As a result, it is very likely that the Solow residual estimated from a production function with only two inputs would overestimate the rate of technical change, hence creating a measurement bias. To minimize the measurement bias in TFP due to inclusion of only two factor inputs, the study utilizes the theoretical insights from the Solow (1956) growth model and its extension by Mankiw et al. (1992) by adding the input "human capital" in the production function. Particularly, the study adopts a Hicks-neutral Cobb-Douglas production function with three factor inputs given by:

$$Y(t) = A(t)[K(t)]^{\alpha}[H(t)]^{\beta}[L(t)]^{1-\alpha-\beta}; \quad 0 < \alpha + \beta < 1 \tag{1}$$

The model in Equation (1) exhibits constant returns to scale in its three factors: physical capital (*K*), human capital (*H*) and labor (*L*), such that: $\alpha, \beta \in [0,1]$, and *t* denotes time. The parameter "A" is a measure of "technology" or "efficiency" and is often called a "multi-factor productivity". *A*(*t*) measures the effects of technical changes or efficiency change on the shifts of aggregate production function over time and is known as TFP. As a matter of fact, changes in the index "A" indicate shifts in the relation between measured aggregate inputs and outputs and in this aggregate model these changes are assumed to be caused by changes in technology (or changes in efficiency and/or in the scale of operations of firms). The model in Equation (1) assumes that all markets (both input and output markets) are perfectly competitive. All firms are assumed to be identical. The economy can then be described by a representative agent.

The functional form of the production function in Equation (1) can be expressed as:

$$Y_t = F(K_t, H, L_t, t) \tag{2}$$

If there is technical progress, the function *F* shifts upwards and a technical regress causes *F* to shift downwards.

The production function in Equation (1) is expressed in per worker variables or intensive form as:

$$y(t) = Ak(t)^{\alpha} h(t)^{\beta} \tag{3}$$

Where: $y = \frac{Y}{L}; \quad k = \frac{K}{L} and \quad h = \frac{H}{L}.$

Making parameter "A" in Equation (3) the subject we have:

$$A = \frac{y}{k^{\alpha} h^{\beta}} \tag{4}$$

Where $\beta = 1 - \alpha$ under constant returns to scale; *y* is output per work and *h* is human capital per worker. Accordingly, Equation (4) gives a measure of multifactor productivity per worker in the context of the augmented Solow growth model, which is taken as a measure of technical change.

In the current study, total GDP is used to measure output; Gross capital formation is used a proxy of physical capital, productive labor is assessed by total working population, ages 15+ and human capital is captured by total average years of schooling.

### 3.4 The Empirical Model

Following the procedure adopted by Hafiz, Mohammad and Mohammad (2010), this study adopts two econometric models, each specified for a particular country group: a pooled cross-section model (with stacked data) and a fixed effects panel model. The former disregards the space and time dimensions and therefore assumes same estimated coefficients across individual countries for each country group. The study adopts the fixed effects regression model and ignores the random effects regression model because the former largely exploits the advantages of panel data and controls for unobserved heterogeneity (Brüderl, 2005). The random effects estimator over assumes the existence of "irrelevant" unobserved heterogeneity (in which case $\text{cov}(x_{ij}, u_{ij}) = 0$). In most cases the assumption of existence of "irrelevant" unobserved heterogeneity is not met in finite samples and therefore the random effects estimator is likely to be biased (Brüderl, 2005; Woodridge, 2013 ).

3.4.1 Model Variables

The study uses the growth rate in GDP per worker (*ggdpw*) as the dependent variable. The study includes growth in Total Factor Productivity per worker (*gtfpw*) and lags of growth rate in GDP per worker as control variables. The econometric model therefore tests the effect of growth in Total Factor Productivity per worker on growth rates in GDP per worker.

3.4.2 Model Specification

For the pooled cross-section of countries belonging to a particular country group, we adopt the following growth specification:

$$ggdpw_i = \gamma_0 + \gamma_1 gtfpw_i + \upsilon_i; i = 1,2; \gamma_1 > 0 \tag{3}$$

Where: $ggdpw_i$ is growth in GDP per worker of the country belonging to country-group *i*, $gtfpw_i$ is the growth in Total Factor Productivity per worker of the country belonging to country-group *i*, and $\upsilon$ is the error term. The coefficients $\gamma_i$; $i = 0, 2$ are model parameters.

We specify the growth equation for the fixed effects panel model as:

$$ggdpw_{kit} = \eta_0 + \eta_1 gtfpw_{kit} + \sum_{j=1}^{m} \eta_j ggdpw_{kit-j}; i = 1,2; \quad j = 1,2,..., m; l = 1,2,...L. \tag{4}$$

In Equation (4) *k* is a country identifier such that *k* = 1, 2,…, 10 for “fast growing” African economies and *k* =1,2,…, 10 for the “slow growing” African economies. Notation “*i*” in Equation (4) defines a country group. The notation “*j*” is used to denote the $j^{th}$ lag of the dependent variable, and “*m*” is the maximum number of lags in the growth specification.

3.4.3 Unit Root Tests

The study tests for stationarity of variables only for the fixed effects panel model and not for the pooled cross-section model. This is because the later disregards time and space and therefore behaves like a pure cross section. On panel model variables, the study adopts two panel data unit root test procedures: the Levin–Lin–Chu (2002) and the Fisher-type developed by Maddala and Wu (1999). These panel unit root test procedures are appropriate on balanced panel data sets, although the Fisher-type unit root test may also be applied to unbalanced panels. Secondly, the suggested panel unit root tests are appropriate with panel data sets where the numbers of cross sections are less than the number of time periods in the panel. Our data set has these features, making the suggested panel unit root test procedures appropriate for the study.

3.4.4 The Cointegration Test

This test is applicable on variables involving time series and panel data. For our panel data model(s), we hypothesize that all the variables in the growth specifications are stationary in levels since these variables are all growth rates. Economic theory often implies equilibrium relationships (cointegration) between the levels of time series variables that are best described as being I(d) such that d ≠ 0; d, indicates the order of integration. If all our variables are I(0), performance of a cointegration test is rendered irrelevant. However we test this hypothesis by adopting the Pedroni (2004) cointegration test.

3.4.5 The Causality Test

This test is particularly important to establish whether some or all of the regressors in our (panel) growth specifications are endogenous or not. Econometric literature maintains that the causality test is supported for a single time series data set (see for example Granger, 1969, 2004; Gujarati & Porter, 2009; Bressler & Anil, 2011). In this study where we have panel data, we go around the causality test by treating the panel data as one large stacked set of data that disregards space but not time, and then perform the usual Granger (1969) causality test, with the exception of not letting data from one cross-section enter the lagged values of data from the next cross-section.

## 4. Results

### 4.1 Estimates of the Input Elasticities of the Production for Each Country Group

The study begins with the estimation of the production function for each country group in order to obtain the estimates of the relative factor shares in total output. The production functions are estimated in terms of per worker variables. The study assumes identical production function for a set of countries pooled as a single cross section for a given country group. The study goes through pre-estimation diagnostic tests such as multicollinearity test, and finds no threat to multicollinearity in all growth specifications (-0.11 and 0.37 correlation coefficient between the regressors: *logkw* and *hw* for the "fast growing" and "slow growing" economies respectively). The Breusch-Pagan heteroscedasticity test performed after the regression failed to detect presence of heteroscedastic residuals in both growth equations at all the usual testing levels (see Appendix IB).

**Table 2 Summary of the Estimated Input Elasticities from the Translog Production Functions in Each Country-Group (The Input Elasticities Using Divisia Weighting System under CRS Assumption Are Indicated in Brackets)**

| Country group | Elasticity of physical capital per worker( $\hat{\alpha}$) | Elasticity of human capital per worker ( $\hat{\beta}$) |
|---|---|---|
| "fast growing economies": *n = 11* | 0.83 ( 0.93) | 0.06 (0.07) |
| "slow growing economies": *n = 15* | 0.69 (0.84) | 0.13 (0.16) |

The input elasticities are the partial slope estimates of the translog production functions. They show the estimates of the relative shares of the two variable inputs per worker in total output per worker. The estimates of the factor elasticities are then used to estimate TFP per worker and hence TFPG per worker. The estimates of the production as shown in Table 2 above show that the relative share of physical capital per worker in total output per worker is approximately 83 percent for the "fast growing economies" and approximately 69 percent for the "slow growing" African economies. On the other hand results in Table 2 above show that the relative share of human capital per worker in total output per worker is approximately 6 percent for the "fast growing economies" and approximately 13 percent for the "slow growing" African economies. The input elasticities using the divisia weighting system under CRS are shown in the parentheses.

It is observed that for both country groups, the relative share of physical capital per worker in output per worker exceeds that of human capital per worker. Results also show that the share of physical capital per worker in output per worker is higher in the "fast growing economies" than in the "slow growing economies". The picture is reversed when it comes to the relative share of human capital per worker in output per worker, which is higher in the "slow growing economies" than in the "fast growing economies".

### 4.2 Country-specific Mean Growth in TFP per Worker and Mean Growth in GDP per Worker

For each country in a particular country group, we calculate the mean growth in TFP per worker over the study period. We give the statistics in Table 3.

Table 3 indicates that over the period of study (2001-2012) the "fast growing economies" recorded an average growth rate in GDP per worker of approximately 13 percent while the "slow growing economies" recorded an average growth rate in GDP per worker of approximately 8 percent. Figures in Table 3 also indicate that over the study period, the "fast growing economies" recorded an average growth in TFP per worker of -0.9

percent while the "slow growing economies" recorded an average growth rate in TFP per worker of -0.3 percent. Chad recorded the highest average growth rate in TFP (of 10.1 percent) followed by Swaziland (9.2 percent), while Central African Republic recorded the lowest average growth in TFP (of -17.8 percent) flowed by Burundi (-8.2 percent).

**Table 3 Country-specific Mean Growth Rate in TFP Per Worker (GTFPW) and Mean Growth Rate in GDP Per Worker (GGDPW) Over the Period 2001-2012**

| "Fast growing economies" | | | "Slow growing economies" | | |
|---|---|---|---|---|---|
| Country | GGDPW (%) | GTFPW (%) | Country | GGDPW (%) | GTFPW (%) |
| Angola | 36.7 | 5.5 | Botswana | 9.7 | 0.9 |
| Chad | 17.4 | 10.1 | Gabon | 11.1 | 1.5 |
| Ethiopia | 12.1 | 0.2 | Guinea | 5.3 | 6.8 |
| Mozambique | 7.3 | 0.1 | Burundi | 8.1 | -8.2 |
| Nigeria | 17.2 | -0.9 | Djibouti | 5.3 | -4.5 |
| Rwanda | 11.8 | -3.1 | Seychelles | 4.1 | 7.2 |
| Tanzania | 6.3 | -5.3 | C. African Rep. | 10 | -17.8 |
| Uganda | 10.0 | -1.1 | Comoros | 7.3 | -2.1 |
| Siera Leone | 6.2 | -5.5 | Cameron | 7.6 | 4.3 |
| Liberia | 7.8 | -8.7 | Swaziland | 12.6 | 9.2 |
| Country group average | 13.3 | -0.9 | country group average | 8.1 | -0.3 |

Source: Authors' Computations

Whereas these figures provide us the statistical relationship between country group averages in GGDPW and GTFPW, they do not necessarily imply country-specific causal relationships between the variables. The study therefore seeks to measure the causal relationships between the two variables.

### 4.3 Correlation between Growth in TFP per Worker (GTFPW) and Growth in GDP per Worker (GGDPW)

Using correlation analysis, the study found it important to first measure the nature and extent of degree of correlation between the variables in the relationship under study. For each country group, the study calculates the correlation coefficients between the variables. Statistical significances of the correlation coefficients are evaluated at the standard 5 percent level. Table 4 below gives a summary of the correlation coefficients and their respective probability values.

**Table 4 A correlation between GTFPW and GGDPW by Country Group**

| | "Fast growing economies" | | "Slow growing economies" | |
|---|---|---|---|---|
| | GTFPW | GGDPW | GTFPW | GGDPW |
| GTFPW | 1 | 0.2683 (P = 0.0046)* | 1 | 0.1757 (P = 0.0663)** |
| GGDPW | 0.2683 (P = 0.0046)* | 1 | 0.2006 (P = 0.0663)** | 1 |

Note: * Statistically significant at 1 per cent level; ** Statistically significant at 5 per cent level

At 10 percent level of significance, the correlation coefficients reported in Table 4 above indicate that for both country groups, there is a statistically significant positive correlation between GTFP per worker and growth in GDP per worker. The degree of correlation is moderate weak positive for the "fast growing economies" and weak positive for the "slow growing economies".

### 4.4 Regression Estimates

4.4.1 Model 1 Regression: The Effect of Growth in TFP on Growth in GDP; A Pooled Cross-section Least Squares Model

In this model, the study considers a pooled cross-section set of observations on model variables for each country group. The dependent variable is growth in GDP per worker (*ggdpw*). Growth in TFP per worker (*gtfpw*) is used as control variable. The least squares estimation procedure is used to estimate the growth equation.

**Table 5a Model 1 Regression Results**

| "Fast growing economies" (n = 110[a]); Method: OLS | | | | "Slow growing economies" (n = 110[a]); Method: OLS | | | |
|---|---|---|---|---|---|---|---|
| *Dep. Var.= ggdpw* | | | | *Dep. Var.= ggdpw* | | | |
| *Indep.vars.* | *coef.* | *St. Error* | *p-value* | *Indep.vars.* | *coef.* | *St. Error* | *p-value* |
| *gtfgw* | 0.209 | 0.0723 | 0.005* | *Gtfpw* | 0.133 | 0.0714 | 0.066** |
| *Cons* | 14.417 | 1.5718 | 0.000* | *Cons* | 7.621 | 1.1804 | 0.000* |
| $R^2 = 0.072$<br>$\overline{R}^2 = 0.063$<br>Prob(F) = *0.0046**<br>Prob*(Breusch-Pagan Chi2) = 0.74* | | | | $R^2 = 0.031$<br>$\overline{R}^2 = 0.022$<br>Prob(F) = *0.0663*<br>Prob*(Breusch-Pagan Chi2) = 0.52* | | | |

Note: * Statistically significant ant 1 percent; ** Statistically significant at 10 percent;

[a] For a panel of 10 fast growing countries observed over the period 2001-2012, the pooled cross-section of these countries gives rise to (10×11 = 110 Observations). Similarly for a panel of slow growing economies observed over the period 2001-2012, the pooled cross-section of these countries gives rise to (10×11 = 110) observations. Note that we multiply 11 "years" because one year is lost for each country when calculating growth rates in the variables.

**Table 5b Heteroscedasticity Test after Model 1 Regressions**

| Heteroskedasticity Test: Breusch-Pagan | | |
|---|---|---|
| Statistic | Equation for the "fast growing economies" | Equation for the "slow growing economies" |
| F-statistic | Prob. F(1,108) = 0.8459 | Prob. F(1,108) = 0.6236 |
| Chi2: Obs*R-squared | Prob. Chi2(1) = 0.8442 | Prob. Chi2(1) = 0.6198 |
| Chi2: Scaled Explained SS | Prob. Chi2(1) = 0.7451 | Prob. Chi2(1) = 0.5253 |

Model 1 regression results in Table 5a above indicate that in both country groups, growth in TFP per worker has a positive causal effect on growth in GDP per worker. This causal effect is statistically significant in both country groups at 10 percent level. At 5 percent significance level however, growth in TFP per worker has a significant positive causal effect on growth in GDP per worker only in the "fast growing economies". Results in Table 4a further indicate that the marginal causal effect is larger and stronger in the "fast growing economies" than in the "slow growing" ones. All the three statistics in the heteroscedasticity test in Table 4b do not reject the null hypothesis of homoscedasticity at all the standard testing levels, indicating that the regression estimates for both country groups reported in Table4a are consistent.

4.4.2 Model 2 Regression: The Effect of Growth in TFP on Growth in GDP in Africa; A Panel Fixed Effects Regression Estimator

4.4.2.1 The panel unit root test results

Before the estimation of model 2 regression (the panel regressiom model), we first conduct some pre-estimation diagnostic tests namely, unit root tests and cointegartion tests. We do this in order to establish the order of integration of the variables as well as the nature of equilibrium relationships between the variables in the growth equations.

**Table 6 Panel Unit Root Test Results in the Panel Model**

| | Growth equation for the "fast growing countries" | | Growth equation for the "slow growing countries" | |
|---|---|---|---|---|
| Variable | Levin Lin Chu (variable in levels) | Fisher Type (variable in levels) | Levin Lin Chu (variable in levels) | Fisher Type (variable in levels) |
| *ggdpw* | t-stat = -6.44029 (p = 00000) | ADF-Chi2 = 57.9297 (p = 0.0000) | t-stat = -8.6586 (p = 00000) | ADF-Chi2 = 60.6517 (p = 0.0000) |
| *gtfpw* | t-stat = -3.95612 (p = 00000) | ADF-Chi2 = 46.9704 (p = 0.0006) | t-stat = -15.814 (p = 00000) | ADF-Chi2 = 68.8174 (p = 0.0000) |

Results from the panel unit root tests as shown in Table 5 above indicate that all the variables are stationary in levels. This implies that for all the variables included in the growth equations for each country group are integrated of order zero, I (0).

4.4.2.2 The cointegration test results

For the regression model specified for each country group, we conduct the Pedroni (2004) cointegration test. The results are shown in Table 7 below:

**Table 7 The Pedroni (2004) Cointegration Test Results**

| Ho: No cointegration | | |
|---|---|---|
| Equation for "fast growing economies" | | Equation for "last growing economies" |
| Ha: Common AR coefs. (within-dimension) | | Ha: Common AR coefs. (within-dimension) |
| Panel rho-Stat. | 1.336024 (p = 0.9092) | 1.421063 (p = 0.89223) |
| Panel PP-Stat. | -0.901009 (p = 0.1838) | -0.306139 (p = 0.3797) |
| Panel ADF-Stat. | -1.026925 (p = 0.1388) | 0.178584 (p = 0.5709) |
| Ha: Individual AR coefs. (between-dimension) | | Ha: Individual AR coefs. (between-dimension) |
| Group-rho-Stat. | 2.475130 (p = 0.9933) | 3.004094 (p = 0.9987) |
| Panel PP-Stat. | -3.974874 (p = 0.0000)* | 0.383915 (p = 0.6495) |
| Panel ADF-Stat. | -2.469708 (p = 0.0068) | 0.395485 (p = 0.6538) |

Note: * Statistically significant at 5 percent level

For the equation specified for the "fast growing economies", four (4) out of six (6) statistics of the Pedroni (2004) cointegration test do not reject the null hypothesis of no cointegration at 5 percent level whereas for the equation specified for the "slow growing economies", all the six (6) statistics of the Pedroni (2004) cointegration test do not reject the null hypothesis of no cointegration at all the conventional testing levels. As expected, the cointegartion test fails to detect any cointegrating relationships between the variables in the equation specifications for both country groups.

After establishing that all the variables in the growth specifications are integrated of order zero and that there are no cointegrating relationships between the variables in all the growth equations, we proceed to estimate a dynamic fixed effects model without differencing the variables. The results are shown in Table 8a.

The heteroscedasticity test results as indicated in Table8b above reject the null hypothesis of homoscedasticity in the growth specifications for both country groups. This means that the residuals in our panel growth equations are heteroscedastic and our fixed effects regression estimates reported in Table 8a are inconsistent. We fix the problem by estimating the regression functions by the method of Feasible Generalized Least Squares (FGLS). This method allows estimation in the presence of cross-sectional correlation and heteroscedasticity across panels. The method therefore produces consistent estimates**.**

**Table 8a The Fixed Effects Estimates: The Effect Of Growth in TFP per Worker on Growth in GDP per Worker**

| "Fast growing economies" (n = 10, T = 11) Method: Panel Fixed effects | | | | "Slow growing economies"(n = 10, T = 11) Method: Panel fixed effects | | | |
|---|---|---|---|---|---|---|---|
| *Dep. var.= ggdpw* | | | | *Dep. var.= ggdpw* | | | |
| *Indep.vars.* | *coef.* | *St. Error* | *p-value* | *Indep.vars.* | *coef.* | *St. Error* | *p-value* |
| *ggdpw(-1)* | 0.136 | 0.1063 | 0.205 | *ggdpw(-1)* | -0.146 | 0.1046 | 0.166 |
| *gtfpw* | 0.142 | 0.0780 | 0.073 | *Gtfpw* | 0.148 | 0.0795 | 0.011** |
| *Cons* | 12.851 | 2.2195 | 0.000* | *Cons* | 9.467 | 1.5673 | 0.000* |
| $R^2$ *(within) = 0.0588*<br>$R^2$ *(between) = 0.8555*<br>$R^2$ *(overall) = 0.1303*<br>*Prob(F) = 0.0693* | | | | $R^2$ *(within) = 0.057*<br>$R^2$ *(between) = 0.212*<br>$R^2$ *(overall) = 0.040*<br>*Prob(F) = 0.0767* | | | |

Note: * Statistically significant at 1 per cent level; * Statistically significant at 5 per cent level

**Table 8b Heteroscedasticity Test after Model 2 Regression**

| Modified Wald test for groupwise heteroskedasticity in fixed effect regression model | | | |
|---|---|---|---|
| Equation for the "fast growing economies" | | Equation for the "slow growing economies" | |
| Chi2-statistic (10) = 1363.94 | Prob(Chi2) = 0.0000* | Chi2-statistic (10) = 1359.61 | Prob(Chi2) = 0.0000* |

Note: *Statistically significant at 1 per cent level

**Table 9 The Feasible Generalized Least Squares Estimates of the Panel Growth Specifications**

| "Fast growing economies" (n = 10, T = 11) , Method: FGLS | | | | "Slow growing economies"(n = 10, T = 11), Method: FGLS | | | |
|---|---|---|---|---|---|---|---|
| *Dep. var.= ggdpw* | | | | *Dep. var.= ggdpw* | | | |
| *Indep.vars.* | *coef.* | *St. Error* | *p-value* | *Indep.vars.* | *coef.* | *St. Error* | *p-value* |
| *ggdpw(-1)* | 0.280 | 0.0921 | 0.002* | *ggdpw(-1)* | -0.081 | 0.0989 | 0.413 |
| *gtfpw* | 0.156 | 0.0748 | 0.037** | *Gtfpw* | 0.149 | 0.0751 | 0.048** |
| *Cons* | 10.761 | 2.0628 | 0.000* | *Cons* | 8.902 | 1.513 | 0.000* |
| *Prob(Chi2)=0.0003** | | | | *Prob(Chi2) = 0.1072* | | | |

Note: * Statistically significant at 1 per cent level; * Statistically significant at 5 per cent level

Consistent with model 1 regression results in Table 5a, the FGLS regression results in Table 9 above show that growth in TFP per worker has a positive causal effect on growth in GDP per worker in both country groups. The FGLS indicate that this positive effect is statistically significantly in both country groups at 5 percent (unlike at 10 percent level in Model1 regression). Like in model 1regression, it is observed that growth in TFP has a larger positive and more statistically significant marginal effect on growth in GDP per worker in the "fast growing economies" than in the slow growing economies'.

From model 1 and model 2 regressions, we note two fundamental results: (1) growth in TFP is an important predictor of growth in output per worker for both country groups, and (2) Higher and stronger gains from growth in TFP separates the "fast growing economies" from the "slow growing economies" in terms of the pace at which the two country groups generate their economic wealth.

### 4.5 Discussion of the Results

Our results from both models adopted for analysis are both theoretically and empirically plausible at least in terms of the sign of the estimated coefficient on our focus independent variable; growth in TFP per worker. From both models, this coefficient is positive. This positive sign of the estimated coefficient on growth in TFP per worker makes sense, since we expect growth in TFP to positively influence growth in GDP. The fundamental results our study provides are twofold: (i) growth in TFP is an important predictor of the country-specific growth in GDP under the panel model and (ii) growth in TFP is an important predictor of the country group growth in GDP under the pooled model analysis. The results from both models consistently show that the size and significance of marginal effect of the variable: “growth in TFP per worker” is slightly higher for “fast growing countries” than for the “slow growing economies”. We argue that this outcome provides a partial explanation as to why the “fast growing economies” in Africa have been able to outpace the “slow growing” ones in the rates at which they have been generating their economic wealth. Although on a different sample, our results tally very well with those of Han (2003) who investigated the predictive ability of TFPG for a large sample of countries over the period 1966-1990 and results showed that TFPG positively and significantly affected future economic growth in the full sample, and in the sub-sample of OECD countries. Our results also agree with those of Fazil et al. (2010) who tested the predictability of TFP for economic growth in Hong Kong, Korea, Malaysia and Thailand using the fixed effects regression model and the pooled regression model over the period 1970-2004 and concluded that productivity growth is a significant source of output growth.

We however contend, based on our results, the argument that growth variations in TFP provide a sufficient explanation to the existing widespread growth differences in Africa, a fact that somehow contradicts Caselli’s (2005) argument that most of the variation in income at the country level is explained by TFP. The study results provide an empirical support on the prominence of TFP in influencing countries’ potential to create more of their economic wealth over time. This empirical evidence on the prominence of growth in TFP in predicting growth in income provides with the policy makers an insight on the need for governments virtually in all countries in Africa to provide incentives that nurture the determinants of TFP.

## 5. Conclusion

The study employs operations research techniques to investigate the contribution of TFP in explaining the sources of existing pervasive cross-country differences in income growth in Africa. A panel of 10 “fast growing” and 10 “slow growing” African countries are studied. The study uses growth accounting and estimates TFP as measured by technical change using the Solow residual. Using the Divisia Index weighing system, factor elasticities are obtained from the estimates of a translog production function specified within the framework of augmented Solow growth model. Given the estimates of the factor elasticities for each country group, the individual country-specific TFP per worker values for each country group are computed.

For each country group, the study estimates two growth specifications using regression analysis: a pooled cross-section least squares model and a fixed-effects panel model. The study finds that the fixed-effects model produces inconsistent estimates, and adopts the Feasible Generalized Least Squares (FGLS) model. Results from all the regressions estimated for each country group show that growth in TFP per worker has a positive causal effect on growth in GDP per worker. However the marginal effect of growth in TFP per worker on growth in output per worker is larger and stronger for the “fast growing economies” than for the “slow growing economies”. Our study results therefore only provide a cursor to the prominence of TFP in growth accounting in Africa but do not provide a sufficient explanation for the existing widespread cross-country growth differences on the continent.

## 6. Policy Implications

The fundamental policy implication this study provides is that to accelerate rates of income growth of countries in Africa, it is important for the governments, especially those of low income and slow income growth, to put in place policies that raise TFP, or at least identify channels through which the policy makers can directly act to enhance aggregate productivity, and provide incentives that nurture the determinants of TFP. The determinants of TFP in Africa is out of scope of this study and we recommend it to be an area of further research.

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