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Foreign Direct Investment, Information Technology and Total Factor Productivity Dynamics in Sub-Saharan Africa

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Abstract

Compared to other regions of the world, the potential for information technology penetration in sub-Saharan Africa (SSA) is very high. Unfortunately, productivity levels in the region are also very low. This study investigates the importance of information technology in influencing the effect of foreign direct investment (FDI) on total factor productivity (TFP) dynamics. The focus is on 25 countries in SSA. Information technology is measured with mobile phone penetration and internet penetration, while the engaged TFP productivity dynamics are TFP, real TFP, welfare TFP, and real welfare TFP. The empirical evidence is based on the Generalised Method of Moments. The findings show that, with the exception of regressions pertaining to real TFP growth for which the estimations do not pass post-estimation diagnostic tests, it is apparent that information technology (i.e. mobile phone penetration and internet penetration) modulate FDI to positively influence TFP dynamics (i.e. TFP, welfare TFP, and welfare real TFP). Policy and theoretical implications are discussed.

JEL Classification: E23; F21; F30; L96; O55

Keywords: Productivity; Foreign Investment; Information Technology; Sub-Saharan Africa

1. Introduction

Three fundamental elements from the scholarly and policy literature motivate the positioning of this research on the importance of information technology in moderating the influence of foreign direct investment (FDI) on total factor productivity (TFP), notably: (i) debates in the literature on the mechanisms by which productivity can be enhanced; (ii) the importance of information and communication technology (ICT) in contemporary development outcomes; and (iii) gaps in contemporary FDI- and TFP-centric research. These highlighted elements are expanded in the same chronological order.

First, while productivity at the aggregate level has been established to be fundamental in the development of Africa, no consensus is apparent yet in the literature on the channels by which this productivity can be realised and consolidated (Baliamoune, 2009; Baliamoune-Lutz, 2011; Elu & Price, 2010; Ssozi & Asongu, 2016a; Cheruiyot, 2017; Tchamyou, 2017). In the light of the attendant literature, a renowned debate has been articulated around TFP and factor accumulation. In a strand of the literature, with regard to Young (1995) who has studied countries in East Asia, relative to TFP, factor accumulation has been more instrumental in driving economic development. Another strand of the literature, however, posits that cross-country disparities in TFP elicit cross-country variations in economic development (Abramovitz, 1986; Romer, 1986, 1993; Klenow & Rodriguez-Clare, 1997; Temple, 1999; Nelson & Pack, 1999; Easterly & Levine, 2001; Durlauf, Johnson & Temple, 2005).

With respect to Devarajan, Easterly and Pack (2003), the unfavourable economic development history of most African countries is not traceable to low investment levels compared to the policy syndrome of low productivity. The narrative maintains that in order to foster economic development; it will be misplaced for policy makers to put more emphasis on higher levels of investment without focusing on the productivity of such investments. This research contributes to the underlying debate by considering how ICT can be releveraged to promote TFP in sub-Saharan Africa (SSA) through the FDI channel. The importance of an ICT policy instrument is motivated by its contemporary relevance in driving development outcomes in the sub-region.

Second, there is a growing body of contemporary development literature documenting the relevance of ICT in driving economic development on various fronts (Tchamyou, 2017; Asongu & Nwachukwu, 2018; Abor, Amidu & Issahaku, 2018; Isszhaku, Abu & Nkegbe, 2018; Uduji & Okolo-Obasi, 2018; MinkouaNzie, Bidogeza & Ngum, 2018; Evans, 2019; Gosavi, 2018; Kaba & Meso, 2019). In light of the debate in the previous section, ICT has been established to consolidate a nation's production capacity and economic prosperity

(Hong, 2016). Furthermore, ICT can also represent a useful connection between the productivity operations in a country and value chains at the global level. In line with Sassi and Goaied (2013) and Asongu, le Roux, Nwachukwu and Pyke (2019), ICT reduces poverty, boosts competitiveness, increases efficiency and augments the ability of officials to manage the public sector more efficiently.

The usefulness of information technology in boosting productivity in SSA is also motivated by the high penetration potential of ICT in the sub-region relative to other regions of the world. According to the attendant literature, while ICT penetration has reached saturation levels in developed countries and emerging Asian and Latin American nations, its penetration is still relatively low in SSA (Penard, Poussing, Yebe & Ella, 2012; Asongu, 2013; Afutu-Kotey, Gough & Owusu, 2017; Asongu & Odhiambo, 2018; Asongu & Boateng, 2018; Efobi, Tanankem & Asongu, 2018; Humbani & Wiese, 2018; Gosavi, 2018; Asongu & Odhiambo, 2019a, 2019b). The corresponding low ICT penetration in the sub-region is an indication that the potential of information technology can be leveraged to address development challenges in SSA such as low productivity, poverty and unemployment, *inter alia*. This research, which focuses on the importance of information technology in the FDI-TFP nexus, is also motivated by an apparent gap in the FDI- and TFP-centric literature.

Third, contemporary studies on TFP and FDI pertaining to SSA can be engaged in two main strands. Research on TFP has largely focused on gender differences and supply of labour in the sub-region (Elu & Price, 2017); the nexus between exporting and manufacturing (Cisse, 2017); child labour intensity and schooling characteristics (Ahouakan & Diene, 2017); assessment of the interaction between TFP and manufacturing corporation within the context of changes in degrees of productivity growth across sectors in the manufacturing industry (Kreuser & Newman, 2018); and the role of information technology diffusion in the convergence of TFP (Maryan & Jehan, 2018). On the other hand, FDI studies have been concerned with, *inter alia*: FDI and regional wealth catch-up (Dunne & Masiyandima, 2017); the importance of global sector influence on Africa's sector portfolios (Boamah, 2017); linkages between economic development, institutional debt, bonds and equity (Fanta & Makina, 2017); the estimation of gaps in output in relation to potential economic growth (Fedderke & Mengisteab, 2017) and the importance of value chains in the role of FDI on TFP and economic growth (Meniago & Asongu, 2019). To our knowledge, the focus on this study has not been engaged in the extant literature. Hence, assessing the importance of information technology in the FDI-TFP nexus addresses the identified gap in the literature.

The positioning of this study does not exclusively depart from the engaged literature by considering ICT as a moderator in the effect of FDI on TFP. In the light of sustainable development challenges in the post-2015 development era, this research departs from the engaged literature that has fundamentally focused on one TFP indicator by taking on board TFP measurements that articulate welfare outcomes of productivity. These include: TFP, real TFP, welfare TFP and real welfare TFP. Hence, the research question this study aims to answer is the following: how does ICT modulate the effect of FDI on TFP dynamics in SSA? While Asongu and Acha-Anyi (2020) have assessed the importance of enhancing ICT for productivity, understanding nexuses between ICT, FDI and TFP is worthwhile.

The importance of ICT in modulating the FDI-TPF nexus is broadly consistent with contemporary global information technology management literature, which has recently documented *inter alia*: the role of ICT in the success of corporations (Bala & Feng, 2019); the importance of ICT in firm-level performance (Arslan, Bagchi & Kirs, 2019) and the mediating role of ICT in institutional developments (Alderete, 2018) and industrial developments (Mishra, Kishore & Shivani, 2018). Three main insights are directly apparent from this narrative, notably: (i) the modulating role of ICT in development outcomes as employed in this study; (ii) the nexus between the problem statement investigated in this study and extant contemporary global information technology management literature; and (iii) how the positioning of the study extends and complements the highlighted contemporary information technology management literature. Moreover, the practical and policy importance of findings of the study build on the low penetration of ICT, which is used in the study as the moderating variable. As discussed above, the penetration of ICT in Africa is low compared with other continents in the world. Hence, if the importance of ICT in increasing the benefits of FDI in productivity dynamics is established in this study, managers of corporations and policy makers at national levels can formulate and implement more strategies and policies designed to increase ICT penetration and, by extension, the benefits of such increased penetration in the rewards of foreign investment in productivity and economic development. In summary, policy makers can leverage on the low penetration of ICT to improve the benefits of FDI in productivity outcomes.

The rest of the research is organised in the following manner: The theoretical exposition on linkages between ICT, FDI and TFP are covered in section 2. The data and methodology are discussed in section 3 while the empirical results are disclosed in section 4. Section 5 concludes with implications and future research directions.

2. Theoretical model on nexuses between FDI, ICT and TFP

Consistent with Hassan (2005) and Asongu and Odhiambo (2020), on the theoretical linkage between FDI, ICT and productivity, many channels exist via which the positive incidence of FDI on development outcomes can be realised. (i) With respect to the *competitive channel*, improved competition is associated with enhanced investments in human and physical capital, greater efficiency and more productivity. Furthermore, increasing competition can boost variations in the industry that ultimately engender competition and export-oriented activities. (ii) The *training channel* entails enhanced training in labour and management operations. (iii) In the *linkage channel*, as much as FDI is enhanced by initial levels of technology, investment from foreign investors can also be a source of technology transfer to domestic corporations. (iv) In the light of the *demonstration channel*, domestic firms imitate foreign firms in the use of technology for the production and distribution of commodities.

Among the discussed channels, the linkage channel that articulates the relevance of information technology is more relevant for this research since the study is positioned within the framework that existing levels of information technology influence the absorption capacity of FDI in a nation. In other words, the importance of FDI in driving productivity is contingent on information technology[1].

The theoretical framework of this study is in line with the theoretical underpinnings that predict the relevance of FDI in driving output and productivity in developing nations (Romer, 1990; Grossman & Helpman, 1991; Borensztein, De Gregorrio & Lee, 1998; Barro & Sala-i-Martin, 1998; Hassan, 2005). Consistent with the attendant theoretical framework, let us consider two sectors within a nation that can be differentiated within their levels of productivity. Sector 1 entails foreign corporations that produce intermediate goods using advanced forms of technology, whereas sector 2, which comprises domestic firms, uses less advanced technology to produce commodities[2]. The theoretical framework which is in accordance with Hassan (2005) is discussed next.

[1] It is important to note that while the linkage channel is concerned with technology, ICT is used within the context of the study to proxy for technology. Hence, for the purpose of adapting the model to the context of the study, technology, information technology and ICT are used interchangeably in the study.

[2] Just two sectors are considered and alliances are not involved. It is important to clarify that economic models can be used in the information technology literature when investigating a problem statement linking information technology with macroeconomic variables. This is essentially because; information technology is almost indispensible in macroeconomic modelling.

The theoretical framework which is presented from Equation (1) to Equation (9) can be further emphasized in two main perspectives: (i) the utility of individuals is maximised when they consume commodities; (ii) and when these commodities are fabricated by foreign corporations (i.e. associated with FDI) and domestic firms, some conditions linked to FDI, such as information technology, can improve the production of the underlying commodities by further increasing the utility derived by individuals consuming the commodities. Accordingly, in line with the context of the study, aggregate utility is acknowledged in terms of TFP dynamics and information technology can increase the absorptive capacity of foreign investment for the attendant productivity dynamics. The corresponding equations are presented as follows.

Preferences: Individuals maximize an intertemporal utility function of the following form:

$$U(0) = \int_0^{\infty} e^{-\rho t} u(c_t) L_t dt \qquad (1)$$

where c_t is the per capita consumption in period t, ρ is the discount rate, and L_t is family size. The instantaneous utility function is of the Constant Relative Risk Aversion (CRRA) type:

$$U(c) = \frac{c^{1-\sigma} - 1}{1-\sigma}, \qquad (2)$$

where σ denotes the intertemporal elasticity of substitution between periods. The utility that is derived from consuming the commodities can be increased further, if the commodities are produced within the framework of a market environment that is competitive and involves both information technology and FDI.

Technology: Let Y represent consumption goods that are sold in competitive markets and produced by two sectors. Therefore, the corresponding economic productivity or output can be disclosed as:

$$Y = Y_1 + Y_2 \qquad (3)$$

And the production function for each of the sectors can be written as:

$$Y_1 = A_1 H^{\alpha} k^{1-\alpha} \text{ given that } 0 < \alpha < 1, \qquad (4)$$

where H reflects human capital endowment while Krepresents the stock of physical capital and is defined as:

$$K = \sum_{i=1}^{N^{FDI}} x_i Y_1 + Y_2 \qquad (5)$$

where x_i denotes intermediate goods when i indexes a plethora of intermediate goods' varieties, and N^{FDI} denotes the number of varieties in the intermediate goods by sector 1 (where foreign corporations are operating). In line with Romer (1990), the intermediate goods are considered in the production function in both an additive and a separate manner. Furthermore, the physical capital stock in a developing nation is denoted by N^{FDI} intermediate goods. In equation (4), K can be substituted and acknowledging that in equilibrium the price and quantity of each intermediate good is similar, $\bar{x}$:

$$Y_1 = A_1 H^{\alpha} N^{FDI} \bar{X}^{1-\alpha} \qquad (6)$$

In sector 2, the production function can also be written as:

$$Y_2 = A_2 L_2^{\beta} \qquad (7)$$

When the following restrictions are reflected in the parameters:

$A_1(1-\alpha) > A_2\beta$

The corresponding efficiency prevailing in sector 2 denotes of fraction of that prevailing in sector 1:

$$A_2 = \varepsilon A_1 \qquad (8)$$

$\varepsilon < 1$

The fixed cost can be written as:

$$F = f(N^{FDI}) \text{ where, } \frac{\partial F}{\partial N^{FDI}} < 0 \qquad (9)$$

This is evidence of the negative relationship and it mirrors rents of monopolistic nature in sector 1. Furthermore, the existence of F requires growing returns to be prevalent in sector 1 and therefore, the availability of incremental profits. On the other hand, when the relationship is positive in the form,

$$\frac{\partial F}{\partial N^{FDI}} > 0$$

an assumption of convergence can be derived as one of the model's predictions in the light of the premise that a nation with a higher technology gap is likely to grow at a faster rate. In accordance with the earlier observations, FDI is linked with competition that enhances the

overall production process's efficiency, and thereby, the maximization of utility that is obtained by individuals who consume the commodities. Furthermore, as shall be substantiated in the subsequent paragraphs to further clarify the context of this study, productivity at the aggregate level, competition and overall utility maximization can be consolidated by mediating production factors such as ICT.

Given the above theoretical exposition, ICT can be theoretically used to moderate the influence of FDI on output and productivity. While in a neoclassical framework, the relevance of FDI in productivity is contingent on decreasing returns in physical capital (Solow, 1956), from the perspective of the New Theory of Economic Growth, FDI can affect productivity and the level of output because of many complementary factors, including technology.

Within the specific context of the study, it is relevant to discuss motivations for the operationalization of ICT as mobile phone penetration and internet penetration. These ICT proxies are factors that improve the absorptive potential of FDI for productivity outcomes. The main motivation that ICT can mediate the incidence of FDI on TFP dynamics is because this era is one of knowledge-based economies in which ICT is considered as a production factor, given that it enhances the productivity through, *inter alia*: (i) the purchase of raw material that is required for the production process; (ii) production management and; (iii) communication between various production departments. Therefore, the documented relevance of ICT in productivity improvements and "domestic investment"-related efficiency in resource allocation (Minkoua Nzie et al., 2018; Gosavi, 2018; Issahaku et al., 2018) can also be relevant to foreign investment, according to Maryam and Jehan (2018). It follows that, within the context of the study, FDI is also conceived as a channel through which ICT improves productivity, in line with the documented importance of ICT in increasing economic prosperity and aggregate productivity (Vu, 2011, 2019). Accordingly, FDI in any economic sector (primary, secondary or tertiary) is contingent on domestic information technology in order to improve the efficiency associated with other factors of production such as physical and human capital. It follows that ICT can enhance the absorptive capacity of FDI in order to engender favorable outcomes, such as productivity. In the light of the insights documented in this section, the hypothesis to be tested in the empirical section of this paper is as follows:

Hypothesis 1: ICT modulates FDI to induce net positive effects on TFP dynamics.

3. Data and methodology

3.1 Data

The emphasis of this research is on a panel of 25 nations in SSA based on data ranging from 1980 to 2014[3]. Data availability constraints motivate the geographical and temporal expositions of the study. Hence, the period of study ends in 2014 due to data availability constraints at the time of the study. The data is reorganised to be consistent with the empirical strategy adopted by the study. Accordingly, the Generalised Method of Moments (GMM) technique adopted by this study requires that the number cross sections should exceed the number of periods in every cross section. Given that the research is dealing with 25 countries over a period of 35 years, the employment data averages in terms of non-overlapping intervals is warranted. To this end, the study computed five seven-year and seven five-year non-overlapping intervals. Upon preliminary exploratory empirical analysis, it was apparent that the former set of non-overlapping intervals leads to instruments proliferation in post-diagnostic estimation tests, even when the option of collapsing instruments is engaged in the GMM procedure. The retained five seven-year non-overlapping intervals for the study are: 1980-1986; 1987-1993; 1994-2000; 2001-2007; 2008-2014. It is also worthwhile to note that the use of data averages also reduces business cycle disturbances that can persist over time and influence estimated coefficients.

The Foreign Direct Investment (FDI) variable is obtained from the United Nations Conference on Trade and Development (UNCTAD) database. It is proxied as FDI inflows measured as a percentage of Gross Domestic Product (GDP) in accordance with the engaged FDI-centric literature (Dunne & Masiyandima, 2017; Fadiran, 2020). The TFP variables are obtained from the Penn World Table database. The indicators include: TFP, real TFP, welfare TFP and real welfare TFP. Consistent with the motivation of this research, more TFP dynamics are involved in the analysis in order to incorporate a dimension of inclusive and sustainable development. Hence, these TFP variables articulate both productivity and welfare associated with the underlying output. The choice of these TFP dynamics is consistent with contemporary TFP literature (Maryan & Jehan, 2018; Kreuser & Newman, 2018; Asongu, 2020). Moreover, the theoretical framework motivating this study that partly builds on the convergence underpinnings is not consistent with business cycle disturbances.

[3]The countries, selected on data availability are: Benin; Botswana; Burkina Faso; Burundi; Cameroon; Central African Republic; Cote d'Ivoire; Gabon; Kenya; Lesotho; Mauritania; Mauritius; Mozambique; Namibia; Niger; Nigeria; Rwanda; Senegal; Sierra Leone; South Africa; Sudan; Swaziland; Tanzania; Togo and Zimbabwe.

The ICT moderating policy variables are sourced from the World Development Indicators (WDI) of the World Bank. These include: mobile phone penetration and internet penetration. The choice of these ICT indicators is motivated by contemporary ICT-centric literature covered in the introduction. Four elements are incorporated into the conditioning information set in order to control for variable omission bias. These variables come from the WDI of the World Bank and the Financial Development and Structure Database (FDSD) of the World Bank. While private domestic credit comes from the FDSD, the remaining three variables are from WDI, namely: inclusive education, government expenditure and remittances. The choice of these variables is motivated by scholarship on drivers of economic output and productivity, *inter alia*: Becker, Laeser and Murphy (1999), Barro (2003), Heady and Hodge (2009), Sahoo, Dash and Nataraj (2010) and Ssozi and Asongu (2016a, 2016b). The research expects all the adopted elements in the conditioning information set to positively affect productivity. Further clarification is provided in what follows.

First, contemporary TFP literature (Asongu, 2020), government expenditure is anticipated to positively influence productivity because part of the underlying expenditure is used to stimulate conditions for economic growth, employment and human development. Second, as documented by Ssozi and Asongu (2016a), education boosts TFP in SSA and the choice of an indicator that embodies the primary and secondary school is motivated by the documented relevance of lower levels of education in economic development when countries are at beginning stages of industrialization (Petrakis & Stamatakis, 2002; Asiedu, 2014; Tchamyou, 2020)[4]. Third, remittances have also been documented to be positively associated with economic output, TFP and industrialisation in contemporary African development literature (Ssozi & Asongu, 2016b; Asongu, Biekpe & Tchamyou, 2019). Fourth, the importance of private domestic credit in boosting economic output and productivity is also consistent with contemporary scholarship relating to Africa's development (Asongu, 2015; Nyasha & Odhiambo, 2015a, 2015b). Appendix 1 provides the definitions and sources of the variables used in the research while the summary statistics is disclosed in Appendix 2. In Appendix 3, the correlation matrix is provided.

[4]The adopted education proxy is primary and secondary (gross), gender parity index (GPI).

3.2 Methodology

3.2.1 Specification

Inspired by contemporary GMM-oriented studies, this exposition underpins the choice of the GMM approach fundamentally on four motivations (Tchamyou, 2020; Meniago & Asongu, 2018). (i) Primarily, the data structure that is consistent with the empirical approach warrants that the number of cross sections (i.e. countries within the framework of this study) exceeds the corresponding number of periods in each cross section (i.e. years within the context of this research). Therefore, the N>T condition is met because the research is using 5 seven-year data averages across 25 countries. (ii) The outcome indicators overwhelmingly reflect persistence because their level values are correlated with their corresponding first-lag values to a height of more than 0.800 which is acknowledged in contemporary GMM-centric literature as the exploratory rule thumb for establishing persistence in a dependent variable (Tchamyou, 2019b; Efobi, Asongu, Okafor; Tchamyou & Tanankem, 2019). (iii) In the light of the panel data structure, cross-country differences are incorporated into the estimation exercise. (iv) The concern of endogeneity that is worthwhile for robust empirical analysis is taken on board from two main perspectives, notably: time invariant omitted variables are employed to account for the heterogeneity that is unobserved while reverse causality or simultaneity is addressed with the engagement of internal instruments.

The following equations in levels (10) and first difference (11) summarize the estimation procedure for the relevance of ICT on modulating FDI to influence TFP.

$$TFP_{i,t} = \sigma_0 + \sigma_1 TFP_{i,t-\tau} + \sigma_2 FDI_{i,t} + \sigma_3 IT_{i,t} + \sigma_4 Inter_{i,t} + \sum_{h=1}^{4} \delta_h W_{h,i,t-\tau} + \eta_i + \xi_t + \varepsilon_{i,t} \quad (10)$$

$$\begin{aligned} TFP_{i,t} - TFP_{i,t-\tau} = {} & \sigma_1 (TFP_{i,t-\tau} - TFP_{i,t-2\tau}) + \sigma_2 (FDI_{i,t} - FDI_{i,t-\tau}) + \sigma_3 (IT_{i,t} - IT_{i,t-\tau}) \\ & + \sigma_4 (Inter_{i,t} - Inter_{i,t-\tau}) + \sum_{h=1}^{4} \delta_h (W_{h,i,t-\tau} - W_{h,i,t-2\tau}) + (\xi_t - \xi_{t-\tau}) + (\varepsilon_{i,t} + \varepsilon_{i,t-\tau}) \end{aligned}, \quad (11)$$

where $TFP_{i,t}$ is total factor productivity (i.e. TFP, real TFP, welfare TFP and real welfare TFP) of country i in period t; FDI is foreign direct investment; ICT is information technology (i.e. mobile phone penetration and internet penetration); $Inter$ is the interaction between FDI and information technology; σ_0 is a constant; τ is the degree of auto-regression which is considered as one within the framework of this empirical exercise because a lag of seven years is enough to capture previous information; W is the vector of elements in the conditioning information set (*government expenditure, education, remittances and private domestic credit)*, η_i is the country-specific effect, ξ_t is the time-specific constant and $\varepsilon_{i,t}$ the

error term. Equations (10) and (11) are replicated for the remaining three outcome variables namely: real TFP, welfare TFP and real welfare TFP. Within the framework of the research, the GMM approach with forward orthogonal deviations that is adopted for the empirical analysis is the extension of the Arellano and Bover (1995) approach by Roodman (2009) which has been documented to provide more efficient estimated coefficients (Boateng, Asongu, Akamavi & Tchamyou, 2018; Tchamyou, Erreygers, & Cassimon, 2019a).

3.2.2 Identification, simultaneity and exclusion restrictions

A discourse on identification, simulatneity and exclusion restrictions is warranted for a robust GMM empirical strategy. These three elements are expanded in turn. First, the identification process consists of defining three sets of variables, namely: the outcome, the endogenous explaining and the strictly exogenous variables. The outcome indicators in this study are the TFP productivity dynamics, while years are considered to represent strictly exogenous variables because according to Roodman (2009) they cannot be endogenous after a first difference. The corresponding endogenous explaining variables are the independent variables of interest (i.e. ICT and FDI indicators) as well as the elements in the conditioning information set (i.e. the four control variables). This identification strategy is in accordance with contemporary GMM-centric literature (Tchamyou & Asongu, 2017; Meniago & Asongu, 2018). Hence, the corresponding exclusion restriction assumption is that the strictly exogenous variables influence the outcome variables exclusively via mechanisms underlying the endogenous explaining variables.

Second, the issue of simultaneity or reverse causality is addressed by means of forward differenced instrumental variables. This consists of employing Helmet transformations to purge the analysis of fixed effects that can bias the estimated model because they are correlated with the lagged outcome variable. This approach to doing away with fixed effects is in accordance with the extant literature on the subject, notably: Arellano and Bover (1995), Love and Zicchino (2006) and Roodman (2009). Such transformations enable parallel or orthogonal conditions between the forward-differenced and lagged observations.

Third, the assumption of exclusion restrictions articulated in the first strand of this study is assessed with the Difference in Hansen Test (DHT) for the exogeneity of instruments. The null hypothesis of this test is the position that the identified strictly exogenous variables influence the outcome variable exclusively via the exogenous components of the identified explaining variables. Hence, in the empirical results section, the failure to reject this null

hypothesis is an indication that the exclusion restriction assumption holds. This procedure for validating exclusion restrictions is also consistent with more traditional instrumental variable procedures in which the rejection of the Sargan/Hansen test is an indication that the identified strictly exogenous variables affect the dependent variables beyond the exogenous components of the identified endogenous explaining variables (Beck, Demirgüç-Kunt & Levine, 2003; Amavilah, Asongu & Andrés, 2017; Tchamyou, Asongu & Odhiambo, 2019b).

4. Empirical results

4.1 Presentation of results

The results of the empirical analysis are presented in this section in Tables 1-4. Net effects are provided in the tables in the light of the testable hypothesis. These net effects are thus a summary of the results pertaining to nexuses, since the dependent and independent variables allow the reader to easily grasp the findings in view of the tested hypothesis. Table 1 focuses on nexuses between FDI, ICT and TFP while Table 2 is concerned with FDI, ICT and real TFP growth. Table 3 shows results on linkages between FDI, ICT and welfare TFP whereas Table 4 focuses on interactions between FDI, ICT and welfare real TFP. Each of the four tables is characterized by two main sub-sections of specifications: the first focuses on "mobile phone"-oriented regressions while the second is concerned with "internet penetration"-centric estimations.

All regressions are specified such that, concerns pertaining to the proliferation of instruments are limited as much as possible. Accordingly, even when the collapse option is implemented on the instruments in the specification exercise, concerns of instrument proliferation abound. Hence, for the purpose of avoiding instrument proliferation for both "mobile phone"- and internet-centric specifications, four of the five specifications exclusively involve one of the four adopted elements in the conditioning information set. Accordingly, the first specifications do not involve any element in the conditioning information set. The involvement of limited elements in the conditioning information set in order to limit concerns of instrument proliferation is not uncommon in the GMM-centric literature. Some examples of studies in the attendant literature that do not involve control variables in order to avoid the underlying issues of instrument proliferation are: Osabuohien and Efobi (2013) and Asongu and Nwachukwu (2017).

For all estimated models, four criteria of information are fundamental for the assessment of the validity of estimated models[5].In the light of the information criteria, the specifications are valid overwhelmingly with some exceptions in: (i) the second column of Table 1; (ii) some columns in Table 2 and (iii) the last column in Table 3. These models are invalid either because of the presence second order autocorrelation in difference and/or evidence of a valid alternative hypothesis of the Hansen test. For the validity of estimated models, the null hypothesis of the Hansen test is preferred to the Sargan test because the Hansen test is more robust, though weakened by the proliferation of instruments. Conversely, the Sargan test which is not robust is not weakened by the proliferation of instruments. A means of addressing the conflicting criteria is to prefer the Hansen test and control the associated concern of instrument proliferation by ensuring that in the post-estimation diagnostic tests, in each specification, the number of instruments is lower than the corresponding number of cross sections.

Consistent with contemporary research based on interactive estimations (Tchamyou & Asongu, 2017; Agoba, Abor, Osei & Sa-Aadu, 2020), in order to assess the relevance of information technology in the impact of FDI on dynamics on TFP, net impacts are calculated. These net effects entail the unconditional effect of FDI on TFP as well as the conditional impact pertaining to the interaction between ICT and FDI. Hence, the net effect is the sum of the underlying conditional and unconditional effects. The computational approach is also in accordance with Brambor, Clark and Golder (2006) who have documented that in interactive regressions, the conditional and unconditional effects should not be considered and interpreted in isolation. To articulate this computation in more detail, an example is worthwhile. In the fourth column of Table 1, the net impact on TFP from the importance of mobile phone penetration in moderating the incidence of FDI on TFP is 0.004 ([15.806 × -0.0001] + [0.006]).In this calculation, the average value of mobile phone penetration is 15.806; the unconditional effect of FDI on TFP is 0.006 while the conditional impact from the interaction between mobile phone penetration and FDI on TFP is -0.0001.

The following findings can be established from Tables 1-4. With exception of Table 2 on regressions pertaining to real TFP growth for which the estimations do not pass post-

[5] "*First, the null hypothesis of the second-order Arellano and Bond autocorrelation test (AR (2)) in difference for the absence of autocorrelation in the residuals should not be rejected. Second the Sargan and Hansen over-identification restrictions (OIR) tests should not be significant because their null hypotheses are the positions that instruments are valid or not correlated with the error terms. In essence, while the Sargan OIR test is not robust but not weakened by instruments, the Hansen OIR is robust but weakened by instruments. In order to restrict identification or limit the proliferation of instruments, we have ensured that instruments are lower than the number of cross-sections in most specifications. Third, the Difference in Hansen Test (DHT) for exogeneity of instruments is also employed to assess the validity of results from the Hansen OIR test. Fourth, a Fischer test for the joint validity of estimated coefficients is also provided*" (Asongu& De Moor, 2017, p.200).

estimation diagnostic tests, it is apparent that ICT (i.e. mobile phone penetration and internet penetration) modulate FDI to positively influence TFP dynamics (i.e. TFP, welfare TFP and welfare real TFP). The significant control variables have the expected signs.

Table 1: FDI, ICT and Total Factor Productivity

	Dependent variable: Total Factor Productivity (TFP)									
	The mobile phone penetration channel					The internet channel				
TFP (-1)	**0.802*** (0.000)**	**0.735*** (0.000)**	**0.838*** (0.000)**	**0.902*** (0.000)**	**0.814*** (0.000)**	**0.827*** (0.000)**	**0.747*** (0.000)**	**0.804*** (0.000)**	**0.910*** (0.000)**	**0.872*** (0.000)**
FDI	**0.008** (0.021)**	0.009 (0.121)	**0.006** (0.044)**	0.003 (0.510)	**0.010*** (0.003)**	**0.006*** (0.005)**	**0.007*** (0.005)**	**0.006*** (0.000)**	**0.003** (0.025)**	**0.006*** (0.000)**
Mobile	**0.001** (0.023)**	**0.001** (0.028)**	0.0004 (0.182)	-0.0007 (0.342)	**0.001** (0.028)**	---	---	---	---	---
Internet	---	---	---	---	---	**0.004** (0.010)**	**0.007*** (0.001)**	**0.007*** (0.000)**	**0.002* (0.070)**	**0.004** (0.029)**
FDI× Mobile	**-0.0001** (0.048)**	-0.0002 (0.149)	**-0.0001*** (0.009)**	-0.0001 (0.329)	**-0.0002*** (0.009)**	---	---	---	---	---
FDI× Internet	---	---	---	---	---	**-0.001** (0.034)**	**-0.001*** (0.004)**	**-0.001*** (0.000)**	**-0.001*** (0.000)**	**-0.001*** (0.001)**
Education	---	**0.162* (0.092)**	---	---	---	---	**0.135* (0.071)**	---	---	---
Gov't Expenditure	---	---	**0.006*** (0.000)**	---	---	---	---	**0.006*** (0.001)**	---	---
Remittances	---	---	---	**0.001*** (0.000)**	---	---	---	---	**0.001*** (0.000)**	---
Private Credit	---	---	---	---	0.0005 (0.158)	---	---	---	---	0.0004 (0.453)
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Net Effects	nsa	na	0.004	na	0.006	0.002	0.003	0.002	-0.00005	0.002
AR(1)	**(0.674)**	**(0.316)**	**(0.448)**	**(0.388)**	**(0.688)**	**(0.581)**	**(0.285)**	**(0.360)**	**(0.383)**	**(0.697)**
AR(2)	**(0.848)**	**(0.796)**	**(0.835)**	**(0.878)**	**(0.449)**	**(0.926)**	**(0.361)**	**(0.942)**	**(0.844)**	**(0.506)**
Sargan OIR	**(0.225)**	**(0.682)**	**(0.478)**	**(0.650)**	**(0.343)**	**(0.104)**	**(0.217)**	**(0.415)**	**(0.520)**	**(0.446)**
Hansen OIR	(0.089)	**(0.348)**	**(0.362)**	**(0.527)**	**(0.239)**	**(0.270)**	**(0.511)**	**(0.381)**	**(0.291)**	**(0.069)**
DHT for instruments										
(a)Instruments in levels										
H excluding group	**(0.115)**	**(0.116)**	**(0.095)**	**(0.148)**	**(0.326)**	(0.083)	(0.060)	(0.093)	(0.089)	**(0.241)**
Dif(null, H=exogenous)	**(0.128)**	**(0.543)**	**(0.604)**	**(0.718)**	**(0.233)**	**(0.437)**	**(0.869)**	**(0.636)**	**(.515)**	**(0.073)**
(b) IV (years, eq(diff))										
H excluding group	**(0.616)**	**(0.563)**	**(0.186)**	**(0.394)**	**(0.167)**	**(0.250)**	**(0.450)**	**(0.287)**	**(0.235)**	(0.035)
Dif(null, H=exogenous)	(0.017)	**(0.142)**	**(0.865)**	**(0.656)**	**(0.526)**	**(0.346)**	**(0.496)**	**(0.556)**	**(0.462)**	**(0.561)**
Fisher	**704.03***	**280.12***	**966.45***	**1158.78***	**2349.77***	**1217.38***	**1274.41***	**1025.42***	**433.53***	**1056.17***
Instruments	18	22	22	22	22	18	22	22	22	22
Countries	24	24	24	24	24	24	24	24	24	24
Observations	96	82	94	86	94	96	82	94	86	94

***,**,*: significance levels at 1%, 5% and 10% respectively. DHT: Difference in Hansen Test for Exogeneity of Instruments Subsets. Dif: Difference. OIR: Over-identifying Restrictions Test. The significance of bold values is twofold. 1) The significance of estimated coefficients and the Fisher statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the AR(1) & AR(2) tests and; b) the validity of the instruments in the Sargan and Hansen OIR tests. Gov't: Government. nsa: not specifically applicable because the estimated model is not valid. na: not applicable because at least one estimated coefficient required for the computation of net effects is not significant. The mean value of mobile phone penetration is 15.806 while the mean value of internet penetration is 3.053. Constants are included in all regressions.

Table 2: FDI, ICT and Real Total Factor Productivity Growth

	Dependent variable: Real Total Factor Productivity Growth (Real TFP growth)									
	The mobile phone penetration channel (Mobile)					The internet channel(Internet)				
Real TFP growth(-1)	**0.758*** (0.000)**	**0666*** (0.000)**	**0.653*** (0.000)**	**0.761*** (0.000)**	**0.782*** (0.000)**	**0.730*** (0.000)**	**0.639*** (0.000)**	**0.631*** (0.000)**	**0.744*** (0.000)**	**0.804*** (0.000)**
FDI	0.012 (0.136)	-0.001 (0.781)	**0.013** (0.031)**	0.006 (0.340)	0.007 (0.304)	**0.005*** (0.002)**	0.004 (0.226)	**0.007*** (0.000)**	**0.003*** (0.001)**	**0.006*** (0.009)**
Mobile	0.0006 (0.577)	-0.0009 (0.345)	0.0006 (0.372)	-0.0006 (0.474)	-0.0003 (0.747)	---	---	---	---	---
Internet	---	---	---	---	---	0.002 (0.134)	0.0008 (0.766)	**0.004*** (0.003)**	0.001 (0.195)	0.003 (0.152)
FDI× Mobile	-0.0003 (0.134)	0.00008 (0.704)	**-0.0003** (0.038)**	-0.0002 (0.304)	-0.0002 (0.274)	---	---	---	---	---
FDI× Internet	---	---	---	---	---	**-0.001** (0.011)**	-0.0005 (0.382)	**-0.001*** (0.000)**	**-0.001*** (0.000)**	**-0.001** (0.044)**
Education	---	-0.073 (0.379)	---	---	---	---	-0.067 (0.384)	---	---	---
Gov't Expenditure	---	---	**0.004*** (0.003)**	---	---	---	---	**0.004*** (0.000)**	---	---
Remittances	---	---	---	0.0007 (0.277)	---	---	---	---	**0.0005* (0.082)**	---
Private Credit	---	---	---	---	0.0003 (0.441)	---	---	---	---	0.00002 (0.975)
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Net Effects	na	nsa	nsa	nsa	Na	nsa	Nsa	nsa	-0.00005	0.002
AR(1)	(0.059)	**(0.242)**	(0.051)	**(0.117)**	**(0.119)**	(0.076)	**(0.311)**	(0.064)	**(0.153)**	**(0.159)**
AR(2)	**(0.139)**	(0.062)	**(0.123)**	(0.086)	**(0.232)**	(0.098)	(0.089)	(0.066)	**(0.141)**	**(0.195)**
Sargan OIR	**(0.200)**	(0.068)	(0.081)	**(0.315)**	**(0.224)**	(0.042)	(0.038)	(0.042)	**(0.444)**	**(0.203)**
Hansen OIR	**(0.246)**	**(0.108)**	(0.051)	**(0.313)**	**(0.321)**	(0.082)	**(0.124)**	(0.041)	**(0.261)**	**(0.150)**
DHT for instruments										
(a)Instruments in levels										
H excluding group	**(0.254)**	**(0.184)**	(0.005)	**(0.378)**	**(0.633)**	(0.029)	**(0.194)**	(0.064)	(0.070)	**(0.646)**
Dif(null, H=exogenous)	**(0.255)**	**(0.137)**	**(0.421)**	**(0.292)**	**(0.232)**	**(0.237)**	**(0.153)**	**(0.095)**	**(0.515)**	**(0.115)**
(b) IV (years, eq(diff))										
H excluding group	**(0.289)**	**(0.117)**	(0.015)	**(0.196)**	**(0.135)**	(0.089)	**(0.265)**	(0.011)	**(0.258)**	(0.064)
Dif(null, H=exogenous)	**(0.251)**	**(0.247)**	**(0.893)**	**(0.657)**	**(0.978)**	**(0.217)**	**(0.090)**	**(0.899)**	**(0.333)**	**(0.797)**
Fisher	**46.14***	**23973.17***	**349531***	**1438.48***	**95.60***	**43.89***	**138.12***	**168.82***	**86988***	**245.56***
Instruments	18	22	22	22	22	18	22	22	22	22
Countries	24	24	24	24	24	24	24	24	24	24
Observations	96	82	94	86	94	96	82	94	86	94

***,**,*: significance levels at 1%, 5% and 10% respectively. DHT: Difference in Hansen Test for Exogeneity of Instruments Subsets. Dif: Difference. OIR: Over-identifying Restrictions Test. The significance of bold values is twofold. 1) The significance of estimated coefficients and the Fisher statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the AR(1) & AR(2) tests and; b) the validity of the instruments in the Sargan and Hansen OIR tests. Gov't: Government. nsa: not specifically applicable because the estimated model is not valid. na: not applicable because at least one estimated coefficient required for the computation of net effects is not significant. The mean value of mobile phone penetration is 15.806 while the mean value of internet penetration is 3.053. Constants are included in all regressions.

Table 3: FDI, ICT and Welfare Total Factor Productivity

	Dependent variable: Welfare Total Factor Productivity (Welfare TFP)									
	The mobile phone penetration channel (Mobile)					The internet channel(Internet)				
Welfare TFP(-1)	**0.832*** (0.000)**	**0.777*** (0.000)**	**0.860*** (0.000)**	**0.958*** (0.000)**	**0.829*** (0.000)**	**0.836*** (0.000)**	**0.729*** (0.000)**	**0.784*** (0.000)**	**0.940*** (0.000)**	**0.872*** (0.000)**
FDI	**0.007*** (0.009)**	**0.008*** (0.002)**	0.005 (0.113)	-0.002 (0.608)	**0.008*** (0.003)**	**0.004*** (0.002)**	**0.006*** (0.000)**	**0.005*** (0.004)**	**0.002* (0.067)**	**0.005*** (0.000)**
Mobile	**0.001*** (0.009)**	**0.001*** (0.000)**	**0.0007* (0.068)**	**-0.0008* (0.073)**	**0.001*** (0.007)**	---	---	---	---	---
Internet	---	---	---	---	---	0.002 (0.102)	**0.005*** (0.000)**	**0.006*** (0.000)**	0.001 (0.323)	0.002 (0.164)
FDI× Mobile	-0.0001 (0.127)	**-0.0001** (0.047)**	-0.0001 (0.122)	0.00009 (0.385)	**-0.0001* (0.050)**	---	---	---	---	---
FDI× Internet	---	---	---	---	---	-0.0003 (0.516)	**-0.0009*** (0.000)**	**-0.001*** (0.000)**	-0.0004 (0.113)	**-0.0007** (0.046)**
Education	---	0.046 (0.551)	---	---	---	---	**0.163** (0.015)**	---	---	---
Gov't Expenditure	---	---	**0.005*** (0.000)**	---	---	---	---	**0.007*** (0.000)**	---	---
Remittances	---	---	---	**0.001*** (0.000)**	---	---	---	---	**0.001*** (0.000)**	---
Private Credit	---	---	---	---	0.0007 (0.203)	---	---	---	---	**0.0009** (0.035)**
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Net Effects	na	0.006	na	na	0.006	na	0.003	0.001	na	nsa
AR(1)	**(0.718)**	**(0.339)**	**(0.714)**	**(0.981)**	**(0.678)**	**(0.769)**	**(0.275)**	**(0.708)**	**(0.940)**	**(0.684)**
AR(2)	**(0.312)**	**(0.231)**	**(0.264)**	**(0.322)**	**(0.770)**	**(0.330)**	**(0.159)**	**(0.330)**	**(0.360)**	**(0.599)**
Sargan OIR	**(0.465)**	**(0.886)**	**(0.802)**	**(0.856)**	**(0.495)**	**(0.234)**	**(0.680)**	**(0.825)**	**(0.724)**	**(0.554)**
Hansen OIR	**(0.384)**	**(0.236)**	**(0.344)**	**(0.350)**	**(0.300)**	(0.096)	**(0.256)**	**(0.443)**	**(0.191)**	(0.096)
DHT for instruments										
(a)Instruments in levels										
H excluding group	**(0.254)**	**(0.148)**	**(0.354)**	**(0.133)**	**(0.372)**	**(0.137)**	(0.052)	**(0.289)**	**(0.101)**	**(0.582)**
Dif(null, H=exogenous)	**(0.406)**	**(0.341)**	**(0.336)**	**(0.519)**	**(0.282)**	**(0.127)**	**(0.566)**	**(0.482)**	**(0.331)**	(0.060)
(b) IV (years, eq(diff))										
H excluding group	**(0.223)**	**(0.223)**	**(0.228)**	**(0.383)**	**(0.189)**	**(0.198)**	**(0.642)**	**(0.274)**	**(0.116)**	(0.084)
Dif(null, H=exogenous)	**(0.671)**	**(0.348)**	**(0.636)**	**(0.303)**	**(0.646)**	**(0.104)**	(0.056)	**(0.769)**	**(0.586)**	**(0.317)**
Fisher	**390.87***	**2526.40***	**653.75***	**548.87***	**896.13***	**5531.61***	**455.10***	**1160.26***	**306.84***	**856.41***
Instruments	18	22	22	22	22	18	22	22	22	22
Countries	24	24	24	24	24	24	24	24	24	24
Observations	96	82	94	86	94	96	82	94	86	94

***,**,*: significance levels at 1%, 5% and 10% respectively. DHT: Difference in Hansen Test for Exogeneity of Instruments Subsets. Dif: Difference. OIR: Over-identifying Restrictions Test. The significance of bold values is twofold. 1) The significance of estimated coefficients and the Fisher statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the AR(1) & AR(2) tests and; b) the validity of the instruments in the Sargan and Hansen OIR tests. Gov't: Government. nsa: not specifically applicable because the estimated model is not valid. na: not applicable because at least one estimated coefficient required for the computation of net effects is not significant. The mean value of mobile phone penetration is 15.806 while the mean value of internet penetration is 3.053. Constants are included in all regressions.

Table 4: FDI, ICT and Welfare real Total Factor Productivity

	Dependent variable: Welfare real Total Factor Productivity (Welfare real TFP)									
	The mobile phone penetration channel (Mobile)					The internet channel (Internet)				
Welfare real TFP(-1)	**0.567*** (0.000)**	**0.540*** (0.000)**	**0.519*** (0.000)**	**0.654*** (0.000)**	**0.671*** (0.000)**	**0.652*** (0.000)**	**0.617*** (0.000)**	**0.598*** (0.000)**	**0.636*** (0.000)**	**0.693*** (0.000)**
FDI	0.008 (0.282)	**0.021*** (0.005)**	0.005 (0.487)	0.007 (0.165)	**0.016** (0.037)**	**0.006*** (0.006)**	**0.006*** (0.005)**	**0.006** (0.013)**	**0.004** (0.037)**	**0.007*** (0.003)**
Mobile	0.0008 (0.260)	**0.002** (0.014)**	0.0003 (0.627)	0.0005 (0.255)	**0.001** (0.018)**	0.001 (0.525)	---	---	---	---
Internet	---	---	---	---	---	---	0.002 (0.157)	0.003 (0.305)	-0.0001 (0.920)	0.002 (0.361)
FDI× Mobile	-0.0001 (0.487)	**-0.0005*** (0.007)**	-0.0001 (0.641)	-0.00007 (0.627)	**-0.0003* (0.082)**	---	---	---	---	---
FDI× Internet	---	---	---	---	---	-0.0007 (0.303)	**-0.001* (0.075)**	-0.001 (0.147)	-0.0001 (0.712)	-0.0008 (0.225)
Education	---	-0.071 (0.377)	---	---	---	---	-0.009 (0.870)	---	---	---
Gov't Expenditure	---	---	**0.003*** (0.003)**	---	---	---	---	**0.003* (0.071)**	---	---
Remittances	---	---	---	**0.0009** (0.013)**	---	---	---	---	**0.0008*** (0.004)**	---
Private Credit	---	---	---	---	**-0.001*** (0.000)**	---	---	---	---	-0.0003 (0.562)
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Net Effects	na	0.013	na	na	0.011	na	0.002	na	na	na
AR(1)	(0.015)	(0.081)	(0.044)	(0.037)	(0.023)	(0.020)	(0.078)	(0.038)	(0.041)	(0.045)
AR(2)	**(0.307)**	**(0.110)**	**(0.201)**	**(0.320)**	**(0.931)**	**(0.455)**	**(0.109)**	**(0.349)**	**(0.342)**	**(0.930)**
Sargan OIR	**(0.131)**	**(0.125)**	**(0.130)**	**(0.412)**	**(0.181)**	**(0.201)**	**(0.278)**	**(0.175)**	**(0.204)**	(0.057)
Hansen OIR	**(0.218)**	**(0.661)**	**(0.235)**	**(0.695)**	**(0.560)**	**(0.563)**	**(0.661)**	**(0.504)**	**(0.697)**	**(0.406)**
DHT for instruments										
(a)Instruments in levels										
H excluding group	**(0.183)**	**(0.165)**	**(0.199)**	**(0.230)**	**(0.481)**	**(0.135)**	**(0.216)**	**(0.355)**	**(0.233)**	**(0.581)**
Dif(null, H=exogenous)	**(0.257)**	**(0.837)**	**(0.294)**	**(0.811)**	**(0.513)**	**(0.718)**	**(0.788)**	**(0.511)**	**(0.811)**	**(0.322)**
(b) IV (years, eq(diff))										
H excluding group	**(0.139)**	**(0.598)**	**(0.113)**	**(0.809)**	**(0.367)**	**(0.272)**	**(0.764)**	**(0.468)**	**(0.702)**	**(0.248)**
Dif(null, H=exogenous)	**(0.496)**	**(0.545)**	**(0.805)**	**(0.297)**	**(0.811)**	**(0.942)**	**(0.304)**	**(0.450)**	**(0.446)**	**(0.752)**
Fisher	**44.81*****	**208.30***	**161.72***	**881404***	**25627.98***	**20.35*****	**71.39*****	**24286***	**137.69***	**22.44*****
Instruments	18	22	22	22	22	18	22	22	22	22
Countries	24	24	24	24	24	24	24	24	24	24
Observations	96	82	94	86	94	96	82	94	86	94

***,**,*: significance levels at 1%, 5% and 10% respectively. DHT: Difference in Hansen Test for Exogeneity of Instruments Subsets. Dif: Difference. OIR: Over-identifying Restrictions Test. The significance of bold values is twofold. 1) The significance of estimated coefficients and the Fisher statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the AR(1) & AR(2) tests and; b) the validity of the instruments in the Sargan and Hansen OIR tests. Gov't: Government. The mean value of mobile phone penetration is 15.806 while the mean value of internet penetration is 3.053. Constants are included in all regressions.

4.2 Discussion of results, contribution to theory and implication for policy and practice

4.2.1 Further discussion of results and nexuses with extant literature

It is worthwhile to articulate that all the adopted elements in the conditioning information set have reflected the expected positive signs, which is an indication that the favorable role of ICT in moderating a net positive FDI-productivity nexus is also contingent on other factors in a system that should be favorable to productivity and competitiveness. This inference builds on the fact that GMM regressions involving control variables are interpreted in terms of conditional modeling such that the established linkages are conditional on the adopted elements in the conditioning information set. Hence, given that the independent variables of interest (i.e. ICT and FDI) do not interact in a real world in isolation to influence productivity, other favorable macroeconomic policies should be taken on board, *inter alia*, policies that are

conducive to the financial access, inclusive education, complementary external follows such as remittances and government expenditure in sectors, and orientations that promote industrial development, productivity and competitiveness. This narrative is consistent with the attendant literature supporting the position that cross-country differences in TPF are traceable to cross-country disparities in factors that explain TFP (Abramovitz, 1986; Romer, 1986, 1993; Klenow& Rodriguez-Clare, 1997; Temple, 1999; Nelson & Pack, 1999; Easterly & Levine, 2001; Durlauf, Johnson & Temple, 2005).

It is also important to note that, as documented in the literature, there is yet no consensus on the channels through which productivity (that ultimately improves economic development) can be enhanced (Baliamoune, 2009; Baliamoune-Lutz, 2011; Elu & Price, 2010). Hence, the findings of this study have made some contributions towards advancing the position that ICT can improve the FDI channel to productivity. This contribution is broadly consistent with the attendant literature on the importance of ICT in productivity and socio-economic development (Uduji & Okolo-Obasi, 2018; Minkoua Nzie, Bidogeza & Ngum, 2018; Evans, 2019; Gosavi, 2018; Kaba & Meso, 2019), especially in the light of Hong (2016) that ICT consolidates a nation's production capacity, Bala and Feng, (2019) and Arslan et al. (2019) on the relevance of ICT in the performance of enterprises and Alderete (2018) and Mishra et al. (2018) on the mediating importance of ICT in industrial and institutional development.

The above clarification elucidates the sparse evidence of negative net effects apparent in Tables 1 and 2. The attendant two negative net effects could be traceable to the fact that, in the concerned specifications, the potential rewards of FDI in productivity are limited by a host of factors, *inter alia,* income inequality, enclaved investments and orientation of FDI to domestic consumption as opposed to export-led performances. Accordingly, FDI-based production should be oriented towards exports in order to improve current accounts and competitiveness in the global market. Hence, in some scenarios, FDI may not engender productivity if ICT is geared towards favoring the operation of foreign companies in sectors that are not competitive and export-oriented.

4.2.2 Contributions to theory and knowledge

In light of the theoretical exposition in section 2, there are obvious theoretical implications for this study. Accordingly, the findings in this study are more consistent with the Neoclassical Growth Model of Solow (1956) than they are with the New Theory of Economic Growth,

from the perspective of how FDI influences productivity and the growth of productivity. Hence, this comparison is exclusively contingent on the variables used in this study and should not be generalized. The findings in Table 2 pertaining to the growth of TFP are overwhelmingly not significant, which is consistent with the Neoclassical Growth Model because according to the attendant theoretical underpinnings, FDI can positively affect productivity, but not the growth rate of productivity, because productivity growth is decreased by diminishing returns to physical capital. Conversely, in the light of the New Theory of Economic Growth, FDI affects both productivity and the growth rates of productivity (Hassan, 2005).

4.2.3 Implications for policy and practice

First of all, it goes without saying that ICT is particularly relevant in the role of FDI in improving productivity in SSA. Therefore, it is up to policy makers to enhance conditions for more ICT penetration and wider access in order to leverage on the nexuses with foreign investment and by extension, enhance productivity and economic development in the sub-region. These policies should consist of, among others: universal access projects, low pricing schemes and the consolidation of infrastructure that is indispensable for more access to and penetration of ICT. Moreover, ICT development policies should be tailored such that manufacturing sectors that are more sensitive to ICT usage and infrastructure deficiency are prioritised. Accordingly, complementary policies that enhance ICT and simultaneously attract FDI, can represent a powerful engine of industrial growth, productivity and competitiveness in the light of the growing pressure of globalisation.

Another important policy implication that speaks to inclusive development objectives in the post-2015 development agenda is the favorable net incidence on the welfare-oriented TFP dynamics. In essence, this clarifies the question of whether productivity could be improving while the majority of the population is growing poorer. Accordingly, ICT modulated FDI-productivity nexuses can improve competitiveness, output as well as broad-based economic development that benefit the poorer elements of society and reduce inequality. It follows that corporate social responsibility policies, poverty reduction schemes and inequality mitigation measures should also be considered when tailoring ICT policies for FDI to improve productivity. This will go a long way to addressing current policy syndromes of income inequality in Africa and by extension, pave the way to the achievement of Sustainable Development Goals (SDGs) that are welfare-oriented for the most part. It is important to recall that about 50% of countries in SSA did not achieve the Millennium

Development Goal (MDG) extreme poverty target in spite of the sub-region experiencing more than 20 years of economic growth resurgence that has been associated with productivity (Tchamyou, 2020). It follows that the underlying productivity has not been broad-based and hence, the potential for ICT represents an opportunity to render FDI-tailored productivity more inclusive and avoid the policy syndrome of exclusive productivity in the post-2015 development agenda. This is essentially because it is projected that extreme poverty will not be reduced to a threshold of below 3% by 2030 unless welfare and poverty reduction schemes are fully taken on board in macroeconomic policies (Bicaba, Brixiova & Ncube, 2017).

5. Conclusion, limitations and future research directions

This study investigates the importance of information technology in influencing the effect of foreign direct investment (FDI) on total factor productivity (TFP) dynamics. The focus is on twenty-five countries in Sub-Saharan Africa with data for the period 1980 to 2014. The empirical evidence is based on the Generalised Method of Moments. The findings show that with the exception of regressions pertaining to real TFP growth for which the estimations do not pass post-estimation diagnostic tests, it is apparent that information technology (i.e. mobile phone penetration and internet penetration) modulates FDI to positively influence TFP dynamics (i.e. TFP, welfare TFP and welfare real TFP).

This research obviously leaves room for future inquiries, notably, in assessing if the established findings in this study are relevant from country-specific frameworks. This policy recommendation builds on the limitation that the GMM framework is designed such that country-fixed effects are not taken on board because they are eliminated in order to address the concern of endogeneity pertaining to the correlation between country-specific effects and the lagged dependent variable. Another caveat to the study is that, these days, the mobile phone and the internet have more functionality than simply facilitating the absorptive capacity of foreign investment. Moreover, as smart phone penetration increases in African countries and more data become available, these data should be considered in future studies, since mobile phone and internet penetration rates can underestimate the computing aspects of ICT.

Appendices

Appendix 1: Definitions and sources of variables

Variables	Signs	Variable Definitions (Measurements)	Sources
TFP1	TFP	Total Factor Productivity (TFP)	Penn World Table database
TFP2	RTFP	Real Total Factor Productivity Growth (RTFPg)	Penn World Table database

TFP3	WTFP	Welfare Total Factor Productivity (WTFP)	Penn World Table database
TFP4	WRTFP	Welfare Real Total Factor Productivity (WRTFP)	Penn World Table database
Foreign Direct Investment	FDI	Foreign Direct Investment Inflows(% of GDP)	UNCTAD
Mobile Phone Penetration	Mobile phones	Mobile phone subscriptions (per 100 people)	WDI
Internet Penetration	Internet	Internet subscriptions (per 100 people)	WDI
Education	Education	SEPSGPI: School enrollment, primary and secondary (gross), gender parity index (GPI)	WDI
Government Expenditure	Gov't Expenditure	Governments final consumption expenditure (% of GDP)	WDI
Remittances	Remittances	Personal remittances, received (% of GDP)	WDI
Credit Access	Private credit	Domestic credit to private sector (% of GDP)	FDSD

WDI: World Development Indicators. GDP: Gross Domestic Product.UNCTAD: United Nations Conference on Trade and Development. FDSD: Financial Development and Structure Database.

Appendix 2: Summary statistics

	Mean	SD	Minimum	Maximum	Observations
Total Factor Productivity	0.539	0.310	0.121	1.884	125
Real Total Factor Productivity Growth	0.539	0.276	0.123	1.381	125
Welfare Total Factor Productivity	0.984	0.189	0.605	1.664	125
Welfare Real Total Factor Productivity	0.927	0.190	0.456	1.785	125
Foreign Direct Investment	1.903	2.795	-3.440	22.118	124
Mobile Phone Penetration	15.806	29.054	0.000	142.980	120
Internet Penetration	3.053	6.020	0.000	31.922	98
Education	0.854	0.177	0.465	1.341	107
Government Expenditure	16.066	5.358	6.085	36.155	122
Remittances	4.768	12.917	0.003	89.354	107
Credit Access	21.009	22.256	2.238	144.397	121

S.D: Standard Deviation.

Appendix 3: Correlation matrix (uniform sample size :122)

TFP	RTFP	WTFP	WRTFP	FDI	Mobile	Internet	Education	Gov. Ex	Remit	Credit	
1.000	0.293	0.954	0.044	-0.094	-0.031	0.124	0.435	0.099	-0.108	0.240	TFP
	1.000	0.295	0.640	0.031	0.323	-0.007	0.009	0.111	-0.140	0.071	RTFP
		1.000	0.064	-0.016	0.012	0.160	0.458	0.205	-0.054	0.290	WTFP
			1.000	0.158	0.310	0.231	-0.036	0.002	0.014	0.122	WRTFP
				1.000	0.284	0.132	0.187	0.188	0.097	0.031	FDI
					1.000	0.740	0.339	0.047	0.058	0.388	Mobile
						1.000	0.301	-0.111	0.032	0.517	Internet
							1.000	0.385	0.196	0.276	Education
								1.000	0.436	0.144	Gov. Ex
									1.000	-0.077	Remit
										1.000	Credit

TFP: Total Factor Productivity. RTFP: WTFP: Welfare Total Factor Productivity. WRTFP: Welfare Real Total Factor Productivity. FDI: Foreign Direct Investment. Mobile: Mobile Phone penetration. Internet: Internet penetration. Gov. Ex: Government Expenditure. Remit: Remittance. Credit: Access to credit.

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