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ICT ADOPTION AND FINANCIAL MARKETS: A STUDY OF THE LEADING STOCK EXCHANGE MARKETS IN AFRICA

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ABSTRACT

This paper examined the effects of ICT adoption on Nigerian and Johannesburg Stock Exchange markets - the leading exchanges in Africa. Analysis was anchored on panel data metrics of ICT adoption, control and transaction capacities measures of the exchanges. Findings: ICT adoption had heterogeneous effects during the study periods. Use of the Internet had negative effects on the market indices, except capitalisation. Some of the regressors had no significant effects on individual merits, but aggregate effects were significant. The regressors well-explained total variations in the stock market measures. Consequently, this paper considered ICT adoption to be sine quo non to the growth and development of Africa's stock exchange and financial markets; and recommended more investments in ICT innovations and adoptions for greater regional and continental co-operations and possible integration into global settings.

Key words: *ICT adoption, Stock exchange markets, Financial markets, Gompertz curve, Disaggregated functional models.* JEL Classification: C12, C13, C23, D53, E43, G23, O55,

1. INTRODUCTION

Studies and experience have shown that information and communication technology (ICT) has tremendously affected innumerable aspects of human

lives, activities and interactions in the last few decades. In the economic, business and financial world, it has been shown that ICT has specifically affected financial markets the world over, including Africa. However, available studies on ICT in relation to stock market development, especially in the past five years, have concentrated on the developed economies, leading and emerging markets as well as high-income economies of the world. Relatively therefore, only a few studies have been on Nigeria and other developing economies (Hossein et al., 2013; Ezirim et al. 2009; and Ngassam and Gani, n.d.). Obviously, the studies have not placed particular emphasis on ICT in relation to transaction capacities of the Nigerian Stock Exchange (NSE), the Johannesburg Stock Exchange (JSE) or any other leading stock exchanges in the African continent. Available literature suggests non-considerable volume of studies yet on ICT and stock market development for South Africa.

Moreover, significant research efforts at investigating the relevance of financial markets in general and stock markets in particular to the growth and development of many developed, emerging and developing economies have focused on the linkage path between capital market development and economic growth. These include Kumar and Vu (2014), Shahram 2014), Saeed (2013), Vincenzo (2013), Lawal and Okunola (2012), Osisanwo and Atanda (2012), Obiakor and Okwu (2011), Francesco (2011), Zagorchev et al. (2011) and Donwa and Odia (2010). Efforts have also been expanded to study the role of ICT in cross-border trade of tangible goods, regional cooperation and integration of exchanges as well as banks' operations and financial performance (Adesola, Moradeyo and Oyeniyi, 2013; Farid, 2013; Onwe, 2013; Benkraiem and Miloudi, 2012; Adejola, 2011; Mihasonirina and Kangni, 2011; Bankole et al., 2010). Similarly, some researchers have examined ICT in relation to corporate governance, financial information communication, intern3alisation flows, investor news valuation as well as socio-economic development (Oyelere and Kuruppu, 2012; Fernandez et al., 2011; Donwa and Odia, 2010; Lattemann, 2005). However, there have not been substantial inquiries to determine the impact of ICT on the transaction capacities of the capital markets, which form the basis of stock market influences on the various indices of research interests in the previous studies particularly in Africa.

To allude to the importance of ICT in transaction capacities of stock exchanges in Eastern and Southern Africa, Irving (2005) noted that closer cooperation and, at a later stage, integration would improve the liquidity, efficiency and competitiveness when anchored on cross-border listings, technology and information sharing.

Available literature also indicates that while studies on ICT in relation to macroeconomic indicators have concentrated on economic growth, there has

been little consideration for the stock market which is the pivot of capital market in driving the process of economic growth and development. Perhaps, this explains the literature dearth on the impact of ICT on transaction capacities of African stock markets in general and the stock markets of the continent's first and second largest economies, Nigeria and South Africa, in particular. Further, while available studies on Nigerian and South African financial markets have tilted toward the banking industry, few have been on Nigeria's Stock Exchange (NSE) market and, perhaps, none yet on the South Africa's Johannesburg Stock Exchange (JSE) market. This has provoked the curiosity and interest in this article to study the impact of ICT on the transaction capacities of the two exchanges, particularly for this transformation era in which regional cooperation and integration of stock exchanges and cross-border listing have become a driving force towards global integration and international competitiveness of financial markets.

Therefore, main thrust of this article is to establish the impact of information and communications technology (ICT) adoption on the transaction capacities of Nigerian and Johannesburg stock exchanges during the 1995 – 2014 periods and, thus, contribute to bridging the identified knowledge gap in the literature. The article identifies ICT uses and relevant metrics of stock market development. The approach is anchored on time series exploratory research design as a launch pad to stimulate further research interests for the NSE and JSE in particular and other African exchanges in general either on cross-sectional or comparative basis.

The article has five sections. Section two which comes after this introduction is the literature review. Section three discusses the methodology. Section four is data analysis and discussion, while section five is the conclusion and recommendations.

2. LITERATURE REVIEW AND SUMMARY OF BACKGROUNDS OF THE STOCK EXCHANGES

2.1 THEORETICAL REVIEW

Several studies have been done to test existing theories and to enhance the understanding of ICT diffusion, adoption, acceptance and usage (Yi et al., 2006; Venkatesh et al., 2003, Rogers, 2003). However, ICT adoption is of specific relevance to this article because it comprises innovation, acceptance and diffusion. On the other front, transaction capacities reflect the outcomes of ICT-driven stock market development, innovations and efficiency of the exchanges measured in terms relevant metrics of stock market performance.

The theoretical launch pad of this article is the Roger's (2003) model of innovation diffusion, which has found application in disciplines like sociology, communications, economics, marketing and technology. Some studies have used it to explain the technology innovation process (Oliver and Goerke, 2008; Tabata and Johnsrud, 2008). Moreover, Jayson (2009) critically examined the innovations diffusion theory and its relevance in developing nations.

In the theory, Rogers (2003; 11) explains diffusion as the "process by which innovation is communicated through certain channels over time among the members of a social system". Innovation is explained as "an idea, practice, or object that is perceived as new by an individual or other unit of adoption" (p. 12), and adoption as "a decision to make full use of an innovation as the best course of action available" (p. 473). Galvanising these concepts, the model explains diffusion as the process through which ideas, practices, or objects are communicate and adopted by members of a given setting. However, as a caveat, Rogers noted that various types of adopters will naturally emerge for any innovation; and that certain attributes influence the choice to adopt an innovation.

This article considers stock market operators, participants and other stakeholders to be among the adopters of technology innovation, adoption and use; and that efficiency and desire for optimal transaction capacities influence the choice to innovate, adopt and use ICT in stock market operations. This implies that the relevance of ICT for optimal stock market activities and outcome has prompted its adoption and acceptance. It has become a vital tool not only for industrial and marketing advantages, but also for effective policy measures to overcome existing and even increasing digital inequalities. To corroborate this, Parida et al. (2009) see ICT as an effective tool improved external communications and quality service delivery to customers [clients].

2.2 EMPIRICAL REVIEW

While some researchers have studied information and communication technology (ICT) in relation to stock market development and performance, especially in the developed and emerging economies, much more studies have investigated ICT in relation to economic growth and some other aspects of socio-economic development. Thus, it is not out of place to note that ICT has been studied in relation to various aspects of human activity. Available literature suggests that the effects of ICT on stock market development and performance are yet to be well researched and documented for Africa. Most of the studies have been on developed countries, high-income economies and emerging markets outside of Africa (Hossein et al., 2013; Oyelere and Kuruppu, 2012; Bhunia, 2011; Fernandez et al., 2011; Yartey, 2006; Lattemann, 2005;

Ngassam and Gani, n.d.). The studies have concentrated on ICT, economic growth and related macroeconomic variables (Kumar and Vu, 2014; Shahram, 2014; Vincenzo, 2013; Benkraiem and Miloudi, 2012; Dahl and Kongsted, 2011; Farhadi and Famah, 2011; Martinez and Rodriguez, 2009; Sophia and Sotiris, 2009; Choi and Cook, 2005).

Similarly, available studies for Nigeria and few other African countries have mainly been on ICT in relation to economic growth and development, trade, financial inclusion, other macroeconomic indicators, regional cooperation and integration, and banking sector performance as well as other financial variables (Binuyo and Aregbesola, 2014; Adesola et al., 2013; Mihasonirina and Kangni, 2011). Also, research efforts have been on stock or capital market in relation to these variables (Kolapo and Adaramola, 2012; Obiakor and Okwu, 2011; Donwa and Odia, 2010). Obviously, related studies have been scanty for South Africa. Available literature also suggests that ICT in relation to capital markets in general and stock exchanges in particular have been sparingly studied for the African continent. And more of the few studies have been on Nigeria relative to South Africa and other African countries (Farid, 2013; Ezirim et al., 2009; Irving 2005). This leaves a knowledge gap on the relevance of ICT to operations of African capital markets in general and stock exchanges in particular.

Lattemann (2005) investigated the actual penetration of ICT into 'external' corporate governance of publicly listed companies in Germany. With the tools of descriptive statistics and Capital Asset Pricing Model (CAPM)-based regression analysis, the study found a negative correlation between ICT usage and stock market returns. Yartey (2006) employed panel data for 76 advanced and emerging countries to examine the role of financial development structure in explaining cross-country diffusion of ICT during the 1990-2003 periods. The study found that credit and stock market development tend to foster ICT development, but financial structure does not appear to have any significant relationship with ICT development. Thus, the study concluded that financial development is an important determinant of ICT development. In France, Benkraiem and Miloudi (2012) employed descriptive analysis and OLS pooled multiple regression models to study access to banking finance by ICT small businesses. They found that the ICT businesses had difficulties in accessing bank debt to finance further ICT investment assets.

In their study, Choi and Cook (2005) documented a steep drop in the liquidity of Japanese stock market in the post-bubble period and a steep rise in liquidity risk. They found also that aggregate liquidity had macroeconomic effects on aggregate demand through its effect on money demand. The study employed methods of descriptive statistics and vector autoregression on time

series market variables via ordinary least squares to consider stock market liquidity and liquidity shocks.

Fernandez, Callen and Gadea (2011) investigated investors' valuation of non-financial corporate news items issued by European companies in the ICT industry. They also analysed stock reaction to the publication of press releases on a sample of 145 firms during 2003 – 2005. Based on relevant variables in a multivariate regression model, they found that investors react positively to information relating to firms' capacity to consolidate positions, diversify and grow, but negatively to information about new product launches and upgrades. Also, while investors in companies with strong market position and growth prospects value highly information on takeovers and internalisations, those in low-performing companies value news of disposal and distribution alliances. Bhunia (2011) examined the impact of ICT on the growth of Indian Stock Exchange (ISE) for the proposition that capital markets have become excessively volatile since the adoption of computer-assisted trading strategies. With relevant ICT adoption and capital market data, the study found that, though the ISE remains thin relative to more developed markets, ICT adoption has significant effects on most of the stock market indicators, such as capitalization, value of shares traded, turnover ratio, liquidity and number of stockbrokers. Similarly, Oyelere and Kuruppu (2012) enquired into the use of ICT as a channel for voluntary communication of financial information by companies listed on the United Arab Emirates (UAE). They investigated the extent and variety of Internet financial reporting (IFR) by the companies and found that, though IFR is still at an embryonic stage, a greater proportion of the companies use their websites to disseminate financial information. The findings also revealed that the UAE has lower level of IFR relative to the western countries.

Hossein et al. (2013) used the techniques of correlation and regression to study how ICT adoption has affected stock market development in world's leading capital markets. The study showed that market capitalisation, turnover ratio and value of shares traded have direct relationship with the ICT adoption components, but found no relationship between ease of access to local markets and ICT adoption. On the aggregate, however, metrics of ICT adoption in the study exerted significant impact on stock market development. In a similar, Ngassam and Gani (n.d.) explored the links between ICT and stock market development in emerging markets and high-income economies. They considered relevant proxies for ICT adoption and stock market development in least squares multiple regression model. The study found that personal computers and Internet hosts have strong effects on stock market development. It also found that credit to private sector and market capitalization exerted significant positive effects on stock market development.

Sophia and Sotiris (2009) investigated the outcomes of FDI and ICT on productivity growth in 42 developing and developed countries during the 1993-2001 periods. Based on descriptive statistics and panel regression model, the study found that the growth contribution of ICT was quite high in both developing and developed countries, while contribution of FDI was relatively low. The impact of ICT was significant positive in all groups, with larger effects among the developing countries. FDI exerted significant positive effects in the developed countries, but insignificant positive effects in the developing countries. The variables of interest were domestic capital and labour, foreign capital and ICT. In a related study, Martinez and Rodriguez (2009) used disaggregated time series approach to examine ICT in relation economic growth and labour productivity in Andalucia, Spain. With hardware and software communication equipment, and such non-ICT assets as transport equipment, buildings and other structures, machinery and others, and gross value added. The study found that while ICT assets moderately improved total market gross value-added growth, they did not significantly improve value-added growth of ICT-intensive sectors.

For newly industrialised countries of Brazil, Russia, India and China (BRIC), Organisation for Economic Cooperation and Development (OECD), and Association of Southeastern Asian Nations (ASEAN), Farhadi and Famah (2011) used panel data in endogenous production growth model to study the external effects of ICT on economic growth during the years 1990-2008. The data are GDP per capita as proxy for economic growth, ICT investment, physical capital, human capital or labour, FDI and trade openness as proxies for ICT adoption, and relevant control variables. They found ICT to have statistically significant effects on GDP growth of the countries collectively and individually. In a related study, Dahl and Kongsted (2011) showed that ICT has significant positive effect on productivity in post-1995 Europe. They used econometric panel regression analysis and data on gross output, value added, ICT capital, non-ICT capital, labour hour, employment, intermediate inputs and total factor productivity. On the basis of EU KLEMS Database, Vincenzo (2013) used econometric model of production function to study the contribution of ICT investments to total factor productivity (TFP) growth in 18 OECD countries for the period 1995-2007. The study examined the entire business sector (26 industries) of the economies, and found variations in the contributions of the ICT components to value added growth. The analysis showed that in most of the countries, computing equipment yielded more than 50% of the entire ICT contribution.

Kumar and Vu (2014) used the methods of descriptive statistics, autoregressive distributed lag (ARDL) bounds procedure and Granger causality to study the short- and long-run effects of ICT, as well as the direction of causality

between ICT, remittances and output per worker in Vietnam from 1980 to 2012. Other variables of interest are FDI, official development assistance (ODA), merchandised exports, commercial services exports, migrants and Internet users. The findings were: ICT exerted momentous short- and long-run effects on per worker output, insignificant positive elasticity coefficient of remittances in the long-run, bidirectional causation between remittances and output per worker, and mixed effects in the short-run effects. Similarly, Shahram (2014) employed historical descriptive analysis methodology to examine the association between ICT diffusion and economic growth Russia. The study considered per capita GDP, proportion of the population using the Internet and telephone, investment in ICT and components. The findings revealed emergence of new industries owing to ICT spread.

Mihasonirina and Kangni (2011) employed standardised growth model and system Generalised Method of Moment (GMM) estimator to analysed the impact of ICT development, particularly mobile phone rollout, on financial inclusion and economic growth in a sample of African countries for the 1988-2007 periods. They found that ICT development contributes to economic growth in the Continent, and that financial inclusion is a transmission channel from mobile phones to growth.

Adesola et al. (2013) used regression analysis technique to investigate the impact of ICT on operations of Nigerian banks. Considering speed of operations, efficiency in service delivery, workers' performance and banks' profit levels, they found that ICT usage has made significant contributions. It is interesting to note that the finding of significant positive contribution to profit levels in Adesola et al. (2013) contradicts that of Adejola (2011). Perhaps, this could be explained in terms of ICT improving banks' profitability over time given the different study periods. In a related study, Binuyo and Aregbesola (2014) used dynamic panel and orthogonal transformation method to examine the impact of ICT on performance of commercial banks in South Africa during the 1990-2012 periods. They found that ICT use increases return on capital employed and return on assets of the banks. The finding supports the study by Adesola et al. (2013) on Nigerian banks and thus, validates the suggestion that ICT enhances banks' performance over time.

Via OLS multiple regression analysis, Donwa and Odia (2010) analysed the impact of the Nigerian capital [stock] market on socio-economic development for 1981-2008 periods, and found that the market significantly improved economic growth but moderately explained growth dimensions during the period. Partial effects of the market indicators on socio-economic development of the country were mixed. They considered gross domestic product (GDP), market capitalisation, total new issues, transactions volume, total listings and government stock. In their study, Obiakor and Okwu (2011) employed multi-

ple regression analysis methodology on relevant capital market development and economic growth indicators to analyse the impact of the former on the latter in Nigeria for the period 1981-2008 period. They showed that while market capitalization, gross capital formation, and foreign direct investment have significant positive impacts on economic growth, the impact of traded shares values was positive but not significant.

Kolapo and Adaramola (2012) studied the impact of Nigerian capital market on economic development from 1990 to 2010. Regarding stock market as the impetus for growth and development, they used GDP as proxy for economic growth, and market capitalisation, total new issues, value of transactions, total listed equities and government stocks as metrics of capital market. Having validated data sets on the time series variables via appropriate diagnostic tests, they found that capital market and economic growth are co-integrated and that a long-run relationship exists between capital market and economic growth variables. They found bi-directional causation between GDP and value of transactions, but a unidirectional causality from market capitalisation to GDP and not vice versa. They also found independence "no causation" between GDP and total new issues as well as GDP and listed equities and government stocks. Therefore, they concluded that capital market activities have positive impact on the economy.

Ezirim et al. (2009) employed a modified version of Gompertz technology diffusion model introduced by Chow (1983) to examine the effects of ICT on the growth and development of capital market in Nigeria between 1998 and 2007. They found that ICT significantly affect market capitalization growth as well as volume and value of shares traded. But ICT does not have significant effect on number of listings and government bonds. A similar study by Farid (2013) attempted to ascertain the possibility of African stock markets to improve informational efficiency via common platform-based operations. The study used the method of Generalised Method of Moments (GMM) for panel data analysis and relevant capital market and macroeconomic indicators. The findings showed that institutional deficiencies and openness to trade have negative impact on economic growth. Financial market integration so far executed is still not sufficient to reflect in the data sets owing probably to the short-term maturity concentration of the financial instruments. Moreover, African economies that were more open to international capital flows do not seem to grow faster than the rest, thereby leading to a number of empirical questions.

2.3 BRIEF SUMMARY OF BACKGROUNDS OF THE STOCK EXCHANGES

2.3.1 Nigerian Stock Exchange (NSE)

The Nigerian Stock Exchange (NSE) was founded in 1960 as the Lagos Stock Exchange (LSE), became the NSE in 1977. Effectively, the NSE/LSE commenced operations in 1961 with 19 securities listed for trading. The NSE has a head office (Lagos, 1961) and several branches in major cities in Nigeria, and each branch has a trading floor. The NSE creates a market place for companies to raise equity capital, and for shareholders to trade on existing stocks. The NSE and relevant media outfits publish market-related data of listed companies on regular basis - daily, weekly, monthly, quarterly and annually. The NSE is licensed under the Investments and Securities Act (ISA), and is registered and regulated by the Securities and Exchange Commission (SEC) of Nigeria. It is a founding member and executive committee member of the African Securities Exchange Association (ASEA), a member of the Intermarket Surveillance Group (ISG), affiliate member of the World Federation of Exchanges (WFE) and International Organisation of Securities Commissions (IOSCO). It officers market data, disseminates services, market indices, and ancillary technology services amongst others. The NSE also offers electronic clearing, settlement and delivery (CSD) services through Central Securities Clearing System (CSCS), which is one of its associates. Over the years, the NSE has undertaken Several ICT-driven reforms as well as developments. As at end-2014, the NSE had over 250 listed securities and 223 active brokers. It brings together the best of African enterprises, the local and global investor communities in its efforts to champion the acceleration of Africa's economic development, and become "the Gateway to African Markets (NSE, 2014: Sustainable Stock Exchange (SSE) Initiatives ((http://www.sseinitiative.org/fact-sheet/nigse/ accessed on June 26, 2015). The NSE is the second largest exchange in Africa.

2.3.2 Johannesburg Stock Exchange (JSE)

The discovery of gold on the Witwatersrand in 1886 led to the opening of many mining and financial companies; and the need for a stock exchange. Subsequently, The JSE was established on 8 November 1887 from the Johannesburg Exchange & Chambers Company owned by a London Businessman, Benjamin Minors Woollan. By 1963, the JSE became a member of the Federation International Bourses de Valeurs (FIBV). It became an active member of the African Stock Exchanges Association in 1993. It officially became JSE Securities Exchange in September 2000. In 2001, the JSE reached an agreement with the London Stock Exchange (LSE) which enabled it to replace its trading system with that of the LSE. On 18 June 2012, the JSE became a founding member of

the United Nations Sustainable Stock Exchanges initiative on the eve of the United Nations Conference on Sustainable Development (Rio+20). Over the years, the JSE has undertaken Several ICT-driven reforms as well as developments. On 14 April 2014, the JSE re-branded to demonstrate the bourse's identity as a modern African marketplace that connects investors to growth opportunities not only in South Africa but globally. As at end-2014, the JSE had over 472 listed companies and a market capitalisation of US$182.6 billion. The JSE is the largest stock exchange in Africa (https://wikipedia.org.wiki/JSE_Limited; accessed on 26 June 2015).

3. METHODOLOGY

3.1 DESIGN, DATA AND SOURCES

The paper employed panel data on exploratory perspective. This is because, as seen in the review of previous empirical studies, there have been no such insights for the Africa's leading exchanges either on comparative or cross-sectional basis. The article is expected to stimulate further empirical inquiries into this and other areas of financial markets in Africa. The study took into cognisance the influences of relevant professional bodies, monetary and regulatory authorities as the capital market moderators in both countries. The study considered stock market development in terms of relevant metrics of ICT adoption and, subsequently, evaluated the effects on transactions capacity of the stock exchanges.

Data used in this study are subset of the ICT ecosystem identified by Perin and Pouillot (2013). The ICT indices are Number of Personal Computers (NPCs) per 100 people, Number of Internet Users (NIUs) per 100 people, Number of Mobile Telephone Subscriptions (NMTSs) per 100 people and Number of Fixed Telephone Subscriptions (NFTSs) per 100 people. The control variables are commercial banks' deposit and lending rates (CBDR and CBLR), and domestic credit relative to size of the economy (RDCPS); i.e. domestic credit to the private sector as a share of gross domestic product (GDP). Metrics of transaction capacities for the stock exchange markets are Stock Market Capitalisation (SMCP), Value of Shares Traded (VSTR), Stock Market Turnover Ratio (SMTR) and Stock Market Liquidity (SMLQ). Stock market turnover ratio (SMTR) and Stock market liquidity (SMLQ) are respectively considered in terms of value of shares traded relative to market capitalisation (World Bank, 2008) and near cash or money as a share of GDP (World Bank, 2008).

Some of these ICT adoption and stock market indices have been used in previous studies (Hossein et al., 2013; Bhunia, 2011; Obiakor and Okwu, 2011;

Ezirim et al., 2009; Choi and Cook, 2005;) while others are derived (own computations) for this article. The data used in this article were originally sourced from World Bank's publications: World Development Indicators (various years), World Development Report (2005, 2001), World Bank Annual Report (2014), African Development Indicators (2007), World Bank's World Development Report (various years).

The data from World Bank databases were sourced during June 2015, and mainly via http://data.worldbank.org/indicator./FR.INR.LEND/countries and https://databank.worldbank.org/data/reports.aspx?

3.2 HYPOTHESES

From a position of neutrality, the following relationships and effects were hypothesised and tested at the 5% level of significance:

- $H_0 1$: Adoption of ICT has not significantly affected capitalisation of the stock exchange markets.
- $H_0 2$: ICT adoption has not significantly affected the values of shares traded on the exchanges.
- $H_0 3$: Adoption of ICT has not significantly enhanced turnover ratio of the stock exchange markets.
- $H_0 4$: Adoption of ICT has not significantly enhanced liquidity of the stock exchange markets.

3.3 ANALYTICAL MODELS

This article adapts the Chow's (1967, 1983) technology diffusion model modified by Rogers (2003). Based on the assumption that technology usage tends to an equilibrium level over time along an S-shaped path, the model is specified as: $\log h_{i,t} - \log h_{i,t-1} = q_i[\log h^*_i - \log h_{i,t-1}]$

where $h_{i,t}$ is ICT use in country [stock market exchange] *i* in period *t,* $h_{i,t-1}$ is ICT use in country [stock market exchange) *i* in the preceding period, *t-1,* h^*_i is post-diffusion [adoption] equilibrium level in country [stock market exchange] *I*, and q_i is the speed of adjustment in country [stock market exchange] *i*.

In the model, ICT is the explained variable and factors that cause changes in ICT level are the explanatory variables. Thus, the model considers ICT usage in relation to the determinants of extent of usage. But in this article, ICT adoption is the explanatory variable while the measures of transaction activities of the stock exchanges constitute the explained variable. This necessitated the need to adapt or modify the model in line with the data sets and study thrust. For convenience, we replaced h and q with Y and Z respectively. Thus, the model becomes:

$$\log Y_{i,t} - \log Y_{i,t-1} = Z_i[\log Y^*_i - \log Y_{i,t-1}] \quad (1)$$

where Y_i is ICT adoption in stock market exchange *i* in time period *t,* $Y_{i,t-1}$ is ICT adoption in stock market exchange *i* in the preceding time period, *t-1*, Y^*_i is post-ICT adoption optimal transaction capacity for stock exchange *i* and Z_i is the speed of adjustment to optimal transaction capacity in stock exchange *i*.

Subsequently, we juxtaposed the metrics of ICT and transaction capacities as the explanatory and explained variables respectively, and introduced an autonomous component, Φ_0, and a stochastic term, μ, such that we obtained a variant of the model as:

$$\log TC_{i,t} - \log TC_{i,t-1} = \Phi_0 + \Phi_1 ICT_{AdPt} + \mu \quad (2)$$

where $\log TC_{i,t} - \log TC_{i,t-1}$ depicts of transaction capacities dynamics responding to ICT adoption in the respective exchanges. ICT_{Adp} encompasses the metrics of ICT adoption in the exchanges. Φ_0, autonomous component, is extent of transaction capacity without ICT adoption. Φ_1 encompasses the interactions (effects) of ICT adoption on transaction capacities. It measures the magnitude and direction of the effects of ICT innovations and adoption on transaction capacities of the stock exchanges. Thus, it shows the measure of responsiveness or sensitivity coefficient of transaction capacities to a given change in ICT innovations and adoption in the exchanges.μ, the stochastic variable, depicts exogenous influences.

Given a dynamic environment such that changes in ICT adoption and the control variables induce changes in transaction capacities, equation (2) becomes:

$$\Delta TC_{k,jt} = \Delta[\Phi_0 + \Phi_{k,jt} \sum_{j=1}^{n=4} ICT_{Adp_{k,jt}} + \alpha_{k,jt} \sum_{j=1}^{m=3} Z_{k,jt} + \varepsilon] \quad (3)$$

Since the autonomous component, Φ_0, is constant while the sensitivity coefficients, Φ_j, and β_j are not constant over time, and given the assumption of constant variance characteristic for ε, equation (3) becomes:

$$\Delta TC_{k,jt} = \Phi_0 + \Phi_{k,jt} \Delta \sum_{j=1}^{n=4} ICT_{Adp_{k,jt}} + \alpha_{k,jt} \Delta \sum_{j=1}^{m=3} Z_{k,jt} + \varepsilon \quad (4)$$

where $\Delta TC_{k,jt}$ is change in transaction capacities of the stock exchange markets, $\Delta \sum_{j=1}^{n=4} ICT_{Adp_{k,jt}}$ $\Delta \sum_{j=1}^{n=4} ICT_{Adp_{k,jt}}$ are the matrices of the respective aggregate changes in ICT adoption and the control variables, $\Phi_{k,j}$ and $\alpha_{k,j}$ are the respective sensitivity coefficients for market *k* over time period *t* given variables *j* (identifier descriptors), Φ_0 is the intercept or autonomous component of the model, and ε is the error term.

This implies that the predicted change in transaction capacity depends on changes in the aggregate ICT adoption indices and the control variables over time plus its long-run mean, which is depicted in Φ_0, plus the stochastic term ε. Essentially, some steps of the model transformation into composite model contained our own contributions to the previous version. Therefore, as we substituted TC for the transaction capacities and assumed a static model since the data sets corresponded to specific points in time, equation (4) translates to a composite model (equation 5 below) of the relationship between ICT adoption and transaction capacities of the stock exchange markets, which we disaggregated and employed for analysis in this article:

$$TC_{k,jt} = \Phi_0 + \Phi_{k,jt} \sum_{j=1}^{n=4} ICT_{Adp_{k,jt}} + \alpha_{k,jt} \sum_{j=1}^{m=3} Z_{k,jt} + \varepsilon \quad (5)$$

Thus, to determine the partial and collective effects of the ICT and control variables on the respective measures of transaction capacities of the stock exchange markets within a panel data environment, we disaggregated equation 5 into the following models:

$$SMCP_{j,t} = \beta_0 + \beta_1 NPCs_{j,t} + \beta_2 NIUs_{j,t} + \beta_3 NMTSs_{j,t} + \beta_4 NFTSs_{j,t} + \beta_5 CBLR_{j,t} + \beta_6 CBDR_{j,t} + \beta_7 RDCPS_{j,t} + \beta_{1,t} \quad \text{Model 1}$$

$$VSTR_{j,t} = \lambda_0 + \lambda_1 NPCs_{j,t} + \lambda_2 NIUs_{j,t} + \lambda_3 NMTSs_{j,t} + \lambda_4 NFTSs_{j,t} + \lambda_5 CBLR_{j,t} + \lambda_6 CBDR_{j,t} + \lambda_7 RDCPS_{j,t} + \lambda_{2,t} \quad \text{Model 2}$$

$$SMTR_{j,t} = \pi_0 + \pi_1 NPCs_{j,t} + \pi_2 NIUs_{j,t} + \pi_3 NMTSs_{j,t} + \pi_4 NFTSs_{j,t} + \pi_5 CBLR_{j,t} + \pi_6 CBDR_{j,t} + \pi_7 RDCPS_{j,t} + \pi_{3,t} \quad \text{Model 3}$$

$$SMLQ_{j,t} = \theta_0 + \theta_1 NPCs_{j,t} + \theta_2 NIUs_{j,t} + \theta_3 NMTSs_{j,t} + \theta_4 NFTSs_{j,t} + \theta_5 CBLR_{j,t} + \theta_6 CBDR_{j,t} + \theta_7 RDCPS_{j,t} + \theta_{4,t} \quad \text{Model 4}$$

where SMCP, VSTR, SMTR and SMLQ are components of $TC_{k,jt}$ while NPCs, NIUs, NMTSs, NFTSs are ICT adoption variables, and CBLR, CBDR and RDCPS are control variables. The variables are as defined earlier. The subscripts $_k$, $_t$, and $_j$ are the identifier descriptors for the respective stock exchange markets in the time periods and variables. β_0, λ_0, $\pi_{0 \text{ and }} q_0$ are the intercepts of the respective models. Each is autonomous; i.e., neither dependent on the ICT indices nor the control variables. The coefficients β_i, λ_i, π_i and q_i, (i = 1, 2, 3, 4 and 5, 6, 7) measure the respective size and direction of effects of the ICT metrics and control variables on $TC_{k,t}$. ε_t (t = 1, 2, 3, 4) are fitted residuals to accommodate disturbances or deviations from line of best fit for the respective models.

The indices of $TC_{k,it}$ are expected to change in the same direction with signs of the coefficients of the ICT variables and RDCPS but change in the opposite direction with the coefficients of the control variable, CBLR. The $TC_{k,it}$ measures are expected to correlate positively or negatively with the sign of the coefficient of CBDR, depending on investors' desire to divest from shares to deposit income as a result of attractive deposit rates. These imply that transaction capacities are expected to increase when more domestic credit, relative to the size of the economy, is available to the investing private sector, and vice versa. On the other hand, transaction capacities are expected to decrease with either increase in CBLR or CBDR or both, owing to the inverse relationship between bank rate and stock market rate. Further, attractive deposit rates will induce investors to sell off share stocks, with the likely consequence of reduction in share prices owing to increased supply of share stocks to the markets, and ultimately a decrease in aggregate value of shares traded. The underlying assumption here is a positive real interest rate, i.e., inflation rate being less than both bank and stock market return rates.

Some previous studies have disaggregated and employed similar models in previous studies (Okwu, 2015; Adesola et al., 2013; Bhunia et al., 2011; Obiakor and Okwu, 2011; Ezirim, 2009; Choi and Cook, 2005).

4. RESULTS AND DISCUSSIONS

Table 1: Partial Correlation Coefficients

	NPCs	NIUs	NMTSs	NFTSs	CBLR	CBDR	RDCPS	SMCP	SMLQ	SMTR	VSTR
NPCs	1.0000										
NIUs	0.3052	1.0000									
NMTSs	0.6804	0.8367	1.0000								
NFTSs	0.2120	-0.0667	-0.0522	1.0000							
CBLR	-0.7764	-0.6249	-0.8579	-0.0863	1.0000						
CBDR	-0.4419	-0.6835	-0.7476	0.0783	0.8478	1.0000					
RDCPS	0.8850	0.1938	0.5326	0.4004	-0.6867	-0.3841	1.0000				
SMCP	0.8867	0.4267	0.7991	0.0985	-0.8146	-0.5384	0.7947	1.0000			
SMLQ	0.7276	0.2553	0.7021	0.1132	-0.7666	-0.4750	0.8291	0.8000	1.0000		
SMTR	0.8722	0.2867	0.6635	0.2702	-0.7213	-0.4008	0.7810	0.7265	0.8873	1.0000	
VSTR	0.8781	0.4140	0.8271	0.0567	-0.7965	-0.5293	0.7382	0.8410	0.8416	0.8433	1.0000

Source: Own Computations using EViews8

Matrix of partial correlation coefficients was used to diagnose the data series for multicollinearity problem. The results in Table 1 below showed the variables were not highly linearly since none of the partial correlation coefficients exceeded 0.95 (Agung, 2009; Iyoha, 2004) or 0.80 when squared (Ken-

nedy, 2008). Therefore, the data series were considered adequate and suitable for regression analysis and investigation of causal effects.

Table 2: Empirical Analysis of the ICT-Capital Markets Relationships

Method: Panel Least squares Sample: 1 40 Included observations: 40

	Model 1	**Model 2**	**Model 3**	**Model 4**
	Dept. Var: Log(SMCP)	**Dept. Var: Log(VSTR)**	**Dept. Var: Log(SMTR)**	**Dept. Var: Log(SMLQ)**
ICT Indices	Effect (β_i)	Effect (λ_i)	Effect (π_i)	Effect (θ_i)
NPCs	0.2011 (0.1329)	0.8015 (0.4018)	0.1704 (0.1005)	1.4876 (0.3264)**
NIUs	0.0297 (0.0259)	-0.4097 (0.2204)	-0.0111 (0.0196)	-0.0475 (0.0262)
NMTSs	0.0030 (0.0123)	0.7657 (0.2408)**	0.0091 (0.0093)	-0.0080 (0.0121)
NFTSs	-0.0034 (0.0549)	0.0286 (0.0643)	0.0376 (0.0415)	-0.0117 (0.0555)
CBLR	-0.1126 (0.340)	-2.6474 (1.1151)**	0.0658 (1.3974)	-2.5564 (1.8020)
CBDR	0.4735 (1.8486)	1.3111 (0.7062)	0.2228 (0.7428)	0.7037 (1.0062)
RDCPS	0.7905 (0.3400)**	0.4238 (0.3387)	0.0666 (0.2570)	0.0001 (0.0055)
	Adjst. R^2 = 0.8045 F-stat = 23.9315** DW-Stat = 1.8133	Adjst. R^2 = 0.8176 F-stat = 59.5542** DW-Stat = 1.7887	Adjst. R^2 = 0.6455 F-stat = 11.1429** DW-Stat = 1.8397	Adjst. R^2 = 0.8277 F-stat = 34.99** DW-Stat = 1.8477

*Standard errors are enclosed in parentheses. **Significant at 5%; p-value < 0.05.*
Source: Own Computations using EViews8

4.1 EFFECTS ON CAPITALISATION OF THE STOCK EXCHANGE MARKETS

As shown in Table 2, estimates of Model 1 showed that the ownership of personal computers and the use of the Internet and mobile telephone subscriptions had positive and significant relationships with market capitalisation of the stock exchanges while fixed telephone lines subscriptions was negatively signed and statistically insignificant. Personal computers, the use of the Internet and mobile telephone subscriptions had positive but not significant effects on the market capitalisation of the stock exchanges while fixed telephone subscriptions had negative and insignificant effect. These were evidenced by the positive but not significant coefficients of NPCs, NIUs and NMTSs, respectively; and the insignificant negative coefficient of NFTSs. The positive relationship of market capitalisation with these ICT indices lends credence to the find-

ing by Hossein et al. (2013) that, for the world's leading capital markets, market capitalisation has direct relationship with ICT adoption. Also, the significant effects are in line with findings by Ezirim et al. (2009) and Ngassam and Gani (n.d) that ICT adoption has strong effects on stock market development in the emerging markets and high-income economies. However, the insignificant effects are contrary to the findings by Bhunia (2011) that of ICT adoption has significant effects on the stock market indicators in the Indian Stock Exchange. Similarly, while commercial banks' lending rates showed insignificant negative effects, the effects of deposit rates, though positive, were also not significant. The Coefficients of NFTSs and CBDR did not have the expected positive and negative signs, unlike the coefficients of CBLR and RDCPS. The insignificant coefficients of CBLR and CBDR suggested that commercial banks' lending and deposits rates, respectively, were not significantly relevant to the market capitalisation of the stock exchanges. On the other hand, the positive and significant coefficient of RDCPS suggested that domestic credit, relative to the size of the economy, significantly affected market capitalisation of the stock exchanges during the study period. The F-statistic value of 23.9315 shows that, at the conventional 5% level of significance, overall effect of the causal variables on the response variable was significant. This supports the findings by Hussein et al. (2013), Ezirim et al. (2009). Therefore, the hypothesis, $H_0 1$, which stated that adoption of ICT had not significantly affected capitalisation of the stock exchange markets was rejected. As indicated by adjusted R^2 value of 0.8045, the causal variables in the model explained approximately 80% of the total variations in the response variable, with approximately 20% variations not explained. Hence, the model was a good fit. The DW-stat of 1.8133 showed that the variables had no serial autocorrelation problem.

4.2 EFFECTS ON VALUE OF SHARES TRADED ON THE STOCK EXCHANGE MARKETS

Estimates of Model 2, as shown in Table 2, revealed that ownership of personal computers and fixed telephone lines subscriptions had positive but not significant relationships with share values traded on the stock exchange markets while mobile telephone subscriptions had significant positive relationship with the share values. This is consistent with the findings by Hossein et al. (2013), Bhunia (2011), Ezirim et al. (2009) and Ngassam and Gani (n.d), However, the use of the Internet had a negative but not significant relationship with the share values traded on the stock exchange markets during the study period. The evidences are shown by the statistically insignificant coefficients of NPCs, NIUs and NFTSs, and the statistically significant coefficient of NMTSs, respectively. The coefficients of NPCs, NMTSs and NFTSs had the expected

signs, while the sign of the coefficient of NIUs was contrary to pre-estimation expectation. This suffices to say that while the effect of mobile telephone subscriptions on the value of shares traded on the stock exchange markets during the period under study was significant, the effects of personal computers ownership, the use of the Internet and fixed telephone subscriptions were not significant. Further, the effect of CBLR was negative and significant while the effects of CBDR and RDCPS were positive but insignificant. The coefficients of CBLR, CBDR and RDCPS had the expected signs. These showed that commercial banks' lending rates had significant relationship with value of shares traded on the stock exchanges, deposit rates and domestic credit relative to the size of the economy did not have significant relationship with the share values traded. Therefore, deposit rates and credit to the private sector relative to the size of the economy were not significantly relevant to value of shares traded on the stock exchange markets during the study period. The independent variables in Model 3 jointly exerted statistically significant effect on the dependent as evidenced by the F-stat value of 59.5542. Consequently hypothesis $H_0 2$, which stated that ICT adoption had not statistically affected values of shares traded on the stock exchange markets, was not validated. Similarly, the adjusted R^2 value of 0.8176 provided empirical evidence that Model 3 was a good fit since the independent variables explained approximately 82% of the total variations in the dependent variable, with unexplained variations of about 18%. The DW-stat value of 1.7887 provided empirical proof that the regressors were free from serial autocorrelation problem.

4.3 EFFECTS TURNOVER RATIO OF THE STOCK EXCHANGE MARKETS

As shown in Table 2, the estimates of Model 3 revealed that personal computers, mobile and fixed telephone subscriptions had positive but insignificant relationships with market turnover ratio (SMTR) of the stock market exchanges while the use of the Internet had negative and insignificant relationship with the turnover ratio. These are evidenced by the positive coefficients of NPCs, NMTSs and NFTSs, and negative coefficient of NIUs which are consistent with pre-estimation expectations, except for NIUs. These showed that, in isolation, none of the ICT indices had significant effect on the turnover ratio of the stock market exchanges during the study periods. Positive relationship of the ICT variables with stock market turnover ratio supports the findings by Hossein et al. (2013) but does not support the significant effects found by Bhunia (2011) and strong the strong effects in the study by Ngassam and Gani (n.d). Though the turnover ratio had positive relationships control variables, none of the variables had significant effect on market turnover ratio. This indicates that, on their individual merits, the control variables were not significant determinants of turnover ratio

of the exchange markets. The coefficients of the control variables (CBDR and RDCPS) were consistent with expectations, except for commercial banks' lending rates, CBLR. However, as indicated by F-stat value of 11.1429, the ICT indices and control metrics in Model 4 jointly exerted a statistically significant effect on turnover ratio of the stock exchange markets. As a result, the third hypothesis, $H_0 3$, was also not valid and, hence, was rejected. The Model exhibited a high explanatory power as indicated by the adjusted R^2 value of 0.6455. This means that the ICT indices and causal variables accounted for approximately 65% variability in stock market turnover ratio during the study period. Further, the DW-stat value of 1.8397 provided empirical evidence that the causal variables were free from serial autocorrelation.

4.4 EFFECTS ON LIQUIDITY OF THE STOCK EXCHANGES MARKETS

Estimates of Model 4 showed that liquidity of the stock markets (SMLQ) had a positive relationship with possession of personal computers but negative relationships the other ICT variables. These were seen in the positive coefficient of NPCs but negative coefficients of NIUs, NMTSs and NFTSs, respectively. The estimates further showed that personal computers had significant positive effect on the liquidity of the stock exchange markets while the use of the Internet, mobile and fixed telephone subscriptions, respectively, had negative and insignificant effects. The coefficients of the control variables (CBLR, CBDR and RDCPS) were consistent with the pre-estimation expectations; but none had significant effect in isolation. On the aggregate, however, the regressors had statistically significant effect on liquidity of the stock exchange markets during the periods under study period as evidenced by the F-stat value of 34.99. The significant effect of ICT adoption on the liquidity of the stock exchange markets validates the finding by Bhunia (2011), Hosein et al. (2013), that ICT adoption has significant effects on the stock market indicators in the Indian Stock Exchange. Therefore, the fourth hypothesis, $H_0 4$, had no validity and, hence, was rejected. Also the power of the variables was high in explaining variations in liquidity of the stock exchange markets, as indicated by the adjusted R^2 value of 0.8277. This shows that the regressors explained approximately 83% of the total variations in market liquidity during the period, while about 17% was unexplained. Therefore, the Model is considered a good fit. The DW-stat value of 1.8477 provided evidence that the variables had no serial autocorrelation problem.

5. SUMMARY, CONCLUSION AND RECOMMENDATIONS

This paper has employed panel data and exploratory perspective to analyse the effects of ICT adoption on stock exchange markets, with specific focus

on the transaction capacities of Nigerian and Johannesburg Stock Exchange markets, which are the leading stock exchanges in the African continent. The paper found that the metrics of ICT adoption considered in the analysis (NPCs, NIUs, NMTSs and NFTSs) exerted heterogeneous effects on the transaction capacity measures (SMCP, VSTR, SMTR and SMLQ) of the stock exchanges. Specifically, results of the analysis showed that personal computers (NPCs) had positive effects on transaction capacities of the stock exchanges and that the effect on market liquidity (SMLQ) was significant. Contrary to pre-analysis expectations, the use of the Internet (NIUs) had negative effects on the transaction capacities measures, except for capitalisation (SMCP) of the stock exchange markets. However, the effects were not significant on their individual merits. On the other hand, mobile telephone subscriptions (NMTSs) exerted positive effects on the metrics of transaction capacities of the stock exchanges, except for market liquidity (SMLQ). The effect of this ICT adoption index (NMTSs) was significant only on value of shares traded (VSTR). Similarly, fixed telephone subscriptions (NFTSs) had positive effects on value of shares traded (VSTR) and turn over ratios (SMTR) of the exchanges, but the effects were negative on capitalisation (SMCP) and liquidity (SMLQ) of the stock markets. Singularly, the effects on the transaction capacities were not significant.

Like the ICT indices, the control variables (CBLR, CBDR and RDCPS) had heterogeneous effects on transaction capacities of the stock exchanges during the study periods. The effects were not significant, except banks' lending rates (CBLR) and domestic credit to the private sector relative to the sizes of the economies (RDCPS) which were significant on value of shares traded (VSTR) on, and capitalisation (SMCP) of, the exchanges respectively.

On the aggregate, however, the ICT adoption indices exerted significant effects on the respective transaction capacity variables of the stock exchanges. Further, the ICT indices exhibited very high powers in explaining total variations in the respective metrics of the transaction capacities of the stock exchanges during the study periods.

Consequently, this paper concludes that ICT adoption has significantly enhanced transaction capacities of the Nigerian and Johannesburg Stock Exchange markets in particular, and Africa's financial markets in general, and that information and communication technology (ICT) is sine-none-quo-none or indispensable to the growth and development of Africa's stock exchange and financial markets. And on the basis of these findings, this paper recommends more investments in ICT innovations and adoptions to the operations of Africa's stock markets in particular, and financial markets in general, if the quest for regional, continental and global co-operations and integrations of the Continent's stock and financial markets must be a reality.

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PRIHVAĆANJE ICT I FINANCIJSKA TRŽIŠTA: ISTRAŽIVANJE VODEĆIH BURZI U AFRICI

SAŽETAK RADA:

Članak se bavi učincima prihvaćanja ICT na burzama u Nigeriji i Johannesburgu, koje su vodeće burze u Africi. Analiza je provedena na metričkim podacima prihvaćanja ICT, uključujući kapacitete kontrole i transakcije na burzi. Utvrđeno je da prihvaćanje ICT ima različite učinke tijekom razdoblja istraživanja. Korištenje interneta imalo je negativne učinke na tržišne indekse, osim kod kapitalizacije. Neki regresori nisu imali značajan učinak na pojedinačne vrijednosti, ali su ukupni učinci bili značajni. Regresori su omogućili zadovoljavajuće objašnjenje ukupnih odstupanja prilikom mjerenja burzovnih transakcija. U članku se navodi kako se prihvaćanje ICT smatra osnovnim preduvjetom za rast i razvoj burzi i financijskih tržišta u Africi. Preporučaju se veća ulaganja u ICT inovacije kao i bolja suradnja u regiji i na kontinentu, što bi omogućilo bolju integraciju u globalnom okruženju.

Ključne riječi: *prihvaćanje ICT, burze, financijska tržišta, Gompertzova krivulja, pojedinačni funkcionalni modeli.*