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## Article

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## Article

# ICT Adoption and Stock Market Development: Empirical Evidence Using a Panel of African Countries

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**Abstract:** The aim of this study was to examine the impact of adopting information and communication technologies (ICT) on the development of African stock exchanges. The study examined a panel of 11 African stock exchanges for the period 2008–2017 and employed the generalised method of moments (GMM) to estimate the results. The results of the study documented that ICT adoption had a positive impact on stock market development in African countries. Firstly, it was found that the stock market traded volume and mobile–telephone user variables were positively related. Secondly, a positive relationship was also proven between the stock market traded volume and the broadband user variable. Thirdly, a positive relationship was documented between the stock market capitalisation variable and the fixed telephone user variable. Fourthly, the research findings confirmed a positive relationship between the stock market turnover ratio and the fixed telephone user variable. The findings of this study imply that policymakers should be more resolute when formulating ICT policies. ICT adoption can spur stock market development which in turn can propel economic growth, resulting in the economic prosperity of the African countries. Moreover, ICT adoption could enhance the integration of African stock exchanges, further buttressing the drive towards the common market areas in various regions.



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**Keywords:** stock exchange; ICT adoption; stock market development; economic growth; Africa

## 1. Introduction

Developments in ICT have affected livelihoods and various other aspects of human activities and interactions in the last few decades. The world has transformed into what could aptly be described as an information society (IS) in virtually all human activities, with ICT as the main driver of the transformation process (Cortés and Navarro 2011). Further, they contended that the transformation force has permeated all strata of human settings, such as households, firms and governments at the local, regional, national and international levels. This assertion by Cortés and Navarro (2011) clearly indicates that ICT plays a very vital role in every sphere of our daily lives. The role that the Internet and mobile phones currently play in every human interaction can never be overemphasised.

Among the aspects of human activities and interactions that have been tremendously affected by ICT is the development of African stock markets. This was reflected in a study of stock markets development and integration in South African Development Community (SADC) member countries, carried out by Bundoo (2017), that highlights the importance of ICT in stock market development. Furthermore, Bundoo (2017) concluded that the SADC member states' stock exchanges must work towards a greater integration so that they can attract more capital portfolio flows. Moreover, Bundoo (2017) also concluded that greater foreign direct investment (FDI) flows, which are much needed for the financial and economic development of the SADC countries in particular and Africa in general, will be attracted through greater stock market integration. Therefore, by implication, the study emphasised the importance of ICT adoption for the development of African stock markets.

Solarin et al. (2019) assert that stock markets are considered as one of the most crucial aspects of a market economy, in the sense that, on the one hand, they make it possible for firms to gain access to capital. On the other hand, stock markets enable investors to have a share of ownership in the listed firm, based on the firm's expected performance in the future. According to Adu et al. (2013), the stock market is considered as one of the most crucial aspects of a financial system. This is in light of the fact that, through the stock market, listed firms can elicit capital by issuing their shares and at the same time bring about an environment through which the same issued shares can be freely traded by market participants. Hence, more recently, a growing strand of literature has focused on stock market development as the main factor for economic growth (see for instance Tsaouri 2018; Bundoo 2017; Okwu 2016). More recently, studies in this realm have identified ICT as one of the determinants of stock market development.

Notwithstanding the gains enjoyed by African stock markets in the last decade, African stock exchanges still face the challenge of integration, especially in the wake of the newly signed African free trade agreement. Moreover, there is need for building the technical requirements and developing institutional capacity to resolve the problem of low liquidity faced by most African stock exchanges (Yartey and Adjasi 2007). Moreover, Schwab (2019) documented the following as some of the major pillars of global competitiveness: ICT adoption, macroeconomic stability and the financial system. Further, Schwab (2019) reported that sub-Saharan Africa recorded an increase of 15.8% in ICT adoption, while Europe and North America had an increase of 3.7% in ICT adoption. However, the corresponding increase in macroeconomic stability was 3.7% for sub-Saharan Africa while Europe and North America had an increase of 0.9%. Arguably, ICT adoption has a bearing on the financial system and by extension on global competitiveness. Investors, policymakers and market participants require adequate studies on the role of ICT adoption in stimulating stock market activity.

African stock exchanges have undergone several reforms in order to attract more portfolio flows over the years. By and large, they all have made ICT adoption one of the major developmental factors of the reforms they experienced over the period of their existence. The adoption of ICT technologies has mainly included the adoption of automated trading systems by the stock exchanges. Some of the stock exchanges have also become integrated, in a sense allowing the dual or multiple listing of shares. On the demand side, there has been an adoption of technologies such as mobile phones, Internet and broadband by consumers. Arguably, this has led to an increase in stock market transactions, as consumers are now able to transact in the comfort of their homes and at the click of a button. In essence, ICT adoption by consumers confers convenience, which make them purchase shares easily. Therefore, the above foregoing demonstrates the importance of ICT to the sustenance of a stock exchange.

Notwithstanding, extant studies have focused on the stock market development and economic growth nexus. There is dearth in literature that has examined the role of ICT in fostering stock market development. The theoretical foundations of the study are anchored on the Schumpeterian growth models (which focuses on the finance–growth linkage) and the ICT adoption theories (the technology acceptance model, diffusion of innovations, the unified theory of acceptance and use of technology, the model of the IT implementation process and the information systems success model). Against this backdrop, the present study sought to examine the impact of ICT adoption on stock market development in Africa. The following hypotheses were empirically tested in this study:

$H_0$ : ICT adoption has no significant impact on stock market development in Africa

$H_A$ : ICT adoption does not have a significant impact on stock market development in Africa

The rest of the paper is organised as follows: Section 2 reviews the related literature of this study. Section 3 presents an overview of the stock markets in Africa. Section 4 describes the research methodology employed in this study. Section 5 presents and discusses the research findings and Section 6 concludes the paper.

## 2. Review of Related Literature

### 2.1. ICT Adoption and Financial Markets

Information and communications technology (ICT) is an umbrella term that includes any communication device or application such as radio, television, cellular phones, computer, satellite systems, network hardware and software as well as the various devices and applications associated with them such as videoconferencing and distance learning (Okwu 2016). ICT is centred on computer applications, telecommunications equipment and infrastructure to generate, process, store, retrieve, transmit and manipulate data or information in the context of businesses or other transactions.

There is an abundance of studies that have examined the role and application of ICT in economic activity. Parida et al. (2009) contended that ICT is an effective tool that can be used for improving external communications and delivering quality service to customers. According to Fulantelli and Allegra (2003), ICT offers a wide range of possibilities for improving their competitiveness and provides mechanisms for getting access to new market opportunities and specialised information services in organisations.

With the development and spread of ICT, and its application to various fields and activities, several studies have been carried out in order to test existing theories and ensure better understanding about its diffusion, adoption, acceptance and usage (Mun et al. 2006; Venkatesh et al. 2003; Rogers 2003). These include the technology acceptance model (TAM), diffusion of innovations (DOI), the unified theory of acceptance and use of technology (UTAUT), the model of the IT implementation process and the information systems success model theories.

Chinn and Fairlie (2010) used panel data analysis techniques to explore the determinants of cross-country disparities in personal computer and Internet penetration in developed and developing countries. The results showed evidence that income, human capital, youth dependency ratio, telephone density, legal quality and banking sector development are associated with technology penetration rates. They found the main factors responsible for low rates of technology penetration in developing countries to include disparities in income, telephone density, legal quality and human capital.

Owusu-Agyei et al. (2020) employed a panel of 42 sub-Saharan African (SSA) countries for the period 2000–2016 to investigate the relationship between ICT adoption, human capital development, economic freedom and financial development. They found that Internet use had a positive impact on different measures of financial development. Further, their results revealed that subsamples of SSA countries differ on their levels of human capital development and economic freedom.

Chien et al. (2020) investigated the effects of information and communication ICT diffusion on financial development for 81 countries over the period 1990–2015. They found that, comparing the different effects of ICT on financial development between the high-income group and the middle- and low-income groups, telephone and Internet positively influenced both groups' financial development, whereas mobile cellular caused a negative effect in high-income countries, but a positive effect in middle- and low-income countries. Secondly, they documented that the growth of the Internet and telephones raises the financial development in all regions, while mobile cellular growth positively affects financial development only in Africa.

Cheng et al. (2021) examined the relationship between financial development, ICT diffusion and economic growth by considering the interlinkage of finance and ICT. They employed a panel of 72 countries from 2000 to 2015 and found that financial development was always unfavourable for economic growth. Secondly, the results of their study documented that ICT diffusion can improve economic growth in high-income countries, but for middle- and low-income countries, only mobile growth could raise economic growth, whereas increasing Internet could not. Finally, the results of Cheng et al. (2021) documented that the interaction effects between ICT and financial development are positive in both income level countries.

Mignamissi (2021) analysed the influence of the digital divide on the new IMF financial development index on a panel of 34 African countries for the period 2005–2017 and found that the ICT divide was a severe handicap for the financial systems development in Africa. Furthermore, we found that the digital divide between countries is also a severe handicap for the financial development of countries lagging behind. In essence, it was found that countries with a technological lead have relatively developed financial systems.

Ejemeyovwi et al. (2021) empirically investigated the interaction of ICT adoption and innovation, and the role of this digitalisation interaction on financial development in Africa and across the subregions. The results of their study documented that ICT–innovation interaction shock positively drives financial development. They reasoned that this implies that, for multinational corporations (MNCs) and other economic agents, the ICT–innovation interaction should be strongly applied across all sectors to drive financial development, since all sectors require finances to improve performance.

## 2.2. ICT Adoption and Stock Market Development

Measuring the relevance of ICT adoption to stock market development has become important not only for industrial and marketing purposes but also for policymakers, who should formulate effective measures to overcome the existing, and even growing, digital inequalities. Notwithstanding, extant studies have invariably examined ICT adoption, either in relation to economic growth or some other features of finance and banking development. Therefore, it will be pertinent to note that ICT has been studied relative to various aspects of human activity. An examination of the literature implies that the effects of ICT on stock market development in Africa is not yet well researched and documented.

Although there is a growing strand of literature that has examined the link between ICT in relation to stock market development and performance, research that focuses on emerging countries is very limited. Amongst others, Ngassam and Gani (2003) explored the link between ICT and stock market development in emerging markets and high-income economies. The study found that personal computers and Internet hosts have strong effects on stock market development. Credit to the private sector and market capitalisation were also found to exert significant positive effects on stock market development. Irving (2005) explored a historical and descriptive approach, as well as progress and prospects perspectives, to assess the possibility of remedying the situation via regional cooperation and integration of stock exchanges in eastern and southern African regions. Identifying ICT-induced diversified risks, efficiency and competition, higher returns, liquidity and cross-border capital flow as potential benefits of such networking, the study adduced that the exchanges stand to benefit more from closer cooperation by encouraging more cross-border and information/technology sharing. Lattemann (2005) set out to investigate whether the process of communication and interaction between investors and boards of companies had an impact on stock market return by examining the actual penetration of ICT into the ‘external’ corporate governance of Germany’s publicly listed companies. The findings suggested that stock market returns were negatively related to ICT usage.

Yartey (2006) investigated the role of financial development in explaining ICT diffusion during the 1990–2003 period. The study documented that financial development is an important determinant of ICT development. Ezirim et al. (2009) examined the effects of information technology on the growth and development of the capital market in Nigeria for the period 1998–2007. They found that the level of ICT-facilitated interaction between stockbrokers and investors significantly affected the growth of market capitalisation and the volume and value of shares traded. However, it was found that information technology does not significantly affect a number of listings and government bonds. Whereas Farhadi and Rahmah (2011) employed a sample of industrialised countries for the period 1990–2008 to analyse the effects of ICT on economic growth and documented a positive relationship.

Bhunia and Ghosal (2011) investigated the impact of ICT on the growth of the Indian Stock Exchange and found that most of the stock market development indicators were significantly affected by ICT adoption, especially the number of stockbrokers. In a rela-



tively more broad-based study, [Zagorchev et al. \(2011\)](#) employed a panel cointegration methodology to examine the dynamic relationship among financial development, ICT and GDP per capita in 86 sample countries. They found that personal computers and GDP per capita increase the liquidity, size and activity of financial systems. They also established that Internet and GDP per capita improve the liquidity, size, stock trading and activity of the financial markets.

[Dolatabadi et al. \(2013\)](#) employed correlational and regression analysis techniques to study the impact of information technology development on stock market development in the world's leading capital markets. Their analysis showed that market capitalisation, turnover ratio and values of shares traded have a direct relationship with the ICT adoption components in the study, but they found no relationship between the ease of access to local markets and ICT development.

[Farid \(2013\)](#) sought to ascertain whether African stock markets can improve their informational efficiency by formally harmonising and integrating their operations on a common platform. The study showed that institutional deficiencies and openness to trade have a negative impact on economic growth. Further, the study documented that those African economies that were more open to international capital flows did not seem to grow faster than the rest.

[Okwu \(2015\)](#) set out to investigate the effect of ICT adoption on financial markets by employing two leading stock exchange markets in Africa, namely the Nigerian and Johannesburg Stock Exchanges, as a unit of analysis. The findings of the study showed that ICT adoption had heterogeneous effects during the study periods. The use of the Internet had negative effects on the market indices, except for capitalisation. Further, [Okwu \(2016\)](#) explored the ICT and stock market nexus in Africa using evidence from Nigeria and South Africa. The study reported mixed findings. Specifically, the effect of a mobile telephone on all market indicators was found to be positive and significant.

In a somewhat broader dimension to the study of ICT in relation to business and economic outcomes, [Donwa and Odia \(2010\)](#) set out to determine the impact of the Nigeria stock market on socio-economic development for the 1981–2008 period. They found that the market indicators significantly enhanced economic growth.

[Marszk and Lechman \(2021\)](#) explored the linkages between ICT penetration and the development and expansion of financial innovation on stock exchanges in ten European countries for the period from 2004 to 2019 and found that ICT spreads evenly in all the countries, laying solid foundations for the development of innovative financial products. Further, the results of their study documented that ICT positively influenced the diffusion of ETFs, regardless of the other possible determinants considered.

[Igwilo and Sibindi \(2021\)](#) examined the causal relationship between ICT adoption and stock market development by employing a panel of 11 African stock exchanges for the period 2008–2017. They applied the panel ARDL bounds testing procedure to test for cointegration and examine the causal relationship between ICT adoption and stock market development. The results of their study documented that ICT adoption and stock market development were cointegrated in the long term. Further, the results of their study documented a bidirectional causal relationship (complementarity) between ICT adoption and stock market development. [Igwilo and Sibindi \(2021\)](#) also established a causal relationship running from financial freedom to stock market development.

The review of the empirical studies leads us to distil the key findings as documented in [Table 1](#). These are the basis of our variable selection in the research methodology section.

**Table 1.** Overview of empirical studies.

Variable Name	Empirical Studies	Apriori Expectation
NFTS = Number of Fixed Telephone Subscription per	<a href="#">Okwu (2015)</a> ; <a href="#">Ezirim et al. (2009)</a>	Increase in number of fixed telephone subscriptions leads to increase in stock market development.
NBU = Number of Broadband Users	<a href="#">Czernich et al. (2011)</a>	Broadband user increase leads to economic development.
IU = Number of Internet Users	<a href="#">Okwu (2015)</a> ; <a href="#">Ezirim et al. (2009)</a> ; <a href="#">Baliamoune (2002)</a> ; <a href="#">Zagorchev et al. (2011)</a>	Increased Internet usage (with technical knowledge) should have a significant positive stock market development or economic growth.
NMU = Number of Mobile Phone Users	<a href="#">Okwu (2015)</a> ; <a href="#">Ezirim et al. (2009)</a> ; <a href="#">Baliamoune (2002)</a> ; <a href="#">Zagorchev et al. (2011)</a>	Positive relationship between the number of mobile users and stock market development or economic growth.
SMTR = Stock Market Turnover Ratio in percentage	<a href="#">Allen et al. (2011)</a> ; <a href="#">Mahonye and Ojah (2014)</a>	An increase in SMTR should bring about increase in GDP.
SMC = Stock Market Capitalisation as a percentage of GDP	<a href="#">Soumaré and Tchana (2015)</a>	An increase in MCap should bring about increase in GDP.
NLC = Number of Listed Companies per 10,000 people	<a href="#">Ezirim et al. (2009)</a>	An increase in listed companies significantly influences economic development.
SMTV = Stock Market Total Value Traded as a percentage of GDP	<a href="#">Ezirim et al. (2009)</a>	An increase in number of shares traded should bring about increase in GDP.
Control Variable: FFI = Financial Freedom Index	<a href="#">Le Roux and I.Gorlach (2011)</a>	Freer and more open economies experience higher growth rates.
GDP = Gross Domestic Product	<a href="#">Zagorchev et al. (2011)</a>	Personal computers and GDP per capita increase the liquidity, size and activity of financial systems.

### 3. An Overview of the African Stock Markets

The African stock markets have witnessed sustained growth over the years. This section presents the key metrics of eleven African stock exchanges which form the unit of analysis of this study. The key metrics are presented in Table 2. Suffice to highlight that, on the one hand, JSE is the most developed whilst, on the other hand, the BRVM is the least developed, as evidenced by their market capitalisation.

The JSE was formed in 1887. It is sub-Saharan Africa's oldest stock exchange. Further, the JSE is the most highly developed in sub-Saharan Africa. The JSE was formed during the gold rush of the late 1800s. This is notable, as Johannesburg is also called gold city and the gold capital of South Africa. Furthermore, in the early 1990s, the JSE upgraded its trading platform to an electronic trading system. Then, in 2005, the JSE demutualised and also listed on its own exchange ([Johannesburg Stock Exchange 2019](#)).

The notable ICT-driven improvement towards stock market development, regional cooperation and integration among the 14 South African Development Community (SADC) member states initiated by the JSE was aptly documented by [Irving \(2005\)](#). The initiatives include the harmonised stock exchange listing requirements. In 2000, based on the 13 principles of the JSE's listing requirements, the JSE's electronic trading system, known as the Johannesburg Equities Trading (JET) system, was installed. In 2002, the JSE adopted the London Stock Exchange's trading system technology, which is known as the Stock Exchange Electronic Trading System (SETS). In addition, the London Stock Exchange (LSE) provided technical support and trading system upgrades and enhancements that enabled brokers in both South Africa and the United Kingdom to access one another's stock markets.

**Table 2.** Selected African stock exchanges.

Country	Name	Abbreviation	Number of Listed Companies	Market Capitalisation
Botswana	Botswana Stock Exchange	BSE	33	USD 37,505,515,000
Côte d'Ivoire	BRVM Stock Exchange	BRVM	45	USD 6,960,322,592
Egypt	Egypt Exchange	EGX	223	USD 45,628,544,290
Ghana	Ghana Stock Exchange	GSE	42	USD 9,951,00,000
Kenya	Nairobi Securities Exchange	NSE	63	USD 22,007,506,496
Mauritius	Stock Exchange of Mauritius	SEM	97	USD 8,980,000,000
Morocco	Casablanca Stock Exchange	Casa SE	75	USD 60,576,297,847
Namibia	Namibia Stock Exchange	NSX	40	USD 141,128,581,560
Nigeria	Nigeria Stock Exchange	NSE	147	USD 35,925,467,734
South Africa	Johannesburg Stock Exchange	JSE	353	USD 898,990,000,000
Tunisia	Bourse de Tunis	BVMT	88	USD 8,922,590,000

Source: Authors' construction based on data obtained from World Bank Global Financial Development database.

The Namibia Stock Exchange (NSX) was founded in 1904 during the diamond rush at that time. However, within six years the diamond rush ended and the stock exchange was closed. In 1992, NSX was relaunched with funds contributed by 36 leading businesses in Namibia. The companies contributed USD 10,000 each, as start-up capital for the exchange. Moreover, the Namibia Stock Exchange (NSX) in 1998, via a telecommunications link to the JSE, and in 2002 joined the JSE in adopting the LSE's trading system technology, which is known as Stock Exchange Electronic Trading System ([Namibia Stock Exchange 2019](#)).

The Nigerian Stock Exchange (NSE) was founded in 1960, and like most African stock exchanges it went through several reforms from inception. The NSE is the largest stock exchange in West Africa and serves the largest African economy ([Nigerian Stock Exchange 2019](#)). Among the several ICT-related developments and reforms in the Nigerian Stock Exchange (NSE) are the introduction, in 1997, of the automated clearing, settlement and delivery system—the Central Securities Clearing System (CSCS)—to ease transactions and foster investors' confidence in the stock exchange. Further, performance information on the NSE was linked to the Reuters International System for the timely dissemination of relevant market information to subscriber investors ([Obiakor and Okwu 2011](#)). The CSCS enables shares to exist in electronic form in a central depository and, thus, helps eliminate risks of the loss, mutilation and theft of certificates, as well as reduce errors and delivery delays. Other ICT adoptions include the CSCS trade alert, phone-in-service, e-bonus and e-dividend payments ([Ezirim et al. 2009](#)).

## 4. Research Methodology

### 4.1. Measures of ICT Adoption and Stock Market Development

This study focused on the impact of ICT adoption and stock market development in Africa. A panel of eleven stock exchanges for the period from 2008 to 2017 was employed in this study. The ICT and stock market development data were sourced from the International Telecommunications Union and the World Bank Global Financial Development databases, respectively, whilst the data for the control variables of GDP and financial freedom were sourced from the World Bank Global Financial Development and Heritage Foundation databases, respectively. The variables employed in this study are described in [Table 3](#). These are the ICT adoption variables, the stock market development variables as well as the control variables. Panel data techniques were used to analyse the data.



**Table 3.** Variable definition.

Variable	Variable Definition
<b>ICT Adoption Variables</b>	
Number of Broadband Users (NBU)	NBU = Fixed broadband subscriptions per 100 inhabitants
Number of Fixed Telephone Users (NFTU)	NFTU = Fixed telephone subscriptions per 100 inhabitants
Internet Users (IU)	IU = Percentage of individuals using the Internet
Number of Mobile Phone Users (NMU)	NMU= Mobile–telephone subscriptions per 100 inhabitants
<b>Stock Market Development Variables</b>	
Stock Market Total Value Traded (SMTV)	$SMTV = \frac{\text{Stock market total value traded}}{\text{Gross Domestic Product}} \times 100\%$
Stock Market Capitalisation (SMC)	$SMC = \frac{\text{Stock market capitalisation}}{\text{Gross Domestic Product}} \times 100\%$
Stock Market Turnover Ratio (SMTR)	$SMTR = \frac{\text{Total value of shares traded}}{\text{Market capitalisation}} \times 100\%$
Number of Listed Companies (NLC)	NLC = number of listed companies per 10,000 people
<b>Control Variables</b>	
Financial Freedom Index (FFI)	FFI = Financial freedom score
Gross Domestic Product (GDP)	GDP = Real gross domestic product

#### 4.2. Empirical Model Specification and Estimation Techniques

This study adopted and modified the model of Okwu (2015) on ICT adoption and stock markets. The following models were specified to test the relationships between the stock market and ICT adoption variables:

$$SMTV_{it} = \alpha_0 + \alpha_1 NBU_{it} + \alpha_2 NMU_{it} + \alpha_3 IU_{it} + \alpha_4 NFTU_{it} + \alpha_5 FFI_{it} + \alpha_6 GDP_{it} + \mu_{it} \quad (1)$$

$$SMC_{it} = \theta_0 + \theta_1 NBU_{it} + \theta_2 NMU_{it} + \theta_3 IU_{it} + \theta_4 NFTU_{it} + \theta_5 FFI_{it} + \theta_6 GDP_{it} + \mu_{it} \quad (2)$$

$$SMTR_{it} = \gamma_0 + \gamma_1 NBU_{it} + \gamma_2 NMU_{it} + \gamma_3 IU_{it} + \gamma_4 NFTU_{it} + \gamma_5 FFI_{it} + \gamma_6 GDP_{it} + \mu_{it} \quad (3)$$

$$NLC_{it} = \beta_0 + \beta_1 NBU_{it} + \beta_2 NMU_{it} + \beta_3 IU_{it} + \beta_4 NFTU_{it} + \beta_5 FFI_{it} + \beta_6 GDP_{it} + \mu_{it} \quad (4)$$

where:

NBU = Number of broadband users;

NMU = Number of mobile–telephone users;

IU = Number of Internet users;

NFTU = Number of fixed telephone users;

SMTV = Stock market total value traded;

SMC = Stock market capitalisation;

SMTR = Stock market turnover ratio;

NLC = Number of listed companies per 10,000 people;

FFI = Financial freedom index;

GDP = Gross domestic product

$\alpha_0, \theta_0, \gamma_0$  and  $\beta_0$  = each model model's intercepts, respectively;

$\alpha_i, \theta_i, \gamma_i$  and  $\beta_i$ , where  $i = 1, 2, 3$  and  $4$  and represent the coefficient of the model's explanatory variables.

The Equations (1)–(4) specified above pose an issue when estimated using the ordinary least squares (OLS) method. There is the problem of endogeneity. To ensure that the estimated results were robust, the system–GMM and feasible generalised least squares (FGLS) estimators were also applied in estimation.

### Generalised Method of Moments

The dynamic model was specified as follows:

$$Y_{it} = \alpha Y_{it-1} + \beta X_{it-1} + \mu_i + \varepsilon_{it} \quad (5)$$

where:

$Y$  = Stock market development proxies, proxied by the number of listed firms (NLC), stock market capitalisation (SMC), the stock market value of shares traded (SMTV), the stock market turnover ratio (SMTR) and the stock market development index (FINDEX);

$X$  = A vector of explanatory variables (other than lagged stock market development);

$\mu$  = An unobserved country-specific effect;

$\varepsilon$  = The error term,

and the subscripts  $i$  and  $t$  represent the country and the time period, respectively.

Taking the first difference of Equation (5), it can be parameterised as follows:

$$\Delta Y_{it} = (\alpha - 1) \Delta Y_{it-1} + \beta \Delta X_{it-1} + \Delta \varepsilon_{it} \quad (6)$$

The GMM, Equation (6), is therefore specified as follows:

$$\Delta SMTV_{it} = \alpha \Delta SMTV_{it-1} + \alpha_1 \Delta NBU_{it} + \alpha_2 \Delta NMU_{it} + \alpha_3 \Delta IU_{it} + \alpha_4 \Delta NFTU_{it} + \alpha_5 \Delta FFI_{it} + \alpha_6 \Delta GDP_{it} + \mu_i + \varepsilon_{it} \quad (7)$$

$$\Delta SMC_{it} = \theta_0 \Delta SMC_{it-1} + \theta_1 \Delta NBU_{it} + \theta_2 \Delta NMU_{it} + \theta_3 \Delta IU_{it} + \theta_4 \Delta NFTU_{it} + \theta_5 \Delta FFI_{it} + \theta_6 \Delta GDP_{it} + \mu_i + \varepsilon_{it} \quad (8)$$

$$\Delta SMTR_{it} = \gamma_0 \Delta SMTR_{it-1} + \gamma_1 \Delta NBU_{it} + \gamma_2 \Delta NMU_{it} + \gamma_3 \Delta IU_{it} + \gamma_4 \Delta NFTU_{it} + \gamma_5 \Delta FFI_{it} + \gamma_6 \Delta GDP_{it} + \mu_i + \varepsilon_{it} \quad (9)$$

$$\Delta NLC_{it} = \beta_0 \Delta NLC_{it-1} + \beta_1 \Delta NBU_{it} + \beta_2 \Delta NMU_{it} + \beta_3 \Delta IU_{it} + \beta_4 \Delta NFTU_{it} + \beta_5 \Delta FFI_{it} + \beta_6 \Delta GDP_{it} + \mu_i + \varepsilon_{it} \quad (10)$$

$\alpha_0, \theta_0, \gamma_0$  and  $\beta_0$  = Each model's intercept, respectively;

$\alpha_i, \theta_i, \gamma_i$  and  $\beta_i$ , where  $i = 1, 2, 3$  and  $4$  and represent the coefficient of the model explanatory variables, while the time invariant country specific effects are captured by  $\mu_i$ , whilst  $\varepsilon_{it}$  the error term and  $\Delta$  is the difference operator.

## 5. Research Findings and Discussion

This section presents the research findings of this study. It first presents the summary statistics of the variables employed in the study. Secondly, it analyses the correlations amongst the variables employed in the study. It progresses to discuss the diagnostic tests that were undertaken to ensure that the models estimated were well specified. Lastly, it presents the panel regression results and then discusses the inferences thereof.

### 5.1. Descriptive Statistics

Table 4 presents the summary statistics of the key variables. First, considering the variables of stock market development, the number of listed companies (NLC) in African countries has a mean of 8.28. This means that there are eight listed companies for every ten thousand persons on average among all the countries adopted for this study. Stock market capitalisation to GDP, on the other hand, has a mean of 49.12 for the sample of African countries, which indicates that on average the stock market capitalisation to GDP of the selected countries is 49.12, and when compared to that of USA, which is 148, it becomes clear that there is growth potential in African stock markets. The stock market total value traded to GDP assumed a mean of 9.98, which indicates that on average the total value of shares traded as a percentage of GDP was 9.98%, while the minimum was 0.14% and the maximum was 123.25% for the African stock exchanges selected for the period of the study. The stock market turnover ratio as a percentage assumed a mean of 12.36%, which means that on average African stock exchanges' value of shares traded in relation to the stock

market capitalisation was 12.36% at a particular period. Furthermore, the ICT adoption variables has the following: the number of broadband users (NBU) has a mean of 507,576, which indicates that on average the number of broadband users in the countries selected for this study was 507,576. The number of fixed telephone users (NTFU) assumed a mean of 1,448,491, which showed that on average the number of fixed telephone users in the African countries selected for this study was 1,448,491, the minimum number of users among the selected countries was 35,000 and the maximum number of users that any of the selected countries had was 11,900,000 users. Internet users as a percentage of population (UI) had a mean of 27.66%, indicating that on average the African countries selected for the study had an Internet penetration level of 27.66%, while the minimum Internet users were 1.9% and the maximum users in the countries of interest was 61%, while the standard deviation was 16.96%. The control variables had the financial freedom index mean of 0.52, which indicates that the African countries selected for this study had a level of financial freedom of 52%. The minimum or lowest financial freedom index ranking for the selected countries was 30% and the highest ranked country on the financial freedom index had 70%. The GDP assumed a mean of USD 121,000,000,000, which is the average GDP of the selected countries. The lowest GDP among the countries was USD 8,490,000. The highest GDP value was USD 568,000,000,000.

**Table 4.** Summary statistics.

Variables	Observations	Mean	Standard Deviation	Minimum	Maximum
NLC	109	8.28	14.56	0.87	59.36
SMC	110	49.12	65.15	7.24	328.36
SMTV	110	9.98	22.74	0.14	123.25
SMTR	110	12.36	14.71	1.08	82.88
FFI	110	0.52	0.12	0.3	0.7
NBU	110	507,576	895,321	320	5,223,311
NFTU	110	1,448,491	2,524,060	35,000	11,900,000
IU	110	27.66	16.96	1.9	61.76
NMU	110	36,400,000	38,100,000	1,033,300	154,000,000
GDP	110	121,000,000,000	146,000,000,000	8,490,000,000	568,000,000,000

## 5.2. Correlation Analysis

The correlation matrix is presented in Table 5. There are a number of relationships that are noteworthy. By and large, the stock market development measures are positively associated with ICT adoption measures as well as the financial freedom variable. This is in line with a priori expectations. Firstly, the stock market capitalisation variable (SMC) exhibits positive association with all four measures of ICT adoption. This implies that the higher the level of ICT adoption, the higher the stock market capitalisation. The highest degree of association of the stock market capitalisation variable is observed in its relationship with the number of fixed telephone users variable, with the level of association of 37.2% and which is highly significant. The stock market capitalisation variable is also positively associated with the financial freedom measure. This means that the higher the degree of financial freedom, the higher the stock market capitalisation. Secondly, the stock market turnover ratio (SMTR) variable is positively associated with a number of ICT adoption measures, namely broadband, fixed telephone and mobile-telephone.

Its degree of association is highest with the fixed telephone variable, explaining 85.3% in the relationship, whilst the broadband variable has a 53.2% explanatory power. Thirdly, the stock market total value traded variable is positively associated across all four measures of ICT adoption. This implies that the higher the level of ICT adoption, the higher the value of the transactions traded on the stock exchanges. Fourthly, the number of listed companies variable is positively associated to the Internet users variable, and the financial freedom variable. This is in line with expectations. Lastly, all the stock market development variables are positively correlated to the gross domestic product variable.

All the associations are highly statistically significant. This lends credence to the view that stock market development fosters economic growth.

**Table 5.** Correlation matrix.

	FFI	IU	NBU	NFTU	NLC	NMU	SMC	SMTR	SMTV	GDP
FFI	1.000									
IU	0.076	1.000								
NBU	−0.196 **	0.398 ***	1.000							
NFTU	−0.147	0.088	0.677 ***	1.000						
NLC	0.497 ***	0.243 **	−0.1293	−0.118	1.000					
NMU	−0.315 ***	0.109	0.473 ***	0.443 ***	−0.351 ***	1.000				
SMC	0.302 ***	0.314 ***	0.191 **	0.372 ***	0.135	0.189 **	1.000			
SMTR	−0.144	0.146	0.532 ***	0.853 ***	−0.143	0.395 ***	0.462 ***	1.000		
SMTV	0.130	0.208 **	0.250 ***	0.565 ***	−0.044	0.299 ***	0.933 ***	0.659 ***	1.000	
GDP	−0.255 ***	0.085 *	0.410 ***	0.485 ***	0.267 ***	0.923 ***	0.391 ***	0.464 ***	0.477 ***	1.000

(\*)/(\*\*) and (\*\*\*) indicate the (10%), (5%) and (1%) level of significance, respectively. Where: NBU = number of broadband users; NMU = number of mobile-telephone users; IU = number of Internet users; NFTU = number of fixed telephone users; SMTV = stock market total value traded; SMC = stock market capitalisation; SMTR = stock market turnover ratio; NLC = number of listed companies per 10,000 people; FFI = financial freedom index; GDP = gross domestic product.

### 5.3. Diagnostic Tests

In examining the impact of ICT adoption on stock market development in Africa, a battery of diagnostic tests were conducted to choose the most fitting estimator to run each model. We took a cue from [Magwedere \(2019\)](#) and [Makoni \(2016\)](#) in the estimation and applied a number of diagnostic tests. These tests encompassed the following: a test for poolability of data by employing the applied [Chow \(1983\)](#) test; the [Breusch and Pagan \(1980\)](#) LM test for random effects; the [Hausman \(1978\)](#) specification test and the modified Wald test for group-wise heteroscedasticity; the Sargan–Hansen test for over-identifying restrictions and the [Arellano and Bond \(1991\)](#) (AR) test for autocorrelation. These tests enabled us to ensure that the estimated model was not mis-specified and that the estimations were consistent.

The pre-estimation tests conducted in estimating the four models affirmed the poolability of the data, the presence of random effects and favoured the use of the fixed effects over the random effects estimator. The tests also confirmed the presence of group-wise heteroscedasticity. As such, the estimation was conducted within the framework of the generalised method of moments, which are efficient in the presence of heteroscedasticity. The Sargan–Hansen and Arellano–Bond tests were relied on to ensure that the estimated models were stable. The diagnostics tests for estimating the four models are appended as Appendix A in Tables A1–A4. As such, three estimators were used to test the relationship. The fixed effects model was the base estimator. For inference, the system–GMM and FGLS estimation results are used, as these yield consistent standard errors in the presence of heteroscedasticity.

### 5.4. Empirical Results on the Impact of ICT Adoption on Stock Market Development in Africa

The panel regression results of testing the impact of ICT adoption measures on the four measures of stock market development are reported in Table 6. The first model (Model 1) that was estimated was on the relationship between the stock market traded volume and the ICT adoption and control variables. The stock market traded volume variable demonstrates persistence over time, as it is highly positively related to its lagged value. The results of both the system–GMM and FGLS estimations document that the stock market traded volume variable is positively related to the broadband user and mobile-telephone user variables and are statistically significant. This is in line with a priori expectations.

**Table 6.** Panel regression results on the estimation of the ICT-stock market development nexus.

	MODEL 1			MODEL 2			MODEL 3			MODEL 4		
	Fixed Effects	Syst-GMM	FGLS	Fixed Effects	Syst-GMM	FGLS	Fixed Effects	Syst-GMM	FGLS	Fixed Effects	Syst-GMM	FGLS
	SMTV	SMTV	SMTV	SMC	SMC	SMC	SMTR	SMTR	SMTR	NLC	NLC	NLC
L.SMTV	1.185 *** (0.194)	1.441 *** (0.314)	1.208 *** (0.0367)									
L.SMC				0.746 *** (0.0539)	0.708 * (0.310)	1.094 *** (0.0258)						
L.SMTR							0.283 *** (0.0444)	0.228 ** (0.0874)	0.397 *** (0.0874)			
L.NLC										0.913 *** (0.0170)	0.927 (0.474)	1.015 *** (0.00620)
NBU	$1.77 \times 10^{-6}$ ( $2.51 \times 10^{-6}$ )	$1.98 \times 10^{-6}$ *** ( $5.27 \times 10^{-6}$ )	$2.29 \times 10^{-6}$ ** ( $8.64 \times 10^{-6}$ )	$-1.39 \times 10^{-7}$ ( $2.59 \times 10^{-7}$ )	$4.05 \times 10^{-7}$ ( $8.98 \times 10^{-7}$ )	$1.99 \times 10^{-6}$ ( $1.87 \times 10^{-6}$ )	$1.20 \times 10^{-6}$ ( $3.30 \times 10^{-6}$ )	$2.18 \times 10^{-6}$ ( $1.42 \times 10^{-6}$ )	$1.61 \times 10^{-6}$ ( $1.29 \times 10^{-6}$ )	$-8.86 \times 10^{-8}$ ( $1.61 \times 10^{-7}$ )	$-1.88 \times 10^{-8}$ ( $1.68 \times 10^{-7}$ )	$5.68 \times 10^{-8}$ ( $1.33 \times 10^{-7}$ )
NFTU	$-3.47 \times 10^{-6}$ ( $2.45 \times 10^{-6}$ )	$-4.80 \times 10^{-6}$ ( $3.98 \times 10^{-6}$ )	$-2.05 \times 10^{-6}$ ( $3.79 \times 10^{-6}$ )	$-1.05e-6$ ( $1.7 \times 10^{-7}$ )	$2.68 \times 10^{-6}$ * ( $7.17 \times 10^{-7}$ )	$1.79 \times 10^{-6}$ * ( $7.24 \times 10^{-7}$ )	$4.29 \times 10^{-6}$ * ( $2.84 \times 10^{-6}$ )	$4.47 \times 10^{-6}$ * ( $3.11 \times 10^{-6}$ )	$2.43 \times 10^{-6}$ *** ( $7.08 \times 10^{-6}$ )	$-2.03 \times 10^{-7}$ ( $1.12 \times 10^{-7}$ )	$-1.60 \times 10^{-7}$ ( $1.35 \times 10^{-7}$ )	$-6.26 \times 10^{-8}$ ( $4.89 \times 10^{-8}$ )
IU	0.0472 (0.0529)	0.142 (0.112)	-0.00562 (0.0312)	0.140 (0.0828)	0.273 (0.226)	-0.00285 (0.0734)	0.0140 (0.0345)	-0.00598 (0.0215)	0.0571 (0.0458)	0.0162 (0.0209)	0.00476 (0.0214)	0.00420 (0.00502)
NMU	$1.13 \times 10^{-6}$ ( $1.02 \times 10^{-6}$ )	$7.59 \times 10^{-8}$ * ( $1.34 \times 10^{-7}$ )	$8.32 \times 10^{-8}$ * ( $3.43 \times 10^{-8}$ )	$1.44 \times 10^{-7}$ ( $1.45 \times 10^{-7}$ )	$1.85 \times 10^{-8}$ ( $2.23 \times 10^{-7}$ )	$5.31 \times 10^{-7}$ ( $8.12 \times 10^{-6}$ )	$3.77 \times 10^{-9}$ ( $6.72 \times 10^{-8}$ )	$-1.55 \times 10^{-8}$ ( $2.76 \times 10^{-8}$ )	$-2.23 \times 10^{-8}$ ( $4.70 \times 10^{-8}$ )	$-1.12 \times 10^{-8}$ ( $1.24 \times 10^{-8}$ )	$-6.28 \times 10^{-9}$ ( $1.49 \times 10^{-8}$ )	$-7.70 \times 10^{-10}$ ( $5.35 \times 10^{-9}$ )
FFI	-11.64 (16.84)	-1.465 (19.40)	-4.231 (3.875)	-69.48 (66.44)	-80.47 (34.98)	-17.04 (9.540)	-44.91 (42.94)	-76.00 (2.381)	-1.420 (5.641)	-0.588 (0.501)	-2.050 (4.106)	-0.802 (0.683)
GDP	$-4.85 \times 10^{-11}$ ( $4.48 \times 10^{-11}$ )	$-5.98 \times 10^{-11}$ * ( $1.29 \times 10^{-11}$ )	$-2.36 \times 10^{-11}$ * ( $9.59 \times 10^{-12}$ )	$-6.12 \times 10^{-11}$ ( $7.06 \times 10^{-11}$ )	$-4.28 \times 10^{-11}$ ( $9.09 \times 10^{-11}$ )	$-1.56 \times 10^{-11}$ ( $2.28 \times 10^{-11}$ )	$-3.78 \times 10^{-11}$ ( $4.33 \times 10^{-11}$ )	$-4.68 \times 10^{-12}$ ( $4.65 \times 10^{-12}$ )	$1.04 \times 10^{-11}$ ( $1.23 \times 10^{-11}$ )	$9.04 \times 10^{-13}$ ( $8.47 \times 10^{-13}$ )	$3.71 \times 10^{-13}$ ( $6.13 \times 10^{-13}$ )	$-1.09 \times 10^{-13}$ ( $1.37 \times 10^{-12}$ )
_CONS	8.270 (13.41)	0.440 (10.76)	1.502 (2.333)	49.00 (35.73)	40.50 (29.90)	5.893 (5.506)	29.00 (26.52)	47.95 (2.654)	1.730 (3.337)	1.235 ** (0.290)	1.186 (1.128)	0.317 (0.384)
N	99	88	99	99	88	99	99	88	99	99	88	99
R <sup>2</sup>	0.775			0.493			0.350			0.707		

Standard errors in parentheses \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ .



The results imply that the higher the number of broadband and mobile users, the higher the demand for shares, which results in increased trading volumes. The findings are consistent with that of [Ashraf and Joarder \(2009\)](#) and [Mwalya \(2010\)](#), who documented a positive relationship between ICT and the stock market traded volumes. In a study on the influence of ICT on the returns on stock and volume of trade on the Nairobi stock exchange, [Mwalya \(2010\)](#) documented that the adoption of information and communication technology increased the mean of daily trade volume and return. The estimation results reveal a negative relationship between the stock market volumes traded variable and the economic growth variable. This is contrary to the presumed relationship.

The second model (Model 2) that was estimated was on the relationship between stock market capitalisation and ICT adoption and control variables. Similarly, the stock market capitalisation variable is persistent over time as it is highly positively related to its lagged value. The results of the estimation system-GMM and FGLS estimators establish that stock market capitalisation is positively related to the fixed telephone user variable. This lends credence to the notion that ICT adoption has a significant and positive effect on stock market development. This finding also resonates with the findings of [Leff \(1984\)](#) as well as that of [Aker and Mbiti \(2010\)](#), who reported a positive relationship between the ICT and stock market capitalisation variables. [Aker and Mbiti \(2010\)](#), in their study, examined the mediating relationship between the spreading of ICT and economic development by investigating specifically how the spreading of ICT, such as broadband internet services and mobile telephone, have influenced a country's market capitalisation. Their results indicated that the number of Internet users, mobile cell subscriptions and fixed broadband subscriptions per 100 individuals each have a statistically strong and positive effect on market capitalisation.

The stock market turnover ratio was employed as the dependent variable in the estimations of the third model (Model 3). The only noteworthy finding is that the number of fixed telephone users variable had a positive and significant effect on this metric. This is similar to the finding on the estimation of the second model.

The fourth model (Model 4) that was estimated was on the impact of ICT adoption measures on stock market development proxied by number of listed companies per 10,000 people. The estimations did not yield any significant results to report on. It could be that the number of listed companies is not a good proxy for stock market development. The other salient finding to report on is that the financial freedom variable does not seem to have a significant effect on the stock market development. The financial freedom variable measures the extent of regulation of these markets. The a priori expectation was that highly regulated markets were bound to stifle portfolio flows and thus impede the development of stock markets. However, in the case of African stock markets, this seems not to be a deterrent.

## 6. Conclusions

The primary aim of this study was to examine the impact of ICT adoption on stock market development in Africa. On the one hand, stock market development was proxied by four measures, namely stock market capitalisation, the number of listed companies, the stock market value traded and the stock market turnover ratio variables. On the other hand, ICT adoption was proxied by four measures, which included the fixed telephone user, mobile-telephone user, broadband user, and Internet user variables. By and large, a positive relationship was established between ICT adoption and stock market development measures. Firstly, it was documented that a positive relationship subsisted between the stock market traded volume and mobile-telephone user variables. Secondly, a positive relationship was also proven between the stock market traded volume and broadband user variables. Thirdly, it was established that the stock market capitalisation variable was positively related the fixed telephone user variable. Fourthly, the research findings confirmed a positive relationship between the stock market turnover ratio and fixed telephone user variable. The results of this study did not find any tangible evidence on the effect of the

level of regulation of financial markets on stock market development in Africa. As such, it could be reasoned that, notwithstanding the highly regulated stock markets in many African countries, this does not seem to stifle stock market activity.

The contribution of the study lies in that, hitherto, no panel study had been conducted to examine the link between ICT adoption and stock market development. This study has demonstrated the impact of ICT adoption on stock exchanges and on the economy in general. Specifically, the study documented that ICT adoption has a positive and significant impact on stock market development in Africa. As such, policy makers must continue to create an enabling environment for ICT adoption and investment in order to induce economic growth. Therefore, if African governments promulgate ICT policies that promote investments in the improvement of Internet services, broadband and telephone (mobile and fixed) infrastructure, this will spur stock market development. For example, African governments can remove restrictions on the repatriation of dividends or profits on ICT-related investments by foreign investors. Further, they can avail other incentives such as tax holidays for specific periods or allowing tax credits for companies that invest in ICT-related infrastructure.

There are two main limitations and caveats to this study that we need to highlight. Firstly, it was beyond the scope of this study to test the effects of the business cycle (namely the 2007–2009 global financial crises and the COVID-19 pandemic) on the relationship between ICT adoption and stock market development. Secondly, the dataset employed in the study only extended up to 2017. As such, for robustness checks, future studies could extend the study period and also examine the effect of business cycles on the relationship between ICT adoption and stock market development. Further research in this realm could also investigate the impact of ICT adoption on the development of African stock markets, especially in this transformational regime of regional cooperation birthed by the signing of Africa Continental Free Trade Agreement by most major African countries. Arguably, this could serve as a catalyst for the integration of stock exchanges and the attendant benefit of increasing the international competitiveness of African stock markets in general.

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## Appendix A

**Table A1.** Diagnostic tests of the data estimations on the impact of ICT adoption on stock market traded volume.

	Fixed Effects	Random Effects	System-GMM	FGLS
Observations	99	99	88	99
Groups	11	11	11	11
F-stats/Wald chi2			333.86	2121.52
Prob > F/Prob > Wald chi2			0.0000	0.0000
Hausman (Chi2)		2.37		
Prob > chi2		0.4993		
Number of instruments			22	

**Table A2.** Diagnostic tests of the data estimations on the impact of ICT adoption on stock market capitalisation.

	Fixed Effects	Random Effects	System-GMM	FGLS
Observations	99	99	88	99
Groups	11	11	11	11
F-stats/Wald chi2			129.84	3866.41
Prob > F/Prob > Wald chi2			0.0000	0.0000
Hausman (Chi2)	11.59			
Prob > chi2	0.0089			
Number of instruments			22	

**Table A3.** Diagnostic tests of the data estimations on the impact of ICT adoption on stock market turnover ratios.

	Fixed Effects	Random Effects	System-GMM	FGLS
Observations	99	99	88	99
Groups	11	11	11	11
F-stats/Wald chi2			287.23	244.02
Prob > F/Prob > Wald chi2			0.0000	0.0000
Hausman (Chi2)	7.33			
Prob > chi2	0.0620			
Number of instruments			22	

**Table A4.** Diagnostic tests of the data estimations on the impact of ICT adoption on the number of listed firms.

	Fixed Effects	Random Effects	System-GMM	FGLS
Observations	98	98	87	98
Groups	11	11	11	11
F-stats/Wald chi2			4309.79	39,592.05
Prob > F/Prob > Wald chi2			0.0000	0.0000
Hausman (Chi2)	3.18			
Prob > chi2	0.3633			
Number of instruments			22	

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