The Effect of Technology Adoption on Financial Inclusion: A Cross-country Panel Analysis between China and Nigeria

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ABSTRACT

Purpose: This study aims to examine the effects of Technology Adoption on Financial Inclusion with focus on Automated Teller Machines, Internet usage and Mobile Cellular subscriptions as the major drivers in a cross-country analysis between China and Nigeria.

Research Design/Methodology: To examine the impact of Technology Adoption on Financial Inclusion, we employed Pooled OLS and Feasible Generalized Least Squares estimators. Financial Inclusion is represented by number of depositors with Commercial Banks per 1,000 adults’ population.

Findings: The results reveal that Automated Teller Machines, Internet usage and Mobile Cellular Subscriptions exert insignificant positive effects on Financial Inclusion both in China and Nigeria. The technology variables however exert significant positive impact on Financial Inclusion as represented by other dummy countries in the Panel. The study also found that GDP growth rate has significant negative relationship with Financial Inclusion in China and Nigeria as well as the rest of the world as represented.

Originality/Value: The findings of the study reveal that Technology Adoption has greater but untapped potentials capable of significantly influencing Financial Inclusion in both China and Nigeria.

Keywords: Automated Teller, Financial Inclusion, Financial Technology, Technology Adoption.

I. INTRODUCTION

Financial Inclusion (FINC) refers to the means and processes that ensure the ease of access to the formal financial system by all members of an economy (Sarma and Pais, 2011). It is a programme aimed at ensuring that financially excluded members of an economy are captured within the formal financial system. The importance of FINC goals has not only necessitate stakeholders to continually formulate policy programmes to achieve the goals but also inform researchers to continuously research into factors that can influence FINC drive.

However, it is essential to continuously research the factors that promotes FINC of the financially excluded population with a view to reducing poverty level, improve country specific and global economy as a whole. The continuous effort at evaluating factors that promotes FINC is in line with the United Nations policy implementation towards ensuring quality and better lives for all. Member States acknowledged that “ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth” (UN, 2015, p.1). Sustainable Development Goals (SDGs) are a continuum of Millennium Development Goals (MDGs), agreed at the UN Millennium Declaration (Summit, 2000), which had a narrower scope than SDGs but aimed at solving similar global problems by 2015, a target that has since been shifted to 2030.

It is not surprising that technology is being considered as likely viable factor that could aid the success of FINC globally.

Therefore, it is imperative to study how Technology Adoption (TechAdpn) could drive the FINC objectives between developed and developing economies given wider disparities in technological advancement and economic indices, hence, this cross-country analysis between China and Nigeria.

II. THEORIES AND CONCEPTS

A. Collaborative Intervention Theory of Financial Inclusion (CITFINC)

This theory states that formal financial services should be delivered to the financially excluded section of an economy through the collaborative intervention from multiple stakeholders (Ozili, 2020). The theory emphasizes that to actualize the FINC objective, a wide range of stakeholders must collaborate with a view to integrating the financially excluded into the formal financial sector of an economy. The involvement of the collaborating stakeholders in the FINC
program oftentimes avail them a greater sense of satisfaction for being a contributor (Ozili, 2020). Collaborative theory promotes synergy among multiple stakeholders working on common forums with public agencies to engage in consensus-oriented decision-making to achieve a common-goal (Ansell and Gash, 2007). Bringing FINC to perspective, it will take the collaborative effort or synergy of multiple stakeholders such as the Government through the Central Bank, the World Bank, and the corporate sector if the FINC objectives must be actualized in an economy. Therefore, considering its focus on collaborative synergy among stakeholders at different levels geared towards actualizing FINC goals, the study finds relevance in CITFINC.

B. Empirical Review

1) The nexus between TechAdpn and FINC

Globally, FINC has continued to dominate the center-stage when the economic well-being of individuals and households are being discussed by the stakeholders with a view to formulating the necessary policies to mitigate the menace (Kanungo and Gupta, 2021). However, technology has penetrated across all the segments and transformed the non-digital economies into digital economies (Tapscott, 1996) whose functionality is based on internet technology (Mesenbourg, 2001). This digital transformation is acknowledged as yet another dominant catalyst that can drive inclusiveness (Bansal, 2014) and accelerate global economic development (Beck et al., 2014; Fung, 2009; Avergou, 2008). The financial services industry is no longer an exception in acknowledging the widespread of digitalization and tried to improve financial inclusion status by leveraging technological adoption as a key variable (Singh, 2017; Kumar and Joseph, 2014).

Not surprisingly, TechAdpn is still an emerging area with no universally accepted definition. In their study, Leong and Sung (2018) opines that TechAdpn in financial services is a cross-disciplinary subject that combines Finance, Technology, Management, and innovative ideas that improve financial service processes through design and deployment of technology. Regardless of lack of a unified definition, technology, innovation, financial services delivery are keywords that unify most or all the various definitions of TechAdpn by different authors.

However, we have proxied TechAdpn from the context of this study with; Automated Teller Machines, Internet Users/usage, and Mobile Cellular subscriptions. The study will test for the impact of these variables on FINC in a cross-country analysis between China and Nigeria. The choice of China and Nigeria is strategic, as we aim to examine how Technology Adoption will influence Financial Inclusion in developed and emerging economies taking into consideration the following disparities include the level of technological adoption, difference in infrastructural development, economic growth, GDP per capita, population, and unemployment rate among others. Likewise, FINC for the purpose of this study will be proxied by the number of adult population that maintain bank accounts with commercial banks in the countries during the period under review. Previously, FINC has been proxied by the number of bank accounts per 1,000 adult population by studies such as Emara and Said (2019); Evans (2018); Kelikume, (2020) among others.

1.1) Impact of Automated Teller Machines (ATMs) on FINC

Players in the formal financial services sector have over the years continued to increase the deployment of ATMs in all parts of the World to achieve different objectives. However, in spite of what their objectives may be, the deployment cannot be said to be unconnected with FINC.

In an attempt to examine the effect of FINC through TechAdpn on the economic growth and poverty reduction in Asia, Ratnawati (2020) found that ATMs density has significant positive influence on FINC, economic growth and poverty reduction in Asia. Also, in their studies on the impact of Technological variables on FINC in Nigeria, Ene et al. (2019) suggests that while ATMs exerts insignificant positive relationship with FINC, Point-of-Sales on the other hand significantly and positively impact FINC. Contrarily, in developing economies such as Africa, ATMs shows significant negative relationship to FINC which suggests the possible effect of obsolete ATMs and limited or absence of ATMs in the rural areas (Williams et al., 2017). A position that was agreed to by Raza et al. (2019) who found that ATMs per 1,000 km² has a significant negative impact on FINC in Pakistan.

Emara and Said (2021) conducted a study on FINC and economic growth in the Middle East and North Africa region, the findings reveal that ATMs exerts significant positive effect on FINC and ultimately the economic growth of the region. This finding aligns with the findings in Sharma (2016) where it was argued that the spread of ATMs other than spread of bank branches has significant positive relationship with FINC and the economic growth of India from 2004-2013.

Attempts have been made to examine the contribution of foreign owned banks within an economy to FINC through TechAdpn. One of such studies was Gopalan and Rajan (2018) who found that the presence of foreign owned banks in 50 emerging and developing economies has significant positive impact on FINC through ATMs per capita and ATMs density rather than bank branches spread from 2004-2009. This is a departure from the findings in William et al. (2017) whose studies found significant negative impact of ATMs on FINC in developing economies as a result of obsolete and low-density of ATMs. This could also mean that foreign owned banks do have competitive advantage over the local banks in the areas of ATMs sourcing and access to adequate capital investment portfolio to finance their investment in ATMs deployment.

Sindani et al. (2019) investigates the effect ATMs and Internet banking on FINC in Kenya from 2012-2017. They found that both ATMs and Internet banking have significant positive relationship with FINC. This probably is evidence of strong presence of FinTech ecosystem in Kenya, the country being one of the major FinTech Hub in Africa.

In view of the conflicting findings from previous studies and in an attempt to achieve the objectives of this study, we have formulated the following hypothesis to evaluate the influence of ATMs on FINC between China and Nigeria:
Hypothesis 1:
H₁: The number of Automated Teller Machines (ATMs) have a positive impact on FINC in both China and Nigeria

1.2) Effect of Internet Usage (Intt) on FINC

The access to the internet is one of the factors driving the adoption and expansion of Technology by the financially excluded population globally. There is no gainsaying that when countries such as China, the UK, and Canada among others can boast of nearly 100% coverage, a reasonable number of communities in Nigeria are still struggling to have access to mobile telephone network let alone internet access. There are prerequisites which may slow the adoption and effect of internet and mobile phones in developing countries where people predominantly depend on agriculture as well as suffer from low per capita income, such prerequisites include education (Chatterjee, 2020).

Evans (2018) investigates the nexus between internet, mobile phones and FINC in a panel of 44 African countries from 2000-2016. The results reveal that internet and mobile phones have significant positive relationship and unidirectional causality effects with FINC in the 44 African countries. This result is consistent with the findings in Kpodar and Andrianaiio (2011); Lenka and Barik (2018) that found significant positive correlation between internet, mobile phones and FINC in Africa and Southern Asia respectively. On the contrary, Senou et al. (2019) in a study on FINC within the West African Economic and Monetary Union from 2006-2017 and found a negative relationship between internet usage, mobile phone and FINC. These they attributed to constraints such as availability, accessibility, and affordability of internet in most WAEMU countries.

Kelikume (2020) concludes that internet usage and mobile phone penetration have significant positive relationship with FINC and ultimately poverty reduction in a panel of 42 African countries. This is consistent with the findings of Nwafor (2018) in a study where he investigated the nexus between internet penetration and FINC in Nigeria from 2001-2016. The study found that internet has significant positive impact on FINC. Contrarily, Shen et al. (2020) investigates the impact of digital technology on FINC in China, in spite of the advanced level of internet penetration in the country, the findings reveal that internet has no direct effect on FINC in China. This could be a case of diminishing returns of internet usage already being experienced in China and possibly a reality to expect at some point in the near future when internet will be available in every part of the World.

Geng and He (2021) in a study of panel of 40 countries along the Belt and Road from 2010 to 2018 concludes that internet usage has an insignificant positive relationship with FINC among lower-middle-income economies but significant positive relationship with FINC in upper-middle-income and higher-income economies. This could be a testament to the affordability, accessibility, and availability of internet by developing countries as argued by Senou et al (2019).

However, internet usage and GDPpc were found to have significant positive impact on FINC of an unbalanced annual panel data of 116 developing countries from 2004-2016, thereby significantly reducing poverty and income inequality (Omar and Inaba, 2020). This is consistent with the findings in Okoroaf et al. (2018) in an empirical study on the determinants of FINC in Nigeria from 1990-2016, they found that internet access and GDPpc have significant positive influence on FINC in Nigeria.

In view of the conflicting findings from previous studies across different continents of the World, we have hypothesized for this study as thus to investigate the impact of internet usage on FINC between China and Nigeria:

Hypothesis 2:
H₂: Internet Usage has a positive effect on FINC in both China and Nigeria

1.3) Influence of Mobile Cellular subscriptions (Phon) on FINC

Since the turn of the millennium, mobile phone technology has almost replaced the fixed (landline phone) telephone technology in the communication World. This development has been found by various studies to have impact on FINC drive globally.

In Uganda, mobile phone is found to have significant positive impact on FINC, the findings of the study reveals that the significant positive effect of mobile phones on FINC is more pronounced among the poor households than non-poor households (Murendo et al., 2017). Also considering gender impact, Abor et al. (2018) found that mobile phone has a significant positive relationship with FINC in Ghana, they further argued that the level of significance was more pronounced among the male-headed households than their female-headed household counterparts. The study suggested that male-headed households are more efficient in their use of mobile phones than their female-headed household counterparts.

Siwela and Njaya (2021) investigated the digital-FINC of women through mobile phones in Zimbabwe, they found that despite extreme convenience, reliability, and accessibility that mobile phones provide to the financially excluded in Zimbabwe, affordability has emerged as a major prohibitive factor that has impaired its FINC potentials especially among the women. It appears that while mobile phone is extremely affordable in African countries like Nigeria where every adult population irrespective of gender owns an average of two mobile phones (NCC, 2021), reverse is the case in countries such as Zimbabwe.

Soumaré et al. (2016) conducted a study on the determinants of FINC in Central and West Africa, the findings reveal that mobile phone is positively related to FINC in Africa and Asia, the study further emphasized that the impact is more pronounced in Sub-Saharan Africa than in other regions, Asia inclusive.

According to Ngo (2019) who investigated the index and FINC in Asia from 2008-2016, the estimation results reveal that mobile phone and employment rate have significant positive relationship with FINC within the period. This is not consistent with the position of Senou et al. (2019) who found a negative relationship between mobile phones, internet usage, and FINC in most West African Economic Monetary Union countries.

In spite of the perceived relevance of mobile phones technology to FINC drive, there still exists divergent findings
from previous studies. As a result, and with a view to establishing the relationship between mobile phones and FINC in a cross-country analysis between China and Nigeria, we have developed the following hypothesis:

**Hypothesis 3:**
Mobile Phones usage has a positive influence on FINC in both China and Nigeria

### III. RESEARCH DESIGN AND METHODOLOGY

#### A. Study Population

The population for this study comprises the developed, developing, and emerging economies. A sample of twenty countries is selected, namely, Nigeria, China and 18 others: Poland, Botswana, Ecuador, Uganda, Burkina Faso, Zimbabwe, Tunisia, Singapore, Argentina, Seychelles, Uzbekistan, Haiti, Rwanda, Côte D’Ivoire, Zambia, Lesotho, Turkey and Georgia. A dummy variable is used to distinguish the two main countries (China and Nigeria). Nigeria and China are being focused on for comparison based on their wider disparities that we expected should give objective cross-country analysis between developed and developing economies. The choice of China and Nigeria is strategic, as we aim to examine how Technology Adoption will influence Financial Inclusion in developed and emerging economies taking into consideration the following disparities include the level of technological adoption, difference in infrastructural development, economic growth, GDP per capita, population, and unemployment rate among others. These factors were also considered in the choice of the other 18 dummy countries that were selected at random.

#### B. Sources of Data

The study is based on secondary data that are published by the appropriate regulatory Agencies and organizations. The data for this study are mostly extracted from the World Bank Group open data source.

#### C. Data Analysis Techniques

The study used descriptive statistics and inferential analysis to analyse the data collected. Panel Data was used due to the nature of the study which involved comparison of two countries over a 16-year period. Fixed and Random Effect regression methods were used to examine the relationship between independent and dependent variables.

#### D. Econometric Model

The general model for this study has been formulated as follows:

\[
FINC_{it} = \alpha + \beta_1 ATM_{it} + \beta_2 Intt_{it} + \beta_3 Phon_{it} + \beta_4 GDPgr_{it} + \beta_5 GDPPC_{it} + \beta_6 Unempl_{it} + \beta_7 Popl_{it} + \epsilon_{it}
\]

where

- \(FINC_{it}\) = Financial Inclusion;
- \(ATM_{it}\) = Automated Teller Machines;
- \(Intt_{it}\) = Individuals using the internet;
- \(Phon_{it}\) = Mobile Cellular Subscriptions;
- \(GDPgr_{it}\) = Gross Domestic Product growth rate;
- \(GDPPC_{it}\) = Gross Domestic Product Per Capita;
- \(Unempl_{it}\) = Unemployment rate;
- \(Popl_{it}\) = Total population;
- \(\alpha\) = Constant;
- \(\epsilon\) = Error term.

\(\beta_1\) \ldots \(\beta_7\) are the parameters for measuring the contribution of each independent variable to the variation in the regression coefficients of dependent variables.

#### E. Contrasting China and Nigeria

For each hypothesis, we contrast the two countries using dummy variables:

\[
FINC_{it} = \alpha + \beta_1 ATM_{it} + \beta_2 Intt_{it} + \beta_3 Phon_{it} + \beta_4 GDPgr_{it} + \beta_5 GDPPC_{it} + \beta_6 Unempl_{it} + \beta_7 Popl_{it} + \epsilon_{it}
\]

\[
FINC_{it} = \alpha + \beta_8 ATM_{it} + \beta_9 Intt_{it} + \beta_{10} Phon_{it} + \beta_{11} GDPgr_{it} + \beta_{12} GDPPC_{it} + \beta_{13} Unempl_{it} + \beta_{14} Popl_{it} + \epsilon_{it}
\]

where \(D_{it}^N\) and \(D_{it}^C\) are dummy variables representing Nigeria and China respectively. A significant \(\beta^N\) means a difference between Nigeria and the rest of the sample. Similarly, a significant \(\beta^C\) means a difference between China and the rest of the sample. Finally, a significant difference between \(\beta^N\) and \(\beta^C\) would mean a difference between Nigeria and China.

### IV. DATA ANALYSIS AND EMPIRICAL RESULTS

#### A. Descriptive Statistics Summary

The result presentation begins with the description of the characteristics of the data series and as indicated in Table I. Also, the determination of the multicollinearity problem among variables was carried out using the Pearson correlation coefficient. It was a balanced panel data of 16 years for China and Nigeria in dummy relationship with 18 other countries. Presented in Table I is the description of the balanced dataset that spanned across 16 years and 20 countries. Based on the main features, it shows that financial inclusion and gross domestic product per capita have the highest mean values of 614.8 and 6801.3 respectively, due to the logistics of the dataset. The standard deviation shows that the variance of the data series from the mean is high.
B. Correlation Analysis

The correlation matrix displayed in Table II shows the non-causal relationship between the explained and explanatory variables for 16 years and across 20 countries. It shows that Automated Teller Machines and Internet Users in China have the highest positive correlation coefficient of 0.823. Except for the above, there is no other correlation coefficient among the explanatory variables that are greater than 0.635. This indicates that the probability of multicollinearity among the independent or explanatory variables is extremely low. Also, the positive non-causal relationship indicates that the variables move in the same direction. That is, an increase in one variable would cause an increase in the other. Contrarily, the negative effect connotes an inverse non-causal relationship. That is, an increase in one variable would cause a decrease in another variable.

C. Inferential Analysis and Hypotheses Testing

Presented in Table III is the regression estimation results to examine the relationship between ATMs and FINC. To decide on the appropriate estimation technique to be employed for this hypothesis, the Hausman test conducted favors the fixed effect. The chi-square statistic for the Hausman test is 68.79 with a P-value of 0.000, which is lower than 0.05 threshold. Although, the Breusch-Pagan LM test with chi-squares statistic of 98.67 and P-value of 0.000 also aligned with the result of Hausman test as it favors Pooled OLS over random-effect. However, the Hausman test result takes precedence and fixed-effect estimation is considered appropriate. The Pesaran CD test with P-value of 0.4992 indicates evidence of no cross-sectional dependence while the Modified Wald Test for Heteroskedasticity shows the variance of the error terms is not constant over-time, that is, absence of homoskedasticity. Also, the model suffered the
problem of serial-correlation because the P-value of the F-statistic is 0.000, which is greater than 0.05 significant level. Consequently, the Feasible Generalized Least Squares (FGLS) is considered appropriate to remove the violations of the OLS assumptions and for interpretation of our hypothesis.

Concerning FGLS, it was discovered that ATMs, ATMs in China, ATMs in Nigeria, Intt, Phon, GDPpc and Unemplr exert positive effects on FINC with their respective coefficient of 6.45, 3.67, 19.89, 2.33, 0.700, 0.02 and 2.13. However, the positive effect was only significant for ATMs, Intt, Phon (in the rest of the World as represented by other countries in the panel), GDPpc and Unemplr with their respective P-values of 0.000, 0.000, 0.039, 0.000 and 0.010, as against the insignificant effect of ATMs in both China and Nigeria with their respective P-values of 0.223 and 0.155. Also, GDPgr and Popl were found to exert negative and significant effects on FINC at -3.49 (p=0.000<0.05) for GDPgr and -5.31 (P=0.000<0.05) for Popl. The F-statistics of 534.74 along with 0.000 P-value reveals that the model is fit. By implication, this affirms the overall significance of the linear regression model since the P-value is less than 0.05.

The corollary of this discovery is that a 1% increase in ATMs, Intt, Phon (in the rest of the World as represented by other countries in the panel), GDPpc and Unemplr would engage a significant increase in FINC by 6.45%, 2.33%, 0.700%, 0.02% and 2.13% respectively. However, FINC in China and Nigeria stands the chance of increasing insignificantly with just a 1% increase in ATMs in both China and Nigeria by 3.67%, 19.89% respectively. Contrarily, GDPgr and Popl could respectively cause a -3.49% and -5.31% significant decrease in FINC with just a 1% increase.

The inference of all these parameters is that while ATMs, ATMs in both China, and Nigeria, Intt, Phon, GDPpc and Unemplr have the capacity to positively influence FINC, GDPgr and Popl would do otherwise.

Presented in Table IV is the estimation results of the impact of Intt on FINC. The table contains both the diagnostic and regression test results. The Hausman test results conducted to decide on the appropriateness of either fixed or random-effects favors fixed-effect as the chi-squares statistic is 83.00 with P-value of 0.000, which is less the 0.05 significance threshold. Similarly, the Breusch-Pagan LM test with the chi-square statistics of 98.64 and p-value of 0.000 makes random-effect appropriate estimation technique for the model. Since the Hausman test favors fixed-effect, further tests for cross-sectional independence, heteroskedasticity and serial/autocorrelation become necessary. The result of Pesaran CD test reveals 0.658 with P-value of 0.5105 indicating the absence of cross-sectional dependence. The Modified Wald test for heteroskedasticity with a P-value of 0.000 and Wooldridge test for autocorrelation in panel data with a P-value of 0.00 led to the rejection of the null hypothesis of homoskedasticity and no serial-correlation. Therefore, the Feasible Generalized Least Squares (FGLS), that correct for heteroskedasticity, and autocorrelation is considered appropriate for our hypothesis testing and result interpretation.

Concerning FGLS, it was discovered that ATMs, Intt, Intt in China, Intt in Nigeria, Phon, GDPpc and Unemplr exert positive effects on FINC with their respective coefficient of 6.57, 2.32, 10.42, 4.18, 0.66, 0.022 and 2.17. However, the positive effect was only significant for ATMs, Intt, Phon (in the rest of the World as represented by other countries in the panel), and GDPpc and Unemplr with their respective P-values of 0.000, 0.004, 0.000 and 0.007 as against the insignificant effect of Intt in both China and Nigeria with their respective P-values of 0.159 and 0.785. Also, GDPgr and Popl were found to exert negative and significant effect on FINC at -3.51 (p=0.000<0.05) for GDPgr and -5.42 (P=0.000<0.05) for Popl. The F-statistics of 583.98 along with P-value of 0.000 reveals that the model is fit. By inference, this confirms the overall significance of the linear regression model since the P-value is less than 0.05.

### TABLE III: RESULTS OF REGRESSION FOR HYPOTHESIS ONE, DEPENDENT VARIABLE: FINANCIAL INCLUSION

| VARIABLES | OLS | FE | RE | FGLS |
|-----------|-----|----|----|------|
| C | 147.33(0.000) | 1222.49(0.000) | 238.71(0.000) | 165.24(0.000) |
| ATM | 6.38(0.000) | 7.38(0.000) | 3.99(0.001) | 6.45(0.000) |
| ATM x China Dummy | 5.66(0.089) | 10.78(0.000) | 5.85(0.045) | 3.67(0.223) |
| ATM x Nigeria Dummy | 7.43(0.617) | 10.13(0.526) | 2.33(0.884) | 19.89(0.155) |
| INTT | 4.90(0.000) | 3.21(0.003) | 4.24(0.000) | 2.33(0.000) |
| PHON | 0.21(0.650) | 1.54(0.001) | 1.03(0.031) | 0.70(0.039) |
| GDP gr | -5.81(0.045) | -10.57(0.000) | -9.08(0.001) | -3.49(0.000) |
| GDPpc | 0.23(0.000) | 0.002(0.600) | 0.02(0.000) | 0.02(0.000) |
| Unemplr | 4.25(0.060) | 3.001(0.171) | 2.48(0.293) | 2.13(0.010) |
| POPL | -5.76(0.000) | -0.000(0.000) | -5.67(0.000) | -5.31(0.000) |
| R-squared | 0.8513 | 0.5041 | 0.8347 | - |
| Adjusted R-squared | 0.8470 | - | - | - |
| F-Stat | 197.23 | 41.43 | Wald chi² = 437.92 | Wald chi² = 534.74 |
| Prob > F | 0.000 | 0.000 | 0.000 | 0.000 |
| Hausman Test | - | 0.676 (0.4992) | - | - |
| Prob > chi² = 68.79 | - | - | - | - |
| Breusch-Pagan LM Test | - | - | Prob > chi² = 98.67 | - |
| Modified Wald Test for Heteroskedasticity | - | chi² = 10328.567 | - | - |
| Prob > chi² = 0.000 | - | - | - | - |
| Woodridge Test for Autocorrelation | - | F₁, i = 172.436 | - | AR (1) = 0.8028 |
| Prob > F | 0.0000 | - | - | - |

\[ F_{inic} = \alpha + (\beta_1 + \beta_2 \text{ATMs}) + \beta_3 \text{Intt} + \beta_4 \text{Phon} + \beta_5 \text{GDPgr} + \beta_6 \text{GDPpc} + \beta_7 \text{Unemplr} + \beta_8 \text{Popl} + \varepsilon_{it} \]
The consequence of this finding is that a 1% increase in ATMs, Intt, Phon (in the rest of the World as represented by other countries in the panel), GDPpc and Unempl would engender a significant increase in FINC by 6.57%, 2.32%, 0.66%, 0.022% and 2.17% respectively. However, FINC in China and Nigeria stands the chance of increasing insignificantly with just a 1% increase in Intt in both China and Nigeria by 10.42%, 4.18% respectively. Contrarily, GDPgr and Popl could respectively cause a -3.51% and -5.42% significant decrease in FINC with just a 1% increase. The inference of all these parameters is that while ATMs, Intt, Phon (in the rest of the World as represented by other countries in the panel), Intt in both China and Nigeria, GDPpc and Unempl have the capacity to positively improve FINC, GDPgr and Popl would do otherwise.

Presented in Table V is the estimation results of panel regression (pooled OLS, fixed and random effect), Feasible Generalized Least Squares (FGLS) and other relevant post-estimation tests. The Hausman test results conducted to decide on the appropriateness of either fixed or random-effects favors fixed-effect as the chi-squares statistic is 85.25 with P-value of 0.000, which is less the 0.05 significance threshold. Similarly, the Breusch-Pagan LM test with the chi-square statistics of 98.64 and P-value of 0.000 makes random-effect appropriate estimation technique for the model. Since the Hausman test favors fixed-effect, further tests for cross-sectional independence, heteroskedasticity and serial autocorrelation become necessary. The result of Pesaran CD test reveals 0.519 with p-value of 0.6035 indicating the absence of cross-sectional dependence. The Modified Wald test for heteroskedasticity with a P-value of 0.000 and Wooldridge test for autocorrelation in panel data with a p-value of 0.000 led to the rejection of the null hypothesis of homoskedasticity and no serial-correlation. Therefore, the FGLS, that correct for heteroskedasticity, and autocorrelation is considered appropriate for our hypothesis testing and result interpretation.

Concerning FGLS, it was discovered that ATMs, Intt, Phon, Phon in both China and Nigeria, GDPpc and Unempl exert positive effect on FINC with their respective coefficient of 6.57, 2.25, 0.71, 4.38, 2.63, 0.002 and 2.12. However, the positive effect was only significant for ATMs, Intt, Phon (in the rest of the World as represented by other countries in the panel), GDPpc and Unempl with their respective P-values of 0.000, 0.000, 0.036, 0.000 and 0.009 as against the insignificant effect of Phon in both China and Nigeria with their respective P-values of 0.260 and 0.563. Also, GDPgr and Popl were found to exert negative and significant effect on FINC at -3.48(p=0.000<0.05) for GDPgr and -5.38(P=0.000<0.05) for Popl. The Wald chi² of 26.98 along with p-value of 0.000 reveals that the model is fit. The inference of this discovery is that with just a 1% increase in ATMs, Intt, Phon (in the rest of the World as represented by other countries in the panel), GDPpc and Unempl, FINC would increase insignificantly by 6.57%, 2.25%, 0.71%, 0.002% and 2.12% respectively. For Phon in both China and Nigeria, FINC would significantly increase by 4.38% and 2.63% respectively with just a 1% increase. On the other hand, with a 1% increase in GDPgr and Popl, FINC would significantly decrease by -3.48 and -5.38 respectively.

D. Validation of Hypotheses and Comparison between China and Nigeria

The comparison would be done based on each of the formulated hypotheses:

H1: The number of Automated Teller Machines (ATMs) have a positive impact on Financial Inclusion (FINC).
TABLE V: RESULTS OF REGRESSION ESTIMATE AND DIAGNOSTIC TESTS OF HYPOTHESIS THREE: DEPENDENT VARIABLE: FINANCIAL INCLUSION

| Variables                  | (1)            | (2)            | (3)            | (4)            |
|----------------------------|---------------|---------------|---------------|---------------|
|                            | OLS           | FE            | RE            | FGLS          |
| C                          | 139.18(0.000) | 1238.23(0.000) | 228.19(0.000) | 162.70(0.000) |
| ATM                        | 6.32(0.000)   | 7.56(0.000)   | 3.96(0.001)   | 6.57(0.000)   |
| INTT                       | 5.04(0.000)   | 3.15(0.003)   | 4.26(0.000)   | 2.25(0.000)   |
| PHON                       | 0.28(0.541)   | 1.52(0.001)   | 1.07(0.025)   | 0.71(0.036)   |
| PHON × China Dummy         | 8.73(0.278)   | 21.26(0.001)  | 10.27(0.145)  | 4.38(0.260)   |
| PHON × Nigeria Dummy       | -4.44(0.653)  | -8.43(0.259)  | -5.25(0.530)  | 2.63(0.563)   |
| GDP<sub>g</sub>            | -6.12(0.034)  | -19.77(0.000) | -9.31(0.000)  | -3.48(0.000)  |
| GDP<sub>p</sub>            | 0.023(0.000)  | 0.002(0.594)  | 0.012(0.000)  | 0.021(0.000)  |
| Unempl<sub>r</sub>         | 4.49(0.047)   | 3.01(0.166)   | 2.64(0.261)   | 2.12(0.009)   |
| POPL<sub>o</sub>           | -5.73(0.000)  | -0.000012(0.000) | 5.71(0.000)   | -5.38(0.000)  |
| R-squared                  | 0.8514        | 0.5030        | 0.8288        |               |
| Adjusted R-squared         | 0.8470        |               |               |               |
| F-Stat                     | F-Stat = 197.27 |               | F-Wald chi<sup>2</sup> = 435.99 | F-Wald chi<sup>2</sup> = 526.54 |
| Prob > F = 0.0000          |               | Prob > F = 0.0000 | Prob > chi<sup>2</sup> = 0.0000 | Prob > chi<sup>2</sup> = 0.0000 |
| Pesaran CD Test            | -             | 0.519 (0.6035) | -             | -             |
| Hausman Test               | -             | chi<sup>2</sup> = 85.25 | -             | -             |
| Breusch-Pagan LM Test      | -             | chi<sup>2</sup> (10) = 98.64 | Prob > chi<sup>2</sup> = 0.000 | -             |
| Modified Wald Test for     | -             | -             | -             | -             |
| Heteroskedasticity         | -             | Prob > chi<sup>2</sup> = 0.000 | -             | -             |
| Woodbridge Test for        | F<sub>1, 9</sub> = 144.461 | - | - | - |
| Autocorrelation            | -             | AR (1) = 0.8427 | -             | -             |

\[ \text{FINC}_{it} = \alpha + \beta_1 \text{ATM}_{it} + \beta_2 \text{INTT}_{it} + (\beta_3 + \beta_4 D_{it}^C) \text{PHON} + \beta_5 \text{GDP}_{it} + \beta_6 \text{Unempl}_{it} + \beta_7 \text{POPL}_{it} + \varepsilon_{it} \]

Extracted from Table III, Table VI shows the FGLS estimation results on whether ATMs have positive impact on FINC for both China and Nigeria. It reveals that there is enough evidence to accept the alternative hypothesis that the number of ATMs have positive impact on FINC for both China and Nigeria. Hence, the null hypothesis is hereby rejected. By extension, the coefficient is insignificant, therefore there is no difference between China and Nigeria in terms of significance. However, the positive effect was significant for the rest of the World as represented by other countries in the sample.

**H<sub>2</sub>: Internet Usage (Intt) has a positive effect on Financial Inclusion (FINC)**

Extracted from Table IV, Table VII shows the FGLS estimation results on whether Intt has a positive impact on FINC for both China and Nigeria. It reveals that there is enough evidence to accept the alternative hypothesis that Intt has a positive impact on FINC for both China and Nigeria. Hence, the null hypothesis is hereby rejected. By extension, the coefficient is insignificant, therefore there is no difference between China and Nigeria in terms of significance level. However, the positive effect was significant for the rest of the World as represented by other countries in the sample.

**H<sub>3</sub>: Mobile Cellular Subscriptions (Phon) has positive influence on Financial Inclusion (FINC)**

Extracted from Table V, Table VIII shows the FGLS estimation results on whether Phon has positive impact on FINC for both China and Nigeria. It reveals that there is enough evidence to accept the alternative hypothesis that Phon has positive effect on FINC for both China and Nigeria. Hence, the null hypothesis is hereby rejected. By extension, the coefficient is insignificant, therefore there is no difference between China and Nigeria in terms of significance level. Although, the positive effect was significant for the rest of the World as represented by other countries in the sample.

**E. Summary and Discussion of Findings**

1) Impact of Automated Teller Machines (ATMs) on Financial Inclusion (FINC)

The results of correlation and regression analysis estimations in Table III shows that number of ATMs have positive though insignificant impact on FINC in both China and Nigeria. This finding aligns with that of Ene et al. (2019); who found insignificant positive effect of ATMs on FINC. However, the number of ATMS in the rest of the World as represented by other sampled countries exert significant
positive impact on FINC, this aligns with the findings of Emara and Said (2021); Ratnawati (2020); Sindani et al. (2019); Gopalan and Rajan (2018); Sharma (2016). This is however contrary to the findings of, Raza et al. (2019); Williams et al. (2017) who found significant negative relationship between ATMs and FINC.

Comparing China and Nigeria, the insignificant positive effect of ATMs on FINC in the two countries seems not in tandem with the level of technological advancement that is more pronounced in China than Nigeria. However, the results remain valid when factors such as the average population and average number of ATMs per 100,000 adults for the two countries were put side-by-side from 2005-2020. With an average population of 1.3 billion, there was average deployment of 49 ATMs per 100,000 adults in China. Likewise, during the period Nigeria has an average population of 170 million while average of 10 ATMs were deployed. We further extend our discussion to other countries in the sample with a view to validating our result (insignificant for China and Nigeria on one hand, significant for the rest of the World on the other). Singapore and Seychelles with average population of 5 million and 90,000 respectively from 2005-2020 have ATMs deployment of 56 and 54 per 100,000 adults respectively during the period. This situation suggests that China and Nigeria still have greater potentials to accommodate massive deployment of ATMs in their bids to achieve their respective FINC objectives.

However, in spite of the very low density of ATMs per 100,000 adults in China and Nigeria, this study finds number of ATMs to have positive effect on FINC, the insignificant level may be attributed to the low density of ATMs per 100,000 adults in China and Nigeria. This position aligns with the findings in Ratnawati (2020); Gopalan and Rajan (2018) who argued that high number of ATMs causes significant positive impact on FINC. The position is however contrary to the findings of Williams et al. (2017) that suggests that low number of ATMs have significant negative effect on FINC.

2) Effect of Internet Usage (Intt) on Financial Inclusion (FINC)

The regression results in Table IV suggests a positive relationship between Intt and FINC. However, the effect is insignificant for both China and Nigeria. This is consistent with the findings of Geng and He (2021) who found insignificant positive impact of Intt on FINC. Although, the impact of Intt on FINC was significant for the rest of the World as represented by other countries in the panel, this aligns with the findings of Omar and Inaba (2020); Okoroafor et al. (2018); Evans (2018). However, the finding is contrary to that of Senou et al. (2019) that found negative relationship between Internet usage and FINC. It also contradicts the finding of Shen et al. (2020) who opined that there is no direct effect of Internet usage on FINC.

We however wish to make further analysis to validate our results. On the average, an in-depth analysis of our dataset reveals that while China and Nigeria have about 40% and 16% of their respective population actively used Intt from 2005-2020. On the other hand, 75% and 64% respectively of Singapore and Poland population were active Internet users during the same period. The level of Intt these two countries when compared to some other countries in the panel further attests to the level of Intt adoption in China and Nigeria. This suggests that there exist huge market potentials for Intt deployment in China and Nigeria. Although, affordability may be a limiting factor has suggested by Senou et al. (2019).

3) Influence of Mobile Cellular Subscription on Financial Inclusion

The findings of the regression analysis in Table V reveals that Phon has insignificant positive impact on FINC in both China and Nigeria. To the best of our knowledge, there is no empirical findings that supports insignificant positive impact of Mobile Cellular Subscriptions (Phon) on FINC. However, this finding partially aligns with the findings of Abor et al. (2018); Murendo et al. (2017); Ngo (2016); Soumaré et al. (2016) only on positive frontier but differ on significance level. This is however contrary to the finding of Senou et al. (2019) that found negative relationship between Phon and FINC.

The insignificant effect of Phon on FINC in China and Nigeria may be attributed to rate of Phon usage in the two countries during the period under review. While China and Nigeria have respective 78 and 63 Phon per 100 people, countries such as Singapore, Poland and Georgia have respective 141, 125 and 104 Phon per 100 people during the same period. These statistics indicate that adoption of Phon is just above average in China and Nigeria. While availability and accessibility of Mobile Cellular subscriptions may not be limiting factors in China and Nigeria, affordability may however be responsible for the just above average Mobile Cellular subscriptions in China and Nigeria. This is a position suggested by Senou et al. (2019) who argued that availability, accessibility, and affordability are the limiting factors for the adoption of Mobile Cellular subscriptions in some emerging economies.

V. CONCLUSION

Overall, the findings of the study reveal that Technology Adoption is a great strategy through which Financial Inclusion objective can be effectively driven to incorporate the unbanked population into the formal financial sector. The results suggest that globally, more people regardless of their income level can be financially included without the banks having to extend their branch-networks provided the necessary technological infrastructures are made available by the governments and other stakeholders.

VI. RECOMMENDATIONS

Based on the findings of this study that found positive effect of Technology Adoption on Financial Inclusion, we recommend that governments, and other stakeholders in China and Nigeria should improve on the enabling environment with a view to improving technology adoption aimed at improving the Financial Inclusion of the unbanked population. There is enough evidence from the findings of this study to suggest that if the governments and other stakeholders provide the enabling technological infrastructures and public awareness, financial sector and other major players in the technology industry will be motivated to innovate products that will enhance ease-of-access to financial services by those who are currently
excluded. It is also important for the governments and other stakeholders to continually review and implement improved data security for technology-based financial transactions.

VII. LIMITATIONS

The major limitation for this study relates to the period (2005-2020) during which data was available for Automated Teller Machines and Internet usage. Although, 2004 signifies the beginning of adoption of Automated Teller Machines by the financial services industry, and the spread of Internet usage also commencing in the same year, not many countries of the world experienced such technological advancement until 2005. Also, the available data did not cover the post-COVID-19 pandemic era, the implications of these are our inability to make a comparison between the two countries over a longer-period of time with a possibility of further considering the effects of Technology Adoption on Financial Inclusion Pre- and post-COVID-19 pandemic period.

VIII. SUGGESTIONS FOR FUTURE RESEARCH

With the whole world experiencing the negative impact of COVID-19 pandemic, it is almost certain that studies on the impact of Technology Adoption on Financial Inclusion cannot be said to have been concluded yet. In view of this, it is imperative to continue to research into the effect of Technology Adoption on Financial Inclusion into the future. Such future studies when data is eventually available should focus on the effects that Technology Adoption has on Financial Inclusion in pre- and post-COVID-19 pandemic period.

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