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Investigating the Level of Financial Inclusion in the African Continental Free Trade Zone Areas (AfCFTA)

MSc Research Project
FinTech

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MSc Project Submission Sheet

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Investigating the Level of Financial Inclusion in the African Continental Free Trade Zone Areas

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Abstract

An economy is inclusive where the financial system is readily accessible, and affordable to end users regardless of their economic strata. Furthermore, the integration of inclusive economies through a common theme like trade openness is advantageous. It strengthens access to credit, innovation, and poverty reduction. Nonetheless, the level of financial inclusion in the African Continental Free Trade Area (AfCFTA) has not exactly been researched, providing avenues for future study. This study employed the two-staged robust principal component analysis (rPCA) to assess the level of financial inclusion in AfCFTA member states over 2011, 2014, 2017 and 2021. Leveraging metrics (quality, usage and access) provided by the Global Partnership for Financial Inclusion (GPFI) and the World Bank, the data utilized were provided by World Bank FINDEX and International Monetary Fund Financial Access Survey (IMF FAS). Evidenced by very low inclusion scores across all countries, the empirical result indicates that the quality of financial services is the main barrier to achieving a highlevel of financial inclusion in AfCFTA. However, Seychelles, Mauritius, Kenya, South Africa, Nigeria, and Capo Verde are highly included countries, driven by increased access to funds, and banking products which facilitate cross-border trade. The result reveals that high transaction costs and lack of confidence in the banks are the biggest inclusion challenges in AfCFTA. This research offers key insights for policymakers and FinTech innovators. Future studies should examine trade's impact on financial inclusion under AfCTA.

1 Introduction

1.1 Research Background

Financial inclusion has grown beyond a national objective to a priority area for international organisations such as the United Nations Sustainable Development Goals (Demirgüç-Kunt *et al.*, 2020). This is because inclusion is a strategic means to achieving objectives like poverty alleviation, economic growth, and trade openness (Mulungula and Nimubona, 2022). A financial system is considered inclusive when financial products and services are made accessible and affordable in such a way that it meets the need of businesses and individuals without barriers (Ayele, Malhotra and Sharma, 2024).

Hence, exclusion occurs when certain populations lack access to basic financial services. FINDEX[1] identifies reasons for exclusion to include low income, lack of education, and mismatched financial products. Financial inclusion enables the unbanked to access formal banking services (Mulungula and Nimubona, 2022; Bertram, Nwankwo and Onwuka, 2016; Sahay *et al.*, 2015). Evans (2015) noted that a fully inclusive financial structure is still lacking globally, especially in Africa[2]. Therefore, it is crucial to strengthen and expand the financial systems across the African continent.

The World Bank Group emphasized the importance of expanding digital financial inclusion through low-cost technology to reach underserved and excluded populations[3]. Conclusively, the benefits of improving the level of financial inclusion in the African continent is not only limited to individuals, but also businesses. Access to an efficient formal financial service can empower the increase of intra-African trade. The usage of financial services is also key for trade finance operations, fund exchange, savings and insurance. Affordability also plays a key role as an enabler to African micro traders in using the formal financial channels for inter-country transactions (Warikandwa, 2023). While previous literature has explored the link between financial inclusion and trade in Africa theoretically, there is a gap in research on the level of financial inclusion within the member states of Africa's largest free-trade zone. This presents an opportunity for future studies.

This study aims to provide research coverage on the level of financial inclusion in the largest African free-trade zone area. It contributes an alternative view to existing literature of inclusion in Africa, but, with a focus on AfCFTA. The World Bank Findex[4] and Financial Access Survey[5] have supported efforts to understand the different spheres of inclusion by the periodic availability of datasets used in this study. This will shed light on the challenges, trends and efforts towards financial inclusion practices that supports trade. This research is valuable to FinTech innovators looking for investment opportunities in Africa based on priority areas of attention, as well as policymakers. Future studies can assess the impact of trade on financial inclusion within AfCFTA and recommend machine learning algorithms that can effectively predict the level of inclusion.

1.2 Question and Objectives of Research

The research question is as given below:

'To what extent are member countries of the African Continental Free Trade Area (AfCFTA) financially included?'

[1] https://documents1.worldbank.org/curated/en/187761468179367706/pdf/WPS7255.pdf
[2] https://www.worldbank.org/en/publication/globalfindex/Report#sec5
[3] https://www.worldbank.org/en/topic/financialinclusion/overview
[4] https://www.worldbank.org/en/publication/globalfindex
[5] https://data.imf.org/fas

The objectives of this study are:

- To compute the index of financial inclusion for countries within the AfCFTA free-trade area.
- To categorize the level of financial inclusion in member countries using access, usage and quality dimensions within 2011, 2014, 2017 and 2021.
- Examine the patterns in the level of financial inclusion in AfCFTA.

Estimating the financial inclusion index over the selected years requires numerous variables. To achieve the stated objectives, robust principal component analysis (rPCA) was used for index estimation. Due to the number of outliers in the voluminous and multidimensional dataset, rPCA, which is outlier resistant[6], is considered appropriate compared to other methods. It deals with dimensionality and manages noise in a dataset. This methodology has been adopted in the works of Cámara and Tuesta (2014) and Ayayi and Dout (2024), where a two-staged principal component analysis was applied. Due to limited availability of data, not all member states are included. A vast investigation in this area should cover all 47 member states of AfCFTA.

The other sections of this research include:

- Section Two provides a detailed review of literature
- Section Three contemplates the research methodology used, providing insight into the technique applied in this study
- Section Four provides the specification of design
- Section Five includes the implementation of the design of the study
- Whereas Section Six contains a detailed explanation of results and research discussion
- Section Seven focuses on the conclusion and future work recommendations that may be considered by other researchers

2 Related Work

2.1 Evaluation of Financial Inclusion

Financial inclusion is considered a necessary tool for the sustained development of any type of economy in today's world (Shaik and Babu, 2018). Research on financial inclusion has expanded significantly in recent years, exploring various dimensions (Langton, 2023; Sharma and Changkakati, 2022; Hendriks, 2019). Sarma (2008) proposed a multi- dimensional index for measuring financial inclusion globally. This methodology follows the aggregation of

[6] https://www.geeksforgeeks.org/python-variations-of-principal-component-analysis/

normalised scores into a single composite index using financial inclusion data. The index for each of the dimensions across usage, access and quality was firstly estimated to compute the financial inclusion index. The index was then categorized as high, medium and low. Similar methodology was adopted in this research. However, some other researchers have established that there is no central definition of financial inclusion (Ayele *et al*., 2024; Abel, Mutandwa and Le Roux, 2018).

The World Bank[7] views financial inclusion as access to affordable financial services. In comparison, Daud and Ahmad (2023) argue that the degree of access and not mere access to financial products, especially as a poverty eradication tool, is a better description. Barajas *et al.* (2020) introduced a different concept of self-exclusion, where people with access to financial services have refused to use them. These barriers can be due to the lack of trust in the system or other reasons such as distance or knowledge gaps thereby enabling exclusion. Hegde and Kavyashree (2024) therefore suggested using training schemes to raise educative awareness of financial services as a solution to pending barriers. Although existing literature like Barajas *et al.* (2020) focused on access and usage, Daud and Ahmad (2023) bring a varied lens of view on self-exclusion. This highlights the different perspectives to defining the concept of financial inclusion and indicates that there is no specific consensus.

In alignment with the World Bank[6], Adalessossi and Kaya (2015) highlight the relevance of broadening the access to financial services in reducing income inequality. However, the World Bank reveals that access is only the first step to increased inclusion. Usage is complementary to access as a second measure of inclusion, especially for countries with a high level of banked population. Thirdly, quality is measured by the level of barriers to financial services. Access, usage and quality were referred to as dimensions. Literature like Sarpong and Nketiah-Amponsah (2022) and Hegde and Kavyashree (2024) have also focused on usage and access as influencing dimensions of financial inclusion. As posited by Cámara and Tuesta (2014), a focus on these two dimensions while neglecting quality as a dimension is a biased measure of viewing financial inclusion.

Allen *et al.* (2016) followed a different approach using a bank sample of over 2,000 in 86 economies over a period. The study revealed that a high level of financial inclusion positively affects the stability of banks. The study further iterated the need for banks to prioritize inclusion among other goals like income and asset size generation. Employing a combination of random effects (RE), fixed effects (FE) and generalized method of moments (GMM) models, Sarpong and Nketiah-Amponsah (2022) researched on the effects of financial inclusion on inclusive growth in the Sub-Saharan region. In alignment with Hegde and Kavyashree (2024), the study discovered that only usage and access are significant factors driving inclusive growth in an economy.

[7] https://www.worldbank.org/en/topic/financialinclusion/overview

Compared to previous literature, Kodom *et al.* (2022) focused on the effect of mobile money transactions on inclusive growth. The analysis of the data generated from a survey of over 120 mobile money agents revealed that the services rendered by mobile banking operators created a substantial level of financial inclusion among the Ghanaian population in Kumasi. In alignment, the usage of digital means of payment was discovered as a driver of financial inclusion, after using principal component analysis on the data collated from Findex (Nuzzo and Piermattei, 2020). The study followed a duo-dimension basis by comparing digitalpayment with the traditional means. In alignment with Kodom *et al.* (2022), Nuzzo and Piermattei (2020) revealed that electronic payment methods are key in driving inclusion. Conclusively, financial inclusion is best evaluated based on the underlying structure, concept, country, specific context and application.

2.2 Cross- Country Based Research on Financial Inclusion

Financial inclusion is pivotal to the stability of any economy (Antwi, Kong and Gyimah, 2024). In emerging economies, integrating the unbanked population through access to formal financial systems remains a focal point (Lyons, Grable and Zeng, 2019). Studies such as Ayele *et al*. (2024) posit that policies regarding financial inclusion and stability should rather be in tandem with the income level of the country. Chinoda (2020) utilized the two- staged principal component technique (PCA) and generalized method of moments (GMM) in examining the relationship between digital inclusion and economic growth in Sub-Saharan Africa (SSA). PCA was used to estimate the financial inclusion index. The study finds a direct link between inclusion and economic growth driven by education, and trade variables.

Nanda and Kaur (2016) and Danisman and Tarazi (2020) carried out a comparative analysis of financial inclusion across countries. The former adopted a modified macro-analysis measure and used bank branches and ATMs as indicators across 68 countries over 3 specific years. The study concludes two things; that countries with high financial inclusion are associated with increased focus on human development. Surprisingly, the study also reveals a negative relationship between high clustering of banks and inclusion. This underscores the relevance of spreading banks to enable access to the financial system especially in low-income countries. Sulehri and Ali (2024) agree with this finding and thereby, suggested the need for human development in form of investment of education to underserved populations as a solution to possible inclusion barriers. Danisman and Tarazi (2020) followed a different approach and employed a two-step generalized method of moments (GMM) to analyse financial inclusion and stability. The findings reveal that account ownership and digitalpayments highly impact the underserved and disadvantaged population especially those in rural areas.

Nuzzo and Piermattei (2020) employed the principal component technique (PCA) to find the correct measure of financial inclusion in the Euro area. Using the data collated from the Financial Access Survey (FAS), Findex and European Central Bank payment statistics (ECB). Indicators such as bank branches, ATMs, adult populations with official bank accounts and debit cards were used. The findings revealed the superiority of digital payment methods in

enhancing inclusion compared to the method adopted by traditional banks such as physical branches. Compared to Nanda and Kaur (2016), the study alluded that the number of branches of a bank is not an adequate metric, rather, digital payment channels are more effective. Easy access to financial products enables economic prosperity especially in Africa,where many are financially excluded. Unlike most cross-country analysis, Ghosh and Chaudhury (2024) included insurance and digital finance indicators to analyse inclusion in over 100 countries. In a two-staged principal component technique, the research reveals that countries with high level of usage and access tend to have a higher financial inclusion index. This aligns with the research of Mose and Thomi (2021).

2.3 Trade Openness and Financial Inclusion

Trade openness and financial inclusion are regarded as major drivers of economic progression, which increases business activities and the flow of funds in countries (Chinoda, 2020; Schuetz and Venkatesh, 2020; Hajilee and Niroomand, 2019). Trade openness is the degree to which countries allow and facilitate cross-border trade. It is also considered a poverty reduction strategy in developing countries. Trade openness creates an avenue to harness the access and usage of innovation around payments, banking transactions and digitization (Masongsong *et al.*, 2024; Wang *et al.*, 2024).

Chinoda (2020) researched the influence of financial inclusion as a channel through which trade influences economic growth in Africa with a focus on 30 countries under the African Continental Free Trade Area (AfCFTA). The studies employed a co-integrated-granger causality test from 2004 to 2017. The outcome of the analysis reveals a combination of positive and negative influences of financial inclusion through trade openness on economic advancement in AfCFTA countries. The findings validate the outcome by Hajilee and Niroomand (2019) where a significant effect of financial inclusion on the trade openness was observed. The studies also revealed that access to a payment and credit system is crucial to a financially inclusive economy. The limitation of Hajilee and Niroomand (2019) is addressed by clearly positing that there is a direct and linear relationship between trade openness and inclusion compared to previous which gave a mixed outcome. Similarly, Qamruzzaman(2023) utilized a combination of statistical tests and granger causality and GMM methods to examine the link between financial systems, trade openness, and innovation in Arab countries. In alignment with the findings of Chinoda (2020), the studies reveal that foreign direct investments as a result of inter-country trade enhances financial inclusion. Compared to the previous studies of Chinoda (2020), Qamruzzaman (2023) concluded that the adoption and availability of financial innovation is paramount in enabling unbanked individuals to become banked.

3 Research Methodology

The Knowledge Discovery in Database (KDD) approach was adopted in this study. It provides comprehensive steps to describe methods used in research. Details on the selected data, research techniques and procedures are provided in this chapter.

Notably, rPCA is favoured over other methods due to its ability to handle the data outlier and missingness. It achieves this by decomposing data into low-rank and sparse to manage outliers. The traditional PCA, factor analysis or even generalized method of moments (GMM) which was initially considered for this study are all very sensitive to outliers,however, rPCA is sensitive to parameter tuning which is not a concern in this research. Factor analysis also assumes linearity of data which can lead to bias while GMM focuses on the estimation of parameters.

3.1 Data Selection

The financial inclusion indicators as provided by the Global Partnership for Financial Inclusion (GPFI)[8] in alignment with the World Bank[9] were determining factors for the typeof data used in this study. The GPFI generally accounts for financial inclusion efforts and the implementation of action plans on financial inclusion among 19 countries including the European Union (EU) and African Union (AU)[10]. The AU joined in September 2023 enabling a transparent representation of Africa on financial inclusion (Adibe, 2023). The Findex data (the supply side) by World Bank was used in this study, as well as the IMF FinancialAccess Survey (FAS) (the demand side). The Findex database which is used in cross- country financial inclusion analysis globally is only collated triennially (every 3 years) and covers 140 countries. The IMF FAS annual data brings a balance. IMF FAS is considered an optimal combination since the data is collected annually (Nuzzo and Piermattei, 2020), therefore, cushioning the data limitation barrier in Findex.

This study focused on member countries of the African Continental Free Trade Area (AfCFTA)[11] agreement which includes 54 African countries. All countries are also members of the African Union except Eritrea. However, data covering only 35 of the (AfCFTA) countries was used in this study due to the following reasons. Firstly, this is due to the limited availability of data on financial inclusion for the remaining countries. Secondly, for fair representation, many of the (AfCFTA) countries that did not adhere to the (AfCFTA) agreement as of August 2023[12] were excluded from this study. Only countries with available data that have signed the most updated agreement with AfCFTA were used in this study.

[8] https://www.gpfi.org/sites/gpfi/files/Indicators\%20note_formatted.pdf
[9] https://www.worldbank.org/en/topic/financialinclusion/brief/how-to-measure-financial-inclusion
[10] https://www.g20.in/en/about-g20/about-g20.html
[11] https://www.tralac.org/documents/resources/faqs/2377-african-continental-free-trade-area-faqs-june-2018-update/file.html
[12] https://www.tralac.org/resources/infographic/13795-status-of-afcfta-ratification.html

Notwithstanding, this study enables a comprehensive review of the extent to which member states of AfCFTA are financially included.

3.1.1 African Continental Free Trade Area (AfCFTA) – Member States

Table 1: Description of the respective member states

Status	Member Countries	Number
Countries that **initially signed** the AfCFTA agreement	Algeria, Djibouti, Egypt, Equatorial Guinea, Es- watini, Ethiopia, Gabon, The Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Kenya, Central African Republic, Chad, Comoros, Congo, Democratic Republic of the Congo Lesotho, Liberia, Libya, Madagas- car, Malawi, Mali, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sahrawi Arab Democratic Republic, S ˜ao Tom´e and Pr´ıncipe, Senegal, Seychelles, , South Africa, Sierra Leone, South Sudan, Sudan, Tanzania, Togo, Mauritania, Mauritius, Tunisia, Uganda, Zambia, Zimbabwe, Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Somalia	54
Updated: Countries that have signed and complied with agreement as of August 2023	Ghana, Tunisia, Cameroon, Nigeria, Malawi, Zambia, Algeria, Burundi, Seychelles, Tanzania, Kenya, Rwanda, Niger, Chad, Eswatini, Guinea, C ˆo te d'Ivoire, Mali, Namibia, South Africa, Congo Rep., Djibouti, Mauritania, Uganda, Senegal, Togo, Egypt, Ethiopia, Gambia, Sahrawi Arab Democratic Rep., Sierra Leone, Zimbabwe, Burkina Faso, S ˜ao Tom´e & Pr´ıncipe, Equatorial Guinea, Gabon, Mauritius, Central African Rep., Angola, Lesotho, Cabo Verde, Democratic Republic of the Congo, Morocco, Guinea-Bissau, Botswana, Comoros, Mozambique	47
Countries that were **excluded** from this study	Lesotho, Comoros, Ethiopia, Eswatini, Egypt, Mozambique, Democratic Republic of Congo, S ˜ao Tom´e and Pr´ıncipe, Equatorial Guinea, Cˆote d'Ivoire, Sahrawi Arab Democratic Republic, Gambia	12

Table 1 below highlights the details of member states. Row 2 includes a list of countries that signed up to the updated agreement as of August 2023[13]. Only countries with available data that have signed the most updated agreement with AfCFTA were used in this study. Row 3 countries were excluded from the study because the available data was insufficient. The exclusion will ensure homogeneity and equitable analysis of the study.

3.1.2 Sub-indices and indicators of Financial Inclusion

The sub-indices are key enablers of individuals and businesses in participating fully in trade without banking barriers which can lead to a better integration within AfCFTA. Indicators are variables used to represent the different dimensions. It is, therefore, imperative to use a

[13] https://www.tralac.org/resources/infographic/13795-status-of-afcfta-ratification.html

comprehensive dataset to fully cover the spheres of financial inclusion. Only available individual and business indicators of financial inclusion as provided by GPFI, and the World Bank were utilized.

Indices(dimensions)	Indicators(variables)	Data source
Access	Number of registered mobile money agents' outlets, debit cards per 1,000 adults, ATMs per 1,000 km^2 , number of ATMs per 100,000 adults and, number of commercial bank branches per 1,000 km^2	FAS
Usage	Account, Savings and SME Loan accounts	Findex and IMF FAS
Quality	Lack of trust in the financial system, unavailability of necessary documents, lack of physical bank branches, getting credit, lesser network of ATMs and inability to afford the financial products and services	Findex

Table 2: Indices and variables of financial inclusion

Access refers to the depth at which the financial system or services have penetrated to its users who are basically the population of bankable adults (Sharma and Changkakati, 2022). Access to credit, debit cards, mobile banking through mobile money agents, ATMs, and a wide spread of banks can help businesses scale and handle cross-country transactions without barriers. Access to financial services is indicated by the number of depositors with banks per 1,000 adults, access to debit card, cashless transactions and the number of transactions per 1,000 adults using mobile money. It also accounts for the percentage of adults without formal accounts just because a member of the family has one. The quality of financial services is key to building trust by ensuring businesses can depend on the services for trading activities[14]. Quality plays a significant role of enabling and increasing the access as well as usage to financial services (Ngo, 2019). The GPFI[15] provided three segmented indicators for quality, however, due to the data unavailability and relevance, only barriers to usage were considered in this study. Barriers are limitations that hinder individuals and businesses from accessing and using financial products and services (Cámara and Tuesta, 2014).

Notably, the GPFI provided updated indicators on usage. They include adults with mobile money or bank accounts, transactions and payments done through mobile money agents or banks, SME loan accounts. Also, adults who used their mobile phones to make payments, adults who used the internet to settle bills or make purchases or for remittances, adults who directly made payments using a debit card or through a mobile money provider and accounts that received wages or transfers from the government (Demirgüç-Kunt *et al.*, 2020). Loans

[14] https://www.policycenter.ma/sites/default/files/202405/BN%20182%20AfCFTA%20investment%20RVCs%20and%20Inclusion.pdf

[15] https://www.gpfi.org/sites/gpfi/files/Indicators\%20note_formatted

were indicated by the number of loans outstanding from borrowers and the number of adult populations who borrowed from using a formal bank. The percentage of adults with savings in a bank and those who saved for old age as well or saved to start, operate or expand a business was considered.

3.2 Pre-processing of Data

Pre-processing is a pivotal step in the data mining process. This phase involved cleaning and structuring the dataset to derive meaningful insights. In this research, pre-processing was conducted using Python on Google Colab. The dataset was sourced and imported from the World Bank Findex database and IMF Financial Access Survey (FAS). Given the extensive global coverage of these datasets, it was necessary to filter the data to focus specifically on the member states of the African Continental Free Trade Area (AfCTA). The preprocessing steps included aligning the country names to ensure consistency between the FAS and Findex datasets and extracting the required columns and rows before combining the two datasets to be unified. This approach enhanced the interpretability of the result from the analysis. After that, steps were taken to identify and handle outliers, visualize the data and normalize it. This is to ensure the uniformity and quality of the dataset.

3.3 Data Transformation

The study utilized two datasets; they were merged into a single comprehensive dataset. Data was wrangled to enable the fitness of data for mining. This included identifying and addressing the variations in country names and years.

3.4 Data Mining

Data mining is pivotal to uncovering patterns, correlations and anomalies, especially in large datasets[16]. In this study, principal component analysis was used to identify the important features and correlation of the variables. Then robust Principal Component Analysis (rPCA) was used to derive a financial inclusion index.

3.4.1 Two-Staged (robust) Principal Component Analysis (rPCA)

In this study, the PCA technique was only used to identify the important features andcorrelation of the variables. The drawback of PCA for analysis is that it does not work well with multidimensional data containing a high level of noise or outliers[17]. Also, one of the assumptions of PCA highlights the need for exclusion of outliers in the dataset (Vaswani, Chi and Bouwmans, 2018). Robust PCA is a solution to the limitation posed by PCA which works well with corrupted data and a huge number of outliers in a dataset. For that reason, this study employed rPCA since it is not affected by missingness and outliers in a dataset. Unlike

[16] https://www.ibm.com/topics/data-mining
[17] https://www.kaggle.com/code/javigallego/massive-pca-outlier-detection-tutorial

the conventional PCA, rPCA breaks down a data matrix into two parts such as a low-rank matrix aimed at capturing the main structure of the data and a sparse matrix which identifies the anomalies[18].

4 Design Specification

The estimation of a financial inclusion index using a two-staged principal component analysis approach (PCA) has been mostly employed by existing literature such as Amidžić, Massara and Mialou (2014) and Cámara and Tuesta (2014). This research incorporated similar methodology in getting a robust overall index, as well as identifying specific areas of improvement. This method avoids bias in assignment of weight by calculating the values for each dimension. This research used the two-stage robust PCA. In the first stage, the dimensions of access, usage and quality were calculated independently, then the outcome was used to determine the overall financial inclusion index.

The model used to estimate the financial inclusion index in this research is defined below:

$$FI_{c,t} = w_1 X^u_{c,t} + w_2 X^a_{c,t} + w_3 X^q_{c,t} + e_{c,t} \quad \textbf{(Equation 1)}$$

In the above (equation 1), $\mathbf{X^u_{c,t}}$, $\mathbf{X^a_{c,t}}$, $\mathbf{X^q_{c,t}}$ is used to represent the weighting of subindices used in this research namely; usage, access and quality in different countries **(c)** in a particular year **(t),** respectively. Due to the minimal expected variance in the indicators used across the dimensions, e is used to represent and explain the variance in financial inclusion (FI).

4.1 Robust Principal Component Analysis (rPCA) – First stage

As utilized by Cámara and Tuesta (2014), this initial stage focused on estimating each of the dimensions. The variables in the equations serve as explanatory variables in estimating the financial inclusion index. A linear equation containing all the indicators was used to compute the sub-indices of the three dimensions. The parameters for the three dimensions are as follows

$$X^u_{c,t} = \beta_1 \mathrm{Sav}_{c,t} + \beta_2 \mathrm{Acct}_{c,t} + \beta_3 \mathrm{Brwgs}_{c,t} + u_{c,t} \quad \textbf{(Equation 2)}$$

$$X^a_{c,t} = \mu_1 \mathrm{MMA}_{c,t} + \mu_2 \mathrm{Debitcard}_{c,t} + \mu_3 \mathrm{CBranches}_{c,t} + \mu_4 \mathrm{Km.ATM}_{c,t} + \mu_5 \mathrm{Pop.ATM}_{c,t} + v_{c,t}$$

(Equation 3)

$$X^q_{c,t} = \gamma_1 \mathrm{loc}_{c,t} + \gamma_2 \mathrm{doc}_{c,t} + \gamma_3 \mathrm{cost}_{c,t} + \gamma_4 \mathrm{trust}_{c,t} + \gamma_5 \mathrm{fund}_{c,t} + \epsilon_{c,t} \quad \textbf{(Equation 4)}$$

[18] https://en.wikipedia.org/wiki/Robust_principal_component_analysis

Where $\mathbf{X^q_{c,t}}$, $\mathbf{X^a_{c,t}}$, $\mathbf{X^u_{c,t}}$ is used to represent quality (q), access (a) and usage (u), subscript time (t) and country (c). Where Sav stands for savings, Acct is for accounts, Brwgs for borrowings, MMA for mobile money agents' outlet. Also, Debit card for debit card ownership, CBranches for commercial bank branches per 100,000 adults, Km.ATM for ATM per 1,000km2, Pop.ATM for number of ATM per 100,000 adults. Loc is for distance barrier, doc for documentation, cost for affordability, trust for lack of trust in the system and funds due to lack of funds. The equations give direction to the classification in the various dimensions, however, to get an outcome for each dimension per country and year, the weighted average will be estimated to get the principal components and eigenvalues (explained variance).

$$X^u_{c,t} = \frac{\sum_{j,k=1}^{t} \lambda^u_j k_{c,t}}{\sum_{j=1}^{t} \lambda^u_j} \qquad \textbf{(Equation 4)}$$

$$X^a_{c,t} = \frac{\sum_{j,k=1}^{t} \lambda^a_j k_{c,t}}{\sum_{j=1}^{t} \lambda^a_j} \qquad \textbf{(Equation 5)}$$

$$X^q_{c,t} = \frac{\sum_{j,k=1}^{t} \lambda^q_j k_{c,t}}{\sum_{j=1}^{t} \lambda^q_j} \qquad \textbf{(Equation 6)}$$

The equations above are the estimate of the weighted average of each dimension. The **jth** number of eigenvalues in each dimension is represented as **λj**, while j is the indicator number for each dimension over the period. The **K** is the weighted principal component estimated per country (c) and period (t).

4.2 Robust Principal Component Analysis – Second Stage

This stage focuses on computing the overall index of financial inclusion (FI) using the same method as stage one to get the eigenvectors of the subindices. The formula for financial inclusion will be defined as follows

$$FI_{c,t} = \frac{\sum_{j,k=1}^{t} \lambda_t k_{c,t}}{\sum_{j=1}^{t} \lambda_j} \qquad \textbf{(Equation 7)}$$

As seen in equation 7, $\mathbf{t^k}$ is the principal component of the three dimensions is ($\mathbf{X^q_{c,t}}$, $\mathbf{X^a_{c,t}}$ and $\mathbf{X^u_{c,t,}}$) rather than the indicators as used in the first stage. The eigenvectors for the three dimensions are denoted as **δ**, following the same step as the first stage to estimate the eigenvector (**λt**) and principal component. The obvious difference is that the first stage decomposed the variables to get Eigenvalues, while the second stage focuses on the subindices with Eigenvector, and this is the strength of this method. However, both stages must derive the principal components. Eigenvector in the second stage is denoted as:

$$T_{1c,t} = \delta_{11}X^u_{c,t} + \delta_{12}X^a_{c,t} + \delta_{13}X^q_{c,t} \quad \textbf{(Equation 8)}$$

$$T_{2c,t} = \delta_{21}X^u_{c,t} + \delta_{22}X^a_{c,t} + \delta_{23}X^q_{c,t} \quad \textbf{(Equation 9)}$$

$$T_{3c,t} = \delta_{31}X^u_{c,t} + \delta_{32}X^a_{c,t} + \delta_{33}X^q_{c,t} \quad \textbf{(Equation 10)}$$

The financial inclusion index is finally computed as:

$$FI_{c,t} = \frac{\sum_{j=1}^{2} \lambda_j(\delta_{j1}X^u_{j,t} + \delta_{j2}X^a_{j,t} + \delta_{j3}X^q_{j,t})}{\sum_{j=1}^{3} \lambda_j} \quad \textbf{(Equation 11)}$$

5 Implementation

5.1 Data Selection

To ensure consistency, only 2011, 2014, 2017 and 2021 were used in this research due to the variation in dates of data provided by the World Bank Findex and IMF FAS. The World Bank releases data triennially, while the latter is collated annually. The World Bank data (csv.) was imported using Python (py.) environment on Google Colab and contained a total of 658 observations and 1,232 variables. Meanwhile, upon importation, the IMF FAS had 3,648 rows and 194 columns. Notably, only variables and years which are relevant to this study were employed.

5.2 Preprocessing and Transformation of Data

The study pre-processed the imported data from two data sources to ensure uniformity. Each dataset was individually pre-processed. This enabled consistency in the merging of the data.

5.2.1 World Bank FINDEX (First dataset)

Upon importation into the Google Colab environment, irrelevant indicators were excluded. Only countries that are member states of AfCFTA were selected. Given that years in this dataset were already in alignment with the triennial pattern employed in this research, that was left untouched. However, the figures in this dataset were given in %, therefore, they were converted to numbers. To ensure consistency with the IMF FAS dataset, the following countries were named to ensure consistency; Arab Rep – Egypt was renamed to Egypt, due to change of name of country, Swaziland was changed to Eswatini, 'Congo, Dem.Rep' to Congo, Democratic Republic of, Congo, Rep to Congo, Republic of. Notably, the two last countries are different even though they look similar. Also, Cote d'Ivoire to Cote d' Ivoire, Mozambique to Mozambique, Republic of'. After this, the missingness of the data was checked, which revealed that 35.6% was missing and 64.4% was present as visualised in the configuration manual.

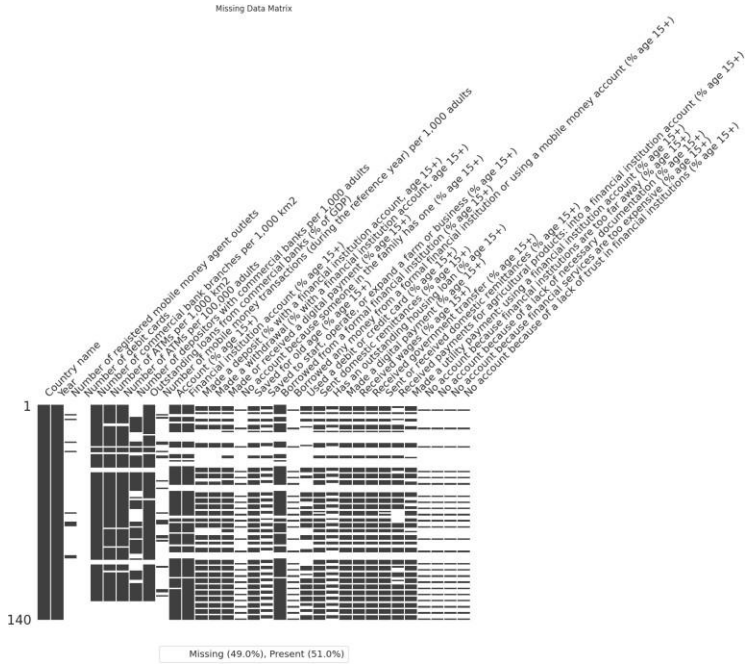
5.2.2 IMF FAS (Second dataset)

The data was cleaned to keep only variables beneficial to this study and in alignment with the Findex database. Upon data importation, the number of observations in this dataset were 3648 while the rows were 194 variables. Next, only countries within the AfCFTA were selected. The FAS dataset is produced annually compared to Findex that is triennially, therefore, the following years were selected (2011, 2014, 2017 and 2021) and others deleted. This reduced the columns to 10 and rows, to 140. The country name and year title were renamed to tally with Findex. Therefore, Country. Name was changed to Country name while Calendar. Calendar element name was renamed to Year. The missingness of the cleaned FAS dataset stood at 17.3% and 82.7% was present.

5.2.3 Combined dataset (Findex and IMF)

The datasets were merged based on the year, and country name, to form a single dataset from each of the individually pre-processed data. However, a pattern of repetition was observed in the number of variables. Therefore, the following countries and years were excluded from the merged dataset; Botswana (2022), Chad (2022), Niger (2022). Cosmoros, Ewsatini, Ethopia, Lesotho, Mozambique and 'Republic of Mozambique' were excluded due to limited data. This brought the data set to 140 rows (representing 35 countries) over 2011, 2014, 2017 and 2021. Lastly, the missingness of the merged data set revealed a total of 49% of the data was missing with 51% present as shown below.

Figure 1: Merged data – missingness



5.2.4 Imputation of missing data (Combined data)

Missingness of data is not a novel challenge especially when dealing with multidimensional data such as the merged dataset in this research. The proportion of missingness in the merged data is as high as 49%, requiring a justifiable method to input missing data. Probabilistic principal component analysis (PPCA) was chosen over other methods. PPCA handles high levels of missingness by leveraging the correlation of the observed variables to estimate the missing values. Python used IterativeSVD to perform PPCA based on the library available in that environment.

5.3 Data Validation and Mining

A data validation test is a key step in data mining (Napitupulu, Kadar and Jati, 2017). Kaiser–Meyer–Olkin (KMO) values typically range from 0 to 1, signifying lowest to highest, therefore, a KMO output of 0.8 is high (Shrestha *et al.*, 2021). The Bartlett test produced a chi-square of 5180.138 typical of a large dataset, however, the p-value of 0.0 is considered the most important metric of this test. The p-value of this research indicates that the correlation matrix of the indicators is not the same as the matrix of identity. This alludes that data is fit for rPCA, which is the selected technique.

6 Evaluation of Result, Discussion and Limitations

6.1 Results

The dimensions were classified based on the three dimensions of usage, quality and access over 2011, 2014, 2017 and 2021. For the financial inclusion index, less than zero is very low, low is between 0 to 0.3, medium is for 0.3 to 0.6, very high is from 0.6 to 1 and, greater than 1 is very high. Only relevant results are shown in the table below.

Table 3: Countries with high level of financial inclusion index (FI)

Country Name	Year	Access	Access Rank	Usage	Usage Rank	Quality	Quality Rank	Financial Inclusion Index (FI)	FI Rank
Cabo Verde	2014	0.818532	**High**	-0.06196	**Very Low**	-1.92126	**Very Low**	1.094348	**Very High**
Cabo Verde	2017	0.853476	**High**	-0.04917	**Very Low**	-1.87078	**Very Low**	1.063871	**Very High**
Cabo Verde	2021	0.944262	**High**	-0.16496	**Very Low**	-2.14277	**Very Low**	1.268211	**Very High**
Ghana	2021	-0.60861	**Very Low**	-1.69837	**Very Low**	-1.2207	**Very Low**	1.414274	**Very High**
Kenya	2017	-0.32221	**Very Low**	-1.75892	**Very Low**	-0.49172	**Very Low**	1.077147	**Very High**
Kenya	2021	-0.10503	**Very Low**	-2.04564	**Very Low**	-0.41451	**Very Low**	1.186965	**Very High**
Mauritius	2011	2.653499	**Very High**	-1.1332	**Very Low**	-3.40909	**Very Low**	2.506126	**Very High**
Mauritius	2014	3.181982	**Very High**	-1.17093	**Very Low**	-2.00174	**Very Low**	1.815987	**Very High**
Mauritius	2017	3.163121	**Very High**	-1.88574	**Very Low**	-2.06004	**Very Low**	2.18627	**Very High**
Mauritius	2021	2.574614	**Very High**	-1.66711	**Very Low**	-3.05967	**Very Low**	2.571447	**Very High**
Namibia	2014	-0.14147	**Very Low**	-0.72543	**Very Low**	-1.59111	**Very Low**	1.175456	**Very High**
Namibia	2017	0.122146	**Low**	-1.58394	**Very Low**	-2.42338	**Very Low**	2.040187	**Very High**
Namibia	2021	0.428546	**Medium**	-2.01826	**Very Low**	-1.31648	**Very Low**	1.683322	**Very High**
Nigeria	2011	-1.57734	**Very Low**	-1.15115	**Very Low**	-1.28204	**Very Low**	1.124029	**Very High**
Seychelles	2011	-1.29533	**Very Low**	-4.93763	**Very Low**	-4.39475	**Very Low**	4.587706	**Very High**
Seychelles	2014	2.252466	**Very High**	0.301824	**Medium**	-3.90356	**Very Low**	2.057115	**Very High**
Seychelles	2017	2.969715	**Very High**	0.556885	**Medium**	-4.47422	**Very Low**	2.282006	**Very High**
Seychelles	2021	3.762366	**Very High**	0.971394	**High**	-4.53534	**Very Low**	2.167115	**Very High**
South Africa	2011	0.499204	**Medium**	0.056426	**Low**	-2.3594	**Very Low**	1.248505	**Very High**
South Africa	2014	0.300168	**Medium**	-0.78082	**Very Low**	-2.94558	**Very Low**	1.943917	**Very High**
South Africa	2017	0.684143	**High**	-0.16269	**Very Low**	-2.27365	**Very Low**	1.319546	**Very High**
South Africa	2021	0.29054	**Low**	-1.41435	**Very Low**	-2.82654	**Very Low**	2.182573	**Very High**

Table 4: Countries with low level of financial inclusion index (FI)

COUNTRY NAME	Year	Access	Access Rank	Usage	Usage Rank	Quality	Quality Rank	Financial Inclusion Index (FI)	FI Rank
ANGOLA	2021	0.122863	**Low**	0.362116	**Medium**	0.121655	**Low**	-0.22892	**Very Low**
BURKINA FASO	2011	-0.20256	**Very Low**	0.811503	**High**	0.721268	**High**	-0.77993	**Very Low**
BURKINA FASO	2014	-0.44256	**Very Low**	0.503168	**Medium**	0.226343	**Low**	-0.38736	**Very Low**
BURKINA FASO	2017	-0.23598	**Very Low**	-0.49202	**Very Low**	0.453018	**Medium**	-0.01926	**Very Low**
BURUNDI	2011	-0.25598	**Very Low**	0.970546	**High**	0.87274	**High**	-0.93898	**Very Low**
MAURITANIA	2022	-0.18951	**Very Low**	0.495559	**Medium**	0.476119	**Medium**	-0.49927	**Very Low**
TANZANIA	2011	-0.24734	**Very Low**	0.120024	**Low**	1.056699	**Very High**	-0.62994	**Very Low**
TANZANIA	2014	0.020689	**Low**	0.149635	**Low**	1.502455	**Very High**	-0.86194	**Very Low**
TANZANIA	2017	0.284387	**Low**	0.58979	**Medium**	0.954661	**High**	-0.76623	**Very Low**
TANZANIA	2021	0.687303	**High**	0.07247	**Low**	0.943111	**High**	-0.48786	**Very Low**

6.2 Discussion

Financial inclusion is one of AfCFTA's core strategies for facilitating trade[19], currently promoted through the "Better Than Cash Alliance" initiative. It focuses on mobile payments and electronic banking. A close examination of the countries that are highly included in Table 3, highlights access as the major strength of these countries compared to the others. This result is in tandem with the conclusion of Hajilee and Niroomand (2019), where access to payment is posited to drive inclusion. In contrast, Mose and Thomi (2021) concluded that countries with a high level of usage and access together tend to have a higher financial inclusion index. However, the analysis in the tables above reveals that a high level of inclusion can be achieved through access itself.

Access to finance, loans and financial services has benefitted the Seychelles, South Africa, Kenya, Nigeria and Mauritius over the years. In alignment with the conclusion of Abdulmumin *et al.* (2019), Seychelles has the highest level of inclusion in AfCFTA. Although, it began with a low level of access in 2011, it recorded an impressive, consistent and very high growth in 2014, 2017 and 2021 at an average of 30%. This is driven by the high level of banked adults[20]. Mauritius consistently scored high in terms of access from 2011 to 2021 and this result tallies with that of the World Bank[21]. This is driven by the increasing access to digital financial services. Cabo Verde is not an exception, the high access score is driven by a targeted focus

[19] https://au-afcfta.org/2023/09/digital-financial-inclusion-in-the-afcfta/

[20] https://www.cbs.sc/Financial/OverviewFinancialInclusion.html#:~:text=As%20per%20the%20survey%2C%20Seychelles,reported%20in%20Sub%2DSaharan%20Africa.

[21] https://digitalfinance.worldbank.org/country/mauritius

on digital infrastructure[22]. However, this is not as high as the Seychelles and Mauritius. Ghana, Kenya, Namibia and Nigeria recorded a mixed score for access, ranging from low to medium and high. This may be due to the lack of stable accessto a wide network of bank branches and mobile money agents as revealed by the feature analysis used in this study. Interestingly, Kenya scored low for access, despite being one of the forerunners of mobile money in Africa. This is due to the high level of unbanked adults, especially the poor and underserved communities.[22] The lack of access to financial services also accounts for the low level of inclusion recorded in countries like Angola, Mauritania andBurundi, although, and Tanzania. Although, Tanzania managed to record a high access score in 2021.

The usage of financial inclusion follows a peculiar pattern in the tables above. The usage of financial inclusion is generally very low in AfCFTA. However, countries like Angola, Mauritania and Burundi and Tanzania that are financially excluded have high usage levels. Depicting that, despite the access challenges encountered in these regions, they are making good use of the traditional and digital banking services available. The significant conclusion here is that, if efforts are made to enable the availability of financial services, theywill most likely use more of the banking products. This can potentially enable inclusion of these countries. This is the same trend with the quality dimension which is very low among member states of AfCFTA. Quality of financial services is a major barrier to all the member states, meaning that if trust is built in the ability of banks to meet the financial needs of traders, businesses and individuals, a very high level of financial inclusion can be achieved inAfCFTA.

6.3 Limitations

This study used 35 out of the 47 member countries of the AfCFTA. This is due to the large number of unavailable data and missingness of business and trade metrics for the selected years. Also, only triennial years were used in this study rather than annually. Annual may be a better reflection of the countries. The high missingness of data (49%) and outliers required the use of probabilistic principal component analysis compared to other techniques. This can lead to influenced results of the analysis.

7 Conclusion and Future Work

This research focused on examining the level of financial inclusion in AfCFTA memberstates using robust principal component analysis (rPCA). The Seychelles, South Africa, Nigeria, Kenya, Capo Verde, and Mauritius were conclusively among the top member states that are financially included in AfCFTA. The study concludes that the level of financial inclusion in AfCFTA is generally very low. This is driven by the lack of access to financial services that

[22] https://www.un.org/en/nairobi-unis/unsgsa-visit-focus-potential-digital-financial-services-increase-access-improve#:~:text=However%2C%20challenges%20remain%2C%20with%20nearly,well%2Dbeing%20of%20Kenyan%20citizens

can facilitate trade within the free trade area and high barriers to financial services. Missingness was handled by employing probabilistic PCA as an imputation technique. AfCFTA as a zone needs policies that can ensure businesses can trust and rely on financial services. The significant and unstable trend in the dimensions highlights areas needing urgent attention. Financial institutions can also collaborate with FinTech innovators to invest in digital products that will address the high costs of business transactions, quality and access to financial services. Unfortunately, not all countries were represented due to data unavailability and missingness. Future studies can work on assessing the impact of trade on financial inclusion and a machine learning algorithm is recommended that can effectively predict the level of financial inclusion

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