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Abstract: Over-indebtedness has emerged as a major factor that entrapped many rural households in poverty and a major cause of depression and rural suicide. Extant literature identified exogenous and endogenous drivers of over indebtedness but social and relationship factors that drive over indebtedness especially in developing country contexts have received limited attention. How these debts are accumulated as well as events that drive rural households into indebtedness need to be understood in order to address the negative implications of over-indebtedness. The objective of this study is to examine the incidence and drivers of over indebtedness among rural households in Nigeria as well as how participation in Ponzi schemes contributed to such rise in household consumer debt. The area of study is rural Southern Nigeria in which over 80% were poor. Households that participated in Ponzi schemes were identified using snowballing technique out of which 320 household heads were randomly selected as sample. Questionnaire was the instrument of data collection and data generated were analyzed using financial formulas and correlation coefficients. Findings revealed that incidence of over indebtedness was significantly high in Nigerian rural households owing to participation in Ponzi schemes, paying medical bills, house related cost, education of children, sending relatives abroad and cost of litigations. Ponzi scheme participants which cuts across sex, age, education and professional barriers were attracted by lure of affinity groups and speculation. They lost huge amount of money much of which was borrowed from family, friends and self-help groups; fueling the level of over indebtedness in rural areas. It is recommended that strict regulation of online and offline financial services should be enforced and financial literacy campaign should be pursued vigorously to reduce irrational and imprudent behavior. Initiatives in form of health insurance, effective mortgage market and educational support should be implemented in order to reduce the incidence of over indebtedness in rural areas.

Abstract: In South Africa, there exists a quest for financial literacy to promote inclusive growth in the country. Financial illiteracy is one of the aftermaths of imprudence and financial mismanagement that are common among the South African youth. The empirical strategy adopts a logistic multivariate regression model. The empirical investigation of financial literacy and financial management outcomes in this study finds that there is a positive and significant relationship between the financial management outcome and financial literacy, gender, educational attainment and living standards. Financial management has a negative and relationship with household size. The findings on the overall financial literacy of the South African youth showed that, generally, individuals in all provinces have inadequate or low financial resources with an overall mean correct percentage score of 80.69. The individuals, however, exhibited some appreciable financial knowledge of savings and borrowing. It is important for policy makers to develop an effective education programme based on the needs and financial literacy level of the youth.

Abstract: A business may use Asian options for improved portfolio protection and hedge market fluctuation risk. Asian options are lucrative derivative instruments due to the underlying average prices. The challenge with Asian options is that the dynamics of the averaged prices does not permit the direct use of the traditional Black, Scholes and Merton model for pricing. In this research, we derive an Asian option pricing model that is based on a differential equation, acting on only one state-space variable originally developed in the physical sciences. We found that the solution to this particular differential

EDITORIAL

I am very pleased to offer this special issue on the very important contemporary topics dealing with the **Recent Trends in Financial Innovation and Development in Emerging Markets**. Professor Pat Obi from Purdue University Northwest, USA is to be congratulated for developing such an excellent collection for our readers. All of the manuscripts are very insightful and thought provoking. These articles will add immensely to the growing body of knowledge.

The 1st paper by Adefemi A. Obalade & Paul-Francois Muzindutsi explores rolling window analysis of several alternative variants of nonlinear models of the GARCH family, notably the asymmetric TGARCH and EGARCH models, to investigate the day-of-the-week (DOW) calendar effect in the selected African stock markets. The authors employed daily returns of All Share Index of the Nigerian Stock Exchange, the Johannesburg Stock Exchange, the Stock Exchange of Mauritians, the Casablancan Stock Exchange and the Tunisian Stock Exchange from 1998 to 2018. Rolling estimation was applied in order to explicate the time-varying element of calendar anomaly, the aim being to ascertain whether the behavior of DOW is in compliance with the adaptive market hypothesis (AMH).

This study is vital in the light of the AMH, which challenges the persistence of market efficiency and by implication, market anomaly and proposes coexistence of efficiency and anomalies in a cyclical version. By the beginning of the 1990s, the debate on the efficiency of stock markets had split researchers into two camps: believers of the EMH on the one hand and proponents of behavioural finance (anomalies) on the other. The empirical studies on the subjects have been conflicting too − some reporting the presence of calendar anomalies and others the absence. The lack of consensus posed a serious problem for asset allocation and portfolio management and led to the advent of AMH. The implication of AMH to the stakeholders, especially the investors, is captured in the concluding part of this study.

The empirical findings from the rolling window GARCH analyses showed that the DOW calendar anomalies seem to disappear and reappear over time in the sampled African stock markets. The effect appears to be stronger in JALSH, SEMDEX and TUSISE but weak in NGSEINDX and MOSENEW. In essence, authors showed that the behaviour of selected African stock markets is in compliance with the cyclical efficiency invented by the proponents of the AMH. Thus, it may be more appropriate to describe African markets as adaptive markets rather than inefficient markets. The findings of this study imply that calendar anomaly may not be an all or nothing phenomenon; in the spirit of Lo (2004), the DOW effect may not be a universal constant but may be time varying and path dependent.

By implication, market participants may not view African stock markets as being anomalous in absolute form. It may be safe for investors to plan a flexible investment strategy to accommodate instability in calendar anomalies. However, investors need to ensure that gains of the anomalies, found in certain periods, cover trading and associated costs before efforts are made to exploit it. In addition, since investment strategy will wax and wane as a result of the instability, the investors are faced with the task of determining the market condition or environment suited to the success of their trading techniques.

Discussions on adequate pensions for retired workers has been a transnational challenge. The pension systems in many countries have been reformed to meet the current challenge of providing adequate pension for pensioners to alleviate wide spread poverty among retirees. Over the last decades, there has been profound shift from low risk defined benefit pension plans which provides smaller pension to high risk defined contribution pension plans which provided higher pensions based on the dynamics of the market. The underlining principle for the shift toward defined contribution plan is the option of

employees making decisions on how their contribution could be invested with any quantitative restrictions as witnessed in most defined benefit plans.

The 2nd paper by Maxwell Baidoo Jnr, Charles Andoh & Godfred Alufa Bokpin investigates asset allocation of defined contribution (DC) plan in Ghana using the Tier 2 Master Trust Occupational Pension Scheme (MTOPS) as a case study. Even though, the Ghanaian pension system has seen gradual reforms over the years, there are quantitative restrictions on investments for fund managers. The paper focuses on comparing optimal asset allocation solutions under quantitative restrictions and prudent person's principle and further assesses the risk exposure of portfolio returns using Conditional Value-at-risk (CVaR).

Secondary data was obtained from the National Pension Regulatory Authority (NPRA) for MTOPS contributors. Data obtained were in the form of investment decisions of fund managers under various financial assets. The financial market invested by MTOPS predominantly consists of six financial assets: government securities and bonds, corporate bonds, the money market, listed equities, other collective investments and open and close end funds. Eight (8) out of the twenty-nine (29) MTOPS that are managed by fund managers currently in Ghana were selected for the study. The total Asset under Management (AUM) of the 8 MTOPS constituted approximately 82.01% in terms of market share of all the 29 MTOPS. Data extracted included annual investment returns on government securities, corporate bonds, fixed deposits, money market, collective investments, listed equities and open/close – end funds, expenses, contributions of members, total asset under management and benefits paid out to members from 2012 to 2016 when most pension schemes in Ghana were active and NPRA regulations were proactively enforced. Returns from investments are modelled as a geometric Brownian motion and simulated for 10,000 scenarios over 50-year time horizon.

The paper revealed that most MTOPSs violated some quantitative restriction guidelines. MTOPS allocated higher Master Trust Funds (MTF) in low-risk assets: government securities and bonds, T-bills and cash deposits. High-risk assets are found to outperform low-risk assets in the long-term. Only MTOPS with large market share allocated considerably in high-risk assets: corporate bonds and listed equities. Investment returns of 20.93% with 12.43% average portfolio risk was obtained under prudent man's rule compared to investment returns of 20.56% with 6.79% portfolio risk under restricted optimization. Given the investment returns over time, CVaR for the total portfolio was 12.81% in worst-case scenario. At optimal levels, portfolios with investment restriction maximize returns with less risk exposure while returns on unrestricted portfolios are slightly higher but associated with high-risk exposure. The implication is that high-return investment is associated with higher risk exposure.

In the context of the need to expand financial liberalization, especially in the underserved rural communities in Nigeria, **the 3rd study by Jude Kenechi Onyima** examines the extent to which participation in Ponzi finance schemes impoverishes rural households. To that end, data were collected from affected households in the period, 2014 to 2017. The study finds that a multiplicity of social factors causes many rural families to fall victim to these schemes.

Extensive studies have been conducted about the macroeconomic dynamics, business-related factors, and household issues that contribute to over-indebtedness in rural communities. In contrast, social and relationship factors that equally lead to this phenomenon have yet to be examined in the literature. This study finds that in many rural communities, social factors including participation in non-traditional credit schemes, exotic marriage and burial rites, conflict settlement, and the desire to educate family members overseas are known contributors to over-indebtedness. Some researchers have identified participation in Ponzi schemes as a form of financial illiteracy. But recent events have revealed that participation in these schemes is not necessarily driven by a lack of knowledge of their financial

consequences but also the crave to attain a high social status in society. There is, additionally, the lure of affinity groups.

Although some behavioral patterns have been identified as drivers of over-indebtedness, sufficient analysis of how social and relationship factors drive this phenomenon has yet to be examined. On that basis, Onyima`s study is guided by three key objectives. The first is to determine the incidence of over-indebtedness among rural families that participated in Ponzi schemes. The second is to identify the drivers and the extent of participation in these dubious financial practices. Finally, the study investigated the linkages between participation in Ponzi schemes and the intensity of household over-indebtedness. Addressing this gap in the literature is imperative because a poor understanding of the drivers of over-indebtedness would undoubtedly prevent the development of helpful intervention strategies.

Participation in a Ponzi scheme may not be an overarching question in developed economies due to the existence of an effective regulatory and institutional framework. However, in developing economies, public corruption and novelties in digital and aggressive marketing techniques often increase the percentage of the population who fall victim to criminal financial schemes. These victims often fail to recover their funds. And this places a significant financial strain on their families, the financial system, and the economy at large.

The findings of this study reveal that there are social factors that drive household indebtedness which have not featured in the existing literature. In line with the hypothesis, these factors include participation in dubious investment schemes, exotic traditional ceremonies, wasteful litigations, and the financing of the education of family members overseas. The incidence of over-indebtedness among rural households that participated in Ponzi schemes was high, confirming the assertion that there is a significant correlation between participation in these schemes and over-indebtedness.

People who participated in Ponzi schemes were individuals who felt the need to make quick money and keep up with the Joneses, as it were. Further, they were victims of the aggressive marketing tactics of the schemers and also, individuals who succumbed to the influence of trusted friends and pressure from peers. Funds invested in these schemes were borrowed mostly from family members, friends, and informal sources. In almost all cases, these funds were never recovered from the Ponzi operators. Unlike in previous studies where participation in Ponzi schemes were found to be driven by sheer greed and ignorance, participation in Ponzi schemes in this case was driven more by the lure of affinity groups, desire to meet societal expectations, and the influence of trusted friends. As a result, participants cut across the educated, the vulnerable, and the elderly.

The study by Onyima contributes in identifying the often-ignored drivers of over-indebtedness in a developing economy. These factors have become increasingly significant and deserve closer attention by scholars and policy makers. Quality and affordable education as well as the availability of employment opportunities should curtail the necessity to send family members overseas to be educated. In many instances, this has become a huge debt burden, especially for the rural poor. A reformed judicial system that provides litigants with the option for out-of-court settlement should also reduce the need to pursue formal and expensive litigation. Most importantly, a strong financial regulation that monitors and supervises offline and online financial services should be instituted by regulators. This is in addition to a financial literacy campaign designed to educate the rural public on the dangers of falling victim to Ponzi scheme operators.

Improving the levels of financial literacy in South Africa is necessary to promote and achieve inclusive growth in the country. Promotion of consumer awareness, consumer education and consumer protection are essential to sound financial decision making and achieve individual financial wellbeing. **The 4th study by Mulatu F. Zerihun & Dinah M. Makgoo** examines the effects of financial literacy on

financial management outcomes among employed youth in South Africa. For the empirical analysis, the authors used survey data from the South African Social Attitude Survey (SASAS) carried out by the Human Science Research Council (HSRC) in 2012.

Authors employed the multivariate logistic model to examine the odds of outcomes. Financial literacy is the ability to process economic information and make informed decisions about financial planning, wealth accumulation, debt, and pensions. In most countries, even among developed economies, the level of financial literacy is generally low. Financial illiteracy has the potential to lead to financial crisis as was the case in the 2008 Global Financial Crisis. That crisis began in the U.S. and affected many countries around the world. Since then, there has been an increasing number of studies analysing the likely impacts of financial literacy globally. So far, most studies have focused on assessing the levels of financial literacy among different family backgrounds, economic groupings (poor, rich), geographical areas (urban, rural) and demographic factors (age, gender, and education) at a country level.

The motivation for this study stems from the low levels of saving and investment among South Africa's youth. To the best of authors` knowledge, there is paucity of studies that have investigated the effects of financial literacy on (personal) financial management in South Africa. The objective of Zerihun & Makgoo study is to examine the understanding and knowledge of financial management outcomes among the employed youth in South Africa. Without an understanding of basic financial concepts, people are not well equipped to make decisions related to financial management. People who are financially literate can make informed financial choices regarding saving, investing, borrowing, and more. Financial knowledge is especially important in times where increasingly complex financial products are easily available to the public. Governments in many countries are promoting access to financial services and this can be seen by the rapidly rising number of people with bank accounts and access to credit. Moreover, changes in the pension landscape transfer decision-making responsibility to participants who previously relied on their employers or governments for their financial security after retirement.

The interpretation for the logistic regression results in this study uses the odds ratio for both categorical and continuous predictors. An odds ratio greater than 1 reflects the increase in the odds of an outcome of 1 with a one unit increase in the predictor; odds ratios less than one reflect the decrease in odds of that outcome with a one-unit change. Zerihun & Makgoo study has unveiled financial literacy as the key predictor of behavioural nature of South African youth in their financial management decisions. In addition, this study finds that there is a positive and significant relationship between financial management outcomes and financial literacy, gender *(1=males, 0=females),* educational attainment and living standards. The findings in this study corroborates the findings of previous studies reviewed in this paper. The authors recommend promoting financial literacy through formal and informal education approaches with the objective of improving financial knowledge. In this regard government and policy makers should recommend for mandated financial education in academic institutions and workplaces. The authors further recommend that studies should be conducted on how South African youth can get assistance to save for their retirement and find ways to make smart investment decisions. In this regard programs targeting specific groups are likely to be more effective than a one-size-fits-all financial education program. Specifically designed and tailored financial literacy programs should be targeted to specific groups of the population since people have different preferences and economic circumstances.

Asian options are derivative instruments that derive their value form the averaged underlying prices. The averaging of the underlying prices can be considered as inhibiting market volatility and therefore expose Asian option investors to a more stable future payoff profile. The underlying price averaging is precisely the reason why Asian options are generally considered to provide a welcome degree of investor protection from the unexpected vagaries of the underlying markets. In **the 5th study by Angelo Joseph & Jan Kruger**, the goal is to focus in on an approach originally developed in physics to price Asian options.

Asian option prices are challenging to estimate, due to the arithmetic average evaluation inputs that cannot directly be cast into the traditional Black, Scholes and Merton option-pricing framework. The constraint exists because an arithmetic average set of lognormal prices is not normally distributed. Asian option prices must, therefore, be approximated, and this induces a risk management issue over the life-time of the derivative instrument. These implications are addressed in the risk section of the study.

A further limitation is that Asian options with either averaging strike prices or averaging spot prices are well researched and published. Unfortunately, Asian options where both the strike and spot prices are averaged are rarely treated in the literature. An Asian option pricing model based on a physics differential equation are theoretically derived in the pricing section of the study. The model are theoretically shown to price any Asian option, including options where both the strike prices and the spot prices are averaged.

The derived option pricing model was stressed by generating fixed strike Asian option prices and comparing it to simulated prices at market volatilities ranging from 10% to 70%. The Asian option pricing model was found to generate prices for options with both averaging strike prices and averaging spot prices within reasonable confidence.

Overall, Joseph & Kruger study demonstrates that an Asian option pricing model can be developed using an approach that originated in physics. Such a pricing model is important for the effective risk management of derivatives where Asian option prices have to be confidently estimated. Furthermore, the Asian option pricing model is shown to not only be fit for pricing fixed strike Asian options but can also be used to price Asian options where both the strike prices and the spot prices are averaged.

N. Delener, Ph.D.
Editor-in-Chief

NOTE FROM THE EDITORS

As an interdisciplinary indexed journal, *The Journal of Global Business and Technology (JGBAT)* serves academicians and practitioners in the fields of global business and technology management and their related areas. JGBAT is also an appropriate outlet for manuscripts designed to be of interest, concern, and applied value to its audience of professionals and scholars.

Readers will note that our attempt to bridge the gap between theory and practice has been successful. We cannot thank our reviewers enough for having been so professional and effective in reiterating to contributors the need to provide managerial applications of their research. As is now obvious, the majority of the articles include a section on managerial implications of research. We wish to reiterate once again our sincere thanks to JGBAT reviewers for having induced contributors to answer the "so what?" question that every *Journal of Global Business and Technology* article is required to address.

Thank you for your interest in the journal and we are looking forward to receiving your submissions. For submissions guidelines and requirements, please refer to the Manuscript Guidelines at the end of this publication.

N. Delener, Ph.D., Editor-in-Chief
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INTRODUCTION: A NOTE ON FINANCIAL REFORMS, INNOVATION AND DEVELOPMENT IN THE EMERGING MARKETS OF AFRICA

Pat Obi, Guest Editor

This special finance issue of the *Journal of Global Business and Technology (JGBAT)* consists of articles focusing on financial trends and innovations in the emerging markets of Africa. The first paper utilizes nonlinear GARCH models to investigate the day-of-the-week effect in five major African stock markets. An important contribution of this study is its attempt to reconcile the adaptive market hypothesis a la Lo (2005) with the efficient market hypothesis. In a case study, the second article examines the risk dynamics and portfolio performance of a defined contribution retirement plan in contrast to the low risk but low-income design of a defined benefit plan. The widespread use of Ponzi schemes in many developing economies as a get-rich-quick tool is the thrust of the third study. The author employs survey data to find that several social factors, including the lure of affinity groups, drive many families, especially those in underserved rural areas, to fall victim to these schemes.

In the fourth article, the authors specify a multivariate logit model to investigate the impact of financial literacy on consumer wellbeing. The negative impact of ill-informed financial decisions on the broader economy is also discussed against the backdrop of lessons learned from the 2008 Global Financial Crisis. Perhaps the reason that most emerging economies escaped the brunt of that crisis was because of their limited involvement in the use of poorly constructed financial derivatives, widely blamed for that crisis. With that as a segue, the final paper wonders if Asian options are a better risk management alternative than the more traditional American or European-style options. Using a novel estimation model borrowed from physics, the study demonstrates how Asian options, which derive their value from the averaged underlying prices, are better at limiting market volatility and by that, produce more stable future payoffs. The findings of these studies have broad implications in terms of how emerging economies can continue to strengthen their presence in the global economy.

As the global economy continues to expand at a steady pace, so have many economies in the developing world. Compared to previous decades, Africa's economic pulse appears to have quickened in recent years. Propelled by a series of market reforms and financial deregulations, several African economies have made great strides in improving the quality of life of their citizens. According to the World Bank, in 2018, Sub-Saharan Africa grew at a pace that mirrored the global rate of 3.1 percent (Global Economic Prospects 2018). This growth rate was projected to increase in subsequent years.

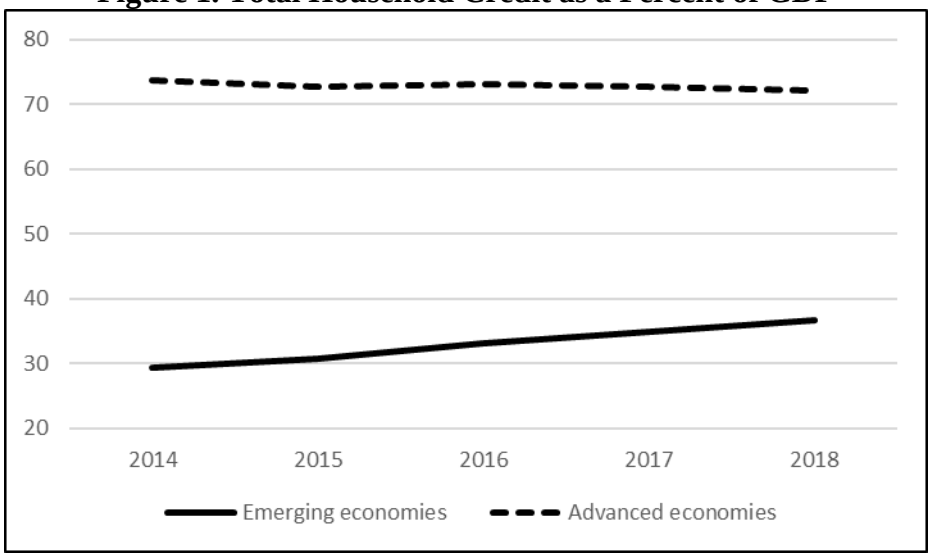
The 2018 report by the Bank for International Settlement suggests that economic activity in Africa has been fueled primarily by inroads in international trade, easy monetary policies, and positive consumer sentiments. In an earlier study, Jacque (2001) explained that the economic dynamics of emerging markets are driven by the skillful transfer of financial innovations to those markets committed to deregulating their financial sector. The inclusion of financial derivatives and securitization of consumer finance, as part of a process for disintermediating traditional banking and managing risk, should help reduce the cost of living for many households in the region. It should also aide in improving access to capital. Perhaps it is in this respect that the introduction of innovative derivatives such as those suggested in this issue might prove useful. But it also poses a challenge.

While emerging economies have greatly increased the efficiency of, and access to, financial markets, substantial risks to economic stability remain. The rapid introduction of new financial

instruments like derivatives and asset-backed securities, as well as the entry of new investments like hedge funds and private equity, raise questions as to how these economies would fare should another severe downturn occur.

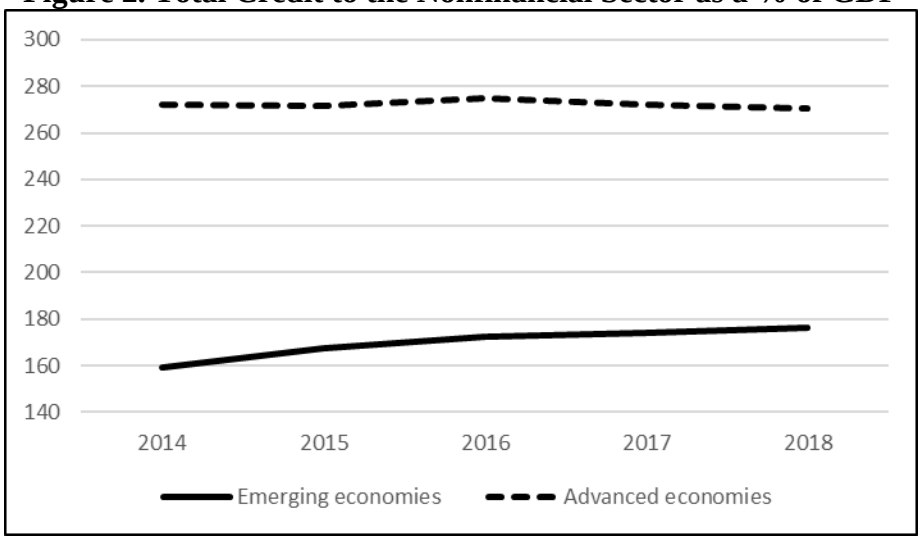
The Global Financial Crises of 2008 was a wakeup call to many countries. The devastating economic impact that resulted from the use of excessive leverage and nebulous financial products cannot soon be forgotten. That crisis discouraged many banks from lending which in turn stifled global growth (Cramer et al, 2009). Ten years on, risks in the form of rising household debt are increasingly apparent. Figures 1 and 2 show the steady increase in both core household debt and credit to nonfinancial sector for emerging economies. Both macroeconomic statistics appear to be trending toward excessive leverage for these economies.

Figure 1. Total Household Credit as a Percent of GDP



Aggregates based on conversion to US dollars at PPP exchange rates
Source: BIS, "Credit to the non-financial sector" (https://stats.bis.org/statx/srs/table/f1.1)

Figure 2. Total Credit to the Nonfinancial Sector as a % of GDP



Aggregates based on conversion to US dollars at PPP exchange rates
Source: BIS, "Credit to the non-financial sector" (https://stats.bis.org/statx/srs/table/f1.1)

Systematic risks such as rising geopolitical tensions and the resurgence of protectionist sentiments appear to slow the gains that have been made during the past decade. Further, some of the leading African economies like Algeria, Egypt, Kenya, Nigeria, and South Africa have been mired in a series of macroeconomic headwinds, including political unrests, terror attacks, and persistent labor strikes. The consideration of these risk dynamics should prove beneficial as these economies carefully weigh the merits of market reform and financial deregulation against what the former U.S. Federal Reserve Chairman, Alan Greenspan, refers to as irrational exuberance.

There is also another aspect of risk unique to many African countries. For years, commodities have dominated, and continue to dominate the economic landscape of many countries in Sub-Saharan Africa. Unfortunately, this overreliance on commodities often comes with considerable downside risks. The persistent slump in commodity prices has led to adverse effects on the growth momentum, especially for single commodity-dependent economies like Nigeria, Congo, and Angola. In its 2019 economic report, the African Development Bank Group concluded that to alleviate the growth problem in the region, more FDI inflows would be required toward these resource-rich countries. And to diversify their economies, all the countries should strive to improve their quality of governance and expand education as well as access to capital in order to increase the size of their middleclass consumers. Doing this, it argues, would ensure more stable economic and political conditions.

Many African economies have continued to undergo structural changes designed to improve their economic prospects. These changes have occurred mostly in the form of regulatory reforms in financial services, an example of which is the removal of interest rate cap in Kenya in 2019. At the micro level, Ayyagari (2011) determined that access to external financing is associated with greater firm innovation in these economies. The author further noted that having a highly educated workforce, family owned businesses, and exposure to foreign competition are trends that support greater firm innovation. Mishra (2018) finds that while not risk free, financial innovations improve financial intermediation as well as reduce financial risks. The author argues that both aspects lower the cost of capital for firms, are welfare enhancing, and should ultimately bode well for emerging economies.

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Pat Obi is the White Lodging Endowed Professor of Finance and Director of the Executive MBA program at Purdue University Northwest. He is also the financial consultant for the City of Hammond, Indiana (USA) and a Certified Hotel Industry Analyst (CHIA). Obi received his Ph.D. in Finance and Econometrics from the University of Mississippi. With professional engagements in several countries, Obi is the author of numerous scholarly publications including two financial books. His corporate consulting expertise includes financial analysis, valuation, and statistical modelling. His current research focuses on the economic impact of global tourism using financial market variables.

TIME-VARYING CALENDAR ANOMALY IN AFRICAN STOCK MARKETS: APPLICATION OF GARCH MODELS

Adefemi A. Obalade and Paul-Francois Muzindutsi

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ABSTRACT

The study investigated time-varying day-of-the-week (DOW) calendar effect in the selected African stock markets. This is important in the light of AMH, which challenged the persistence of market efficiency and by implication, market anomaly. We employed daily returns of All Share Index of the Nigerian Stock Exchange, the Johannesburg Stock Exchange, the Stock Exchange of Mauritians, the Casablancan Stock Exchange and the Tunisian Stock Exchange from 1998 to 2018. This study explored rolling window analysis of several alternative variants of nonlinear models of the GARCH family, notably the asymmetric TGARCH and EGARCH models, to track variation in the behaviour of the anomaly. The contribution of the study comes from the conclusion that the DOW effect disappears and reappears over time. This implies that behaviour of African stock markets follows the cyclical efficiency invented by the proponents of the AMH.

Keywords: Day-of-the-week effect, AMH, African stock markets, GARCH, rolling window

INTRODUCTION

Finance as a field of study has witnessed a fascinating development in the past decades. The famous efficient market hypothesis (EMH) of Fama (1965, 1970) dominated academic finance literature in the 1970s. An efficient market is one in which large numbers of rational investors compete to predict the expected prices of individual assets and where participants have free access to important current information (Fama, 1965). In such a market, the rivalry among various rational investors results in a situation where information based on past, present and future events is already incorporated in prices of individual assets (Fama, 1965). It implies that the stock prices adequately reflect all information, thereby undermining stock prices' predictability. However, the discovery of a broad range of stock market anomalies greeted the field of finance during the 1980s and 1990s.Sedeaq (2016) defines stock market anomalies as the existence of abnormal patterns of stock returns in the stock markets. In addition, Lo,

Adefemi A. Obalade (PhD) *is a postdoctoral researcher in the School of Accounting, Economics and Finance, University of KwaZulu-Natal in South Africa. His research interests revolve around financial market, financial economics and time series analyses of macroeconomic variables.*

Paul-Francois Muzindutsi (PhD) *is an associate professor of Finance in the School of Accounting, Economics and Finance, University of KwaZulu-Natal in South Africa. His research interests include financial markets, behavioural finance, financial risk management, investment analysis, time series analysis of macroeconomic variables, and development economics.*

Blume and Durlauf (2007) held that market anomalies present an important challenge to the EMH as they represent a regular pattern in an asset's returns, which is reliable, common and inexplicable. The regularity and reliability of the pattern implies a degree of predictability and the common knowledge of the regularity implies that many investors can exploit it.

In support of the presence of anomalies, it was shown in the 1980s that stock prices are too volatile for their behaviour to be determined solely by new information (Robert Shiller, 1981) and that the possibility of a perfectly efficient market is considered impossible (Grossman & Stiglitz, 1980). One popular type of the market anomaly is known as the calendar anomaly, defined as anomalies in stock returns, which depend on the time period at calendar. Also, Alagidede and Panagiotidis (2006) and Alagidede (2013) view calendar anomalies as the likelihood that returns on financial securities would exhibit systematic patterns during particular year, month, week, day or time of the day. Hence, the presence of calendar anomaly is a notable violation of the EMH. To justify the presence of various anomalies or contradictions of the EMH, behavioural explanations have been provided. Consequently, anomalies have been placed under the umbrella of behavioural finance (BF) (Kapoora and Prosad, 2017), which has to do with the study of psychological influence on the financial practitioners' behaviour and markets. BF brings in the fact that investors may react or behave irrationally because their investment decisions are based on the mixture of fact and feelings; hence, BF is usually regarded as the opposite end of the EMH.

Thus, the EMH continues to generate controversies as market participants continue trying to better average returns with their stock selections. Consequently, theorists began to consider the development of a more suitable framework for the explanation of stock return or price behaviour. To this end, Lo (2004) advocated the adaptive market hypothesis (AMH), which challenged the notion of absolute efficiency and called for the exploration of time-changing efficiency. He used evolutionary analogy to derive market dynamics, interactions and innovation. An important insight of the AMH, derived directly from theory of evolutionary biology, is that convergence to equilibrium is unguaranteed or unlikely to occur at any point in time due to factors such as institutional changes or entry and exit of participants (Lo, 2005). Hence, the idea that evolving systems must march inexorably toward some ideal stationary state is an illusion. In line with the AMH, it is possible for the efficiency and anomaly to swap over time. Thus, the AMH is suggestive of a new way of investigating calendar anomalies, which is to examine how the pattern in stock return during calendar periods changes or behaves over time. Consequently, calendar anomalies, just like the efficiency, have been evaluated within the time-varying approach, especially in a few developed markets (Urquhart and McGroarty, 2014).

Therefore, the main objective of this study is to test for time-varying day-of-the-week (DOW) calendar effect in the selected African stock markets. Although there are several types of calendar anomaly, DOW effect is the most common and established effect. In the spirit of AMH, can DOW effect vary over time? This question is worth exploring in African stock markets in the interest of investors who may want to take advantage of the anomaly without restraint since the markets are often considered inefficient. African markets possess several institutional characteristics that distinguish them from developed and other emerging markets (Alagidede and Panagiotidis, 2009; Alagidede, 2013). A study of calendar anomalies within the AMH in African markets can provide insight on the role of institutional characteristics on return behaviour. This insight may be of vital importance to investors and stock exchange regulators in terms of policy decisions (Alagidede, 2013). The study becomes one of the leading studies to examine fluctuation in DOW effect in the context of AMH in the African stock markets with application of GARCH models.

LITERATURE REVIEW

The DOW effect is the tendency for stock returns to be abnormally higher on some days of the week than on other days, often in a recurring pattern over the years (Hassan et al., 2015). Pandey and Samanta (2016) state that DOW effect is evidenced by significantly different returns on some week days; notably larger Friday and lower Monday. According to Dragan, Martin and Igor (2012), DOW effect is like weekend effect, which holds that securities displayed much smaller returns in the period between Friday's close and Monday's close. One of the most common explanations for the negative weekend effect is rooted in settlement regime hypothesis, which holds that the delay between the trade date and the settlement date create an interest-free loan until settlement (Lakanishok and Levi, 1982). Friday buyers get two extra days of free credit, creating an incentive to buy on Fridays and pushing Friday prices up (Gibbons & Hess, 1981). On the other hand, French (1980) explains the information release hypothesis and shows that firms and governments generally release good news between Monday and Friday but wait until the weekend to release bad news. As a result, bad news is reflected in lower stock prices on Mondays and good news is reflected in higher stock prices on Fridays. Also, investors' psychology hypothesis may play a significant role in explaining DOW effect. Rossi (2007) and Rystrom and Benson (1989) argue that if investors feel more pessimistic on Mondays than on other days of the week, they sell their securities and depress prices. In contrast, on Fridays, optimistic investors buy securities and create upward pressure on prices. However, in an efficient market, rational investors should recognise this and should short sell on Friday at a higher price and buy on Monday at a lower price, if the expected profit covers the transaction costs and a payment for risk. This type of trading should lead to the elimination of the anomaly, since it should result in prices falling on Friday and rising on Monday.

Until the advent of AMH, large numbers of calendar anomaly studies had been carried out on the DOW effect, using single state models. For instance, Berument and Kiymaz (2001) show that the DOW effect is present in both volatility and return equations in the US with the highest and lowest returns observed on Wednesday and Monday and highest and lowest volatility observed on Friday and Wednesday respectively. Also, Lei and Gerhard (2005) report that the Mondays are seen to be weak and Fridays show significant positive average returns in the Chinese stock market. South American markets have also been examined by Rossi (2007) with the popular positive Friday effect found in Brazil, lowest Monday in Chile, highest Wednesday return in Mexico and absence of DOW anomalies in Argentina. However, the analyses of 30 stocks traded on the German Stock Exchange by Lukas (2009) established that the DOW effect started fading in the second half of the 1990s. In addition, Lukas (2012) investigated six major industrial sectors for seasonality in the US stock exchange and showed that DOW effect cannot be accepted in the US stock market.

In addition, Julio and Beatriz (2013) evaluated six emerging markets (Colombia, Indonesia, Vietnam, Egypt, Turkey and South Africa (CIVET)) stock indices returns from inception to 2012 using GARCH and IGARCH models. There is DOW effect in CIVETS; there is evidence of lags in the effect. Bundoo (2011),in Mauritius, examined stock indices of 10 companies from 2004-2006. Dummy regression result finds negative Tuesday returns but positive returns for other days of the week especially significant Friday and September effect. Similarly, dummy variables regression and GARCH models were also adopted by Alagidede (2013) in an examination of calendar effect in African countries stock markets using data from inception of the markets to 2006. Holiday effect is reported in South Africa, February effect for Morocco, Kenya, Nigeria and South Africa and January effect in Egypt and Zimbabwe. Shakeel, Douglas and Chimwemwe (2013) submitted that Zambia, Botswana, Nigeria and Morocco displayed significantly different DOW effects in the pre- and post-financial crisis while South Africa did not exhibit such. However, the descriptive statistics and the two sub-periods employed cannot provide rich information on the time-varying behaviour depicted in AMH. Furthermore, Derbali and Hallara (2016) show that positive Thursday effect is found in Tunisian market stock returns while negative Tuesday effect is present in both return and volatility. More recently, Du Toit, Hall and Pradhan

(2018) studied eight sectors of JSE for DOW effect over 1995 to 2016 using GARCH model. The study found a significant positive Monday/Tuesday and negative Friday effect respectively.

Such single-state models failed to account for the cyclical behaviour of asset returns, hence could not capture the time-varying characteristic of market efficiency as described by the new AMH. Considering the studies on cyclical behaviour of calendar anomaly, Alagidede and Panagiotidis (2009) seem to be the only recognised African stock market calendar anomaly study where a rolling window analysis was used to examine the persistence of DOW effect. The study employs OLS, GARCH, EGARCH and TGARCH and submits that there is significant Friday effect in Ghana stock exchange; however, the effect evaporates with rolling window estimation. Further, Borges (2009) investigated 17 European stock market indices and documented evidence of cross-country rather than across-the-board calendar anomalies, especially in August and September. He submitted that the identified anomalies vary with time and could be more as a result of data mining due to high instability in the behaviours of the anomalies over time. Based on Borges' finding, "the calendar effects may only be a 'chimera' delivered by intensive data mining as they are country-specific results and may not be stable over time (Ching, 2015, p. 25)". Similarly, various GARCH family models are analysed in rolling windows by Bampinas, Fountas and Panagiotidis (2016) to establish that the DOW effect, found in two regional and six national indices and Monday effect found in three national indices, all experienced significant reduction in power when rolling window analyses are carried out. Via the application of GARCH model, Zhang et al. (2017) also established the presence of DOW effect in 25 countries (made up of 13 developed and 15 developing markets) the anomalies of which disappear with rolling windows in all except six countries. Additionally, Chatzitzisi, Fountas and Panagiotidis(2019) show that DOW is present in all the sectors and the general S&P500 indices using nonlinear models (EGARCH and TGARCH) in full sample but only one-fifth of the total number of regressions/windows is associated with the anomaly. Hence, the study concluded that the anomalies are weak, and time-variant as opposed to being persistent. Moreover, Urquhart and McGroarty (2014) in the US also showed that the behaviour of the Monday, January, Halloween and the turn of the month calendar anomalies change over time using similar rolling window estimations for the S&P 500 index.

It can be seen from the above review that consideration of time-changing calendar anomaly is new, and the investigation is limited to few developed markets. The few studies, which have proved that the behaviour of calendar anomalies supports the AMH, include Urquhart and McGroarty (2014) and Osamah and Ali (2017) while Shake el et al. (2013) pre- and post-financial crisis two sub-period analyses are not sufficient to establish the cyclical behaviour depicted by AMH as the rolling estimation employed in the current study. Further, the GARCH-type model used in this study overcomes the weakness of descriptive statistics and other models hitherto adopted in other studies. It is noteworthy that Smith and Dyakova (2014), Seetharam (2016), Obalade and Muzindutsi (2018), Heymans and Santana (2018) show that weak-form efficiency of African markets is time-varying. However, the examination of time-varying calendar anomalies is limited, especially in the emerging markets such as the African stock markets. Hence, further studies in the Africa setting will make meaningful contribution to the validation of AMH.

RESEARCH METHOD

Data and Sampling

The study employed daily stock indices' returns of the major stock markets in African (presented in Figure 1). Daily frequency data is required for the study of DOW effect in stock returns. The data covered a period of 20 years (1998-2018) selected based on data availability. The data were sourced from Bloomberg database. The selected indices include the Nigerian Stock Exchange All Share Index (NGSEINDX), Johannesburg Stock Exchange (JSE) All Share Index (JALSH), Stock Exchange of

Mauritius (SEM) All Share Index (SEMDEX), Casablanca Stock Exchange (MOSE) All Share Index (MOSENEW) and Tunisia Stock Exchange All Share Index (TUSISE)1. The simple returns were calculated using the following formula:

$$\mathbf{IR_t = \log\left(\frac{P_t}{P_{t-1}}\right)} \quad (1)$$

Where $\mathbf{IR_t}$ is the time $\mathbf{t}$return of stock index and $\mathbf{P_t}$and $\mathbf{P_{t-1}}$ are the time $\mathbf{t}$and $\mathbf{t-1}$ stock price index.

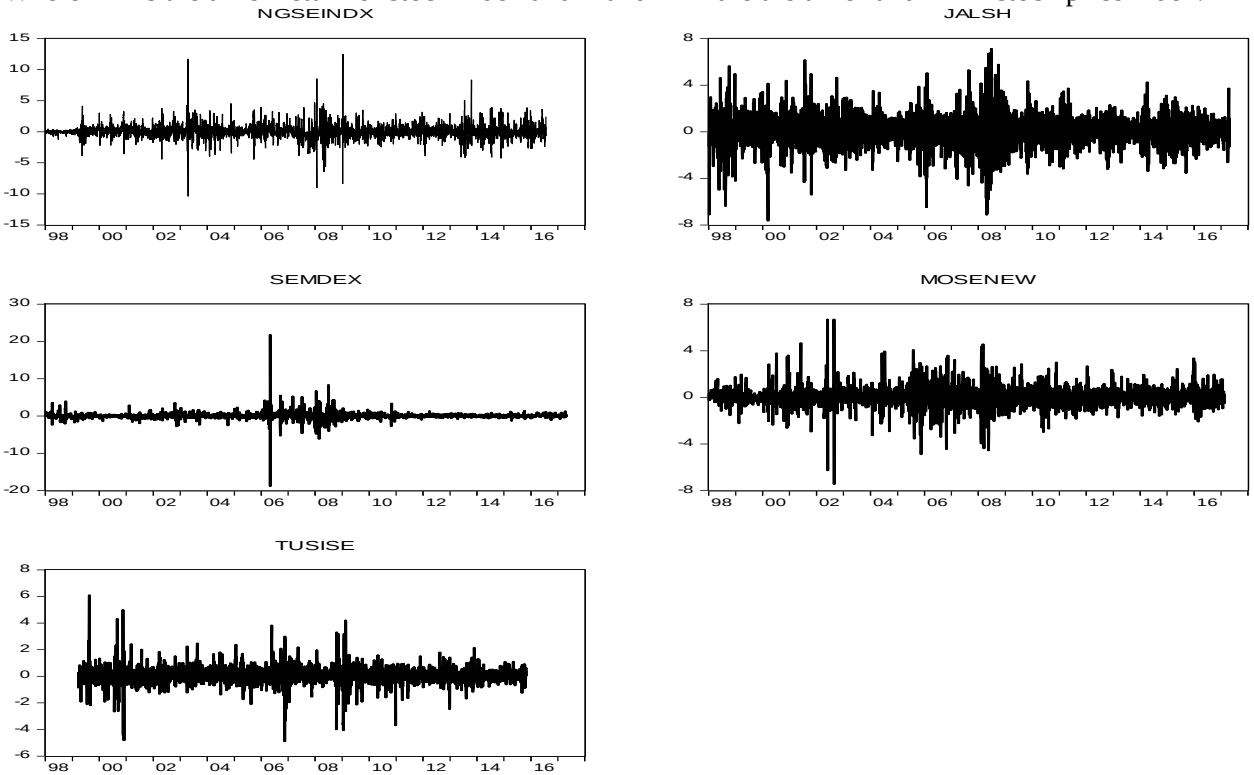

Figure1: Time Plot of NGSEINDX, JALSH, SEMDEX, MOSENEW and TUSISE Returns

Calendar Effect Model

The actual mean equation estimated for the DOW effect in this study is given as:

$$DR_t = \sum_{i=1}^{5} \beta_i D_i + \sum_{i=1}^{k} \alpha_i DR_{t-i} + \varepsilon_t \quad (2)$$

$$H_0: \beta_i = 0 \ldots\ldots H_1: \beta_i$$

Where DR_t is the index returns on day t, D_1 the dummy variable which takes value 1 if t is Monday and 0 if not, $D_2$the dummy variable, which takes the value of 1 if t is Tuesday and 0 if not and

[1]NGSEINDX (Only ordinary shares are included in the computation of the index. It is value related and computed daily. JALSH (FTSE JSE All Share Index, is a MCAP-weighted index. Included companies make up the top 99 % of the total free-float MCAP of all companies listed in JSE) SEMDEX (MCAP weighted index, including all shares traded on the SEM and obtained as market value of all listed shares over base market value of all listed shares multiplied by 100), MOSENEW (a broad based free float index comprising all shares listed on the Casablanca stock exchange), TUSISE (is a capitalisation-weighted index containing all equities from TSE, it has become a free float weighted index from January 2009).

so on and so forth. $\boldsymbol{\beta_i}$ $\boldsymbol{(i = 1, 2, .., 5)}$are coefficient estimates. The presence of seasonal effect in a given day is indicated by a statistically significant $\boldsymbol{p}$-value of the dummy coefficient for that day. The absence of constant from Equation 1 is to avoid the dummy variable trap.

Estimation Technique

The modern model in the investigation of calendar anomaly is the GARCH family model, selected over the OLS due the presence of volatility clustering in the stock index returns. From the mean equation of DOW (Equation 2),this study estimates GARCH models, which permit modelling and forecast of conditional variances, capture the possibility for volatility clustering and are able to incorporate heteroscedasticity into the estimation procedure. The linear model cannot capture these features of stock returns.

1. Generalised ARCH (GARCHq,p) Models

The GARCH model emerged from independent works of Bollerslev (1986) and Taylor (1986) in which current conditional variance is dependent on $q$lags of the squared residual and p lags of the

conditional variance. Consider the conditional variance in its simplest case, GARCH (1,1), which is a one-period-ahead estimate for the variance depending on any relevant previous information:

$$\delta_t^2 = w + \pi_1 \varepsilon_{t-1}^2 + \Lambda_1 \delta_{t-1}^2 \qquad (3)$$

π_i indicates short-run persistence of shock and $\Lambda_j$long run. Brooks (2014) noted that GARCH (1,1) model

adequately captures the volatility clustering in the data and it is uncommon to have higher order model estimated or considered as far as the academic finance literature is concerned. There are various extensions (Bollerslev et al., 1992) of GARCH model as a result of the shortcoming of the GARCH (p, q), for example, possible violation of the non-negativity conditions and inability to explain leverage effects and failure to provide feedback between the conditional variance and the conditional mean.

2. Asymmetric GARCH models

The general GARCH model presumes that the effects of positive and negative shocks on volatility are the same since it depends on the square of the previous shocks. However, it has been argued that equity returns respond differently to positive and negative shocks. Hence, there is high tendency of a negative shock causing volatility to increase by more than a positive shock of the same magnitude. In the case of equity returns, such asymmetries are typically attributed to *leverage effects*. Hence, the duo of the most popular asymmetric models, namely the threshold GARCH (TGARCH) and exponential GARCH (EGARCH), which are widely used and able to overcome the identified shortcomings of GARCH, are also estimated in this study.

2.1 GJR (1993) TGARCH

The TGARCH (Glosten, Jagannathan and Runkle, 1993) added additional terms to the GARCH model to provide explanation for likely asymmetries. The specification for the conditional variance is given by:

$$\delta_t^2 = w + \pi_1 \varepsilon_{t-1}^2 + \Lambda_1 \delta_{t-1}^2 + \gamma_1 \varepsilon_{t-1}^2 I_{t-1} \quad (4)$$

Where $I_{t-1} = 1$ if $\varepsilon_{t-1} < 0$ and = 0 otherwise. For a leverage effect of ith order,$\gamma_i > 0$, hence bad news increases volatility. The impact is asymmetric if $\gamma_k \neq 0$. The condition for non-negativity will be $w > 0,\ \pi_1 > 0, \Lambda_1 \geq 0$ and$\Lambda_1 + \gamma_1 \geq 0$ i.e. the model is still admissible, even if$\gamma_1 < 0$, provided that$\pi_i + \gamma_i \geq 0$. In this model, good news,$\varepsilon_{t-1} > 0$ and bad news, $\varepsilon_{t-1} < 0$ have differential effects onδ_t^2 the conditional variance; good news has an impact ofπ_i , while bad news has an impact of$\pi_i + \gamma_i$.

2.2 EGARCH

The exponential GARCH (EGARCH) model was credited to Nelson (1991). The conditional variance specification is:

$$ln(\delta_t^2) = w + \Lambda_1 \ln(\delta_{t-1}^2) + \pi_1 \left|\frac{\varepsilon_{t-1}}{\delta_{t-1}}\right| + \gamma_1 \frac{\varepsilon_{t-1}}{\delta_{t-1}} \quad (5)$$

The natural log (ln)attachedto the conditional variance shows that the leverage effect is not quadratic but exponential and that forecasts of the conditional variance are certainly positive. Hence, it is not necessary to impose artificially non-negativity constraints on the model parameters. Further, asymmetries are allowed for under the EGARCH formulation, since if the relationship between volatility and returns is negative,γ_k, will be negative. The presence of leverage effects can be tested by the hypothesis that $\gamma_k < 0$. The impact is asymmetric if$\gamma_k \neq 0$.

The three models (GARCH (1,1), TGARCH(1,1) and EGARCH(1,1))are estimated with the intention of selecting the best since different markets may possess different features. For instance, some data may be asymmetric while others may not. The appropriate models are selected using information criteria and diagnostic tests. Maximum value of likelihood and minimum values of AIC and BIC are compared. Equality of the variance equation parameters to approximately unity (1) is also considered. GARCH models of the DOW effect are estimated in full sample and rolling windows.

3. Rolling Regression Approach

The above GARCH models are estimated using rolling window approach. Rolling analyses has so far been pointed out as the best-developed class of alternative methods while researchers are still facing the task of identifying models best suited to capture cycles or dynamics inherent in the new AMH (Lim & Brooks, 2011; Verheyden *et al.*, 2013). The procedure of rolling estimation was employed by Lo (2004, 2005) in the maiden test of the AMH in the US. The procedure challenged the constancy of identified anomaly over time. Rolling regression has two main features, which are the window size and step. The former represents the amount of successive observations used for each regression, while the latter represents the amount of increments between consecutive rolling windows. Rolling window estimation involves breaking the full sample (N) into several consecutive observations *m* (window size), pushed by a certain number of observations *k* (step size) ahead at each repetition (Chatzitzisi *et al.*, 2019). Different windows overlap as they rolled (k step) forward, dropping the farthest K observation until the entire sample is exhausted. This rolling method enables one to look at underlying changes in calendar effect on a shorter time scale. The mean equation of the DOW model (in Equation 2) is estimated in five-year fixed length rolling window, rolled forward by one year to generate enough regressions to account for the changes in behaviour of calendar anomalies over time. It is such that the first window covers 1998-2002, followed by 1999-2003, 2000-2004 and so on. From the mean equation, various GARCH models were estimated and information criteria were used to select the best GARCH model for each window period.

EMPIRICAL RESULTS

Descriptive Statistics

Descriptive statistics of return indices for the full sample period are found in Table 1. It shows that JALSH, followed by NGSEINDX have the highest mean return and volatility. MOSENEW has the lowest mean return while the remaining two markets are similar. The least volatile return is found in TUSISE while SEMDEX and MOSENEW, which are identical in terms of volatility. Four of the five markets are positively skewed, which is an indication of longer right tails. Only the JALSH has longer left tail compared to the mean values with negative S. The values of kurtosis are positive and greater than the 3, expected of normal distribution, for all the markets. It means that indices returns are peaked relative to normal distribution and hence leptokurtic. For further confirmation of the non-normality of the return series, as shown by $S$and K, the JB test of normality is carried out and presented in the last column of Table 1. Significance tests are applied to the Jarque-Bera statistics. P-values of JB statistic are less than 1%, which implies a rejection of the null hypothesis of normal distribution of the return series.

Table 1: Descriptive statistics

Period	Obs	Mean	Median	Max	Min	SD	Skewness	Kurtosis	JB
NGSEINDX	4840	0.051419	0.00000	12.47760	-10.36450	1.066686	0.446663	17.15621	40574.62***
JALSH	5038	0.066408	0.084450	7.119500	-7.638400	1.227568	-0.153936	6.586793	2720.492***
SEMDEX	5036	0.045077	0.017850	21.75500	-18.74110	0.752092	2.089486	229.2859	10748247***
MOSENEW	4989	0.03244	0.019300	6.689500	-7.448400	0.752995	0.017988	13.32256	22150.46***
TUSISE	4232	0.047619	0.025500	6.092900	-4.880500	0.571153	0.056720	17.90639	39183.60***

***, **, * indicate significance at 1%, 5% and 10% respectively.

Rolling Window GARCH Results

Given the motivation for GARCH models in the methodology section and the discovery of ARCH effect in the OLS regression (not reported), this study estimates the DOW model using the GARCH(1,1), EGARCH(1,1) and TGARCH(1,1) with student t distribution. The t distribution minimises information criteria compared to GED. From the full sample results in Tables 2, 3, 4, 5 and 6 there is a presence of the weekend effect in the selected African stock markets, characterised by negative Monday and positive Friday, except in JSE, where the reverse of weekend effect is the case.

Nigerian Stock Index Results

Information criteria select mixture of EGARCH and ordinary GARCH models for different windows in NGSEINDX as shown in column 2 of Table 2. Neither the full sample nor the rolling windows displayed significant leverage effect (γ). In NGSEINDX returns, though most of the windows have negative Monday effect, significant negative Monday effect is found in 1998-2002, 2000-2004 and 2008-2012 windows and it shifts to negative Tuesday from 2007-2011 to 2009-2013 window. Weekend or Friday effect is fluctuating over time as shown by six (out of 16) windows of statistically significant coefficients.

Table 2: Rolling window GARCH regression results for NGSEINDX

SAMPLE	MODEL	MON	TUE	WED	THU	FRI	A	Γ	B	Heter.	L-Box
					NGSEINDX						
FULL	EGARCH(1,1)	-0.0436***	-0.0136	0.0001	0.0106	0.0511***	0.3958***	0.0222	0.9534***	0.3262	0.149
1998-2002	GARCH(1,1)	-0.0666***	0.0074	-0.0250	-0.0126	0.0144	0.1647***	-	0.8547***	0.1229	0.503
1999-2003	GARCH(1,1)	0.0064	0.0602	0.0489	0.0737*	0.0695	0.2457***	-	0.7160***	0.1111	0.484
2000-2004	GARCH(1,1)	0.0851*	0.1077**	0.0749	0.1354***	0.1158***	0.3018***	-	0.6074***	0.4521	0.255
2001-2005	EGARCH(1,1)	0.0397	0.0661	0.0591	0.1114***	0.0723	0.4368***	0.0590	0.8286***	0.9466	0.167
2002-2006	EGARCH(1,1)	0.0035	0.0679	0.0060	0.0998**	0.1047**	0.4295***	0.0530	0.8689***	0.9774	0.118
2003-2007	EGARCH(1,1)	0.0465	0.081297*	0.0832*	0.0988**	0.1482***	0.4275***	0.0667*	0.8781***	0.6201	0.146
2004-2008	EGARCH(1,1)	0.0069	0.0015	-0.0111	-0.0080	0.0690	0.4154***	0.0086	0.8954***	0.3963	0.149
2005-2009	EGARCH(1,1)	-0.0192	-0.0548	-0.0399	-0.0206	0.0796	0.4338***	-0.0013	0.9156***	0.9362	0.238
2006-2010	EGARCH(1,1)	-0.0150	-0.0593	-0.0248	-0.0517	0.1019**	0.5054***	0.0022	0.8894***	0.8583	0.148
2007-2011	EGARCH(1,1)	-0.0840	-0.1578***	-0.0426	-0.0869	0.0527	0.5047***	-0.0155	0.8773***	0.8417	0.108
2008-2012	EGARCH(1,1)	-0.1225***	-0.1531***	-0.0296	-0.0443	0.0196	0.4931***	-0.0284	0.8735***	0.9910	0.212
2009-2013	EGARCH(1,1)	-0.0608	-0.0782*	0.0701	0.0619	0.1161***	0.4535***	-0.0479	0.8962***	0.7998	0.222
2010-2014	GARCH(1,1)	-0.0467	-0.0372	0.0832**	0.0194	0.0960**	0.2260***	-	0.6682***	0.8338	0.457
2011-2015	GARCH(1,1)	-0.0414	-0.0678	0.0186	0.0064	0.0737	0.1760***	-	0.7572***	0.5980	0.101
2012-2016	GARCH(1,1)	-0.0331	-0.0487	0.0149	0.0391	0.0745	0.2114***	-	0.7333***	0.8983	0.199
2013-2017	GARCH(1,1)	-0.0383	-0.1001	0.0082	0.0364	0.0809	0.3450***	-	0.6044***	0.6076	0.132
Remarks					Adaptive						

*, **,*** signifies significance at 10%,5%&1%[2]. **A, γ, B, Heter and L-box**[3]

[2] Ditto to Table 3, 4, 5 & 6

[3]The ARCH parameters, leverage effects & GARCH parameters correspond to A, γ, B respectively while Heter & L-box corresponds to probabilities of arch heteroscedasticity and Ljung-box respectively. Ditto to Table 3, 4, 5 & 6.

JSE Results

From Table 3, information criteria favours EGARCH model for JALSH in full sample and rolling windows except of 1999-2003 and 2010-2014 windows. All the windows are characterised with significant leverage effect (negative and significant signs of γ) suggesting that the negative shock causing volatility to increase by more than a positive shock of the same magnitude all the time.

There is the DOW effect in JALSH, especially the positive Monday and Thursday effects. These DOW effects fluctuate in rolling windows. JALSH results show the opposite of weekend effect in full sample, evidenced by significantly positive and higher Monday returns. In addition, the positive Monday effect was present in the first nine windows except 2004-2008. The effect disappears in 2007-2011, 2008-2012, 2009-2013, 2011-2015 and 2012-2016. Thus, the rolling EGARCH results provide stronger proof of fluctuation in DOW (Monday and Thursday) effects.

Table 3: Rolling window GARCH regression results for JALSH

SAMPLE	MODEL	MON	TUE	WED	THU	FRI	A	γ	B	Heter.	L-Box
					JALSH						
FULL	EGARCH(1,1)	0.1826***	0.0264	0.0204	0.1049***	0.0327	0.1468***	-0.0777***	0.9834***	0.6999	0.957
1998-2002	EGARCH(1,1)	0.2859***	0.0016	-0.0312	0.0751	0.0184	0.1503***	-0.0680***	0.9617***	0.3062	0.192
1999-2003	TGARCH(1,1)	0.2601***	0.0086	-0.0900	0.0595	0.0651	0.0308***	0.0949***	0.8559***	0.1222	0.137
2000-2004	EGARCH(1,1)	0.1350**	0.0578	-0.0903	0.0659	0.0467	0.1120***	-0.0751***	0.9739***	0.2287	0.312
2001-2005	EGARCH(1,1)	0.2010***	-0.0125	-0.0544	0.1719***	0.1068*	0.1379***	-0.0671***	0.9763***	0.6311	0.218
2002-2006	EGARCH(1,1)	0.1957***	0.0022	0.0160	0.1335***	0.1475***	0.1150***	-0.0787***	0.9781***	0.2364	0.551
2003-2007	EGARCH(1,1)	0.2356***	0.0058	0.0228	0.1598***	0.1629***	0.1354***	-0.0910***	0.9724***	0.3547	0.746
2004-2008	EGARCH(1,1)	0.2027***	0.0024	0.0379	0.2126***	0.0833	0.1439***	-0.1061***	0.9832***	0.1812	0.997
2005-2009	EGARCH(1,1)	0.2860***	-0.0644	0.0609	0.1967	0.0684	0.1341***	-0.1025***	0.9845***	0.1092	0.798
2006-2010	EGARCH(1,1)	0.2627***	-0.0537	0.0915	0.1624***	-0.0833	0.1340***	-0.1194***	0.9820***	0.1297	0.840
2007-2011	EGARCH(1,1)	0.1254*	-0.0803	0.0365	0.0870	-0.0939	0.0756***	-0.1239***	0.9864***	0.1687	0.947
2008-2012	EGARCH(1,1)	0.0690	-0.0066	0.0677	0.1142**	-0.0810	0.0894***	-0.1172***	0.9914***	0.1398	0.769
2009-2013	EGARCH(1,1)	0.0810	0.0361	0.0590	0.1416***	-0.0094	0.0819***	-0.1032***	0.9899***	0.1225	0.749
2010-2014	TGARCH(1,1)	0.0985**	0.0645	0.0186	0.0945**	-0.0158	-0.037***	0.1630***	0.9378***	0.1480	0.391
2011-2015	EGARCH(1,1)	0.0370	0.0721	0.0005	0.0971**	0.0095	0.0449***	-0.1384***	0.9846***	0.1031	0.646
2012-2016	EGARCH(1,1)	0.0633	0.0557	0.0032	0.0899**	0.0012	0.0614***	-0.1400***	0.9817***	0.3605	0.927
2013-2017	EGARCH(1,1)	0.1458**	0.0404	-0.0139	0.0231	-0.0096	0.1072***	-0.1432***	0.9751***	0.3227	0.230
Remarks						Adaptive					

Stock Exchange of Mauritius Results

SEMDEX results are presented in Table 4 in which EGARCH is selected for most of the windows, although there are five windows and three windows where ordinary GARCH and TGARCH are selected respectively.

Table 4: Rolling window GARCH regression results for SEMDEX

SAMPLE	MODEL	MON	TUE	WED	THU	FRI	A	γ	B	Heter.	L-Box
					SEMDEX						
FULL	EGARCH(1,1)	0.0100	0.0092	0.0263***	0.0334***	0.0366***	0.4450***	0.0102	0.9324***	0.3547	0.101
1998-2002	EGARCH(1,1)	0.0064	-0.0048	0.0052	0.0042	0.0337*	0.3527***	0.0243	0.9203***	0.4347	0.186
1999-2003	EGARCH(1,1)	0.0091	-0.0167	0.0122	-0.0007	0.0328*	0.2161***	0.0318	0.9679***	0.5092	0.466
2000-2004	GARCH(1,1)	0.0062	0.0049	0.0094	0.0246	0.0544***	0.1141***	-	0.8935***	0.2684	0.205
2001-2005	EGARCH(1,1)	0.0519***	0.0173	0.0292	0.0533***	0.0838***	0.4052***	0.0637	0.8395***	0.8996	0.145
2002-2006	GARCH(1,1)	0.0813***	0.0341	0.0563***	0.0780***	0.0942***	0.5475***	-	0.5142***	0.6056	0.547
2003-2007	GARCH(1,1)	0.0884***	0.0544**	0.0795***	0.1005***	0.0938***	0.6702***	-	0.4521***	0.9526	0.169
2004-2008	EGARCH(1,1)	0.0758***	0.0386	0.0611***	0.1012***	0.1016***	0.6531***	0.0289	0.8896***	0.9559	0.116
2005-2009	EGARCH(1,1)	0.0741***	0.0216	0.0731***	0.0637**	0.1018***	0.7186***	0.0155	0.8859***	0.9691	0.207
2006-2010	EGARCH(1,1)	0.0556*	0.0488	0.0885***	0.0933***	0.1289***	0.6231***	-0.0040	0.8705***	0.9674	0.477
2007-2011	EGARCH(1,1)	-0.0439	0.0245	0.0526*	0.0528*	0.1115***	0.6261***	-0.0834**	0.8774***	0.9471	0.317
2008-2012	EGARCH(1,1)	-0.0366*	-0.0206	0.0147	-0.0046	0.0638**	0.4328***	-0.0286	0.9516***	0.1514	0.550
2009-2013	TGARCH(1,1)	0.0007	0.0226	0.0438**	0.0422*	0.0597***	0.2253***	0.0067	0.7541***	0.0697	0.116
2010-2014	TGARCH(1,1)	-0.0201	0.0080	0.0237	0.0409**	0.0374**	0.2125***	0.0631	0.6158***	0.1383	0.116
2011-2015	TGARCH(1,1)	-0.0330*	-0.0112	-0.0041	0.0190	0.0080	0.1389***	0.0890	0.5596***	0.1107	0.226
2012-2016	GARCH(1,1)	-0.0124	-0.0150	0.0072	0.0229	0.0037	0.1077***	-	0.7077***	0.6731	0.240
2013-2017	GARCH(1,1)	-0.0072	0.0121	0.0234	0.0403***	0.0119	0.0845***	-	0.7461***	0.5667	0.313
Remarks						Adaptive					

There is a significant asymmetric effect in 2007-2011 window when negative shock causes volatility to increase by more than a positive shock of the same magnitude. SEMDEX results show the presence of DOW and weekend effect in full sample. Friday returns are higher than other weekdays and the coefficients are significant except Monday and Tuesday, suggesting the presence of weekend effect. Rolling window results reveal that there is no DOW effect in the first two windows (1998-2002; 1999-2003) and the last three windows (2011-2015; 2012-2016; 2013-2017), which implies that the market switches between period of anomaly and efficiency, hence adaptive. Also, Tuesday seems to be more negative than Monday. Friday effect dominated other weekdays for at least 10 windows, which constitutes 62.5% of the entire windows.

Moroccan Stock Exchange Results

Table 5 contains the MOSENEW results and EGARCH is selected for most of the windows. Results in Table 5 show that there are only two windows (1998-2002 and 1998-2012) of significant leverage effect. The results also show that there is DOW effect characterised by weekend anomalies in full sample. There is no DOW effect for seven windows from 2007-2011 to 2012-2016. The negative Monday/Tuesday effects vary from significant negative in the first three windows to insignificant effect from 2001-2005 and to positive effect in the 2003 to 2009 windows. Friday effect is not found before 2002-2006 and after 2006-2010 windows but reappears in the last window (2013-2013). This results in the presence of Friday effect in seven (7) regressions, representing 43.75% of the entire windows.

Table 5: Rolling window GARCH regression results for MOSENEW

SAMPLE	MODEL	MON	TUE	WED	THU	FRI	A	γ	B	Heter.	LBox
					MOSENEW						
FULL	EGARCH(1,1)	-0.028380**	-0.015828	0.030990**	0.022183	0.04315***	0.48449***	-0.026473	0.89480***	0.6192	0.123
1998-2002	EGARCH(1,1)	-0.11460***	-0.11722***	-0.030110	-0.024723	0.005806	0.60286***	-0.087232**	0.83642***	0.9940	0.168
1999-2003	EGARCH(1,1)	-0.10321***	-0.10893***	-0.022297	-0.026698	-0.015810	0.58949***	-0.057504	0.82734***	0.9604	0.129
2000-2004	EGARCH(1,1)	-0.07216***	-0.06518***	0.013499	0.023709	-0.012039	0.61575***	-0.030995	0.74673***	0.8776	0.158
2001-2005	EGARCH(1,1)	0.003135	0.008796	0.054194*	0.07029***	0.053778*	0.60456***	-0.022939	0.69269***	0.8169	0.101
2002-2006	EGARCH(1,1)	0.050767	0.065589**	0.09125***	0.09251***	0.09838***	0.49676***	0.022355	0.89198***	0.8673	0.293
2003-2007	EGARCH(1,1)	0.11883***	0.13363***	0.12285***	0.09665***	0.12956***	0.39847***	0.039548	0.94995***	0.2739	0.329
2004-2008	EGARCH(1,1)	0.08993***	0.11185***	0.062799*	0.11258***	0.13245***	0.52679***	0.009998	0.96111***	0.8375	0.433
2005-2009	EGARCH(1,1)	0.10216***	0.12746***	0.027607	0.079036**	0.11548***	0.38380***	0.006567	0.94748***	0.1563	0.473
2006-2010	TGARCH(1,1)	0.007794	0.081760**	0.017555	0.080327**	0.085965**	0.24996***	-0.033107	0.71085***	0.1898	0.692
2007-2011	TGARCH(1,1)	0.001430	0.032516	0.011299	0.008078	0.043135	0.27595***	0.147423	0.51032***	0.8576	0.479
2008-2012	TGARCH(1,1)	-0.059195	-0.026034	0.003055	-0.013939	-0.047925	0.17126***	0.26703***	0.58328***	0.6444	0.175
2009-2013	GARCH(1,1)	0.001071	-0.002418	0.048696	-0.020193	-0.064720**	0.25411***	-	0.46275***	0.5772	0.122
2010-2014	TGARCH(1,1)	-0.008092	-0.024274	0.050333	-0.021991	-0.031125	0.25175***	0.045656	0.50466***	0.5219	0.076
2011-2015	TGARCH(1,1)	0.002236	-0.067486**	0.036258	-0.040874	-0.021874	0.13055***	0.098625*	0.67218***	0.1351	0.146
2012-2016	TGARCH(1,1)	0.006443	-0.010616	0.041904	0.020676	0.013767	0.36421***	0.004404	0.80891***	0.9670	0.242
2013-2017	EGARCH(1,1)	0.008823	0.006516	0.061723**	0.017084	0.07103***	0.27246***	-0.098654	0.53462***	0.4628	0.338
Remarks						Adaptive					

Tunisian Stock Exchange Results

TUSISE results are given in Table 6, based on the combination of the two asymmetric models and the results show that there are at least four windows having leverage effect. Return displayed DOW and weekend effect in full sample as evidenced by significant high Friday returns and low and insignificant Monday and Tuesday. The effects, however, move between era of significance and insignificance in rolling window. Negative/low Monday effect is insignificant for most windows and there is significant positive Monday effect in 2006-2010. At least four windows are not associated with DOW effect. Friday return is significantly higher than other days of the week for at least 10 windows constituting 62.5% of the total windows.

Table 6: Rolling window GARCH regression results for TUSISE

SAMPLE	MODEL	MON	TUE	WED	THU	FRI	A	Γ	B	Heter.	L-Box
					TUSISE						
FULL	TGARCH(1,1)	0.020827	-0.019413	0.019320	0.047864***	0.086869***	0.246456***	0.077946*	0.568821***	0.3348	0.452
1998-2002	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
1999-2003	EGARCH(1,1)	0.005496	-0.05455*	0.002701	0.016198	0.039552	0.382208***	0.039610	0.872675***	0.8864	0.558
2000-2004	EGARCH(1,1)	0.002944	-0.065***	-0.012060	-0.006953	0.011159	0.434497***	-0.016564	0.854674***	0.7224	0.373
2001-2005	EGARCH(1,1)	-0.019542	-0.066***	-0.032261	0.016323	0.031778	0.436279***	-0.041789	0.862468***	0.6929	0.279
2002-2006	EGARCH(1,1)	0.033929	-0.034864	-0.001333	0.068581***	0.072577***	0.327479***	-0.007111	0.844195***	0.7715	0.745
2003-2007	EGARCH(1,1)	0.037778	-0.006661	0.037939	0.070238***	0.113653***	0.358132***	-0.001078	0.828570***	0.7593	0.637
2004-2008	EGARCH(1,1)	0.028940	-0.030133	0.039462	0.072094***	0.138907***	0.210994***	0.173627*	0.541411***	0.2921	0.490
2005-2009	TGARCH(1,1)	0.045336	-0.010679	0.071254***	0.120501***	0.187763***	0.169728***	0.100736	0.655262***	0.1423	0.229
2006-2010	TGARCH(1,1)	0.061307**	-0.003846	0.098109***	0.124722***	0.195640***	0.220957***	0.167167*	0.476138***	0.2363	0.057
2007-2011	TGARCH(1,1)	0.032301	-0.032947	0.067983***	0.042805	0.158966***	0.171390***	0.183498**	0.606743***	0.7186	0.427
2008-2012	TGARCH(1,1)	0.022013	-0.0582**	0.063962***	0.053098**	0.134077***	0.156113***	0.223758***	0.591428***	0.6782	0.291
2009-2013	TGARCH(1,1)	0.003953	-0.029040	0.054679***	0.077338***	0.089654***	0.232501***	0.258971***	0.462821***	0.9946	0.086
2010-2014	TGARCH(1,1)	-0.010433	-0.030799	0.014426	0.046935***	0.060437***	0.297393***	0.210489**	0.445810***	0.9993	0.167
2011-2015	TGARCH(1,1)	-0.028015	-0.03626*	0.000177	0.024705	0.033171	0.300923***	0.160621	0.448796***	0.7914	0.125
2012-2016	EGARCH(1,1)	-0.004778	-0.03442*	-0.021139	0.016798	0.038763*	0.479227***	0.004830	0.736342***	0.6299	0.103
2013-2017	TGARCH(1,1)	0.018643	-0.007965	-0.019484	0.020802	0.055709***	0.237716	-0.036365	0.549346	0.8236	0.541
Remarks						Adaptive					

The overall results reveal that the asymmetry term (γ) in Tables 2, 3, 4, 5are significant in all windows for JALSH, in few windows for SEMDEX, MOSENEW and TUSISE. However, the asymmetry

term is not significant in NGSEINDX. Therefore, this study documents significant leverage effects indicating that negative news causes volatility to rise by more than positive news of the same magnitude at all time in JSE and on few occasions in SEM, MOSE and TSE. The estimated GARCH term (B) is always significantly positive in the GARCH, EGARCH and TGARCH, respectively. As is typical of GARCH model estimates for financial asset returns data, the sum of the coefficients on the lagged squared error and lagged conditional variance is, in most cases, very close to unity. This sum being close to unity implies that volatility converges to the steady state slowly.

Diagnostic Tests

The robustness of the estimated GARCH models is performed to ensure model adequacy. The Ljung-box Q statistics test on the standardised residuals of the selected GARCH model is carried out. The results show that there is no trace of serial correlation as the probability of Q statistics is greater than the 5% level of significance for each of the selected models. The test for heteroscedasticity is also carried out to establish a constant variance of the error terms or homoscedasticity of the fitted autoregressive conditional heteroscedasticity (GARCH) model. The result shows that F-statistics probability values (reported in the last column of Tables 2,3,4,5 & 6) are greater than 0.05, hence, the ARCH (1) tests indicate that there is no evidence of conditional heteroscedasticity in the residuals. Thus, the study establishes that the models have been successfully corrected and this implies that the fitted models are adequate. Therefore, there is no serial correlation or conditional heteroscedasticity in the standardised residuals of the fitted models.

Discussion of Results

Since the study of calendar anomalies is one of the ways of examining market inefficiency in the literature, this study evaluates the behaviour of the popular DOW effect using a rolling window GARCH approach. The findings show that the DOW anomalies appear to conform to the time-varying behaviour initiated by the proponents of AMH. Unlike Alagidede and Panagiotidis (2009) who submitted that there is significant Friday effect in Ghana stock exchange, which vanishes with rolling windows, our study shows a disappearance and reappearance of DOW effect. The finding of the current study can also be compared with Bampinas *et al.* (2016), Zhang *et al.* (2017) and Chatzitzisi *et al.* (2019) who applied rolling window methodology in the investigation of DOW effect. Most of these studies mentioned here including Borges (2009), however, doubted the existence of the calendar anomalies due to the high instability in the behaviours of the anomalies over time. Rather than considering the instability in the behaviour of the anomalies as a reflection of time-varying behaviour alluded by the proponents of AMH, virtually all these scholars (Alagidede & Panagiotidis, 2009; Borges, 2009; Bampinas *et al.*, 2016; Zhang *et al.*, 2017) imply that the presence of calendar effects in stock market could be as a result of data mining**.** However, the findings from our study pitch tent with the supporters of time-varying anomalies inherent in the AMH with more than 60% of the total windows boasting significant weekend or Friday effect, except in Nigeria and Morocco. Hence, the findings of this study support the submission of Urquhart and McGroarty (2014) who show that the behaviour of Monday effect changes over time using similar rolling window estimation of S&P 500 index in the USA. By capturing all the weekdays, our study extended Urquhart and McGroarty (2014) study, which only considered Monday effect in the USA.

SUMMARY AND CONCLUSION

The need for the examination of the changing behaviour of the calendar anomalies has become glaring since the advent of AMH. This study examines time-varying behaviour of the DOW effect in the selected African stock markets by exploring rolling window analyses of several alternative variants of nonlinear models of GARCH. This study ranks among the foremost studies to investigate time-changing calendar anomaly. Consequently, the study contributed to the growing knowledge on AMH by documenting how DOW anomalies have behaved over time in the selected African stock markets. We conclude based on the findings from rolling window GARCH analyses that the DOW calendar anomalies seem to disappear and reappear over time in the selected African stock markets. The effect appears to be stronger in JALSH, SEMDEX and TUSISE but weak in NGSEINDX and MOSENEW. The behaviour of African stock market follows the cyclical efficiency invented by the proponents of the AMH. Thus, it may be more appropriate to describe African markets as adaptive markets rather than inefficient markets. Our findings imply that calendar anomaly may not be an all-or-nothing phenomenon; in the spirit of Lo (2004), the DOW effect may not be a universal constant but may be time-varying and path-dependent. Hence, market participants may not view African stock markets as being anomalous in absolute form. It may be safe for investors to plan a flexible investment strategy to accommodate instability in calendar anomalies. However, investors need to ensure that anomalies in certain periods cover trading and associated costs before efforts are made to exploit it. In addition, since investment strategy will wax and wane as a result of the instability, the investors are faced with the task of determining the market condition or environment suited to the success of their trading techniques.

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OPTIMAL ASSET ALLOCATION OF DEFINED CONTRIBUTION PENSION FUNDS IN GHANA

Maxwell Baidoo Jnr, Charles Andoh and Godfred Alufar Bokpin

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ABSTRACT

The paper investigates asset allocation of defined contribution (DC) plan in Ghana using the Tier 2 Master Trust Occupational Pension Scheme (MTOPS) as a case study. The paper focuses on comparing optimal asset allocation solutions under quantitative restrictions and prudent person's principle, and further assesses the risk exposure of portfolio returns using Conditional Value-at-risk (CVaR). The financial market invested by MTOPS predominantly consists of six financial assets: government securities and bonds, corporate bonds, the money market, listed equities, other collective investments and open and close end funds. Returns are modeled as a geometric Brownian motion and simulated for 10,000 scenarios over a 50-year time horizon. Most MTOPSs violated some quantitative restriction guidelines. MTOPS allocated higher Master Trust Funds (MTF) in low-risk assets: government securities and bonds, T-bills and cash deposits. High-risk assets are found to outperform low-risk assets in the long-term. Only MTOPSs with large market share allocated considerably in high-risk assets: corporate bonds and listed equities. Investment returns of 20.93% with 12.43% average portfolio risk were obtained under prudent man's rule compared to investment returns of 20.56% with 6.79% portfolio risk under restricted optimization. Given the investment returns over time, CVaR for the total portfolio was 12.81% in worst-case scenario.

Maxwell Baidoo Jnr *(MPhil., PGDE, Bsc.) teaches mathematics at St. Augustine's College, Cape Coast, Ghana. He holds a BSc. Actuarial Science from University of Cape Coast and a Post Graduate Degree in Education (PGDE) from the University of Education, Winneba, Ghana. He also has Master of Philosophy in Risk Management and Insurance (MPhil) from University of Ghana Business School. Maxwell's research interests are actuarial practices in the financial sectors, risk management decisions, financial modelling, assets and liabilities of pension fund, as well as educational related topics that focuses on educational management and leadership and risk factors associated with educational policies.*

Charles Andoh *is the head of Department of Finance and teaches undergraduate and graduate level courses in Insurance and Risk Management at the University of Ghana Business School. He holds a BSc. Mathematics from the Kwame Nkrumah University of Science Technology and MSc. degrees in Mathematics and Financial Mathematics from respectively the Norwegian University of Science and Technology and the University of Kaiserslautern, Germany. His PhD is in the Natural Sciences obtained from the Mathematics Department at the Technische Universitaet in Kaiserslautern, Germany. Areas of research interests include risk evaluation in investment decisions, stochastic volatility modelling and product pricing.*

Godfred A. Bokpin *is an Economist and Professor of Finance. He earned his Doctor of Philosophy (PhD) in Economics from the Graduate School of Economics, Osaka University in Japan, Master of Philosophy Degree in Finance and B.Sc. (Admin) in Accounting with First Class Honours from the University of Ghana. Professor Bokpin combines three broad disciplines of accounting, finance and economics and the interrelations between them in his teaching and research that uniquely distinguishes his output. His research and advocacy have focused on pro-poor programs including sustainable development, inequality and climate change issues.*

Keywords: Defined contribution, Master Trust Occupational Pension Scheme, optimal asset allocation, Prudent Person, quantitative restrictions

INTRODUCTION

As we age through time, we may not be able to perform certain functions and activities we used to do. It is therefore imperative to plan during our working lives to mitigate any contingencies in the future that may require the meeting of financial obligations. The future of most pensioners especially in developing countries is characterized by inadequate financial preparation coupled with deteriorating health and longevity risks. Pension provides employees regular fixed-income amount or a lump sum after retirement age (Josa-Fombellida & Rincon-Zapatero, 2012). Ordinarily, pensioners are expected to live similar or better life as enjoyed during their active working lives in retirement. Josa-Fombellida and Rincon-Zapatero (2012) underscored the point that a good retirement plan helps in the reallocation of individuals' wealth from their working life to retirement.

Globally, pension has not only been a source of retirement income for pensioners, but also served as a source of national savings for the capital market due to its deferred-payment nature. Stimulation of private and public national savings, high economic growth through improved corporate performance and influencing of the stock and equity market volatility are some roles of pension fund investments in an economy (Thomas, Spataro & Mathew, 2014; Antón, Mu˜noz & Fernández-Macías 2011; Rezk, Irace & Ricca, 2009). According to Judd and Yin (2012), the Global Pension Assets Study (GPA) in 2012 by Towers Watson revealed that pension assets or investment grew by 3.9% on the average globally. The study further identified countries such as US, Japan and UK as having the largest pension assets markets relative to GDP (Gross Domestic Product) ratios of 58.5%, 12.2% and 8.7% respectively (Judd & Yin, 2012). The global outlook of pension today indicates robust and rapid growth of the world's pension system. Pension systems in developing countries including Ghana, have not only provided adequate retirement income for pensioners but have also introduced social protection systems (Stewart & Yermo, 2009). Some of these social protections are poverty reduction among the elderly, reduction of government cost of funding pensions and redirecting funds to other important sectors of the economy and encouraging national private and public savings.

The public outcry of public servant retirees on their inadequate retirement incomes and the harsh realities of an unstable economy in Ghana have been resolved by government's implementation of the TTPS (Three-Tier Pension System) reform (National Pension Regulatory Authority [NPRA], 2012). As a result of the reform, the current private pension fund is growing exponentially amidst allocation challenges. The fund has grown from 1% of GDP in 2012 to 4.5% of GDP in 2016 (NPRA, 2017). The fundamental challenge has been the untimely migration of the Temporary Pension Fund Amount (TPFA) onto the Assets under Management (AUM) fund amount for onward investments. However, the TPFA earns a minimal base rate interest from the Bank of Ghana (BoG) as returns on the TPFA before finally being transferred to the AUM fund managed by the pension fund trustees (NPRA, 2017).

One major challenge encountered after the reform is the issue of asset allocation subject to investment restriction by the NPRA. Given the volatile nature of Ghana's economy, these restrictions are aimed at deterring pension fund managers from allocating funds into more risky investments, and thereby closing the window for more diversified portfolio. However, Bodie and Davis (2000), pointed out that investors and portfolio managers will underperform if investment decisions largely depend on quantitative restrictions that lack the requirement for robust portfolio construction.

A more efficient way of taking optimal investment decisions for allocation of assets is the risk-based approach. Fund managers and trustees will make optimal asset allocation decision using the prudent person's rule. The first cohorts of the tier-2 occupational pension plan will receive their retirement income

lump sum in 2021. Will the fund achieve its objective of providing an improved retirement income for current active members with all the restrictions from the regulator on the activities of the fund managers and trustees? Are retirees better off under the risk-based approach of a prudent fund manager or trustee than the current arrangement?

Global research papers on optimization of asset allocation revealed that in the presence of a high-risk and a low-risk asset; the returns are correlated in the market (Haberman & Vigna, 2002). Chen, Sun and Li (2017) and Campbell, Chan and Viceira (2003) indicated that long-term bond portfolios depend largely on the impact of real interest rate risk with respect to other sources of risk. Studies conducted in the pension sector of Ghana have mostly concentrated on stochastic models and risk behaviour of asset classes' allocations of pension funds (Tee & Ofosu-Hene, 2017; Judd & Yin, 2012). Many studies on optimal assets allocation have been conducted on the defined benefit (DB) plans of SSNIT (Social Security and National Investment Trust). None has been conducted on defined contribution (DC) pension plan, which is privately managed by registered corporate trustees and supervised by NPRA. The focus of the paper is to investigate the optimal asset allocations of defined contribution pension plans in Ghana under quantitative restrictions and prudent man's rule. The study specifically limits its scope to the mandatory occupational pension scheme of the Tier-2 (Master-Trust Fund) for the formal sector in Ghana. The paper is motivated to investigate the government newly introduced pension reform that is intended to solve the problem of pension inadequacies with the quantitative restrictions to regulate the investment opportunities of fund managers. The paper also argues on the basis of the importance of the prudent man's rule and how it would serve the purpose of pension adequacy rather than the quantitative restriction strategy adopted by the government. The outcome of the study opens a new chapter for discourse on pension reform restrictions and inform policy makers on the impact of the restrictions on investments and pension funds. This would contribute to the body of knowledge on the comparative analysis between prudent man's rule and regulatory restrictions on investments on pension funds which is a navel dimension in the Ghanaian pension system.

THEORETICAL FRAMEWORK

The theories underlying the research paper are the prudent person's rule and regulatory quantitative restrictions based on the objective of the paper which is, to elucidate the nature and consequences of regulations on the asset portfolios. The main objective of a pension fund manager and trustees is to take optimal investment decision strategies on the allocation of pension fund assets under management. The objective of regulatory bodies in most countries, such as Ghana's NPRA, is to regulate the activities of fund managers and trustee and ensure that they take prudent investment decisions that would provide sufficient retirement incomes for active members who retire from the scheme. Again, the regulations ensure that a framework for legal provisions in respect of contracts, bankruptcy, fraud and corporate governance are put in place to formalize the plan (Booth, Chadburn, Haberman, James, Khoransanee, Plumb & Rickkayzen, 2005; Bodie & Davis, 2000). They argued that the government's intervention with regulation is only necessary when the operations of the market activities fail due to information asymmetry, eternality and monopoly to attain a Pareto optimal outcome. They further indicated that when competitive markets achieve efficient outcomes, there is no case for regulation.

These regulatory guidelines formulated by government for pension funds are referred to as quantitative portfolio restrictions which are simply quantitative limits on holdings of a given asset class. This means the government determines the holdings that are invested in each asset class subject to the levels of risk irrespective of the returns. Quantitative portfolio regulations and restrictions have been criticized because they lead to lower returns, are inflexible when necessary to adjust and adapt investment

strategies and tend to discourage competition among investors (Horváthová, Feldthusen & Ulfbeck, 2017).

For these reasons, most countries are moving away from the expensive but secure sponsoring of defined benefit (DB) pension plans to more sustainable defined contribution (DC) plans which give higher rewards but involve higher risks. It is important, however, to underscore the role of regulators whose main objective is to seek the interest of active members by giving guidelines and restrictions to fund managers on how investment decisions should be made. These restrictions have been identified by some studies as bottlenecks to optimal asset allocation by portfolio managers. The restrictions limit holdings of certain types of asset within the portfolio. Davies (2000) observed that though investment restrictions typically apply most strongly to asset allocation between instruments, they may also affect security selection. The nature of pension funds allows strategic asset allocation in the long-term, but for tactical asset allocation to meet the short-term needs of paying liabilities and cost of administrative expenses, these restrictions are necessary to regulate the activities of the fund. The alternative suggested by most studies is the "prudent person's rule". The prudent person's rule allows the fund manager and trustee to take optimal investment decisions without restrictions. The prudent person's rule was historically developed in common law jurisdictions, namely England and the US, via case law (Horváthová, Feldthusen & Ulfbeck, 2017). The legal restrictions on trustees' investment then were very conservative and preserved wealth instead of reproducing wealth. The evolvement of the markets and novel investment possibilities necessitated the need for open market investment to increase the wealth of investors.

Bodie and Davis (2000) argued that the prudent person's rule ensures adequate diversification, thus protecting the beneficiaries against insolvency of the sponsor and investment risks. It is advantageous for two basic reasons: firstly, fund managers are allowed to use risk-based measures to allocate resources in a more diversified portfolio in return for higher rewards and secondly, good investment decisions by fund managers provide adequate and sufficient incomes for pensioners in their retirement age. Prudent person's rule enjoins portfolio diversification and broad asset-liability matching (Davis, 2000). Goldman (2000) indicated that the logic of the quantitative restriction or "prudent investment" approach is that prudence is equal to safety, where security of assets is measured instrument by instrument according to a fixed standard. Prudent person's principle focuses on the behaviour of the person concerned such as the asset manager, the institutional investor and the process of decision-making (Davis, 2000). This involves the need to assess among other things, whether there has been a thorough consideration of the issues, a dearth of blind reliance on experts, and a thorough "due diligence" investigation in forming the strategic asset allocation. The same exercise is to be conducted before any change or variation to it. The institution would also be expected to have a coherent and explicit statement of investment principles. The prudent person's rule, in effect, allows the free market to operate throughout the investment process while ensuring, along with solvency regulations, that there is both adequacy of assets and appropriate levels of risk (Davis, 2000).

METHODOLOGY

Data Source

The research uses secondary data from financial reports of defined contribution Master Trust Occupational Pension Schemes in Ghana from NPRA. 23 data points from selected schemes were employed. Given the inconsistency in data as well as small size of the data obtained, data was simulated for 10,000 scenarios over 50-year time horizon using Monte Carlo simulation. The result of the simulation is presented in Table 2. Analysis of data for Table 1 was done with SPSS version 20 while Table 6 and Figure 1 was done in Excel. The rest of the data analysis was done in R.

Portfolio Returns Modeling

According to Chalabi and Wurtz (2015), the most common transformation yields arithmetric returns. It is defined at time t by

$$r_t = \frac{P_t - P_{t-1}}{P_{t-1}} = \frac{P_t}{P_{t-1}} - 1 \tag{3.1}$$

where P_t and P_{t-1} are the prices of the financial asset at time t and $t-1$ respectively. The aggregation of annual returns over period T is

$$r_T = \frac{P_T}{P_0} - 1 = \frac{P_T}{P_{T-1}} . \frac{P_{T-1}}{P_{T-2}} \dots \frac{P_1}{P_0} - 1 = \prod_{t=1}^{T} \frac{P_t}{P_{t-1}} \tag{3.2}$$

Let W_t be the portfolio wealth at time, t. W_t is given as

$$W_t = \sum_i P_{i,t} \tag{3.3}$$

The portfolio return at time, R_t, transforms as

$$R_t = \frac{1}{W_{t-1}} (W_t - W_{t-1}) \tag{3.4}$$

$$\begin{aligned} R_t &= \frac{1}{W_{t-1}} \left(\sum_i P_{i,t} - \sum_i P_{i,t-1}\right) \\ R_t &= \frac{1}{W_{t-1}} \left(P_{1,t} + P_{2,t} + P_{3,t} + \cdots + P_{N,t} - P_{1,t-1} - P_{2,t-1} - P_{3,t-1} - \cdots - P_{N,t-1}\right) \end{aligned} \tag{3.5}$$

$$\begin{aligned} R_t &= \frac{1}{W_{t-1}} \left(P_{1,t} - P_{1,t-1} + P_{2,t} - P_{2,t-1} + P_{3,t} - P_{3,t-1} + \cdots + P_{N,t} - P_{N,t-1}\right) \\ R_t &= \frac{1}{W_{t-1}} \left(P_{1,t-1} r_{1t} + P_{2,t-1}\, r_{2t} + P_{3,t-1} r_{3t} + \cdots + P_{N,t-1} r_{NT}\right) \\ R_t &= \sum_i^N \frac{P_{t-1}}{W_{t-1}} r_i = \sum_i^N w_i\, r_i \end{aligned} \tag{3.6}$$

where w_i is the allocated weights.

The price of financial asset especially on stock, follows a Brownian motion due to their leptokurtic nature. Brooks (2008) opines that returns follow a random drift. The return is modeled stochastically using the Geometric Brownian Motion (GBM). A process takes on geometric (also known as exponential) Brownian motion if its logarithm follows a Brownian motion (Reddy & Clinton, 2016). In other words, only fractional changes take place as random variation. The return on investment could be derived as

$$r_t = \text{In} \left(\frac{P_t}{P_0}\right) \tag{3.7}$$

Assume the price of stock or any investment instrument at time t, P_t, follows a geometric Brownian motion and Ito process, then

$$dP_t = \mu P_t dt + \sigma P_t dB_t \tag{3.8}$$

$\mu P_t dt$ is a non-stochastic or deterministic part that is the expected return from investment during a period of dt. $\sigma P_t dB_t$ is the stochastic part with constant part σ which is the volatility and a Brownian

motion process dB_t . The stochastic differential equation in (3.8) which is the Brownian motion with drift followed by investment returns could be solved using Ito's process to obtain the Geometric Brownian Motion. Given the generalized Ito's formula of function $G\ (P,t)$

$$dG\ (P,t) = \left(\frac{\partial G}{\partial P}\mu P_t + \frac{\partial G}{\partial t} + \frac{1}{2}\frac{\partial^2 G}{\partial P^2}\sigma^2 P^2\right)dt + \sigma P_t \frac{\partial G}{\partial P} dB_t \quad (3.9)$$

and using $G(P,t)$ as (3.7) where $G = Pe^{r(T-t)}$ is considered as the future price of investment at $T > t$. We obtain solution for (3.7) using (3.9) as

$$\frac{\partial G}{\partial P} = e^{r(T-t)} \quad (3.10)$$

$$\frac{\partial^2 G}{\partial P^2} = 0 \quad (3.11)$$

$$\frac{\partial G}{\partial t} = -rPe^{r(T-t)} \quad (3.12)$$

It follows by substituting (3.10), (3.11) and (3.12) in (3.9) that

$$d\left(Pe^{r(T-t)}\right) = \left(\mu Pe^{r(T-t)} - rPe^{r(T-t)} + \frac{1}{2}\sigma^2 P^2(0)\right)dt + \sigma P_t e^{r(T-t)} dB_t \quad (3.13)$$

$$d\left(Pe^{r(T-t)}\right) = \mu - r\left(Pe^{r(T-t)}\right)dt + \sigma P_t e^{r(T-t)} dB_t \quad (3.14)$$

$$d\ (G) = (\mu - r)Gdt + \sigma G dB_t \quad (3.15)$$

Just like in (3.8), G in (3.15) follows a geometric Brownian motion with G as the future price of financial asset with a growth rate of $\mu - r$, where the growth rate of G is the excess return over risk free rate. The total asset allocated in the chosen portfolio is

$$\sum_{n=1}^{6} X_{n,t} = A_t + C_t - (B_t + E_t) \quad (3.16)$$

where $t = 1, 2, \ldots$ The total portfolio is modeled as A_t, value of the fund at time t and contributions made at time wages of active members at time t, C_t, excluding paid out benefits, B_t and expenses incurred in running the fund, E_t. A_t, could also be described as the available asset for paying benefits. The forecast for future value of asset available is modeled as;

$$\text{Projected Value of Fund} = A_t \prod_{t=0}^{T}(1 + r_t) \quad (3.17)$$

Risk Exposure Measure

The paper adopted the Conditional Value at Risk (CVaR) which is also known as the expected shortfall for estimating the risk exposure of financial assets of pension schemes. The quantile $q_\propto$ is defined as:

$$q_\propto = min\ \{x: F_X\ (x)\ \geq \propto\} \quad (3.18)$$

where $F_X(x)$ is the $\propto$-quantile of X and X is a random number between 0 and 1.

CVaR of X quantity given the probability of error α is mathematically written as

$$CVaR_\propto(X) = q_\propto + \frac{1}{1-\propto} E(X - q_\propto)_+ \quad (3.19)$$

where X is the loss in the discrete form.

In the continuous case, the CVaR is

$$CVaR(X) = q_{\propto} + \frac{1}{1-\propto}\int_{q_{\propto}}^{\infty}(x - q_{\propto})f(x)dx \quad \text{(Promsilow, 2011)} \tag{3.20}$$

$q_{\propto}$ is the probability of loss and $f(x)$ is the probability of loss distribution function of X.

Portfolio Optimization of Assets

In line with the study objectives, optimization problem is solved both with constraints and without constraints. Let $x = (x_1, x_2, x_3, x_4, x_5, x_6)$ be return vector of government securities and bonds, corporate bonds, money market, listed equities, collective investments, open and close end funds respectively. Let $w = (w_1, w_2, w_3, w_4, w_5, w_6)$ be the vector of weights for government securities and bonds, corporate bonds, money market, listed equities, collective investments, open and close end funds respectively. The objective function is formulated based on quantitative restrictions assumption as

$$\max \ (f(x) = w' \ x) \tag{3.21}$$

$$\text{subject to} \begin{cases} \sum_{i=1}^{6} w_i = 1 \\ \sum_{t=1}^{6} \sigma_t x_t = \sigma_A A_t \\ x_1 \geq 0, x_2 \geq 0, x_3 \geq 0, .., x_6 \geq 0 \\ w_1 \leq 0.75 \\ w_2 \leq 0.30 \\ w_3 \leq 0.35 \\ w_4 \leq 0.10 \\ w_5 \leq 0.05 \\ w_6 \leq 0.05 \end{cases} \tag{3.22}$$

A_t is the amount available for investment at time *t* and σ_t is the average risk of the portfolio a *t*. Weights assigned are based on NPRA investment limits.

Another objective function is formulated based on prudent man rule assumption (unrestricted by investment weights) as

$$\max \ (f(x) = w' \ x) \tag{3.23}$$

$$\text{subject to} \begin{cases} \sum_{i=1}^{6} w_i = 1 \\ \sum_{t=1}^{6} \sigma_t x_t = \sigma_A A_t \\ x_i \geq 0 \end{cases} \tag{3.24}$$

A_t is the amount available for investment at time *t* and σ_A is the average risk of the portfolio at *t*.

RESULTS, ANALYSIS, AND DISCUSSION

Table 1 : Correlation Matrix of Investment Returns of Financial Assets

	Government Securities	Corporate Bonds	Money Market	Listed Equity	Collective Investments	Open/Close end Funds
Government Securities	1					
Corporate Bonds	-0.372	1				
Money Market	-0.325	-0.020	1			
Listed Equity	0.277	-0.178	-0.182	1		
Collective Investments	-0.313	-0.222	0.292	-0.128	1	
Open/Close end Funds	0.319	-0.235	-0.328	0.801**	-0.301	1

**. Correlation is significant at the 0.01 level (2-tailed)

As indicated in Table 1, government securities and bonds have weak and negative correlation with investment returns from the money market, other collective investments, and corporate bonds. The negative correlation implied that fund manager invested in corporate bonds, the money market and other collective investments given a fall in investment returns on government bonds. This was because rewards from corporate bonds, the money market and other collective investment were more attractive. Investment returns on corporate bonds correlated negatively with government securities, listed equities, the money market, collective investments, and open/close end funds. This reflected the diversity among financial asset returns. This implied that, as investment returns on corporate bonds increase, fund manager shifted from other portfolios with lesser returns such as money market and other collective instruments to invest in corporate bonds and vice versa. It is, therefore, appropriate for portfolio managers to assemble negatively correlated financial instruments in other to mitigate risk of loss in the total portfolio.

Table 2: Distribution of Financial Instruments (in millions of Ghana Cedis)

Financial Assets	Average Returns (%)		Std Dev. (%)		Jarque-Bera
	Original[1]	Simulated[2]	Original	Simulated	
Government Securities	22.56	22.45	13.89	7.98	91.77 (0.0000)
Corporate Bonds	14.09	13.47	8.14	46.77	16.29(0.0003)
Money Market	18.95	18.88	8.46	4.86	52.72(0.0000)
Listed Equities	17.10	16.85	39.70	19.93	28.17(0.0000)
Collective Investments	14.74	14.67	9.38	5.34	26.92(0.0000)
Open/Close-end Funds	16.13	16.05	10.78	6.19	70.67(0.0000)

Notes

[**]Averages for financial asset allocations from original 23 data points of MTOPs.

[2]Averages for financial asset allocations from 10,000 simulations.

Table 2 shows the distribution of financial assets and the comparative analysis between the original values of returns on data and simulated values of the raw data. Due to inconsistency in data and

[**] Table 2 presents averages and standard deviations of original and simulated values of data from MTOPs. The values are simulated using Excel.

few data points from individual MTOPS, data was simulated for further in-depth analysis. The preliminary analysis showed significant for all return averages for the various asset classes in a Jarque-Bera test. This implied that average returns for the entire asset classes were not normally distributed which is typical of financial data. The leptokurtic nature of returns necessitated the modeling of returns in GBM before simulating 10,000 random numbers. The results showed slight variances in values between the original and simulated data. The differences are due to variance in time.

Table 3: Optimal Asset Strategy for MTOPS with Restrictions

Financial Asset	Weights of Returns (%) Portfolio Return (μ) and Risk (σ) $\mu = 20.53\%$ $\sigma = 6.74\%$	$\mu = 20.49\%$ $\sigma = 6.73\%$	$\mu = 20.56\%$ $\sigma = 6.73\%$	$\mu = 19.31\%$ $\sigma = 14.27\%$
Government Securities	55	55.09	55.11	43.01
Corporate Bonds	0	0	0.08	17.48
Money Market	35	34.99	34.99	32.99
Listed Equities	0	9.83	0.81	3.89
Collective Investments	0.05	0.047	4.75	1.44
Open and Close end Funds	0.05	0.049	4.98	1.48

Table 3 presents the optimal solutions for MTOPS under quantitative restrictions subject to full investment and long only strategies assumptions in R. This presents optimal solution for setting an objective to fully maximize investment returns when all the six financial assets are invested in. The result indicated that MTOPS managers must invest 55.11% of MTF in government securities and bonds. The result further revealed that fund managers must invest 0.08% in corporate bonds, 34.99% in the money market (T-bills and other forms of cash deposit), 0.81% in listed equities, 4.75% in other collective investments and 4.98% in open/close end funds. For the purpose of comparative analysis, the optimal solution for MTOPS in Ghana based on prevailing return averages for each financial asset was determined. The result indicated that MTOPS were operating at a maximum investment returns on assets of 19.31% at a higher risk of 14.27% given the current 43.01% in government securities and bond, 17.48% in corporate bonds, 32.99% in the money market, 3.89% in listed equities, 1.44% in collective investments and 1.48% in open/close end funds.

Table 4: Optimal Asset Strategy for MTOPS without Restrictions (Diversified)

Financial Asset	Weights of Returns (%) Portfolio Return (μ) and Risk (σ) $\mu = 18.57\%$ $\sigma = 6.67\%$ Portfolio 1	$\mu = 19.85\%$ $\sigma = 13.27\%$ Portfolio 2	$\mu = 20.93\%$ $\sigma = 12.43\%$ Portfolio 3	$\mu = 18.44\%$ $\sigma = 20.46\%$ Portfolio 4
Government Securities	41.70	55	70	40
Corporate Bonds	0.000026	12	10	30
Money Market	11.28	18	10	15
Listed Equities	1.41	10	7	10
Collective Investment	44.23	2.5	1.2	2.5
Open/Close end Funds	1.39	2.5	1.8	2.5

Table 4 displays the optimal solutions for unrestricted allocation of assets in four different portfolios by selecting from six asset types. Portfolio 1 indicated that fund managers earn an average investment return of 18.57% at a minimal risk of 6.67%. The risk is comparatively small due to more investments in less risky assets. The objective of Portfolio 2 was to invest more than 90% of MTF in top two risky and other two less risky assets. Hence, higher weights were assigned to corporate bonds and listed equities in relative terms. The result indicated 19.85% investment return on Portfolio 2 with a significantly high risk of 13.27% relative to risk in Portfolio 1.

Portfolio 3 was created apportioning higher weight to financial assets with the highest rate of investment returns. The result indicated an investment return of 20.93% with 12.43% average portfolio risk. Even though the investment return earned was higher than optimal solution obtained from the restricted portfolios in Table 3, the risk of losing part of the return was higher. Finally, Portfolio 4 invested fully in risky assets based on the NPRA investment limits. The investment return on Portfolio 4 was 18.44% with a risk of 20.46%.

The result of the optimization indicated that fund managers could operate at optimal levels without restrictions while obeying the regulations of the NPRA. However, such portfolios were risky as indicated in Table 4. Again, even though fund managers could operate using the prudent man's rule, it must be stated that such portfolios are riskier than portfolios created using quantitative restrictions. Davis (2000) indicated that prudent person's rule was superior to quantitative restrictions for pension funds except in certain specific circumstances. This is because fund managers are allowed to invest given a certain level of risk in high return assets. The situation may be slightly different when restrictions are binding in asset allocation. Papaioannou and Rentsendorj (2015) argued that investment performance critically depended on its permissible asset classes, risk tolerance and strategies mandated in attaining the set portfolio objectives, such as stability of returns over an assumed time horizon. They added that, to achieve a long-term investment objective portfolio, appropriate asset weights rebalancing may allow for higher returns.

Horváthová et al. (2017) added that under the prudent person's principle, the approach towards investments is liberalized, and it is of best interest to beneficiaries of pension funds. It is, however, associated with higher risk, which is unfavorable for developing economies. A comparison of the optimal solutions under quantitative restrictions and unrestricted optimization showed that the unrestricted optimization was superior to the restrictive optimization. This confirms evidence from the European Commission (1999) that using only quantitative restrictions for optimization of asset allocation and security selection results in suboptimal return and risk taking.

Table 5: Conditional Value at Risk for Financial Asset Returns and the total Portfolio of MTOPS

Risk Exposure of Returns	Govt. Sec.	Corp. Bonds	Money Market	Listed Equities	Collective Investment	Open/Close end Funds	Total Portfolio Risk
CVaR (95%)	0.0932	-0.6355	0.1088	-0.1598	0.0587	0.0589	0.1281
CVaR (99%)	0.0878	-0.6670	0.1056	-0.1733	0.0551	0.0546	0.0953
CVaR (99.9%)	0.0868	-0.6728	0.1050	-0.1757	0.0545	0.0537	0.0874

As indicated by table 5, given 95% confidence level, 9.32% returns on government bonds and securities investment is lost in the worst-case scenario. The worst-case scenario return on government securities and bonds given 99% and 99.9% confidence levels are 8.78% and 8.68% respectively. The CVaR of corporate bonds returns given a confidence interval of 95% was – 63.55%. Given a confidence interval of 99%, the investment returns on corporate bond lost in the worst-case scenario is given as – 66.70%. The worst-case scenario at a confidence interval of 99.9% is – 67.28%. The negated percentages

are because of the negative part of the distribution. This confirms corporate bonds as a risky asset. The money market is expected to lose 10.88% of investment return in the worst-case scenario at 95% certainty. Given confidence levels of 99% and 99.9%, the investment is likely to lose 10.56% and 10.50% respectively in the worst-case scenarios. Listed equities are expected to lose -15.98% of investment return in the worst-case scenario at 95% certainty. Given a confidence levels of 99% and 99.9%, the investment is likely to lose -17.33 % and -17.57% respectively in the worst-case scenarios.

Other collective investment is expected to lose 5.87% of investment return in the worst-case scenario at 95% certainty. Given a confidence level of 99% and 99.9%, the investment is likely to lose 5.51% and 5.45% respectively in the worst-case scenarios. The open/close end fund is expected to lose 5.89% of investment return in the worst-case scenario at 95% certainty. Given confidence levels of 99% and 99.9%, the investment is likely to lose 5.46% and 5.37% respectively in the worst-case scenarios. The total portfolio risk exposure is 12.81% at 95% confidence level in the worst-case scenario. Given a confidence levels of 99% and 99.9%, the total portfolio investment is likely to lose 9.53% and 8.74% respectively in the worst-case scenarios. This collaborates the finding of Chen, Sun, and Li (2017) that corporate bonds and equities are high-risk assets. They suggested that significant proportion of pension assets should be invested in direct equity investments, bonds and stocks. This is because they yield higher returns in the long term than low risk assets.

Table 6: Projected MTOP Fund Values (in GHS)

Year	Time Horizon	Scenario 1 (Best Case)	Scenario 2 (Worst Case)	Scenario 3 (Sector Average)	CVaR (95%)
2018	-	961,147,112.6	879,673,578.6	943,902,426.9	-
2021	**3 years**	**1,116,829,559**	**925,078,391.3**	**1,079,667,011**	**0.0601**
2026	8 years	1,479,052,024	1,011,634,659	1,401,193,093	0.0636
2031	13 years	2,032,222,975	1,114,087,083	1,902,676,386	0.0661
2036	18 years	2,885,799,721	1,235,561,571	2,695,913,521	0.0662
2041	23 years	4,212,797,904	1,379,934,987	3,970,876,908	0.0687
2046	28 years	6,287,013,399	1,551,682,507	6,059,331,523	0.0794
2051	**33 years**	**9,540,507,329**	**1,756,234,114**	**9,555,455,872**	**0.0897**
2056	**38 years**	**14,656,615,701**	**2,000,186,708**	**15,557,495,728**	**0.1058**
2061	**43 years**	**22,717,311,113**	**2,291,362,629**	**26,157,768,833**	**0.1084**

Based on the current average of portfolio investment returns of MTOPS, the expected amount is GHS 943,902,426.9. The fund value is expected to grow from GHS 961,147,112.6 to GHS 1,116,829,559 in 2021 for the best-case scenario and from GHS 879,673,578.6 to GHS 925,078,391.3 in the worst-case scenario with the risk of losing 6.01% of the investment returns in the worst-case scenario at 95% confidence level. Based on the current MTOPS weights, the expected fund value will grow from GHS 943,902,426.9 to GHS 1,079,667,011 in 2021. Interestingly, the current average exponentially outgrows the expected growth in the best-case scenario from 33 years and beyond. The fund will grow from GHS 6,287,013,399 in 2046 to GHS 9,540,507,329 in 2051 in the best-case scenario with risk exposure of 7.94% while the sectorial average is expected to grow from GHS 6,059,331,523 in 2046 to GHS 9,555,455,872 in 2051 with risk exposure of 8.79% with 95% certainty in the worst-case scenario.

Intuitively, the fund amount in the Scenario 3 outgrows the fund amount in Scenario 1 from 2046 to 2051 due to the accumulation factor cumulating from allocating higher weights in risky assets that are expected to yield higher returns in the long term. Due to the high risk associated with financial assets such

as corporate bonds and listed equities, MTOPS who are likely to invest in such risky assets will experience marginal investment return losses. However, risky assets losses are stabilized over time, earn higher returns to overcome portfolios that are likely to invest only into risk free assets during the accumulation period. This explains why large MTOPSs in terms of market share, such as Petra and Enterprise Trust, invest considerably in risky assets. However, small funds allocate smaller weights to risky assets due to investment risk to build up capital that could be used to invest in risky assets in future. The CVaR values also indicate that as the fund grows, the risk exposure increases. The figure below displays the trend in the growth of fund values.

The result of the paper confirms the result of Chen, Sun and Li (2017) that time horizon has significant effect on asset allocation of pension fund. The longer the time horizon, the more significant the effect on asset allocation of pension fund. Equity investments and stocks of pension funds perform better in the longtime.

Scenario 1 exceeds the fund value of Scenario 2 and fund value of Scenario 3 marginally. The difference in fund values between Scenario 1 and Scenario 2 begins to widen significantly after 2021. This is due to the cumulative performance of funds with respect to accumulation factor that is expected to grow exponentially. The losses made in the worst-case scenario in Scenario 2 reduce the growth rate of the fund value. The difference between the growth in Scenario 1 and Scenario 3 is fundamentally derived from the allocations assigned to each of the financial instrument. Empirical studies show risky assets result in capital losses in early investment period. However, the high returns yielded on risky assets in the long term builds up appreciable accumulation factor that exponentially outgrows portfolios created with less risky assets.

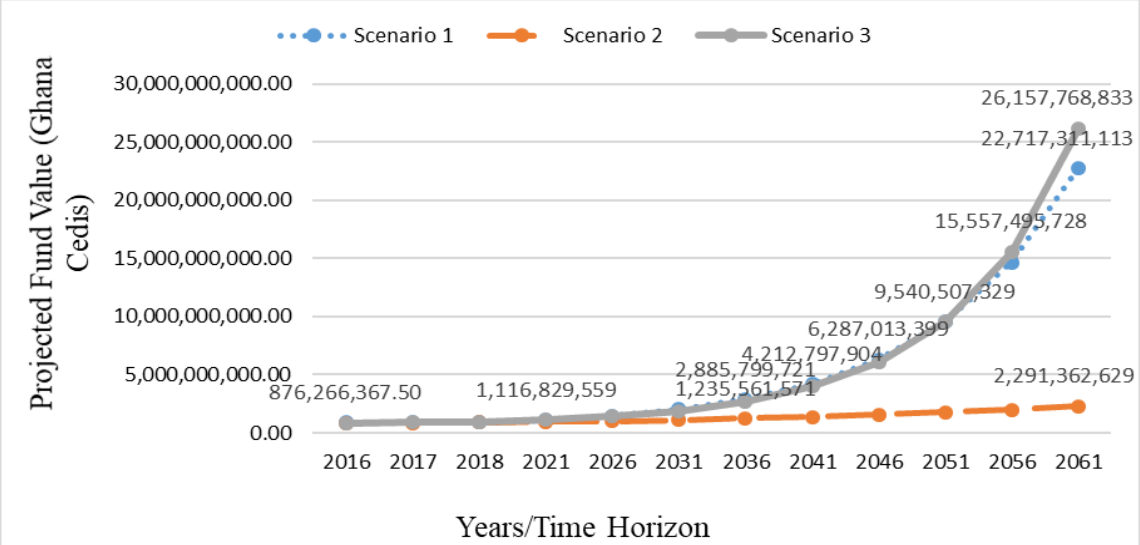

Figure 1 Projection of MTOPS Fund Values (2016 - 2061)

As confirmed by Papaioannou and Rentsendorj (2015) investment performance critically depended on its permissible asset classes, risk tolerance and strategies mandated in attaining the set portfolio objectives, such as stability of returns over an assumed time horizon. Time horizon significantly influences asset allocation of pension fund. Longer time horizon significantly influences asset allocation of pension fund. If the time is longer, more allocation to stock and equity investments helped pension fund to achieve better performance (see also Chen et al., 2017). From a similar theoretical perspective, Davies (2000) compared portfolio regulations to prudent man's rule for life insurance and pension in UK. He asserted that institutional investors are assumed to make long-term investments using the prudent

person's rule. He found quantitative restrictions to be less superior to prudent person rule for pension funds except for certain specific circumstances.

Although general restrictions were desirable for life insurance than pension funds in most cases, using the prudent person's rules were more appropriate for pension funds. Similarly, Cuthbertson, Nitzche and O'Sullivan (2008) asserted that the performance of firms improves when managers adopt skills and expertise rather than rely on mere luck. Adopting the appropriate skills by MTOPS fund managers to allocate assets strategically would enable pension fund value to increase astronomically to meet the objective of the reform. This could be done through strategic allocation of more assets in high-risk asset based on financial market indicators. Skilled managers produce risk adjusted excess return large enough to cover the expenses imposed on the investor through prudent person principle (Cuthbertson, Nitzche, & O'Sullivan, 2008).

CONCLUSION AND RECOMMENDATIONS

Majority of MTOPS in Ghana on the average, violate the investment restrictions guidelines by exceeding investment limits in most of the portfolio investment. The approved and permissible financial assets investment correlated negatively. The advantage of the negative correlation is diversification of risk exposure. This implies that MTOPs should carefully select financial assets that are negatively correlated in terms of investment returns into a pension fund portfolio. This reduces the long run risk of losing investment returns. MTOPS generally allocate higher proportion of pension fund assets in government securities, followed by money market and corporate bonds. Proportion of assets into collective investments, listed equities, and open/close end fund portfolios were smaller. At optimal levels, portfolios with investment restriction maximize returns with less risk exposure while returns on unrestricted portfolios are slightly higher but associated with high-risk exposure. The implication is that high-return investment is associated with higher risk exposure. The growth of Master Trust Fund is dependent on strategic asset allocation and tolerable level of portfolio risk. Risky assets increase their investment returns exponentially and build up appreciable accumulation factor during the accumulation period that can significantly increase fund values over time.

NPRA should properly supervise the allocation strategies of Corporate Trustees and fund managers through risk-based assessments and ensure that the practices of MTOPS conform to the rules and regulations of the Pension Act 766. NPRA as part of their investment guidelines should set minimum investment restrictions that would ensure that MTOPS diversify their investment portfolios to include reasonable level of risky assets that may earn higher returns than risk-free assets. This would discourage MTOPS that invest large proportions of their MTF into government securities and bonds and the money market to invest in listed equities and corporate bonds that increase fund values significantly in the long term. NPRA should also allow to some extent, fund managers to use their discretion and risk-based approaches to allocate assets in high yielding investment to ensure significant pension for pensioners in the future. Lastly, fund managers should be encouraged to use scientific and risk-based approach to invest in lucrative portfolios rather than the current practice of shifting from one asset to the other that yields higher returns at the beginning of each year.

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PONZI SCHEMES AND RURAL HOUSEHOLD OVER INDEBTEDNESS IN NIGERIA: INCIDENCE, DRIVERS AND LINKAGES

Jude Kenechi Onyima

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ABSTRACT

Over-indebtedness has emerged as a major factor that entrapped many rural households in poverty and a major cause of depression and rural suicide. Extant literature identified exogenous and endogenous drivers of over indebtedness but social and relationship factors that drive over indebtedness especially in developing country contexts have received limited attention. How these debts are accumulated as well as events that drive rural households into indebtedness need to be understood in order to address the negative implications of over-indebtedness. The objective of this study is to examine the incidence and drivers of over indebtedness among rural households in Nigeria as well as how participation in Ponzi schemes contributed to such rise in household consumer debt. The area of study is rural Southern Nigeria in which over 80% were poor. Households that participated in Ponzi schemes were identified using snowballing technique out of which 320 household heads were randomly selected as sample. Questionnaire was the instrument of data collection and data generated were analyzed using financial formulas and correlation coefficients. Findings revealed that incidence of over indebtedness was significantly high in Nigerian rural households owing to participation in Ponzi schemes, paying medical bills, house related cost, education of children, sending relatives abroad and cost of litigations. Ponzi scheme participants which cuts across sex, age, education and professional barriers were attracted by lure of affinity groups and speculation. They lost huge amount of money much of which was borrowed from family, friends and self-help groups; fueling the level of over indebtedness in rural areas. It is recommended that strict regulation of online and offline financial services should be enforced and financial literacy campaign should be pursued vigorously to reduce irrational and imprudent behavior. Initiatives in form of health insurance, effective mortgage market and educational support should be implemented in order to reduce the incidence of over indebtedness in rural areas.

Keywords: Ponzi Schemes, indebtedness, financial literacy, Nigerian economy

INTRODUCTION

Household indebtedness has been growing especially in developing economies (Barber and Pivetti, 2008). Recent studies in South Africa, Kenya, India and many developing nations revealed that

Jude Kenechi Onyima *is a senior lecturer at the Faculty of Management Sciences, Nnamdi Azikiwe University, Awka, Nigeria. He holds a Ph.D. from Nnamdi Azikiwe University specializing in Cooperative and Rural Finance. Jude has over twelve years of experience in teaching, research and consultancy. He is a two time recipient of IMTFI research grant for studies on financial practices of adolescent girls and rural women. Jude has served as consultant to some youth entrepreneurship programmes in Nigeria and has published numerous articles in scholarly journals.*

there is sustained increase in the indicators of over-indebtedness (IMF, 2012; Dynan and Kohm,2007). Rising household debt is not necessarily a problem as long as it is sustainable. Debt becomes a problem when it leads to over indebtedness. In many developing nations, more than half of credit active consumers are struggling to meet their debt repayment (South Africa Reserve Bank, 2007).Despite the belief that sustained increase in debt among households could mean well for an economy, such increase if unabated spells doom for poverty reduction efforts and achievement of sustainable development goals. As Colombo (2014) observed, unsustainable increase in consumer debt creates systemic vulnerability. When consumers become over indebted, there will be default resulting in lenders making losses in their portfolio. This will affect employment, prices and level of demand.

Household over indebtedness exist when households are having persistent challenge in meeting their commitment towards their secure and unsecured debts (Kreanda, 2018). Households do not suddenly become over indebted; there are usually series of events that drive indebtedness. Extant literature classified drivers of over indebtedness into exogenous and endogenous factors. Exogenous factors are macroeconomic factors that are beyond the control of households such as cost of living, income level, employment conditions and structural changes in the economy. Endogenous factors include wrong economic behaviors, financial illiteracy, and personal factors that create chances of indebtedness (Du Caju et al, 2016). Over indebtedness usually starts when households take up secured or unsecured debt. Owing to unforeseen circumstance or poor decision, the accumulating liability of the principal and interest becomes overwhelming, creating the need to get another loan. As a result, large percentage of income is spent on repayment of debt.

Unlike urban communities where rising consumer debt could propel economic growth by increasing consumption and investment, increase in rural indebtedness portends danger. In Nigeria just as in many developing economies, majority of rural dwellers depend on agriculture and labour is their principal asset (Barbie and Lopez, 1998). Significant proportion of people in rural areas are poor. CBN (2016) defined poor households as those families who lack sufficient resources to live at a standard considered normal in a society. A large percentage of poor households in developing countries are engaged in farming. Since farming nurtures and shapes the rubrics of rural society, whatever affects farming also affects the rubrics of rural society. Rural over indebtedness is therefore a cause and effect of widening poverty gap. There are harmful economic, social and political consequences of over indebtedness. As Radhakrishma et.al (2007) observed, over indebtedness was the major cause of farmers' suicides. Rural debt unlike urban debt has social-cultural identity and because these debts came from friends, family and solidarity groups, they cannot be settled with bankruptcy or write off as done in urban credit system.

Gathergod (2012) observed that irrational participation in consumer credit market creates indebtedness. He advocated for a shift towards financial literacy as a missing link in solving rural poverty problem. Lugard and Mitchel (2008) and Amerika et al (2007) equally noted that there is inverse relationship between self-control and debt accumulation. However, literature have not paid considerable attention to how the urge to meet societal expectations influence over indebtedness. A number of studies focused on macroeconomic factors and household income shocks as significant drivers of indebtedness ignoring the influence of financial imprudence. Indeed, many consumers especially in developing economies have low financial literacy (Brown et al, 2005). Many do not understand the true cost of poor financial decisions despite exhibiting behavioral pattern fueled by greed and ignorance. This shows that even when macroeconomic factors and household conditions are stable, some households could still be driven into debt because of irrational decisions. There is knowledge gap in research and policy on how behavioral pattern driven by greed and lure of affinity groups such as participation in Ponzi scheme contributes to household over indebtedness. In Nigeria, participation in Ponzi schemes reached a record high between 2015 and 2017 when the country, the largest economy in Africa, was plunged into recession (Biscaya et al, 2017). Different unorthodox financial schemes started gaining attention and interest of

citizens from legal ones such as betting and network marketing to illegal ones such as Ponzi and money multiplication schemes. According to Ebuka (2016), there were over ten Ponzi schemes that captivated the interests of many Nigerians with over three million participants and over $4billion exchanging hands. A Ponzi scheme is a fraudulent investment operation where the operator pays returns to its investors from new capital rather than from profit earned through legitimate sources. Dozens of Nigerians who patronized the Ponzi schemes immediately at commencement benefited immensely, leading to influx of customers into these schemes. Many Nigerians diverted loans and borrowed money from variety of sources to invest in these schemes. Sadly, a larger percentage were unable to get their principal and promised returns before the schemes collapsed (CBN, 2016).

Extensive studies have been conducted on macroeconomic factors (Kim et al, 2014), rural business related factors (Dutta, 2012), and household related factors (Oksanem et al, 2015) that drive over indebtedness. In contrast, social and relationship related factors that drive over indebtedness seemed to be neglected in the literature. How craving for social status, lure of affinity group and desire to meet up with societal demand drive over indebtedness have not been given considerable attention in literature. In developing economies context, social factors such as participation in Ponzi schemes, exotic marriage ceremonies and burial ceremonies, settlement of conflicts and urge to send relatives abroad contribute significantly to rural over indebtedness but these factors have been neglected in literature. Some researcher identified participation in Ponzi scheme as form of financial illiteracy but recent events revealed that participation in Ponzi schemes is not driven by lack of knowledge but by craving for social status and lure of affinity groups (Smith, 2015). Although some behavioral patterns have been identified as drivers of over indebtedness, sufficient analysis of how social and relationship factors drive over indebtedness is still lacking in literature. Using recent events that occurred in Nigeria as a case, this study explores the extent to which participation in Ponzi schemes impoverishes rural households. The objective of this study is to determine the incidence of over indebtedness among rural households that participated in Ponzi schemes; drivers and extent of participation in Ponzi schemes; and the linkage between participation in Ponzi scheme and household over indebtedness.

Addressing this gap is imperative because poor understanding of drivers of over indebtedness has made development of intervention strategies difficult. Participation in Ponzi scheme may not be an overarching question in developed economies because of effective regulatory and institutional framework. However, in developing country contexts, institutional corruption and novelties in digital and aggressive marketing techniques usually increase percentage of the population who become victims of Ponzi schemes (Guerin, 2006). These victims usually fail to recover their money, putting financial strain on their household, financial system and the economy at large. Poverty reduction efforts would not achieve expected result if this perennial epidemic is not addressed. Unhealthy participation in Ponzi schemes affect household welfare, increase rural suicide rate, reduces social cohesion and increases chase for speculative investment in place of productive investments. The impact on the economy is also encompassing; it can increase non repayment of credits and higher non-performing loans which affect the health of the financial sector; decreasing employment and general demand in the economy. The study will make theoretical contribution towards understanding causes of indebtedness by exploring social dimension of over indebtedness. It will give voice to those twice marginalized by structural inequalities prevalent in developing economies and by speculations in unauthorized schemes. It will also contribute to content development of financial literacy campaign of regulatory agencies.

This paper is arranged as follows: The literature review consisting of the conceptual framework, which explores how drivers of indebtedness such as participation in Ponzi schemes contribute to household over indebtedness. The study methodology; presentation of data; discussion of findings; conclusion of the study and recommendations.

LITERATURE REVIEW

Household over Indebtedness

Debt generally refers to as an obligation or liability arising from borrowing money or taking goods and services on credit (Prinsloo, 2002). Most debts in rural household debts fall under secured debt and unsecured debt. Debts are secured when there are collaterals like land and personal effect while unsecured debt means that the lenders have no claim on borrowers' assets. Household debt is rising because of increase in consumer debt (Schiicks, 2014). This is exacerbated by widening income gap, financial indiscipline and inability to manage financial shocks. In the views of Morgan and Christen (2002), the poor in a bid to keeping up with the Jones purchase goods, services and recognition, spending both monetary and social income. Fisher (1930) argued earlier that households borrow to augment current consumption. In other words, debt transfers consumption to the present. Betti et.al (2001) deepened the life cycle hypothesis arguing that debt is used over different stages of life cycle to stabilize consumption level. This means that individuals shift from one debt to another as they move from one life cycle to another. Since debt is targeted at current consumption, it does not depend on current income.

Household over indebtedness is defined by Hartfree and Collard (2014) as a condition where household members are unable to fulfill contractual obligations on consumer credits and household bills for consecutive periods. Indebtedness relates to imbalance or shortfall between income and expenditure. Households are considered over indebted if they are having on an ongoing basis difficulties in meeting their commitments whether these relate to servicing secured or unsecured borrowing, or to payment of rent or other household bills (O'Loughlin, 2006; Guteno, 2005). Indebtedness exist when available information shows that a consumer is unable to meet his/her credit agreement timely resulting to panic and stress. Fatoki (2015) differentiated being broke from over indebtedness, insisting that over indebtedness is persistent inability to meet financial obligations. According to him, indebtedness has three components: capacity, time and reduction in standard of living. An over indebted individual lacks the capacity to meet his short and long term financial obligations for a reasonable period of time and cannot do so without reducing his minimum standard of living despite resorting to his financial and non-financial assets (D'Allessio and Lezzi, 2013). O'Loughlin (2006) averred that indebtedness on its own relates to the level of debt accumulated through consumption whereas over indebtedness relates to a situation where expenditure to meet credit repayment is excessive compared to income. He concurred that forgetting to pay a bill which he called nonstructural arrears does not amount to indebtedness. In his view, indebtedness is structural arrears and occurs when an individual is indebted in the medium and long term.

Liv (2013) argued that a consumer is over indebted once his/her total debt is higher than the net income during a timeframe. He used net indebtedness index (which is equal to monthly installments on all debt minus monthly income) to measure who is indebted or not. Index above 100% shows insolvency, 76-99% shows that the consumer is at risk while less than 75% shows solvency. That means that indebtedness exists when a borrower makes frequent and unacceptable sacrifice to pay off loans that significantly affect his/her living standard. Although there could be variations in the levels and nature of the financial difficulties households face, months of arrears of payment on bills, defaults on rent and loan agreements are examples of indebtedness (Guteno, 2015). Income is the strongest predictor of

indebtedness. The lower the income the higher the risk of indebtedness. Households with income less than 60% of country's income average usually stand the risk of indebtedness. Bryan et.al (2010) observed that household debt is independently related to household income revealing that lowest income households are at greater risk of indebtedness.

Aside net indebtedness index, there are other measures of indebtedness. They include debt to income ratio, debt to asset ratio, proportion of household debts that are in arrears and debt service ratio (Schicks, 2014). Debt to income ratio which has become popular in recent times is defined by Finmark (2013) as percentage of consumer's monthly gross income that is spent on paying debt. Debt to income ratio is categorized into front end ratio which shows the percentage of income that is spent on mortgage related matters; and back end ratio which shows percentage of income spent on repaying other recurring debts. Debt to asset ratio is defined as percentage of asset that is financed by debt. This ratio reveals the financial leverage of households. Despite that high income households may have higher level of debt in nominal value, low income households have higher incidence of debt in real terms. According to Luttmer (2005), over indebtedness manifest when significant portion of household income is spent on loan repayment. Researchers have been unable to agree on threshold of proportion of income that would be spent on debt repayment before households would be considered over indebted. However, households that spend over 80 percent of their income on repayment of consumer debt within a particular time frame is considered over indebted (Bouquet et al, 2007). Financial vulnerability index can also be used to measure incidence of indebtedness. Vulnerability indices such as income vulnerability, savings vulnerability, expenditure vulnerability and debt service vulnerability can be used to understand incidence of debt on households.

Drivers of Indebtedness

Literature classified drivers of over indebtedness in many ways. However, exogenous drivers, which have to do with factors outside the control of household members, and endogenous factors which are factors within the control of household members are the major classifications. According to Guteno (2015) exogenous drivers include macro-economic factors such as income level, cost of living, financial shocks and sudden events such as death and loss of job. Endogenous drivers of indebtedness include wrong economic behaviors and poor financial choices by households. Fatoki (2015) classified drivers of indebtedness into three: macroeconomic shocks, financial imprudence and household income shocks. Macroeconomic shocks refers to factors in the general economy such as unemployment level, interest rate and demand level. Financial imprudence refers to poor understanding of financial concept and irrational behaviors. Household shocks refers to unexpected events in the household such as loss of job, death of breadwinner, flooding and illness. Naerum (2012) examined the demand and supply drivers of over indebtedness. Supply side consist of behavior of lenders in form of credit market practices, interest rate, competition, financial innovations and deregulation. Demand side consist of household impatience, consumption habit, ignorance and easy access to credit.

Significant number of macroeconomic factors that drive over indebtedness have been identified in literature. Betti et al (2007) observed that market failure and lack of access to formal credit drive over indebtedness. Their findings were similar to what Pandey et al (2005) discovered among Indian peasants that use of different borrowing sources increases chance of over indebtedness. In rural communities, where farming constitute major source of livelihood, over indebtedness is attributed to high transaction cost of credit (Rao,2005). Dutta (2012) identified high production cost, loan diversion, use of loans for unproductive ventures and presence of middlemen in farm market as drivers of over indebtedness in rural areas. Howley and Dillion (2012) in their study of over indebtedness among Irish farmers discovered that farm size and farming system contribute to over indebtedness. Bensoussan (2009) found out that change

in government policies, such as displacement of street vendors, political crises and shocks from foreign exchange market contribute to over indebtedness. Vandone (2009) discovered that amount of credit alternatives available and market information sharing channels drive over indebtedness. Meniago et.al (2013) observed that household debt is significantly affected by changes in household consumption, consumer price index and nations' gross domestic product. Singh (2010) identified rising healthcare expenditure as a significant driver of indebtedness in developing economies. According to Morgan and Christen (2002), inability of many households to manage financial shocks increases incidence of over indebtedness. Asogwa et.al (2007) who studied incidence of over indebtedness in Nigeria identified expansion of credit access, proliferation of unregulated finance-related businesses and divergent informal lenders as significant drivers of indebtedness.

Extant literature identified varieties of demographic factors that drive household over indebtedness. Bridges and Disney (2004) discovered that young people, less educated people and individuals with unstable jobs are vulnerable to over indebtedness. Hartfree & Collard (2014) and Disney et.al (2008) observed that being a tenant predisposes households to indebtedness. Kempson (2004) and Collard & Furry (2013) observed that part-time workers and families headed by unemployed household heads have higher propensity to becoming over indebted. Fatoki (2015) and Prinsloo (2002) concluded that households with many dependents, migrants and single parent households are at higher risk of becoming indebted. Especially in sub-Saharan Africa, Low income, drop in income level, health related challenges, relationship breakdown, poor financial management, low financial awareness, over commitment to credit and child raising have considerable influence on indebtedness position of households (Keese, 2009).

Certain behavioral patterns have emerged as significant drivers of over indebtedness. Kilborne (2005) discovered that over confidence bias and tendency to underestimate possibility of failure contribute to over indebtedness. His findings is apt as it explains why educated people become victims of Ponzi schemes. Schicks (2010) observed that making decisions based on imperfect information, inability to plan for long term and making strategic decision using proxies cause over indebtedness. Brown et al (2005) discovered that financial indiscipline and inadequate debt management skills drive households towards over indebtedness. In his 2006 study of how consumption pattern fuel over indebtedness, Roesch discovered that tendency to respond to advertisement and consumer trend as well as willingness to impress others contribute to over indebtedness. Brix and Mckee (2010) added that craving for 'easy money' and lack of self-control in resisting attractive financial offers contribute to over indebtedness. Guerin (2006) concurred that door to door solicitation and aggressive marketing techniques of some financial operators lure some households into over indebtedness. Luthmer (2005) discovered that societal pressure to help relatives and friends have pushed many households into over indebtedness. Other behavioral patterns that cause over indebtedness include large credit commitment, attitude to spending, impulsive buying behavior, consistent credit buying and poor savings habit (Bryan et.al, 2013 and European Commission, 2008). Bouquet et al (2007) in their study in Madagascar identified sudden drop in expected income caused by job or illness as driver of over indebtedness. Schicks (2014) in his study of over indebtedness in Ghana identified illiteracy and imprudence as major drivers of over indebtedness. His result is in line with other studies conducted in developing country contexts where weak institutions and ignorance fuel irrational financial decisions.

Effect of over indebtedness can be viewed from both household and macro levels. Blacklisted borrowers hardly get new loans and this situation exacerbates their vulnerability. Studies have linked suicide to over indebtedness (Sajad et. al, 2016).Over indebtedness leads to decline in general productivity, breakdown of marital relationships, insufficient savings and stressful old age. Over indebtedness adversely affect living standard by reducing disposable income and increasing the cost of servicing debt. According to Hartfree and Collard (2014), over indebtedness deepens poverty which in turn leads to social exclusion. Over indebtedness reinforces debt trap- a cycle in which people service

their debt but unable to pay the original principal borrowed (Ellison et.al, 2011). Indebted households are overwhelmed by financial difficulties live in isolation and stressful conditions (Schicks, 2010) depression and increase in crime. It limits the capacity of household to access competitive credit owing to poor credit history and constrained mobility of resources which cause strain on the financial system. Individuals in over indebted household are vulnerable to committing crimes and are usually depressed. At macro level, over indebtedness affects level of investments, weakens consumption, affects the financial system performance and weakens employment capacity (Asogwa et al, 2017).

Ponzi schemes and Nigerian Economy

Prevalence of pyramid and Ponzi schemes since 2013 in Nigeria is attributed to digital revolution, economic challenges and increased entrepreneurship awareness. The Nigerian economic recession in 2015 opened door for unorthodox financial schemes, both legal and illegal. In the view of Asogwa et al (2017), Many Nigerians who were looking for a way out of the massive hunger and lack that hit the economy during the recession got attracted to the outlandish promises of these financial schemers. Vanguard (2016) reported that more than 10% of Nigerian population participated in one or more Ponzi schemes between 2013 and 2017. These people were attracted by the influence of affinity groups, high rate of returns promised, aggressive marketing tactics of the schemers and its simplicity. Majority of Nigerians who participated in the schemes first benefited immensely, leading to mass movement of people into the scheme. Many people who wanted to make huge returns from the scheme committed their savings and took loans from various sources in order to participate in the schemes. Some students and businesses diverted their monies hoping to reap more than 30% returns on any amount invested within 30 days (Ebuka, 2015). High hopes were dashed when these Ponzi schemes collapsed one after the other.

A Ponzi scheme is a fraudulent investment operation where the operators which may be an individual or organization pays return to its investors from new capital rather than from profit earned through legitimate sources. United States Security and Exchange Commission (2016) defined a Ponzi scheme as investment fraud that involves payment of purported returns to existing investors through the fund contributed by new investors. Its history is dated back to an Italian businessman Charles Ponzi who developed a system that reward old investors through the fund generated by new investors. The system pays abysmally high returns to participant who simply does aggressive marketing for them and attract new customers. New entrants are enticed by extremely high return on investment in the form of short term payments that is unusually high but inconsistent. The scheme uses success of other investors to attract new investors into the system knowing that typically almost all earlier investors will return.

Krige (2010) sees Ponzi scheme as form of occult economy that thrives in speculation and gambling. He observed that the surge in the level of participation in high risk pyramid and money multiplication schemes which hitherto was for the marginal section of the society reveals that these schemes have become an expression of both expectation and dissatisfaction with a system. Little wonder many Nigerians did not heed to warnings, advice and propaganda by the government and regulatory authorities about participating in these schemes. Comaroff & Comaroff (1999) argued that unlike before when it is generally believed that participation in Ponzi is driven by greed and ignorance, participation is driven by structural issues in the socio-economic system which affect even the middle class and educated sections of the society. They observed that such high risk taking appear in different form such as money multiplication schemes, betting, gambling, network marketing and other fraudulent investment; gaining patronage of different segments of the population. Ponzi schemes often solicit new investors by promising to invest the fund in opportunities claimed to generate high returns with little or no risk. Since these schemes are not licensed or registered, it is difficult to prosecute them or recover the assets of investors. According to SEC (2013), these schemes utilize latest innovations, technologies, products or growth

industry to entice investors knowing that investors are skeptical of novel opportunities. Common features of Ponzi schemes include high returns, little or no risk, unregistered investment, secretive or complex strategies, no investor qualification, skepticism about paper works, roll over options in payment and grass root marketing through someone with shared affinity (Asogwa et.al, 2017; Krige, 2012).

Ponzi schemes that operated in Nigeria between 2014 and 2017 included Marrodi Mondial Moneybox (MMM), Ultimate Cycler, Zarfund, Icharity, Crowd Rising, Gethelp Worldwide, Givers forum, Twinkas, NNN Nigeria, Zigma, Paradise Payment and Naira donation. MMM, the most popular Ponzi scheme during the period dated back to Panteleeuch Marodi of Russia founded in 1989. It was declared bankrupt in 2003 but relaunched in Nigeria in November, 2015. The scheme promised 30% return on investment within 30days cycle to members and 10% of amount invested by new person who refers others to it. It operated in 27 countries with over 30 million members out of which over three millions were Nigerians. MMM crashed in January, 2016 (Ebuka, 2015). Ultimate Cycler was the second most popular Ponzi scheme in Nigeria. It was a peer-to-peer donation business model created by Peter Wolfing, a US-based network marketer. Over two million Nigerians participated in this 2x2 cycler scheme with direct member to member payment plan. Once an investor pays $25 to get his account activated, the system administrator will arrange four people who will pay the investor $25 each. The scheme crashed together with MMM.

These schemes are similar in operation, using aggressive marketing, influence of affinity group, digital technology and successes of earlier investors to gain trust and many Nigerians could not resist the 'temptation'. Ebuka (2017) observed that over $600million were lost to Ponzi schemes by Nigerians between 2014 and 2016 out of which over $200 million were borrowed funds. Participants in these Ponzi schemes cut across every segment of the society both the poor, the middle class, the educated, politicians, entrepreneurs and rural farmers. In the short-term, the scheme helped many Nigerians to earn income without productive means. However, its negative implications in medium and long term were dire. Aside contributing to over indebtedness, participation in Ponzi schemes stifles creativity, discouraged savings, increased vulnerability, exacerbated poverty and created negative attitude to risk and hard work. Krige (2009) concluded that these schemes are same as money multiplication schemes which are illegal since no product is bought or sold. Such schemes usually collapse once recruitment dries up. These schemes are considered harmful and unsustainable because there can never be enough investors to sustain the scheme for long time.

Ponzi scheme participation affected households in many ways. In the views of Ebuka (2016), it reduced the standard of living of many families, contributed to relationship breakdown and depression. Young people were drawn to crime and violence as many families lose their seed capital. Some micro enterprises collapsed, increasing financial burden and psychological trauma of few bread winners. CBN (2016) observed that participation in Ponzi scheme weakens the gains achieved in poverty reduction initiatives and create societal tensions between families.

The conceptual framework for this study focuses on understanding drivers of household over indebtedness in developing country context such as Nigeria. The framework argues that apart from macroeconomic and demographic factors, certain behavioral factors cause over indebtedness. Social factors such as the need to meet societal expectations and lure of affinity groups which manifest in participation in Ponzi schemes, exotic ceremonies, sending relatives abroad and litigations drive many households into over indebtedness. Some households participate in Ponzi schemes because of influence of friends and relatives. They borrowed money, diverted loans and utilized farm capital to invest in Ponzi schemes with hopes of exploiting opportunities. These schemes owing to their fraudulent nature usually collapse leaving households in debts. As households search for new loans to pay off the old debts, debt cycle sets in resulting in household over indebtedness.

Materials and Methods

The area of study was rural areas in Southeast and South-south regions of Nigeria where over 50million Nigerians live. The economy revolves around agriculture as over 80% of inhabitants depend on it. Over 40% of people in the study area live below the poverty line of $1.90 per day and literacy level is about 62%. Multi-stage sampling was used to identify probable respondents. In the first stage, five states that were agrarian in nature were judgmentally selected from 11 states in the area of study. In the second stage, two agrarian districts (Local government areas) were selected from each of the five states. In stage three, two rural communities were selected from each of the 10 districts. 320 Household heads who had participated in one or two Ponzi schemes were selected from the twenty communities selected. Snowballing technique and chain referral were used to identify the respondents. Out of the 364 respondents that were approached, only 320 agreed to participate in the study.

Descriptive research design was employed in this study so as to provide statistically inferable data. The focus of the study was not to provide new insight but to quantify and describe preexisting conditions. Questionnaire was the main instrument for data collection. However, respondents who do not wish to fill the questionnaire were interviewed and their responses were recorded in the questionnaire. Questionnaire method was chosen because of the size of respondents and also because of the nature of data required. This approach was supplemented by interview method to accommodate the views of respondents who would not be able to fill the questionnaire or those who preferred interview. The questionnaire contained questions on demographic characteristics, sources of debts/loans, reasons of taking loans/debt, length of arrears, frequency of participation in Ponzi schemes, reasons for participation in Ponzi schemes and sources of the money invested in Ponzi schemes.

Data generated were for four year period (2014 – 2017). Choice of the time period was informed by the need to capture the financial status of the rural dwellers before they participated in the Ponzi schemes as well as after the collapse of the schemes. Data generated were analyzed using percentages, financial computations and Pearson correlation analysis. Percentages were used to analyze some demographic data and to rank drivers of over indebtedness and participation in Ponzi schemes. Debt-income ratio and debt-asset ratio were computed by dividing debt by income and assets respectively. Aging of arears was computed by disaggregating the debts according to the time they became due (First quarter, within 12 months and after one year). Pearson correlation analysis was employed to test the relationship between participation in Ponzi schemes and over indebtedness.

Data Presentation and Analysis

Table 1. Debt incidence of respondents

Socio-economic characteristics	**Percentage of respondents**	**Debt-income ratio**		**Debt- asset ratio**	
Age		**2014**	**2017**	**2014**	**2017**
Less than 25 years	49	33	62	24	49
25 -40years	42	43	76	20	36
41-65years	7	40	52	18	27
Above 65 years	2	36	39	18	23
Sex					
Male	56	36	53	18	33
Female	44	39	58	22	37
Education qualification					

Tertiary	53	30	48	17	33
Secondary	44	35	57	23	45
Basic	03	43	64	27	51
Income level (Poverty line of $1.90)					
Below the poverty line	23	44	60	22	39
Close to the poverty line	71	35	56	20	36
Above the Poverty line	06	30	43	14	30
No. of dependents					
Less than 3 persons	37	35	51	17	33
4 – 7 persons	32	38	55	19	37
Above 7 persons	31	42	58	23	38
Job status of household head					
Full-time engagement	42	33	49	16	32
Part-time engagement	55	36	57	24	38
Unemployed	03	41	58	26	41
Livelihood source					
On-farm	27	43	50	27	31
Off-farm	36	39	56	23	39
Nonfarm	37	32	62	20	42

Table 1. revealed that majority of the respondents were young people who were less than 40 years old (91%). Fifty-six percent were male while forty-four percent were female. More than half of the respondents attempted tertiary education and 97% of them were literate. Ninety-four percent of the respondents live either below the poverty line or close to the poverty line. Majority of them were into part-time job (55%) whereas forty-two percent were into full time job. Only twenty-seven percent of the respondents were farmers, the rest were into agriculture related businesses (36%) and white collar jobs (37%).

Incidence of indebtedness among respondents was measured by debt-income ratio and debt-asset ratio using 2014 as base year and 2017 as current year. Findings revealed that there was a significant difference in the indicators of debt incidence especially among young people, people below the poverty line and people who were not into full time employment. Both indicators depict similar trend showing over 40% increase in debt burden between 2014 and 2017.

Table 2. Aging of arrears of outstanding loans/debt

Source of the debt/loan	Percentage of respondents-borrowers	debt < 3 months (Naira)	debt 4 -12 months (Naira)	debt >12 months (Naira)
Family and friends	48	13,310	25,900	42,625
Cooperative societies	22	2,680	6,730	5,900
Microfinance Institutions	12	4,510	3,720	1,240
Informal lenders	09	6,390	5,835	3,480
Commercial banks	01	1,630	-	-
Self-help groups	13	4,730	7,960	28,600
Utility companies/bills	79	22,400	11,280	18,910

Table 2 revealed that major source of loans that became debt were families and friends (48%), cooperative societies (22%) and utility companies. Seventy-nine percent of the respondents owed household bills: electricity bills, school fees, litigation costs and medical fees. Micro finance institutions and informal lenders were also owed to a minimal degree probably because of their stringent measures against default. Only one percent of the respondent got loan from commercial bank which was paid within the first three months. It is important to note that whereas debt owed to utility companies, microfinance institutions and informal lenders were decreasing, debt owed to family and friend, cooperative societies and self-help institutions were increasing. This result reveals who borrowers would prefer to owe in times of financial difficulties. This attitude can help to explain the high incidence of default in cooperatives and self-help groups as well as why family lending is becoming chaotic in developing country contexts.

Table 3. Extent of participation in Ponzi schemes

Socio-economic characteristics	Percentage of 1st attempt	Percentage of repeat attempt	Maximum loss (Naira)		Maximum profit (Naira)	Net loss/Profit (Naira)	Percentage of annual income lost
Age							
< 25 years	47	49	(630,000)		490,000	(125,000)	38
25 -40years	42	44	(1,480,000)		750,000	(144,300)	47
41-65 years	7	5	(2,800,000)		1,450,000	(163,200)	55
>65 years	4	2	(2,610,000)		1,641,000	(182,610)	71
Sex							
Male	56	58	(2,800,000)		1,641,000	(156,500)	51
Female	44	42	(1,800,000)		1,450,000	(143,900)	58
Education							
Tertiary	59	51	(2,800,000)		1,641,000	(159,650)	46
Secondary	32	38	(1,800,000)		1,520,000	(162,400)	59
Basic	09	11	(1,260,000)		820,000	(165,300)	64
Income level (Poverty line)							
Below the line	26	29	(600,000)		310,000	(154,700)	68
Within the line	58	61	(1,320,000)		840,000	(169.950)	52
Above the line	16	10	(2,800,000)		1,641,000	(152,150)	47
No. of Dependents							
Less than 3	31	32	(2,800,000)		1,530,000	(162,400)	49
4-7	36	35	(1,40,000)		840,000	(168 500)	56
Above 7	33	33	(1,320,000)		750,000	(150,200)	62
Job status of household head							
Full-time	39	36	(2,800,000)		1,641,000	(163,100)	51
Part-time	48	51	(1,260,000)		840,000	(155,200)	57
Unemployed	13	13	(630,000)		310,000	(149,630)	66
Livelihood source							
On-farm	17	16	(600,000)		820,000	(152,200)	65

Off-farm	36	36	(1,320,000)		840,000	(157,750)	59
Non-farm	47	48	(2,800,000)		1,641,000	(167,430)	50

Note: Losses were written in bracket

Table 3. revealed that eighty-nine percent of participants in Ponzi schemes were young people(Below 40 year old). Whereas the percentage of young people that went for repeat attempt increased, the percentage of adults that did same decreased. There were more male participants than female in the first attempt and percentage of male participants that went for repeat attempt increased while that of female decreased. Interestingly, unlike previous belief that participation in Ponzi is driven by illiteracy as noted by (Krige, 2010); ninety-one percent of participants were literate. This is also because participation in the scheme requires computer and internet proficiency. Whereas the percentage of highly educated people who went for second attempt decreased, the percentage of less educated people that went for second attempt increased. Majority of the participants in Ponzi schemes were not people below the poverty line (26%) or people quite above the poverty line (16%) but people who were close to the poverty line (58%). They felt that participating in Ponzi schemes was an opportunity to pull out of poverty. The table also revealed that whereas people who were quite above the poverty line declined going for repeat attempt, the percentage of poorer household that went for the second attempt increased. Families with large dependents participated more than households with fewer dependents. Also, household heads on part time job status (48%) participated more that those on full-time jobs (39%). Thirteen percent of the participated were unemployed indicating that people were willing to borrow in order to participate. People who were in non-farm operations participated more followed by those in farm related businesses (36%). Only seventeen percent of farmers in the sample participated in Ponzi schemes.

The table revealed that although few people made reasonable returns from participating in Ponzi schemes, the venture on the average ended at a loss. Despite that some people made about 2,800,000 naira from the scheme, average participant lost 182,610 naira. Many people lost more than half of their annual income to Ponzi operators especially old people, females, illiterates, people below the poverty line and the unemployed.

Table 4. Drivers of over indebtedness and participation in Ponzi schemes

Drivers of indebtedness/ reason for accumulating debt	Reasons for participating in Ponzi schemes	Source of money used for Ponzi investment	Ranking of drivers of indebtedness and reasons for participating in Ponzi schemes
Medical/health related reasons	Make more money	Borrowed from family and friends	1st
Participate in Ponzi schemes	'Join the Jones'	Personal savings	2nd
Marriage/burial/social and ceremonial reasons	Aggressive marketing techniques	Self-help groups	3rd
Mortgage related reasons	Income growth	Thrift collectors	4th
Children education	Influence of trusted friends/relatives	Informal lenders	5th
Send relatives abroad	Attractive offer and lure of 'easy money'	Cooperatives	6th
Litigations	People I trusted joined	Micro finance Institutions	7th
Acquire productive assets	Satisfy curiosity	Sale of assets	8th
Business operations	Exploit opportunities	Employers	9th
Pay bills/ family upkeep	External and internal pressure to follow the	Suppliers	10th

	trend		

Table 4. revealed that major events that contributed to over-indebtedness were health related, participation in Ponzi Schemes and social reasons. Aside health related reason, other reasons revolve around need to meet societal expectations and lure of affinity groups. Apart from the need to make more money, majority of participants were motivated to participate in Ponzi schemes because of peer pressure, aggressive marketing tactics, and need to make more money. Findings revealed that participants did not get significant proportion of the fund invested in Ponzi scheme from commercial banks rather from their families and friends, their personal savings, self-help groups and cooperative societies.

Table 5. Pearson Correlation showing the relationship between indebtedness and participation in Ponzi schemes

		Amount invested in Ponzi Schemes	Total debt
Amount Invested in Ponzi	Pearson Correlation	1	0.691
	Sig. (2-tailed)		0.037
	N	320	320
Total debt	Pearson Correlation	0.691	1
	Sig. (2-tailed)	0.037	
	N	320	320

Table 5. revealed that there was reasonable positive relationship between level of indebtedness and participation in Ponzi schemes. This result was in line with reality in Nigeria, where a large percentage of fund invested in Ponzi were borrowed. The coefficient of correlation (0.691) indicates a significant relationship between the two variables.

Discussion of Findings

This study established that participating in Ponzi schemes exacerbates household over indebtedness by increasing the debt incidence of participants. In line with findings made in Krige (2010) and Barba & Pivetti (2008) incidence of debt is higher in households with large dependent, among farmers, people with unstable employment, young people, poorly educated people and women. Major events that contributed to indebtedness in these households were health related, participation in Ponzi schemes, meeting societal expectations, mortgage related requirements and for children's education. It is imperative to note that most times, the rural poor experienced overwhelming financial constraints such that most loans taken were usually diverted from productive use to dealing with emergencies (Schicks, 2014). This study affirmed that providing access to loans for rural households without mitigating the effects of other emergent demands such as medical bills, needs for shelter, and education of children will not pull the poor out of poverty. These findings underscore the importance of health insurance, effective mortgage market and affordable education in poverty reduction efforts (Sajjad et al, 2016; Singh, 2010). Credit plus package such as health insurance scheme will play significant role among rural populace than urban populace. It will reduce their vulnerability to financial shocks and enable them to use loans for productive purposes; minimizing loan diversion. The urgency of events for which loans were taken explains why most rural household obtain credit from expensive sources. This is because events like

paying rent, medical bills and litigations happen suddenly, giving borrowers little or no time to explore cheaper sources of loan.

Indicators of over indebtedness used in the study revealed similar trend, showing an unusual increase in debt burden between 2014 and 2017. The question has been what increased the debt burden? Although the country was plunged into recession during the period, most rural dwellers only felt the pulse of increase in price level. Pilot study conducted before the study revealed that there was significant difference in debt incidence of households that participated in Ponzi and those that did not. This study discovered that majority of people who participated in the Ponzi scheme lost huge sum of money up to half of their net worth. More than 80% of them borrowed the fund invested in the Ponzi; this increased the level of indebtedness (CBN, 2016). This loss was very high among old people, non-farm workers and less educated people who participated in the scheme for more than once. Older people invested more fund with less caution. Many people participated in Ponzi schemes because of imprudence and pressure to meet expectations of their affinity groups. Participants in Ponzi schemes cut across all segment of the population including the educated, the old, males, non-farmers, people above the poverty line and even the unemployed. This finding is dissimilar to previous findings in Amerik et.al (2007) which claimed that educated people do not usually participate in Ponzi schemes. This study confirmed that being educated is not same as being financially literate. Most of the borrowed fund that were invested in Ponzi schemes came from family and friends, cooperative and self-help groups; where terms of repayment were less stringent. Increasing abuse of these friendlier loan sources need to be addressed as it affects social cohesion which lubricates rural societies.

CONCLUSION AND RECOMMENDATIONS

The study affirmed that there are social factors that drive household indebtedness which have not featured significantly in literature. These factors include participation in Ponzi schemes, exotic ceremonies, litigations and sending relatives abroad. Incidence of over indebtedness among rural households that participants in Ponzi schemes was high confirming the assertion that there is significant correlation between participation in Ponzi schemes and over indebtedness. People participated in Ponzi schemes because of the need to make more money, to 'join the Jones', aggressive marketing tactics of the schemers, influence of trusted friends and pressure from peers. Funds invested in the Ponzi schemes were obtained largely from family, friends and informal sources; and these funds were not recovered from Ponzi operators. Unlike in previous studies where participation in Ponzi schemes were driven by sheer greed and ignorance, participation in Ponzi scheme in this was driven by lure of affinity groups, meeting societal expectation and influence of trusted friends. As a result, participants cut across the educated, the vulnerable groups and even elderly people.

Contribution of this study lies in identifying neglected drivers of indebtedness in developing country contexts. Literature have not identified participation in Ponzi schemes, litigations and sending relatives abroad as drivers of household indebtedness. These factors however have become significant and should be giving attention by scholars and policy makers. Quality and affordable education as well as availability of employment opportunities will reduce the urge to send relative abroad which has become a source of debt burden for rural households. Effective justice system with options for out of court settlement mechanism will also reduce the burden of litigation/conflict on households.

Based on this study, it is recommended that strong financial regulation that will monitor and supervise offline and online financial services should be put in place by public monetary authorities to curb the infiltration of Ponzi scheme operators. Financial literacy campaign need to be intensified by government agencies, financial institutions, civil societies and academia to minimize financial imprudence and poor money management. Households should understand the implications of 'joining the

Jones' and resist unnecessarily pressure from affinity groups. Government should initiate policies to address rising rural debt through friendly policies especially in form of health insurance scheme and effective mortgage framework. These suggestions will help to minimize household over indebtedness which contributes to depression, farmers' suicide and breakdown of socio-economic structures in rural areas.

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ASSESSMENT OF FINANCIAL LITERACY ON FINANCIAL MANAGEMENT OUTCOMES: EVIDENCE FROM THE SOUTH AFRICA EMPLOYED YOUTH

Mulatu F. Zerihun and Dinah M. Makgoo

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ABSTRACT

In South Africa there exists a quest for financial literacy to promote inclusive growth in the country. Financial illiteracy is one of the aftermaths of imprudence and financial mismanagement that are common among the South African youth. The empirical strategy adopts a logistic multivariate regression model. The empirical investigation of financial literacy and financial management outcomes in this study finds that there is a positive and significant relationship between the financial management outcome and financial literacy, gender, educational attainment and living standards., Financial management has a negative and relationship with household size. The findings on the overall financial literacy of the South African youth showed that, generally, individuals in all provinces have inadequate or low financial resources with an overall mean correct percentage score of 80.69. The individuals, however, exhibited some appreciable financial knowledge of savings and borrowing. It is important for policy makers to develop an effective education programme based on the needs and financial literacy level of the youth.

Key words: Financial literacy, financial management, logit model, South Africa, OLS, Saving, Investment

INTRODUCTION

The concept of financial literacy is differently understood by different people based on their status in life vis-à-vis the parameters of occupation, income level, etc. (Remund, 2010). It is the ability of individuals to make decisions to ensure their financial well-being. In addition, financial literacy entails the basic knowledge of key financial concepts or skills like the ability to calculate interest rates and prepare a family budget, attitude towards money, spending and saving, and behaviour to secure the financial future (Jang et al., 2014). Planning, budgeting and calculated spending are also termed as financial literacy (Lusardi and Mitchell, 2006).

Mulatu F. Zerihun (PhD, DBA) *is a Senior Lecturer in Economics and Acting Head of Department of Economics at the Faculty of Economics and Finance, Tshwane University of Technology, Pretoria, South Africa. He has published widely in areas related to Open Economy Macroeconomics, Development Economics, and Environmental Economics. He has been actively engaged in the supervision of postgraduate students as well as in collaborations with various international research projects with academic institutions in Africa and beyond.*

Dinah M. Makgoo *is a postgraduate student in the Department of Managerial Accounting and Finance at the Faculty of Economics and Finance, Tshwane University of Technology, Pretoria, South Africa. Her research interests include development finance and cost and management accounting.*

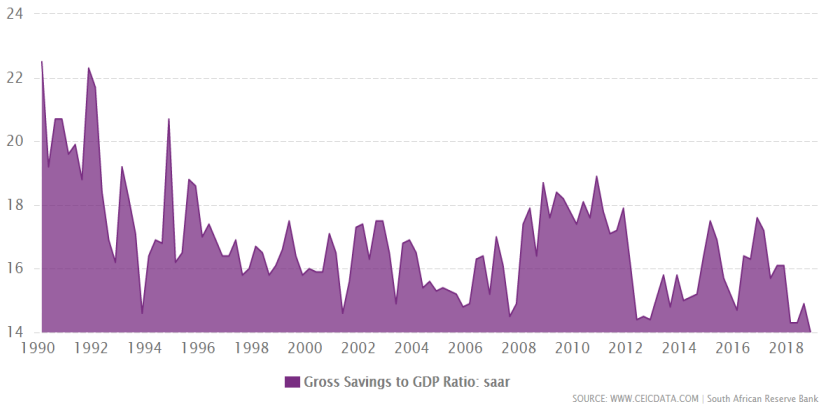
Financial literacy promotes better financial decision-making, thus enabling better planning and management of life events such as education, illness, housing purchase, or retirement. At the macroeconomic level, the individual's saving habit benefits the entire nation (Ali, Rahman, and Bakar, 2014). Financial literacy has a positive impact on the economy because funds that are placed in financial assets are channelled through financial intermediaries to make investments (Lusardi and Mitchell, 2005). Subsequently, investments by firms will ultimately benefit the nation through higher productivity and economic growth. Furthermore, high financial literacy can also hedge countries against economic downturns and financial crisis (Ali, Rahman, and Bakar, 2014). One of the avenues to boost national saving is by encouraging individuals to increase personal savings. This can be achieved by implementing financial education programmes to increase individual financial literacy.

The motivation for this study is the overwhelming spending behaviour of the South African youths, without the corresponding curiosity to invest. For instance, in 2010, about 37 percent of the 33 million South African adults were financially excluded i.e. deprived from access to financial services (OECD, 2012). Financial inclusion has become a crucial matter in South Africa because, as indicated by National Treasury (2011), many South Africans are not registered with the financial service providers. To the best of our knowledge, there is paucity of studies that have investigated the effects of financial literacy on financial management in South Africa. This study hypothesizes that financial literacy has significant effect on financial management outcomes. Therefore, the objective of this study is to examine the understanding and knowledge of financial management, saving and borrowing amongst employed South African youths. The next section presents the context of the study followed by literature review section. Section four presents data and research methodology. Section five presents empirical analysis followed by summary and discussions. The last section presents conclusion and policy implications.

CONTEXT

In South Africa the household saving rate is considerably lower than in many other developing and middle-income countries and has dropped consistently (Cronje, et.al. 2010; SARB, 2018). Cronje, et.al. (2010) mentioned that debts levels and individual consumption have increased significantly, mainly as a result of financial liberalisation and enlarged financial inclusion as illustrated in figure 2. The individual's character has been found to affect the financial outcomes relative to savings, in South Africa (Du Plessis, 2008; Chauke, 2011) and debt management (Prinsloo, 2002). The saving rate has also been declining for the last three decades, as shown in figure 1. This, therefore, calls for aggressive financial literacy campaigns in the country.

Figure1: Savings Rate in South Africa (1990 – 2018)

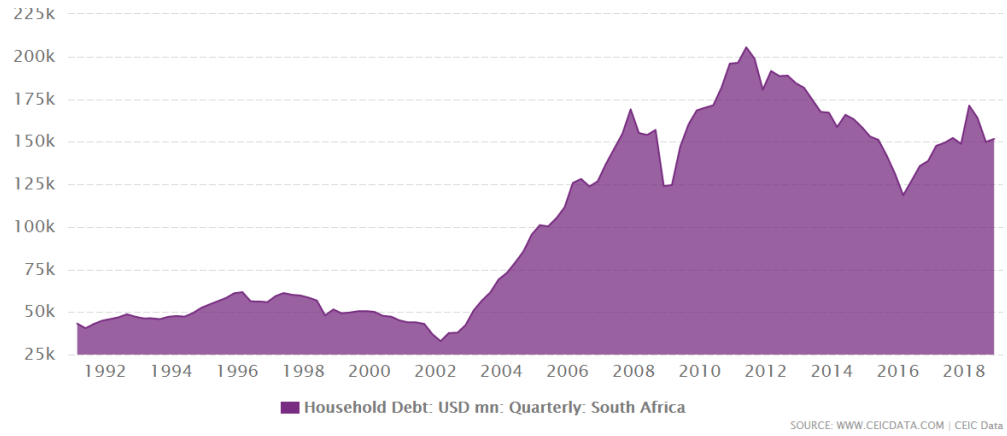


Source: South African Reserve Bank (SARB) (2018)

In South Africa, there exists the quest for financial literacy to promote inclusive growth in the country. According to the Financial Sector Conduct Authority (FSCA) (2011) and the Association for Savings and Investment South Africa (ASISA) (date missing) , promotion of consumer awareness, education and protection is essential., Financial literacy comes in handy when the economy is not strong and the individual's adequate financial knowledge and skills to survive are required (Fatoki,2014). In such instances the individual household strives to find a balance between meeting the immediate demands and saving for the future needs. Most individuals are faced with having to meet the most basic needs such as education costs, housing, transportation and health care (Atkinson and Messy, 2012) Therefore, to achieve good financial management, appropriate planning and budgeting are needed.

Lusardi (2008) observed that although the financial system is well developed in South Africa the financial products on offer are often complex and too difficult to be understand by members of previously disadvantaged groups who have had little access to formal education. Furthermore, South Africa is facing serious problems such as high unemployment rate, poverty, inequality and increase in the household debt over time.

Figure 2: South Africa Household Debt (1992 – 2018)



Source: South African Reserve Bank (2018)

Financial literacy indeed matters for all the nations as it challenges many nations across the globe. In most countries, even among developed countries, the level of financial literacy is generally low. Financial illiteracy has the potential to lead to financial crisis as observed in 2007/8 that started in the US and affected many countries in the world. Since the 2007/8 financial crisis, there has been an increasing number of studies analysing the likely impacts of financial literacy globally. According to Standard & Poor's ratings services global financial literacy survey (2015) globally; country-level financial literacy ranges from 71 percent to 13 percent. In Africa it ranges from 55 percent to 15 percent. In this range countries above 40 percent comprises; Botswana (52%), Tunisia (45%), South Africa (42%) and Zimbabwe (41%). For details see Table 1.

Table 1: Financial Literacy Index for African Countries

Country	**Financial Literacy Index**	**Country**	**Financial Literacy Index**
Algeria	33	Mauritania	33
Angola	15	Mauritius	39
Botswana	52	Niger	31
Burundi	24	Nigeria	26
Cameron	38	Rwanda	26
Chad	26	Senegal	40
Congo, Rep.	31	Sierra Leone	21
Côte d'Ivoire	35	Somalia	15
DRC	32	South Africa	42
Egypt, Arab Rep.	27	Sudan	21
Ethiopia	32	Tanzania	40
Gabon	35	Togo	38
Ghana	32	Tunisia	45
Kenya	38	Uganda	34
Madagascar	38	Zambia	40
Malawi	35	Zimbabwe	41
Mali	33		

Source: S&P Global Financial Literacy Survey (2015)

The next section presents the literatures reviewed and conceptual framework employed in this paper.

LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

Financial Literacy on Financial Management Outcomes

Financial literacy is a contemporary issue in developing countries. Fatoki and Oni (2014) noted that financial literacy is at a low level in South Africa. Most studies examined the correlation between financial literacy and socio-demographic factors (Lusardi and Mitchel, 2011; Lusardi, 2012; Xu and Zia, 2013; Lusardi and Mitchel, 2013; Fatoki and Oni, 2014). These studies find out that promotion of financial education policies had positive outcomes. However, the overall empirical evidence is mixed. There are scant financial literacy surveys available with inconsistent measurements and research methods that limit the policy and practical implications of the available evidences. In developed countries, such as the US, the effect between financial literacy and financial management outcomes has however been studied more comprehensively (Lusardi, 2008; Lusardi and Tufano, 2009; Turnham, 2010; Lusardi, Michaud and Mitchell, 2012). The United States Financial Literacy and Education Commission (2007) describe financial literacy as the ability to use knowledge and skills to manage financial resources effectively for a lifetime of financial well-being. Knowledge involves having an idea of your financial needs through extensive research and obtaining the most cost-effective means of meeting these needs for a long time. This could be in form of saving money in a bank account to earn interest, investing to accumulate funds or, even, reducing the amount of spending.

Owing to global economic challenges, consumers are compelled to be financially conscious of their day-to-day economic activities. Financial Management refers to the management of money in its various forms to ensure short- and long-term financial security (Brigham and Houston 2012). Saving is the root of financial management and it requires high financial literacy skill. Lusardi, (2010) noted that it is important for people to save money for emergencies. Financial education or literacy is therefore vital for individuals to make appropriate financial decisions (Fernandes, Lynch, and Netemeyer, 2014). Most studies focused on the determinants of specific financial outcomes such as demographic characteristics (that is, age, gender and income). Macroeconomic indicators that are associated with financial management include GDP per capita growth, interest and inflation rates and government spending. From the gender perspective, there is no generally accepted position of understanding of financial management (Du Plessis, 2008).

The department for International Development conducted a study in Zambia and located that solely 0.5% of the adult population knew how to use basic financial products. The identical study revealed that, in seven African countries, solely twenty-nine percent of adults had bank account while around fifty percent use none of the financial products. The Adult Financial Literacy Advisory Group (Ad FLAG)[§§] undertook a study to see how to push higher access to financial education of youth and adults within the UK (Ad FLAG, 2000). Delafrooz and Laily (2011) conducted a study in Malaysia to look at the degree to which financial literacy influences the saving behaviour. The findings showed that saving behaviour is considerably influenced by the financial literacy whereby people with low level of financial literacy aren't meant to save lots or eventually encounter financial distresses.

Hilgert, Hogarth and Beverly (2003) explored the affiliation between information and behaviour in relation to individual’s or business owner’s social unit. Through the University of Michigan`s monthly Surveys of customers conducted in 2001the study shows that households get higher money scores and tend to possess higher scores on saving index. Furthermore, this study finds that increase in financial information will result in higher saving behaviour. he analysis of Sabri and MacDonald (2010) additionally demonstrates that financial accomplishment had a positive and important result on faculty

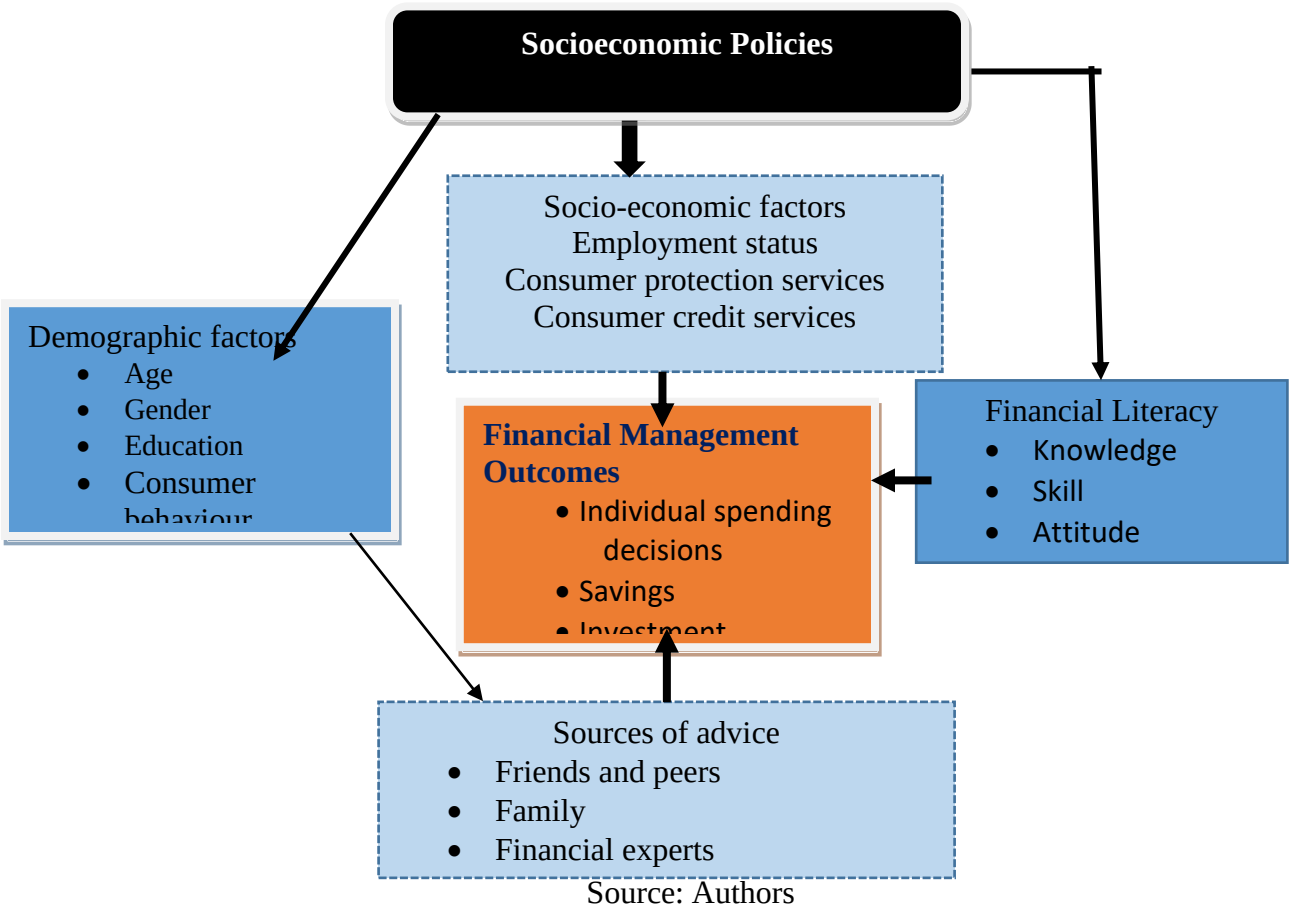
[§§] Adult Financial Literacy Advisory Group (AdFLAG) was established in February 2000 and produced a key report to the Secretary of State for Education and Employment.

students' savings behaviour. The results of this analysis suggested that participants who have larger information on personal finance tend to have interaction in effective saving behaviour.

Conceptual Framework

From the literatures reviewed in this section, we developed the conceptual framework of the study that highlights the relationship among the variables examined in this study as shown in figure 3.

Figure 3: Conceptual Framework of the Study



Source: Authors

DATA AND METHODOLOGY

Data

This study follows a quantitative approach. The study used secondary data, namely the 2012 South African Social Attitude Survey from Human Science Research Council (HSRC) that was collected for South Africa's for the nine provinces. This dataset has all the variables that are aligned with the objectives and question for this study. The survey covers questions related to the financial literacy, savings behaviour, and investment decision making process of respondents. The dataset was aligned to fit the target age categories of this study which is 18 to 34 years. Table 2 presents the variables definitions.

Table 2: Variables Definition

Variable name	**Shorthand form used in the model**	**Variables Definition**
Dependent variable (Dummy variable)	FM_Dec_N	Financial management outcomes (savings, individual spending decisions and investments)
Independent variables		
Financial literacy (Dummy variable)	*IS_FL*	Financial literacy (Knowledge, skill and attitude)
Household size (children and adult)	*Hs_N*	Number of household (children and adult)
Gender (Dummy variable)	*gender_dum*	1= males, 0 = females
Individual income	Pincome	Personal monthly income before tax and other deductions
Household income	*HhIncome*	Household monthly income
Education	*Educ*	Education level of the respondent
Living standard measurement	*LS*	Living standard measurement
Age	*Age*	18 – 34
Province	*Province*	Nine provincial areas in South Africa

Source: Authors

Model Specification

Logistic regression model was performed to assess the impact of financial literacy on attitudes towards individual savings and investment decisions. The modelling approach considers financial literacy as a dichotomous independent variable, which takes "1" if the literate youth saves or invests and "0" if otherwise. Information on literacy has been said to be the basis for sound saving and investment, thus it is the dependent variable and the independent variables are saving and investment patterns along with other relevant variables. The independent variables are the amount saved and invested income level, gender, educational status and employment status.

Following logistic regression model from (Zerihun et al., 2014; Kabwe, 2010; Agrestic &Finlay 2009; and Peng & So, 2002) our model is specified as follows;

$$\ln\left(\frac{\pi}{1-\pi}\right) = \log(odds) \Rightarrow \log Y = \alpha + \beta X \quad (1)$$

Taking the antilog of both sides of equation 1, we derive the equation to predict the probability of the occurrence of the outcome of interest as:

$$\pi = P(Y) = \frac{e^{\alpha+\beta\chi}}{1+e^{\alpha+\beta\chi}} \quad (2)$$

where

π is the probability of the outcome of interest (Y=1);

α is the Y- intercept (constant of the equation);

β_i are the regression coefficients of the explanatory variables (vector of coefficients to be estimated);

X_i are a set of predictors and 'e' is the base of the system of the natural logarithms.

$$\text{The dependet variable } Y_{1i} = \begin{cases} 0 \text{ if the youth do not do financial management} \\ 1 \text{ if the youth do financial management} \end{cases}$$

$$\pi = P(\text{Y = Outcome of interst}/\chi_1 = x_1, \chi_2 = x_2, \ldots \chi_k = x_k) \Rightarrow \pi = \frac{e^{\alpha+\beta_1 x_1+\beta_2 x_2 \ldots \beta_k x_k}}{1+e^{\alpha+\beta_1 x_1+\beta_2 x_2 \ldots \beta_k x_k}} \quad (3)$$

The odds ratio or the probability of making one choice relative to the other is:

$$Odds(Y=1) = \frac{P(Y=1)}{1-P(Y=1)} \quad (4)$$

$$\ln\left(\frac{P(Y=1)}{P(1-P(Y=1))}\right) = \alpha + \beta_2 \ln SVGR_i + \beta_3 GR_i + \beta_4 AGE_i^{\,2} + \beta_4 \ln Y_i + \beta_5 ED_i + \beta_6 ES_i + \varepsilon_i \quad (5)$$

where; SVGR= saving regularity; GR= gender; AGE= age of the respondent; Y= income level; ED is dummy variable for the level of education, and ES= employment status; 'α' is a constant term, βn are the coefficients to be determined, and "ε_i" is the error term.

Empirical Analysis

This section presents data analysis and findings made based on questions that individuals answered in the South African Social Attitudes Survey 2012. Table 3 presents the descriptive statistics; the average age for the observation in the sample is 18 to 34 years. Standard deviation is a measure of quantifying variation in the dataset. Low standard deviation indicates that the data points tend to be close to the mean, and the high standard deviation indicates that the data points are spread out over a wider range of values.

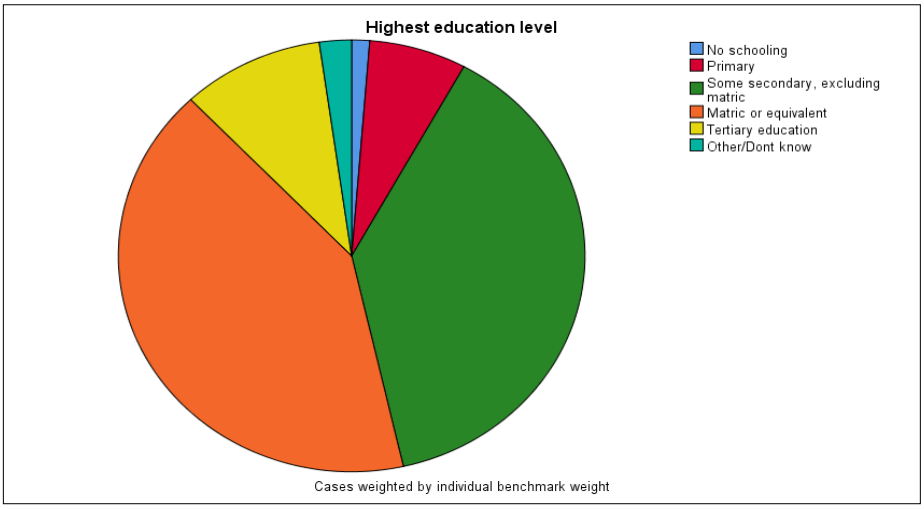
Table 3: Descriptive Statistics

Variable Description	Minimum	Maximum	Mean	Std. Deviation

Household Size	1.00	4.00	1.20	1.06
Financial Literacy; 1= those who have acquired some basic knowledge, skill and attitude, =0, otherwise	0.00	1.00	0.39	0.29
Financial Management Decision (1= those who have experiences on savings, individual spending decisions and investments, = 0, otherwise)	0.00	1.00	0.78	0.29
Gender (1= male, 0= female)	0.00	1.00	0.67	0.47
Living Standard	1	3	2.09	0.57
Education	0	9	2.67	1.27
Personal Income	1	98	22.05	34.19
Household Income	1	8	1.87	1.49
Age	18	34	28.80	4.05

Source: Computed from survey database

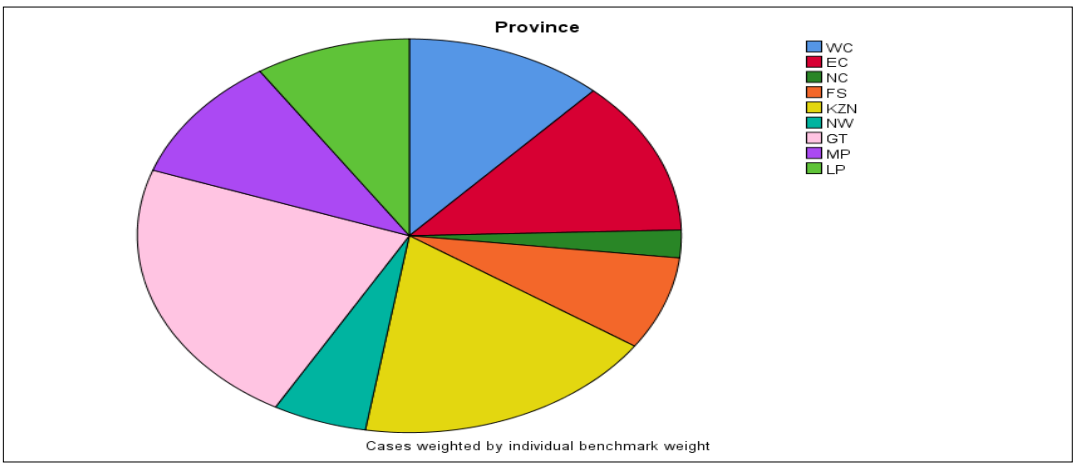
Figure 4: Percentage of respondents based on education



Source: Own analysed from data

Figure 4 with the pie-chart describe the categories of education, the education level of the respondents as follows: most of the respondents had matric or equivalent 39.1 percent, followed by secondary excluding matric 36.7 percent. Then, tertiary education recorded 9.3 percent, primary 6.4 percent, other 2.1 percent, no schooling 1.2 percent, and missing system recorded 5.8 percent for unbalanced standardised dataset.

Figure 5: Percentage of respondents per Province



Source: Own analysed from data

As shown in figure 5, the respondents in provincial areas are as follows: Western Cape 11.8 percent, Eastern Cape 12.7 percent, Northern Cape 2.3 percent, Free State 7.7 percent, Kwazulu-Natal 18.1 percent, North West 5.6 percent, Gauteng 22.2 percent, Mpumalanga1.3 percent and Limpopo 9.3 percent.

Logistic Regression Results

The interpretation of the logistic regression results in this study uses the odds ratio for both categorical and continuous predictors. An odds ratio greater than 1 reflects an increase in the odds of an outcome of 1 with a one unit increase in the predictor. Odds ratios of less than one reflect a decrease in the likelihood of outcome. Table 4 presents the logistic regression results.

Table 4: Logistic Regression Results

```
Logistic regression                                 Number of obs     =        314
                                                    LR chi2(7)        =      10.81
                                                    Prob > chi2       =     0.1473
Log likelihood = -6.7029297                         Pseudo R2         =     0.4463
------------------------------------------------------------------------------
         FMO |  Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          FL |   8.218182   1.09e+08     1.21   0.228      .0000475    1.42e+18
   Household |   0.2567244   3.129233     0.77   0.439      .2354674    27.99003
      Gender |   3.468468   6.720159     0.64   0.521      .0777919    154.6469
Life satisfy |   0.2719938   69.76625     1.29   0.198       .178333    4148.453
   Education |   1.139671   .9349317     0.16   0.873      .2282937    5.689377
    P_Income |   3.678802   7.258651     0.66   0.509      .0769484    175.8788
    H_income |   .2646848   .5226147    -0.67   0.501      .0055214    12.68847
       _cons |   .0321768   .1606621    -0.69   0.491      1.81e-06    572.3705
------------------------------------------------------------------------------
Note: _cons estimate baseline odds.
```

The logistics regression analysis employed Stata 15 and the result presents in Table 4. The statistical package pruning to use 314 observations and predicted odds ratio of financial management outcomes is positively related to financial literacy (p-value > 0.05), household size, gender, life satisfaction, personal income and household income are positive but not statistically significant. In addition, logistic regression results are positive and insignificant with gender. We also run a robust test and below is the outcome of the regression.

Table 5. Robustness Check- Logistic Regression Maximum Likelihood Analysis

```
Logistic regression                                 Number of obs     =        314
                                                    Wald chi2(7)      =      25.95
                                                    Prob > chi2       =     0.0005
```

Log pseudolikelihood = -6.7029297 Pseudo R2 = 0.4463

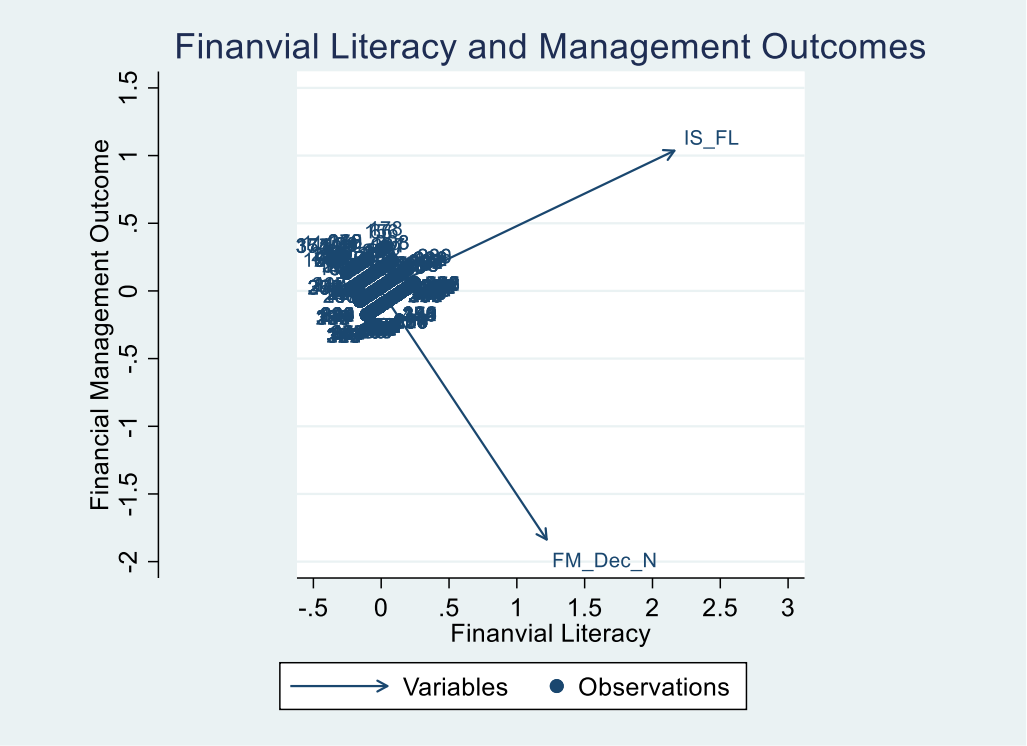
FMO	Odds Ratio	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
FL	8.218182***	4.45e-07	2.94	0.003	3.8879	3.31e+11
Household	0.2567244	2.570849	0.94	0.346	.360637	18.27527
Gender	3.468468	10.5548	0.41	0.683	.0089099	1350.221
Life satisfy	0.2719938	74.71032	1.20	0.229	.1248843	5923.934
education	1.139671	.3465841	0.43	0.667	.6279445	2.068414
P_Income	3.678802**	1.91825	2.50	0.012	1.32392	10.22236
H_income	.2646848*	.1359945	-2.59	0.010	.0966904	.7245604
_cons	.0321768	.2056072	-0.54	0.591	1.17e-07	8843.996

Note: _cons estimate baseline odds.

* Significant at 10% level of significance (P<0.10)
** Significant at 5% level of significance(P<0.05)
*** Significant at 1% level of significance(p<0.01)

Robustness test presents in Table 5, maximum likelihood analysis predicts that for odd ratio coefficient describe the difference in literacy and illiteracy, with very low standard error and with a p-value of 0.003. The findings are compatible with that of Kebede, and Kuar, (2015) study. Looking at the outcome of the logistic model, one observes that information on gender and financial literacy (the composition of information on savings and investment) has an association towards individual financial management outcome. Exponentiation for explanatory variable gives default (that is, **yes – the finances are well managed, otherwise no).** As reported in Table 5; financially literate youth can have more than eight times higher capabilities in their financial management outcomes than the illiterate group. Males are almost 3.5 times higher financial management outcomes than the females included in the survey. More educated youth in South Africa have more than 1.14 times better financial management skills compared to youth with low level of education. Likewise, South African youth with higher personal income levels have more than 3.7 times higher financial management outcomes than with low personal income.

Figure 6: Biplot of Multivariate analysis



Multivariate analysis graph (Biplot) in figure 6 shows the projection of variance-covariance structure of the variables, the value of observation on variable and Euclidean distance between financial literacy (FL) and financial management outcomes (FMO). The dots are the observations and lines show main outcome and the regressor[***].

SUMMARY AND DISCUSSIONS

The findings identify that financial literacy is important for the South African youths to maintain an effective saving behaviour. It becomes clear that increasing financial literacy will enable them to manage their money effectively. This finding corroborates with the findings by Falahati (2011) and Fatoki (2014). Male participants constituted a higher percentage, than their counterpart females. In terms of provinces, male dominance in this study is higher in Gauteng (GP) with 22.2 percent followed by Kwa-Zulu Natal which is 18.1 percent. The third one is Western Cape with 12.7 percent of population per province while Northern Cape is rated lowest with 2.3 percent. However, the outcome on financial management per province shows Gauteng as the highest. It is followed by Kwa-Zulu Natal and the lowest is Northern Cape. Kwa- Zulu Natal and Gauteng provinces have the largest size in both economy and population. From a simple empirical investigation of financial literacy and financial management, the results show that most of South Africans have borrowed money for consumption purposes such as food, water and electricity, gifts for the other people, impulse purchases, supporting people outside one`s household or lastly paying off existing debts among others. There are, however, an unexplained behavioural factor that influence financial management outcome.

[***] See Kohler, U. and Luniak, M., 2005. Data inspection using biplots. *The Stata Journal*, *5*(2), pp.208-223 for more detail on Biplot.

On the question of whether consumers considered affordability before purchasing an item, most respondents confessed that they don't always consider affordability before purchasing. Affordability consideration is arguably the most consistent influence on the relative odds of savings and investment outcomes are the extent of research before obtaining financial product and the general awareness of financial products. Also, on the question of whether respondents paid their bills on time, most of the respondents answered that they do not pay bills on time. This indicated poor financial literacy and management as paying of debt late is one of the main reasons for credit blacklisting in South Africa.

Furthermore, the results show that the associated independent variables influence the relative odds of savings related outcomes much more than they do debt-related outcomes. The occurrence of individuals with good financial literacy is more than twice as likely as someone with poor financial literacy by not having any '*non-ideal debt'*. In fact, an individual with good financial literacy is almost four times as likely as someone with poor financial literacy by saving from their income. Even those individuals with only a reasonable level of financial literacy are still almost three times as likely as to' save from their income' as someone with poor financial literacy. Furthermore, since typically non–significant predictor element of financial product choice and of financial knowledge and understanding are included in the overall financial literacy score, it is worth noting the considerable effect that this variable has on the relative odds of the savings related outcomes. This effect is even more profound when one disregards the top categories of the income and education variables- categories that include only a small portion of the population.

The provincial level results showed that, Kwa Zulu Natal Province had the highest percentage in terms of financial management. This is followed by North West, (NW) while Gauteng Province comes third. Although Gauteng has a higher GDP per capita, this does not equate to its residents having better financial management rating. Based on this evidence we conclude that the overall provincial GDP per capita is not equivalent to the province`s residents' financial management skill. The province with lower percent on financial management is Western Cape (WC). Like Gauteng, Western Cape Province is one of the richest provinces in South Africa (Nag 2018). However, the province ranks lower in its citizen`s financial management skills. Although there have been some shifts for regional salaries across the different categories. Northern Cape had a smallest number of respondents; however, it shows to have higher financial management skills than some of the big province. The size of the respondents could be responsible for the higher rating as there could have been concentrated instead of spread-out financially skilled respondents.

CONCLUSION AND POLICY IMPLICATIONS

Results from empirical analysis section finds that financial literacy has significant effect on financial management outcomes. In addition, the lack of adequate financial knowledge (education) in the long run has far reaching consequences on the individual as it is observed that the knowledge on savings and investment is not good and encouraging. For a long term, it will limit participant`s financial decisions making and planning. The findings of the study are also important for policy makers. Having identified that financial literacy is important for the South African youths to maintain an effective saving behaviour; it becomes clear that increasing financial literacy will enable them to manage their money effectively. This finding corroborates with the findings by Falahati (2011) and Fatoki (2014).

This study recommends promoting financial literacy through formal and informal educational means with the goal of improving financial education. This study further recommends that studies should be conducted on how South African youth can get assistance to save for their retirement and find ways to make smart investment decisions. In this regard, programs targeting specific groups are likely to be more effective than a one-size-fits-all financial education program. Specifically, designed and tailored financial

literacy programs should be targeted to specific groups of the population since people have different preferences and economic circumstances.

It is therefore important for policy makers to develop an effective education programme based on the needs and financial literacy level of the youth. The education programme should focus on improving the youths' basic financial knowledge and skill. Not all the academic programmes in South Africa have financial courses included in them, especially non-business programmes. Organizing seminars or workshops can provide an alternative way for improving the youths' financial knowledge, attitudes and behaviour. Providing effective financial education before starting work could mitigate the bad financial habits and attitudes of the employed youths and, at the same time, decrease the rate of default in payment of personal loan.

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A PRICING MODEL FOR ASIAN OPTIONS: AN APPROACH FROM PHYSICS

Angelo D. Joseph and Jan W. Kruger

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ABSTRACT

A business may use Asian options for improved portfolio protection and to hedge market fluctuation risk. Asian options are lucrative derivative instruments due to the underlying average prices. The challenge with Asian options is that the dynamics of the averaged prices does not permit the direct use of the traditional Black, Scholes and Merton model for pricing. In this research, we derive an Asian option pricing model that is based on a differential equation, acting on only one state-space variable originally developed in the physical sciences. We found that the solution to this particular differential equation can be used to fairly price Asian options with arithmetic strike and, or spot price averaging. The Asian option price estimation model results were compared to that simulated at 95% confidence intervals and externally published results. For market volatilities ranging from 10% - 70%, the estimated at-the-money Asian option prices were found to be well within the simulated 95% option price error bands. However, for very high volatilities (70% and above) the estimated deep out-the-money option prices understate that of the simulation. Overall, the differential equation, physics approach to modelling the fair Asian option prices were found to be reliable and sound.

Keywords: Asian options, differential equations, physics and finance

INTRODUCTION

The application of differential equations began in 1675 when the physicist, Isaac Newton and mathematician, Gottfried Wilhelm Leibniz independently discovered their use to describe the dynamics of complex systems (Wikipedia, 2019).

One way of appreciating differential equations is to consider them to estimate the weather. Estimating the weather requires a solid knowledge of how the humidity, rainfall and temperature evolve. Estimating the weather is non-trivial, as there is no clear linear, direct relationship between the humidity,

Angelo D. Joseph *holds a M.Sc. degree in Physics. He has extensive knowledge of derivatives, risk management, trading, and investment analytics. He held research and consulting roles at top tiered international banks. He holds membership at the Institute of Financial Markets and the Certified Quantitative Finance Institute. He regularly publishes research outputs at high-impact international conferences in Romania, Oxford, and Sydney. He holds a Doctoral degree in Business Leadership from the School of Business Leadership at the University of South Africa (UNISA SBL). He is a research supervisor for the Master and Doctoral programmes at the UNISA SBL.*

Jan W. Kruger *is a Professor of finance at the School of Business Leadership at the University of South Africa and the Global Humanistic University. He published more than 30 research papers and supervised more than ten doctoral candidates to completion. He holds a PhD in computer science and has a natural flair for applications of science in business.*

rainfall, and temperature. Relationships between the variables and their rates of changes do, however, exist. These relations can be expressed as a set of rate equations. The set of rate equations is called differential equations. Given the differential equations and initial values for the humidity, rainfall, and temperature, it is then possible to estimate the weather at any time in the future.

The concept of differential equations is interesting because it enables the approximation of the essential features of the real process using equations that depict the rate of change that reflects reality (Steward, 1998). In fact, in differential equations, the variables are determined as functions of time in such a way that it becomes possible to make future estimates of the real process (Baxter and Rennie, 1996).

Asian options, especially fixed-strike Asian options, have been well researched. For example, Kemna and Vorst (1990) tried to find an analytical solution for arithmetic averaged Asian options and instead only found a lower bound for the option price. Reynaerts et al. (2006) researched the fixed-strike Asian option price problem from a binary tree model perspective and found bounds for the price that induces small hedging errors only when the options are in-the-money. Curran (1994) proposes to value arithmetic Asian options by conditioning the simulation using closed-form geometric average option prices. Even though the geometric conditioning Asian option price approximation is fast and accurate, it limits the user to only price and invest in Asian options with certain specific payoff types.

The fact that option pricing is about estimating the financial market expectations in the future led us to look into the Asian pricing problem based on partial differential equations (first developed in physics). In fact, as early as 1987, Ingersoll (1987) observed that a reduced partial differential equation (PDE) could be used to price fixed-strike Asian options. Rogers and Shi (1995) exploited this scaling property in a PDE setting and found a lower bound which is so accurate that it is essentially the true price. Večeř (2001) recognized Asian option prices as a particular case of a passport option and this enabled him to characterized the Asian option price by a simple one-dimensional PDE. In the Večeř study, the focus is Asian options with either arithmetic average strike or arithmetic averaged spot prices. The Asian option case where both the strike and the spot price are averaged are rarely treated in the literature.

In this research, we focus in on a particular PDE (originally developed in physics) to price Asian options. Introducing a change of variable similar to Andersen et al. (1998) enabled us to derive a PDE, acting only on one state-space variable that can be used to price Asian options with both arithmetically averaged strike and spot prices.

Accordingly, this article is structured as follows: In section 2, we define the context of the Asian option pricing risk problem. In section 3, we present an overview of the physics differential equation Asian option pricing model. In section 4, we present the results of using the differential equation to price Asian options (with both average strike and, or average spot prices). Finally, in section 5, the summary and conclusion are given.

RISK

Risk is often in finance, referred to as volatility. Volatility is the statistical deviation of the changes in the financial market price returns (Nelken, 1997).

When the volatility is low financial markets are classified usually as being more certain (trending), and investor-friendly. When the volatility is high financial markets are characterized as being very uncertain, and usually not investor-friendly, in the traditional sense. For this reason, volatility is said

to be the enemy of all growth and value investments (Aizenman and Marion, 1999). To hedge investment returns from volatility, investors may use derivative instruments (Curran, 1994; ISDA, 2012).

A particularly interesting class of derivative instruments are options on the underlying average price. Options on the underlying average price were traded initially in Tokyo (in Asia) and are therefore called Asian options (Zhang, 2003). Asian options were introduced to the financial markets in 1987 (Fallon and Turner, 1999). The use of these options by investors enables exposure to the underlying market that inhibits volatility, because of the more stable payoff nature resulting from the averaging of the underlying market prices. The averaging with Asian options is precisely the reason why these options are generally considered to provide a welcome degree of investor protection from the unexpected vagaries of the underlying markets (Kemna and Vorst, 1990; Reynaerts et al., 2006).

The risk of using Asian options is in the pricing and hedging. The problem with Asian options is that the arithmetic average option evaluation inputs cannot directly be cast into the traditional option-pricing framework. The constraint exists because the arithmetic average set of lognormal prices is not normally distributed (Curran, 1994; Dufresne, 2000; Reynaerts, et al., 2006). However, for geometric average Asian options, the underlying average price is log-normally distributed; consequently, a closed-form solution in the traditional option pricing framework do exist for these options (Kemna and Vorst, 1990; Zhang, 1998).

Asian options where the underlying prices are arithmetically averaged are the most common in practice and is the focal point of this research. The Black, Scholes and Merton (BSM) traditional option pricing model framework is constructed around a known lognormal underlying price distribution (Black and Scholes, 1973). The lognormal BSM model assumption is precisely the reason why options on the arithmetic average market prices cannot directly be fairly priced or valued in the traditional option pricing model.

The inability to directly use the BSM closed-form option solution to price and hedge Asian options, particularly arithmetic average Asian options has led many researchers to approximate the value of Asian options (Andersen et al., 1998; Curran, 1994; Dufresne, 2000; Fu et al., 1999; Ingersoll, 1987; Kemna and Vorst, 1990; Reynaerts, et al., 2006; Rogers and Shi, 1995; Večeř, 2001). The risk of a bad option price estimation are even more pronounce for Asian options where both the strike and spot prices are arithmetically averaged, especially because academic literature on their valuation hardly exists.

In the next section we focus on the use of a particular differential equation, acting only on one state variable, to approximate the price of Asian options. After some manipulation of the stochastic processes involved in the model, we show how the model is used to approximate the value of Asian option prices where both the strike and spot prices are arithmetically averaged.

PRICING

Consider a call option that gives the investor the right, but not the obligation to pay the average strike price, in exchange for the average spot price in future. In the option pricing literature, to our knowledge, this type of option is rarely treated. This option is attractive to investors because (when effectively priced) it can be instrumental in hedging market volatility. More formally, an investor of this Asian call option has the payoff at maturity,

$$max\{S_{average} - \varphi K_{average}, 0\} \quad (1)$$

with $S_{average}$ and $K_{average}$ arithmetic averages of market prices. To distinguish between the prices, practitioners usually refer to the strike averaging, $K_{average}$ as IN and the spot averaging $S_{average}$ as OUT. Asian IN (OUT) options will average the prices over a fixed market price window (e.g. few days or weeks) at the start (end) of the option to set the strike (spot) level. Asian IN-OUT options will average both the strike and the spot price over the specific IN and OUT windows.

The parameter φ in equation (1) is unique in that it specifies the percentage participation (by the investor) in the average strike price. For example, φ = 50 implies a 50% participation in the average strike price. Note that the payoff articulated in expression (1) includes the payoff of Asian options where either the spot price is fixed (by setting $S_{average} = S_T$ in equation (1)) or the strike price is fixed (by setting $K_{average} = K$ in equation (1)). The payoff specified by equation (1) are therefore general and the price solution to this payoff can be used to price any Asian option.

What is the fair price or how should we value Asian options? The actuarial fair price that an investor should pay for an Asian option is the present value of the payoff expression (1). However, the payoff is only known at the maturity time of the option after the averages are known. The fair price of the Asian option must, therefore, be estimated using a model where the averaged underlying financial market prices are stochastic, and estimated under uncertainty. When we focused in and manipulated some of the stochastic processes involved in option pricing, we find that the price of a general Asian option can be obtained as a solution to a particular differential equation.

In fact, given the payoff of a continuously averaged Asian option, introduce a change of variable **Z** with the underlying spot price as the numeraire. A similar change of variable was introduced by Andersen et al. (1998). By application of Itô's (1951) lemma, the introduced variable **Z** is shown to be a stochastic process of **Z** itself. Using the Girsanov (1960) theorem, the **Z** is identified to be a Brownian motion under an equivalent risk-neutral probability measure. The fair price of an Asian option at time **t**, expiring at time **T** can then be defined as a result of the risk-neutral expectation (Black & Scholes, 1973):

$$V_0 = S_0 e^{-qT} g(0, Z_0) \tag{2}$$

By theoretical physicist Richard Feynman, and mathematician Mark Kac (Kac, 1949) the Asian option price must, therefore, be a solution to the following second-order linear partial differential equation (acting on only one state space variable):

$$\frac{\partial g}{\partial t}(t,x) + (r_t - q_t)(g_t - x)\frac{\partial g}{\partial x}(t,x) + \frac{1}{2}\sigma^2 (g_t - x)^2 \frac{\partial^2 g}{\partial x^2}(t,x) = 0 \tag{3a}$$

with boundary condition:

$$g(T,x) = x^+ \tag{3b}$$
$$x^+ := max(x, 0)$$

here r_t and q_t is the interest rate and dividend yield, respectively and σ is the constant volatility. For a more rigorous mathematical outline of the derivation of the differential equation acting on only one state space variable, please read Annexure A.

The gamma symbol, γ_t in the differential equation (3) is a deterministic function giving the instantaneous position in the underlying. The gamma is the discrete solution to the continuously averaged option framework that allows the usage of the differential equation (3) to price general Asian options. For

a more rigorous mathematical outline of configuring the deterministic function in order to use the physics differential equation to price Asian IN-OUT options, please read Annexure B.

The novelty of equation (3) is in the fact that it is a variant of the partial differential equation first developed in physics in 1822 by Joseph Fourier to describe how heat evolves through time in a solid medium. In the traditional Black, Scholes and Merton vanilla option model, the heat equation carries the same fundamental importance in finding the pricing solution. Similarly, in this research, Asian options could be theoretically priced because of the realization that the price solution is alike to that of the heat equation in physics.

Calibration

The partial differential equation (3) is in a theoretical or continuous format. In order to be able to use the equation in the discrete or real-world, the discretization of equation (3) must be performed. The discretization of equation (3) is necessary for confidently using the solution to the differential equation and ultimately to approximate fair prices to Asian options.

The discretization of equation (3) is done using a finite difference scheme. The idea underlying the finite difference scheme for Asian option pricing is to construct a range of underlying prices **Z** at each time node. The underlying **Z** prices at different vertical (space) nodes and horizontal (time) nodes, are then used to discretise the Asian option partial differential equation. The price of the Asian option is then obtained by backward induction on the finite difference grid.

A finite difference (discretization) scheme usually requires specifying the intervals into which the space step is discretize. The minimum number of intervals required to discretize the physics differential equation (3) controls the pricing operational risk or error (between the theoretical and real worlds) and must first be determined.

The minimum number of intervals are found by pricing at-the-money European call options, assuming a constant annual interest rate of 9%, a dividend yield of 1% and volatility varying from 15% to 100%, in increments of 5%. The pricing error is defined as the difference between the European call option price (using the Black, Scholes and Merton model) and that using the derived Asian option-pricing model (equation (2)). The mean pricing error and deviations overall the volatilities for each number of discretization steps are plotted in Figure 1.

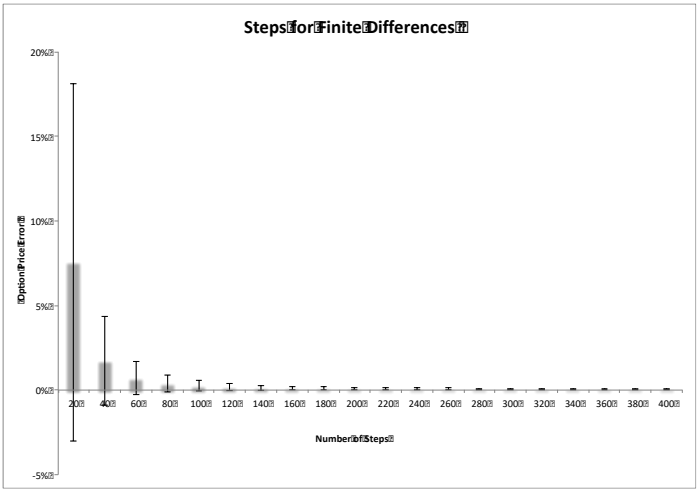

Figure 1: Option pricing error dependency on the number of intervals (steps) for discretizing the PDE. The column graph denotes the mean errors, and the bar sizes denote the standard deviations of the errors.

The average error incurred with pricing European call options, using the derived Asian option pricing model, appears to be an exponentially decreasing function with an increase in the number of space intervals (or decrease in finite grid interspaces). The average pricing error seems to converge quickly and is relatively stable after 200 intervals (see Figure 1). The minimum discretization steps were therefore taken to be 200. Furthermore, for an interval number of 300, a mean absolute price error of 0.049% is obtained. From a financial perspective, this is equivalent to 0.00049 monetary units, significantly less than the smallest monetary unit of 1 cent.

To ensure sound pricing of Asian options with the physics differential equation a finite difference scheme with 300 discrete intervals were used.

RESULTS

Setup

The Asian option with both the arithmetic averaging of the strike and spot price (Asian IN-OUT options, equation (1) in section 3) is central to this research. To appreciate the Asian option pricing model it is imperative that the market input parameters under which the results are generated are given. The market input parameters to the Asian option-pricing equation (2) in the finite difference scheme (discretisation of the PDE equation (3)) with 300 discrete intervals are given next.

Let the time to maturity of the Asian option be one full business cycle of five years. Suppose all the averaging occurs once a week for a total period of one full business year. Also, let the weekly strike averaging dates occur before the weekly spot averaging dates. Moreover, let the strike averaging occur for 26 consecutive business weeks in the first half-year of the option lifetime, and let the spot averaging occur for 26 consecutive business weeks in the final half-year of the option lifetime. In other words, the window of the IN (strike) is one half year at the start of the option, and the window of the OUT (spot) is also one half year but at the end of the option lifetime. The risk-free annual rate is set at 5%, and the annual dividend yield is set at 1%.

This setup is analogous to an investor buying an Asian call option as a market risk hedge against an unexpected violent decrease in the underlying market during the first half-year and then a sudden unexpected increase during the last half-year of the five-year option lifetime. If the sudden market changes realize and the hedge is effective, the option matures well in the money since the fair price that was paid was the lowest average strike price in return for the highest possible average spot price. The lucrativeness of this Asian option lies in the fact that the averaging optimizes the payoff defined by equation (1). By using this Asian option the investor is hedged against sudden market changes or volatility for a full one year, a half-year at the beginning of option and another in the last half-year of the five year option lifetime (at a cost less than that of traditional European options, as pointed out by Kemna and Vorst, 1990).

To stress-test the price solution (equation (3)) we compare the fixed strike, Asian OUT options prices obtained with the PDE to that obtained from a Monte Carlo simulation (at 95% confidence).

For absolute confidence in the PDE based Asian option pricing model, Asian IN-OUT with the model are compared to Monte Carlo simulated results (at 95% confidence) and to independently published results.

Comparisons

For purposes of stress testing the derived PDE model, thirty five Asian OUT option prices were generated using equations (2) and (3) and compared to independently simulated prices. For robustness measurement, the comparisons are made at five different volatility sets ranging from 5% to 35%; where for each volatility point, seven different options by moneyness (alternating the initial spot price and fixing the strike to 100) are considered. See Table 1.

Volatility	Strike = 100 Spot	Monte Carlo Simulation	Simulation 2 Standard Error	PDE Approach
5%	80	0.00	0.00	0.00
	90	0.02	0.00	0.03
	95	0.75	0.01	0.73
	100	4.01	0.02	3.98
	105	8.68	0.03	8.68
	110	13.45	0.03	13.46
	120	23.03	0.03	23.03
15%	80	0.08	0.01	0.08
	90	1.20	0.03	1.21
	95	2.95	0.04	2.94
	100	5.78	0.06	5.73
	105	9.39	0.07	9.43
	110	13.69	0.08	13.72
	120	23.15	0.09	23.04
20%	80	0.35	0.02	0.35
	90	2.10	0.04	2.13
	95	4.07	0.06	4.07
	100	6.81	0.08	6.80
	105	10.28	0.09	10.25
	110	14.20	0.10	14.24
	120	23.08	0.12	23.18
25%	80	0.80	0.03	0.80
	90	3.12	0.06	3.12
	95	5.22	0.08	5.19
	100	7.94	0.10	7.90
	105	11.29	0.11	11.19
	110	15.00	0.13	14.97
	120	23.46	0.15	23.50
35%	80	2.08	0.06	2.09
	90	5.17	0.09	5.18
	95	7.47	0.12	7.42
	100	10.07	0.13	10.13
	105	13.29	0.15	13.26
	110	16.76	0.17	16.76
	120	24.70	0.20	24.65

Table 1: Asian OUT option prices obtained using the PDE.

The stress testing results show that the PDE approach of pricing fixed strike, Asian OUT options are sound to within the 95% simulation errors. The only exception occurred at the very low volatility (5%). See Table 1. However, at the very low volatility end, the maximum error is only about 0.02 monetary units. For Asian options that are developed mainly to mitigate volatility, and therefore designed to work effectively in high market volatility regimes, this is not surprising. Furthermore, the literature suggests that a misestimation at the very low volatility end for Asian options is not uncommon (Dufresne, 2000; Fu et al., 1999). Hence, for all practical purposes, the results of stress testing suggest the derived PDE model is sound.

For testing the performance of the Asian IN-OUT options under the derived PDE option price model, twenty general option prices were generated using equations (2) and (3) and compared to forty independently generated prices. For robustness measurement, the comparisons are made at four different volatility sets ranging from 10% to 70%; where for each volatility point, five different options by moneyness (alternating parameter φ in equation (1)) are considered. See Table 2.

Market Parameters		**Average Option Prices**				
Volatility	**Percent Participation Average Strike, φ**	**PDE approach**	**Monte Carlo Simulation**	**Simulation 2 Standard Error**	**Krekel (2003)**	**Deviation PDE-Krekel**
10%	**50**	54,87	54,74	0,18	54,87	0,00
	80	31,42	31,41	0,17	31,42	0,00
	100	17,42	17,41	0,15	17,43	-0,01
	120	7,70	7,80	0,11	7,71	-0,01
	150	1,55	1,56	0,05	1,55	0,00
30%	**50**	56,22	56,10	0,57	56,22	0,00
	80	38,59	38,49	0,53	38,59	0,00
	100	29,80	29,47	0,49	29,80	0,00
	120	23,01	23,22	0,46	23,01	0,00
	150	15,72	15,65	0,40	15,72	0,00
50%	**50**	61,42	61,91	1,21	61,42	0,00
	80	48,88	47,70	1,07	48,92	-0,04
	100	42,46	43,60	1,11	42,56	-0,10
	120	37,15	38,25	1,10	37,35	-0,20
	150	30,68	31,25	1,02	31,13	-0,45
70%	**50**	67,67	67,26	2,31	67,88	-0,21
	80	58,17	57,65	2,24	58,87	-0,70
	100	52,97	51,85	2,04	54,18	-1,21
	120	48,35	50,85	2,20	50,22	-1,87
	150	42,15	45,61	2,18	45,28	-3,13

Table 2: Asian IN-OUT option prices estimated using the derived PDE model

The results showed that at the lower volatility points of 10% and 30%, the differential equation option prices are well within the simulated option price bands (at 95% confidence). At these lower volatility points, the differential equation option prices are also found to be generally very close to the independently published results of Krekel (2003). See Table 2. The only slight mispricing, as compared to the Krekel (2003) results, occurs when the volatility is very low at 10%, and the call option is at-the-money (100 per cent strike participation) and 20% out-the-money (120 per cent participation in strike average) (see Table 2). In the light of the option pricing literature (Dufresne, 2000; Fu et al., 1999), a

misestimation at the 10% volatility is not surprising. According to the literature, the Asian option misestimation is because the variance term σ^2 T is lower than 8% (in this case, 0.12 x 5 = 5%). Furthermore, even though a misestimation is common at this volatility level, fortunately, the mispricing with the differential equation at the 10% volatility level (of about 1c) is so small that, for all practical purposes, it can in any way be classified as random and negligible. See Table 2.

When the volatility is at 50%, and the call option goes from in-the-money (80 per cent participation in strike average) to out-the-money (150 per cent participation in strike average), the price misestimation of the differential equation relative to the simulation appears to move from over-estimating to under-estimating (see Table 2). Interestingly, a similar misestimation pattern appears to concur with the independent Krekel (2003) results relative to simulation (see Table 2). The misestimation at the high 50% volatility can then be taken to be reasonable since the same trend is evident with the independently published results.

When the volatility is very high at 70%, the deep out-the-money (120 and 150 per cent strike average participation) call options, priced using the differential equation, appear to underestimate the simulation results (see Table 2). Krekel (2003) also do find that the out-the-money option prices are more inconsistent with their independent simulations. Interesting to note that at the high volatility of 70%, Krekel (2003) finds that their moment matching method of estimating the at-the-money Asian option more severely overestimates the prices relative to the simulation. See Figure 2.

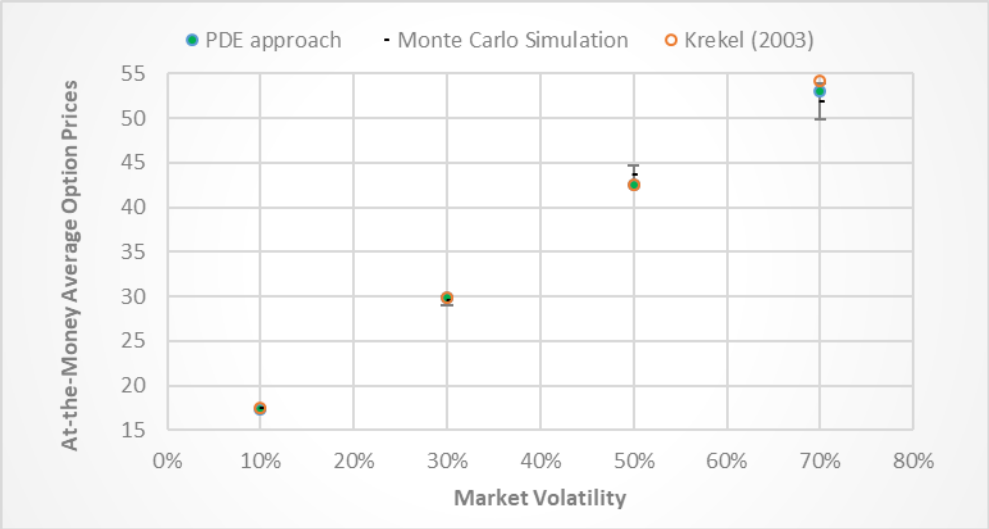

Figure 2: Asian option PDE pricing at various market volatility. The simulation is denoted by the error bars.

The physics equation approach to Asian option pricing appears better than the Krekel (2003) method as it does not display severe at-the-money option pricing misestimation (relative to the simulation results). When the volatility increases from 10% to 70%, the at-the-money average option prices with the physics approach do become more accurate relative to the simulation results. See Figure 2. This finding is in good agreement with Rogers and Shi (1995), that reports that the accuracy of numerically pricing options by differential equations improves as volatility increases.

SUMMARY AND CONCLUSION

In this paper, an equation that originated in the physical sciences, the partial differential equation was relied upon to estimate the fair prices of Asian options.

We motivated the fact that in finance, it is not straightforward to price options on the underlying average market prices or Asian options. There exists no closed-form solution to finding the fair price of arithmetic average Asian options. Asian option on the arithmetic average prices must therefore be estimated. The contribution of this paper is the realization that the price of a general Asian option with arithmetic spot and, or strike averaging can be theoretically derived using a physics partial differential equation acting only on one state space variable.
The Asian option pricing model was numerically tested assuming the Black, Scholes and Merton model constant input parameters (interest rates, dividend, and volatility). Given that Asian options are used (amongst other applications) to mitigate volatility risk – the testing of the effectiveness of the pricing model was done under various at-the-money volatilities. In order to gauge the effectiveness of the physics differential equation pricing model, the tests were performed, assuming no volatility skew or smile and only parallel shifts of the entire volatility surface. Asian option volatility surfaces are a topic of another forthcoming note.

The physics equation Asian option price solution was implemented and compared to simulated and independently published results. For robustness testing, the differential equation Asian option model comparisons was performed under stressed market volatilities ranging from 5% to 70%. Except for a few minor deviations, the physics differential equation Asian option model performed well.

Annexure A: Asian option pricing differential equation

Consider the differential equation obtained by the application of the mathematical chain product differentiation rule (Steward, 2000),

$$d\left(tS_t\right) = tdS_t + S_t dt \tag{A1}$$

Forming the definite integral on the equality in (A1) and rearranging gives:

$$\frac{1}{T}\int_0^T S_t\,dt = S_T - \int_0^T \frac{t}{T}\,dS_t \tag{A2}$$

By definition of the definite integral, it is clear that the terminal spot price:

$$S_T = S_0 + \int_0^T dS_t \tag{A3}$$

Substituting equation (A3) into (A2) we can write that:

$$\frac{1}{T}\int_0^T S_t\,dt = S_0 + \int_0^T \left(1 - \frac{t}{T}\right)dS_t \tag{A4}$$

Suppose now that Y_t is a process satisfying:

$$dY_t = \left(1 - \frac{t}{T}\right) dS_t \tag{A5a}$$

With the boundary condition:

$$Y_0 = S_0 - K. \tag{A5b}$$

Substituting the formulae defined by equations (A5a) and (A5b) into (A4) and rearranging yields:

$$Y_T = \frac{1}{T} \int_0^T S_t \, dt - K \tag{A6}$$

It is then clear that $(Y_T)^+$, with $x^+ := max(x, 0)$, is the payoff of a continuously averaged Asian call option.

We have therefore showed that consideration of a certain differential equation under the application of simple mathematical laws results in the payoff of (a continuously averaged fixed strike) Asian option.

This realisation prompted us to consider more general Asian options.
Consider an arbitrary derivative with the property that the payoff at maturity is of the form $(X_T)^+$ for some X_t satisfying:

$$dX_t = g_t dS_t \tag{A7}$$

Here g_t is a deterministic function giving the instantaneous position in S_t.
Now assume the stock price S_t follows the risk-neutral process (Bachelier, 1900):

$$dS_t = (r_t - q_t) S_t dt + \sigma S_t dW_t \tag{A8}$$

Here r_t and q_t are the continuously compounded interest rate and dividend yield respectively and σ is the constant stock price volatility. The process W_t is a Brownian Motion under the risk-neutral probability measure $\tilde{P}$.

Substituting equation (A8) into equation (A7) yields:

$$dX_t = g_t (r_t - q_t) S_t dt + g_t \sigma S_t dW_t \tag{A9}$$

Now define the change of variable (Andersen et al., 1998):

$$Z_t := \frac{X_t}{S_t} \tag{A10}$$

Then by Itô's lemma (Itô, 1951):

$$dZ_t = (g_t - Z_t)(r_t - q_t - \sigma^2) dt + \sigma (g_t - Z_t) dW_t \tag{A11a}$$

with boundary condition: $Z_0 = \frac{X_0}{S_0}$ (A11b)

Equation (A11a) can then be rewritten as:

$$dZ_t = (r_t - q_t)(g_t - Z_t) dt + \sigma (g_t - Z_t) d\tilde{W}_t \tag{A12}$$

Here $d\tilde{W}_t$ is a Brownian Motion under $\tilde{P}$ and

$$d\tilde{W}_t := -\sigma dt + dW_t$$

Consistent with the Girsanov (1960) theorem.
Applying the risk-neutral valuation principle and Feynman-Kac (Kac, 1949), the Asian option fair price at time $t = 0$ can be written to be:

$$V_0 = S_0 e^{-qT} g(0, Z_0) \tag{A13}$$

where $g(t,x)$ satisfies the PDE:

$$\frac{\partial g}{\partial t}(t,x) + (r_t - q_t)(g_t - x)\frac{\partial g}{\partial x}(t,x) + \frac{1}{2}\sigma^2 (g_t - x)^2 \frac{\partial^2 g}{\partial x^2}(t,x) = 0 \tag{A14a}$$

with boundary condition:

$$g(T,x) = x^+ \tag{A14b}$$

A similar PDE with reduction to one space variable for option pricing was also used by Ingersoll (1987).

Annexure B: Deterministic function

In this annexure we give the configuration of the deterministic function (first defined in equation (A7)) used in the PDE equation (A14) that allowed us to consider the more path dependent, general Asian options.

The general Asian call option‡‡‡ with averaged strike and averaged spot has a payoff at time T of the form:

$$\left(\frac{k_1 + S(t_{m+1}) + S(t_{m+2}) + \cdots + S(t_n)}{k_2} - \frac{k_3 + S(t_1) + S(t_2) + \cdots + S(t_m)}{k_4}\right)^+ \tag{B1}$$

The strike average times are given by the set $(t_i)_{i=1}^m$ and the spot average times are given by the set $(t_i)_{i=m+1}^n$, assuming that:

$$0 < t_1 < t_2 < \cdots < t_m < t_{m+1} < t_{m+2} < \cdots < t_n \le T \tag{B2}$$

The constants $(k_i)_{i=1}^4$ are related to averaging dates, which have passed as follows:

$k_1 =$ product of the number of spot averaging times that have passed and the spot average to date

$k_2 =$ total number of spot averaging times (past and future)

$k_3 =$ product of the number of strike averaging times that have passed and the strike average to date

$k_4 =$ total number of strike averaging times (past and future)

In order to use the pricing theory derived in the Annexure A, the underlying must be replicated by keeping fixed stock positions, $(\gamma_i)_{i=1}^n$ to the left of each averaging date. This requires solving

$$\begin{aligned} &X_0 + \int_0^{t_1} \gamma_1 \, dS(t) + \int_{t_1}^{t_2} \gamma_2 \, dS(t) + \cdots + \int_{t_{n-1}}^{t_n} \gamma_3 \, dS(t) = \\ &\left(\frac{k_1 + S(t_{m+1}) + S(t_{m+2}) + \cdots + S(t_n)}{k_2} - \frac{k_3 + S(t_1) + S(t_2) + \cdots + S(t_m)}{k_4}\right)^+ \end{aligned} \tag{B3}$$

Some basic algebra gives the solution to the general Asian deterministic function as:

‡‡‡ The equivalent put option price can be obtained using put-call parity.

$$\gamma_i = -\frac{m-i+1}{k_4} + \frac{n-m}{k_2} \quad for \quad i \in \{1,2,\cdots,m,\} \tag{B4a}$$

$$\gamma_i = \frac{n-i+1}{k_2} \quad for \quad i \in \{m+1,m+2,\cdots,n,\} \tag{B4b}$$

together with the initialisation:

$$X_0 = \gamma_1 S_0 + \left(\frac{k_1}{k_2} - \frac{k_3}{k_4}\right) \tag{B5}$$

We then combine the $(\gamma_i)_{i=1}^n$ into a step function $\gamma(t)$ and (together with X_0) applied the pricing results of previous Annexure A to find the general Asian option fair price.

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