A COMPREHENSIVE FRAMEWORK FOR FORECASTING BITCOIN PRICES USING STATISTICAL DISTRIBUTIONS AND VOLATILITY MODELS: IMPLICATIONS FOR RISK-EDUCATION, JOB CREATION, AND WEALTH DEVELOPMENT IN AFRICA AND NIGERIA

Ekoh, L. A.[1*], Ezeja, E.[2], Eneh, C.[3]

[1]Department of Educational foundations, Nnamdi Azikiwe University, Awka
[2]Department of Statistics, Institute of Management and Technology, Enugu state
[3]Department of Agricultural economics, University of Nigeria, Nsukka
[*] Corresponding Author: la.ekoh@unizik.edu.ng

Abstract

This paper outlines a framework for forecasting Bitcoin prices using various statistical distributions and volatility models, implemented within Python. The framework incorporates log-normal, normal, Pareto, Cauchy, exponential, and power law distributions, alongside volatility clustering models to forecast Bitcoin prices. The paper also discusses the implications of this methodology for risk education, job creation, and wealth development in Africa, with a particular focus on Nigeria. By demonstrating the practical application of statistical forecasting tools, this study highlights how such techniques can be leveraged to enhance financial literacy and economic opportunities in emerging markets.

Keywords: Statistical distribution, risk education, wealth economics, sustainable development.

INTRODUCTION

The emergence of Bitcoin and other cryptocurrencies has significantly impacted global financial markets. Cryptocurrency is designed to serve as a medium of exchange. The "crypto" prefix comes from the fact that cryptocurrencies use cryptography to secure and verify transactions as well as create new currency units (coins). Cryptography makes it easy to encode something that is easy to decipher with a key and difficult to decipher without a key, which means that coins can be difficult to create, but transactions can be easy to verify (Nwosu and Emilia, 2022). Thus, it is found significant to many countries where digital money operations have continued amidst in Nigeria.

Previous studies on financial forecasting methods, including the use of statistical distributions and volatility models, have laid the groundwork for this research. Notable works include Bouchaud and Mézard's (2000) research on wealth condensation and Engle's (1982a; b) seminal work on ARCH models. In that regard, this study deviates by furthering literature via determining cryptocurrency's effect on the Nigerian economy towards wealth creation.

Also, on the other hand whilst, Cryptocurrencies, and particularly Bitcoin, have been recently a subject of many studies and analyses mainly in terms of their economic properties; these analyses, such as of Pattison (2011), Ober,

Katzenbeisser and Hamacher (2013), Britto and Castillo (2013) or Combs and Mitsoff (2014) are usually focused on the range of functions of cryptocurrencies, and not broader contexts of furthering functional risk-education. The study focus, in part on, deepening financialization processes of contemporary financial markets. Thus, the authors develop the hypothesis that the creation and emergence of comprehensive frameworks for forecasting Bitcoin prices is a vital need of the financialization of the global economy.

Research has also explored the impact of financial forecasting on emerging markets. For example, studies by Bonga-Bonga (2018a; b; c; d; 2020; 2022), Adam, Frimpong & Boadu (2017), Afgani, Pringgabayu, Waruwu & Clement (2021), Alaaraj & Bakri (2020), Asmara & Wiagustini (2021), Baidoo, Boateng & Amponsah (2018) and Akinwande et al. (2019) highlight the role of financial literacy and economic models in driving economic development in African countries. In lieu, using; statistical distributions and volatility models in Stata this; event-full study generate data and subsequently apply econometric tools to a reliable conclusion of the impact of cryptocurrencies trading/price on the global digital finance towards implications for Risk-education, job creation, and wealth development in Africa and Nigeria.

Historical overview

There have been many attempts at producing a digital currency during the 90s tech boom (Bech, 2017). Post-golden window, the US dollar was at the forefront as the world's main reserve currency system which was tantamount to breaking the exchangeability of the US dollar for physical gold. This monetary system was created in 1944 on the basis of the post-war order in Bretton Woods and ultimately failed to stand the test of time; collapsing on August 15, 1971 (Poskart, 2022). From that historical moment on, a new and very important player emerged in the architecture of the global financial system, in the form of private capital, which has benefited from diversified financial activities, until now (Dembinski, 2008; Galbraith, 1994; Griffin, 2002).

In the current financial system, parallel to money in paper form, there is also non-cash (intangible) money in the form of electronic money. The consequence of this is that money has both electronic character and the character of symbolic money – representing denomination (Skawińska, Sobiech- Grabka, Nawrot, 2010). Further, the emergence of; opportunities for the unrestricted creation of money by the banking system; innovative but also risky financial engineering products in the form of complex derivatives, the abolition of capital flow controls, the globalization of corporate activity and the pressure of shareholders to maximize stock market capitalization and the rate of return on the capital of transnational corporations (Mishkin, 2006; Stiglitz 2003).

Consequently, enabled an explosive increase in the value of global financial assets in relation to non-financial assets, manifested by the dynamic growth of the former's share in global GDP. This progressing financialization of the world economy trigger irreversible changes that has been in the entire global economy (Bitros, Economou & Kyriazis, 2020; Kyriazis, 2019; Stosic, Stosic & Ludermir 2018; Geuder, Kinateder & Wagner, 2018; Eyal & Sirer, 2014; Dembinski, 2008).

Also, excessive increase in the importance of markets and financial institutions (the financial sphere of the economy) compared to the constantly decreasing importance and shrinking potential of the real sphere, where specific goods and services are produced for the needs of real investments and current consumption. In the case of some countries (USA, UK, Switzerland) the financial sector has even become the main engine of economic growth (Stanisławski, 2013).

The financial sector itself evolved from a bank-based system model to a financial market model. The unrestrained development of the latter, combined with the ever-present temptation to abuse the global financial system – moral hazard – resulted in a dramatic drop in confidence, not only in the financial markets but also in the very essence of money, which was one of many serious consequences of the global financial crisis that erupted in 2008 (BIS, 2019; Roubini, Mihm, 2010; Schiff, 2012). Despite a gigantic crisis of confidence in the ubiquitous fiduciary currencies - fiat, based only on faith in their so-called value, the system did not return to the gold standard that had been known for centuries, and there was a certain revolution not so much in the system itself, but on its "periphery". It resulted in its 'independence' from the main system, at the same time, completely uncontrollable from outside and independent in its essence cryptocurrencies, based on blockchain technology. This even revolutionized the process of financialisation further and pushed its development in a completely new, so far unpredictable direction, which is part of a slightly broader framework of the increasingly common phenomenon, the so-called virtualization of money (Poskart, 2022; Gilder, 2015).

Following, decentralized digital currencies started to have a significant impact on the future of the traditional financial system, becoming its successor or an important (key) complement (Laboure, 2020), as they have the properties to compensate for the significant shortcomings of the traditional system, thanks to the use of new technologies such as blockchain and IT ecosystems built on its architecture, revolutionary in their capabilities (Poskart, 2020). In this growing global financial system, classical banks are beginning to play a smaller and smaller role, slowly losing their market position to FinTechs. The current capitalization of the latter, together with non-bank payment institutions, already represents about 30% of the value of the 500 global financial institutions (Dimon, 2020). The processes of the inevitable transformation have been further amplified by the emergence of the so-called "black swan" of the COVID-19 pandemic and the subsequent lockdowns implemented by governments of the most developed countries of the world. Given the spread and rise of digital money and monetisation, authorities of monetary institutions, such as central banks and international regulators, in all developed countries seem to be concerned out of fear for the future of the legacy and developments of contemporary financial system in lieu (D'Urbino, 2021; Lagarde, 2018, Carstens, 2018).

The appearance of the first private cryptocurrency in the world, known as bitcoin (BTC) was initiated by publishing in the Internet, on November 1, 2008, a manifesto signed by an anonymous creator (or a group of creators) under the pseudonym Satoshi Nakamoto. The manifesto contained both, the explanation of the cryptocurrency mechanism itself, and the entire architecture of the so-called blockchain system. It had many "advantages" over the classical money system architecture, among which the leading one seems to be decentralization, preventing any "manual" control of the blockchain system (Nakamoto, 2008), not to mention the "empty money printing", used on a mass scale and in a coordinated way in the current money system by central banks of the leading world economies (US Federal Reserve System (FED), European Central Bank (ECB), Bank of England (BOE), Bank of Japan (BOJ), Swiss National Bank (SNB)) (Lien, 2022; Doumenis, Izadi, Dhamdhere, Katsikas & Koufopoulos, 2021; Kayani & Hasan, 2024).

The rapid growth in the valuation of the entire cryptocurrency market, is expressed, among other things, in the ever-increasing number of digital currencies, of which there are now more than 10,000, which, compared to about 180 (according to

UN data) national currencies, means that there are now about fifty-five digital currencies per national currency. It is not without significance to observe the relatively large market capitalization of digital currencies, currently exceeding USD 1.6 trillion (Poskart, 2022; Coinmarketcap, 2021), which, on the one hand, testifies to the enormous potential of this market (Kyriazis, 2019) and its constantly growing importance in the so far, as a rule, conservative financial world. On the other hand, this phenomenon may also be related to the declining trust in centralized financial markets, regulatory institutions, supervision combined with a simultaneous increase in inflationary fears and the desire of investors and other money users to escape negative interest rates (Poskart, 2022). It seems that in the current difficult situation in which the world economy found itself: in the era of the global COVID-19 pandemic and lockdowns of the world's largest economies, the search for answers to questions about the future of the global financial system has become even more urgent than before.

Admission of cryptocurrency into the Nigerian financial sector is gaining wide popularity but with fears and doubt about its functionality since no regulatory framework from the apex bank exists. But there is a broad call for Central Bank of Nigeria to begin a proper regulatory action. Nevertheless, it is appropriate to note that the Central Bank of Nigeria financial policy restrictions on foreign exchange have steered Nigerians to modernize bitcoin to access foreign exchange. Hence, the possibility to promote domestic innovation (Nwosu and Emilia, 2022).

Methodology

Daily Bitcoin price data was sourced from CoinMarketCap, covering all the years since Bitcoin inception. Data was pre-processed for analysis in Python, cleaned, and transformed as needed.

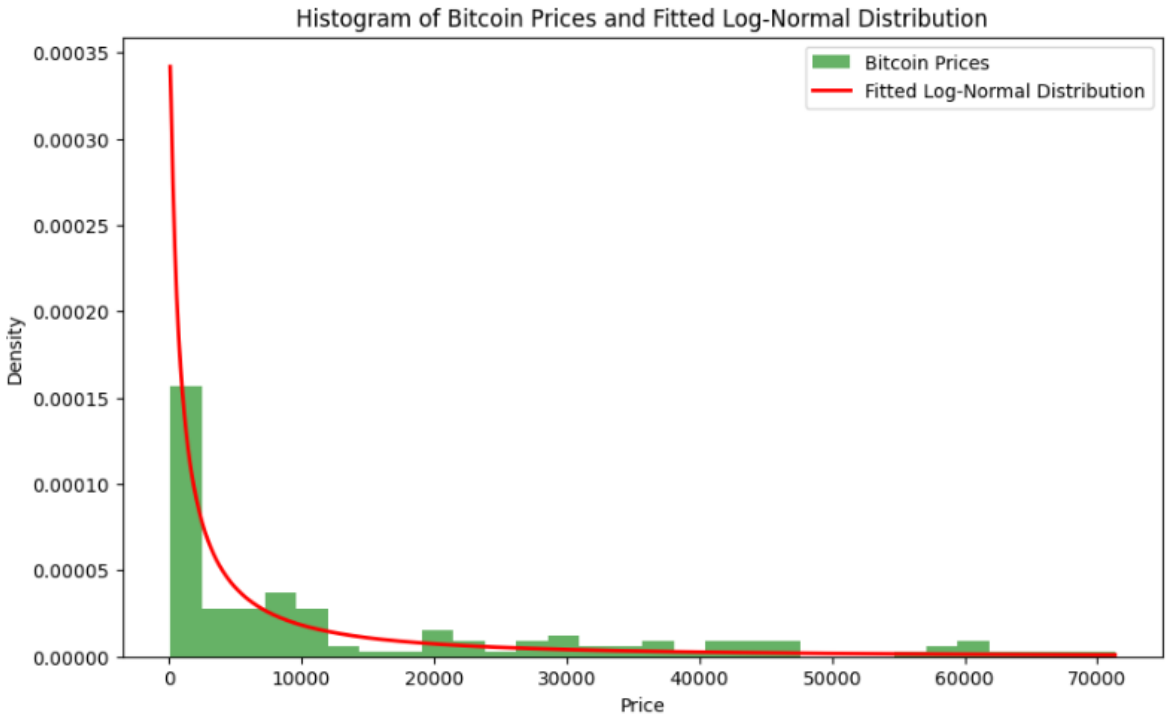
The post-processing/data transformation and analytical framework involved; model implementation, forecasting future prices, and interpretation.

Result and discussion

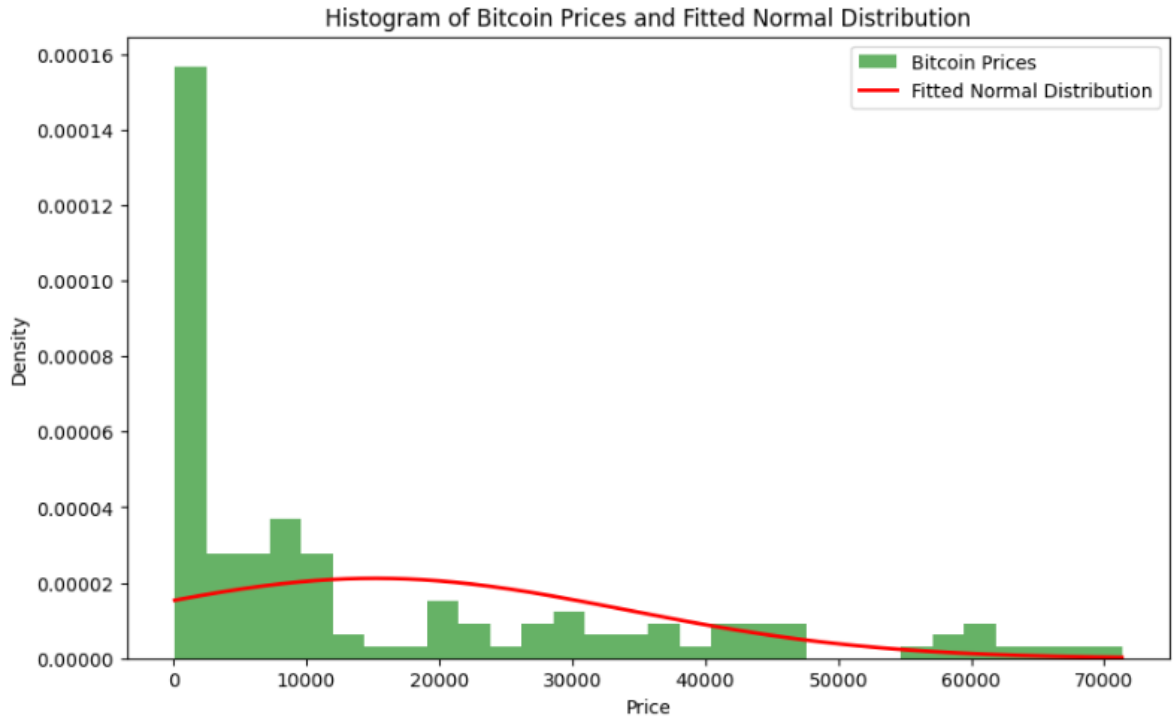
Model implementation: Log-normal distribution

Fitted log-normal mean (mu): 8.33366795751556

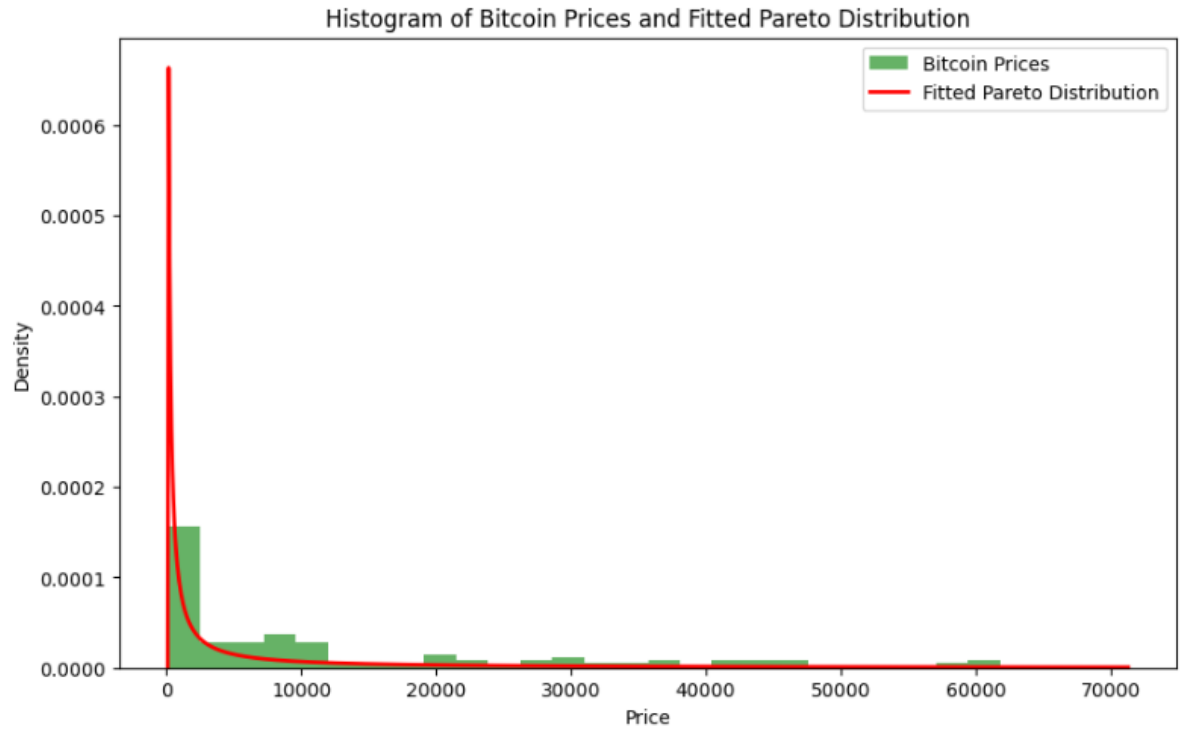
Fitted log-normal standard deviation (sigma): 1.9784252485483427



Model implementation: Normal distribution
Fitted mean (mu): 15179.43091282219
Fitted standard deviation (sigma): 18841.603651945064



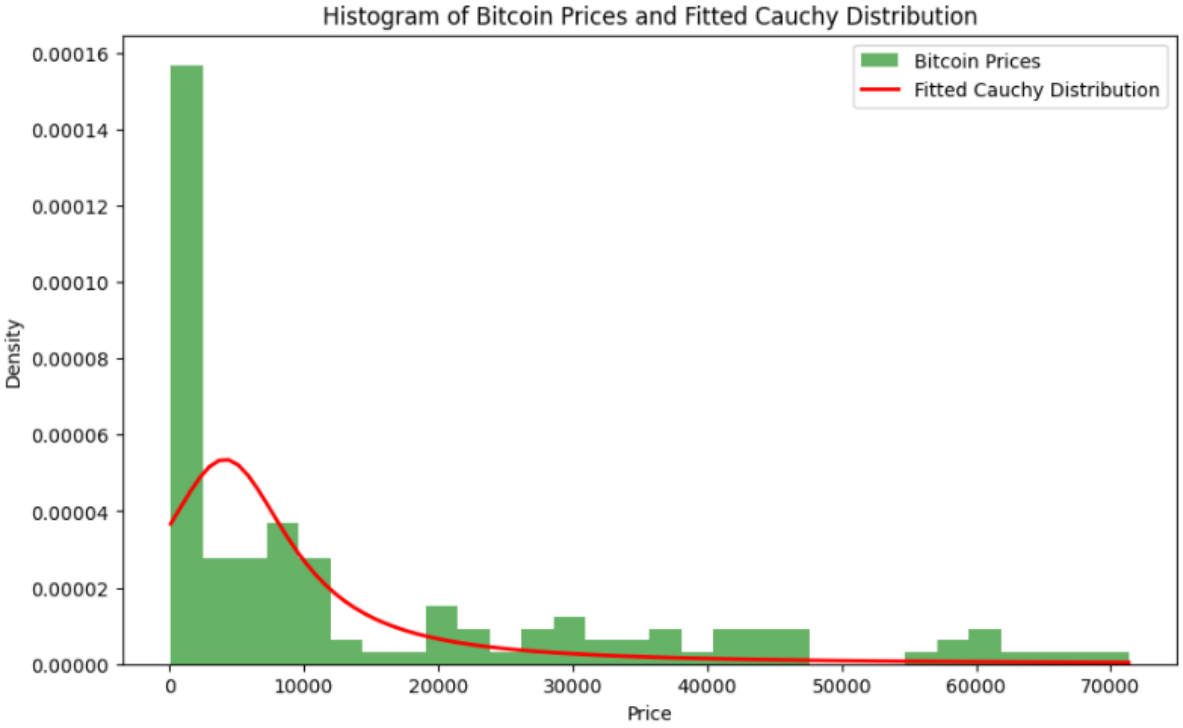
Model implementation: Pareto distribution
Fitted shape parameter (alpha): 0.11959874375290425
Fitted minimum value (x_min): 97.51382536276236



Model implementation: Cauchy distribution

Fitted location parameter (x0): 4128.097239460039

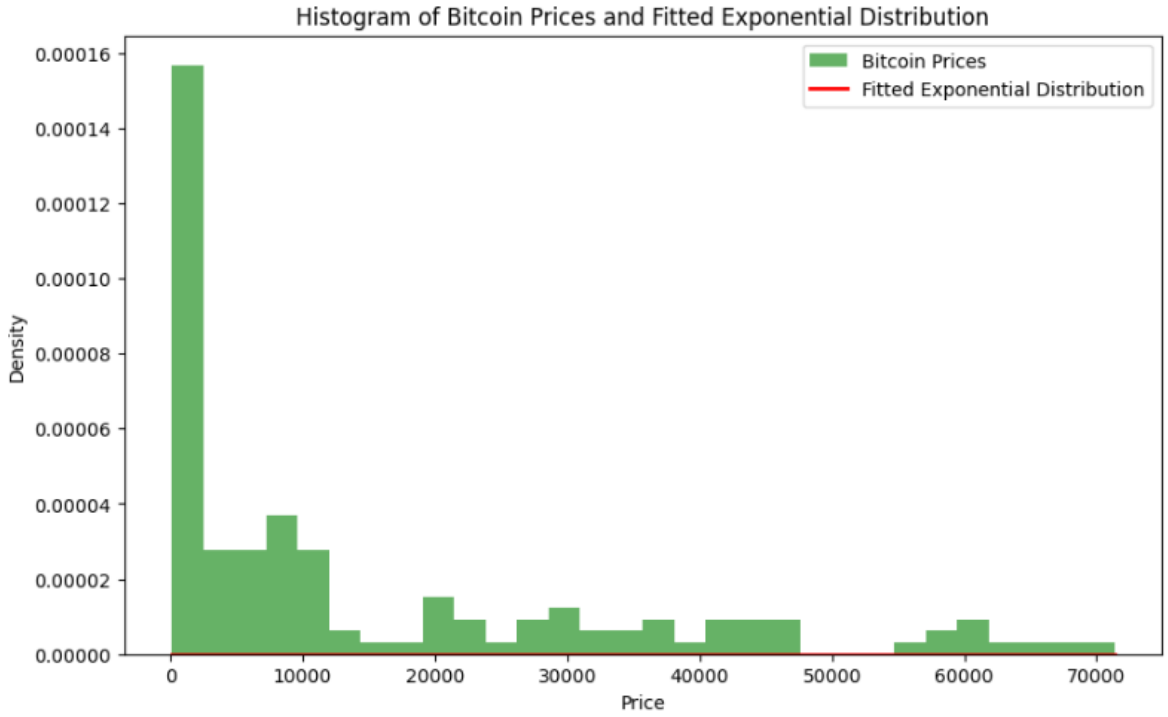
Fitted scale parameter (gamma): 5943.446573467602



Model implementation: Exponential distribution

Fitted rate parameter (λ): 0.0

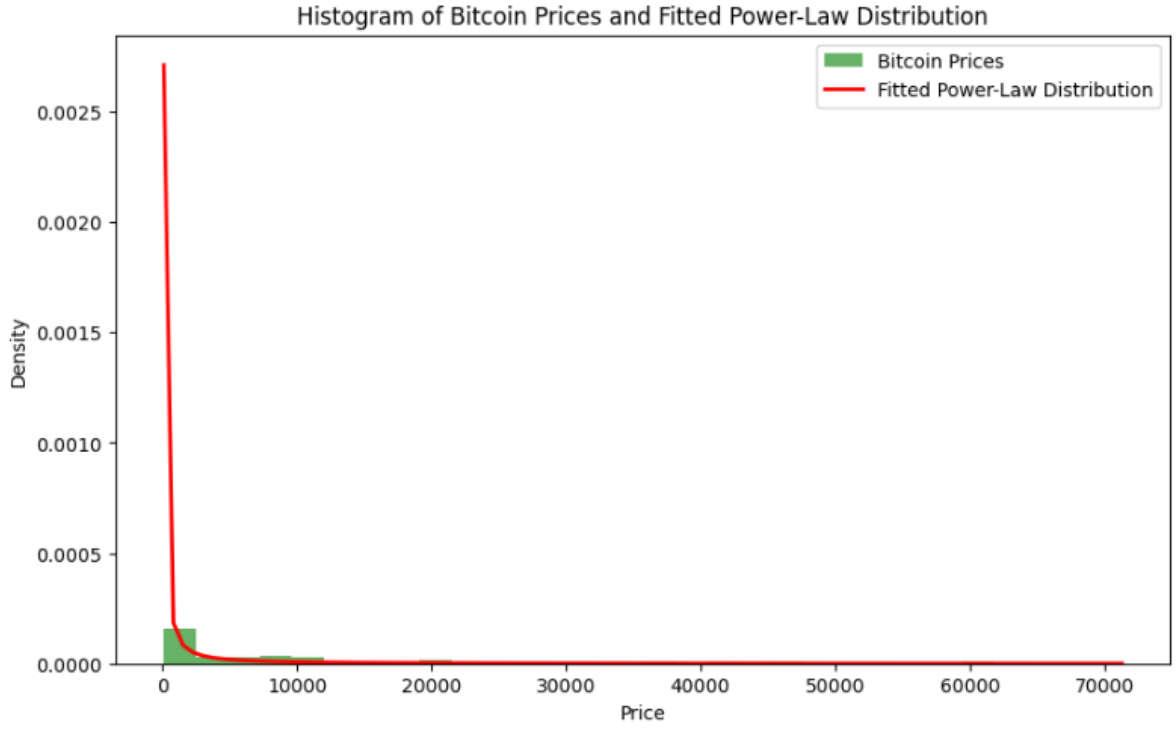
Fitted scale parameter (1/λ): inf



Model implementation: Power law distribution

Fitted exponent parameter (α): 1.2644618501883111

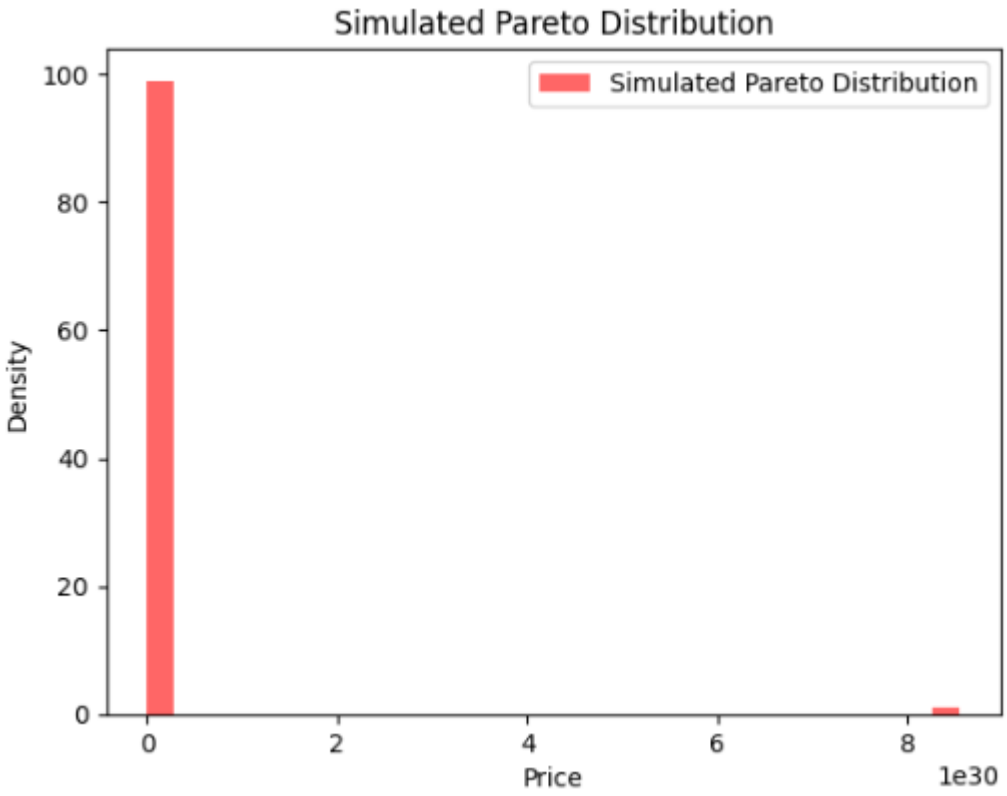
Fitted minimum value (x_min): 97.51622916458467



Power law distribution using the Pareto-alternative ('scipy' for Power-Law Fit)

Fitted shape parameter (alpha): 0.11959874375290425

Fitted minimum value (x_min): 97.51382536276236



Model implementation: Volatility clustering using GARCH model

Constant Mean - GARCH Model Results

Dep. Variable:	y	R-squared:	0.000
Mean Model:	Constant Mean	Adj. R-squared:	0.000
Vol Model:	GARCH	Log-Likelihood:	5.74803
Distribution:	Normal	AIC:	-3.49605
Method:	Maximum Likelihood	BIC:	8.15457
		No. Observations:	136
Date:	Mon, Aug 26 2024	Df Residuals:	135
Time:	07:45:07	Df Model:	1

Mean Model

	coef	std err	t	P>|t|	95.0% Conf. Int.
mu	0.0441	2.013e-02	2.191	2.844e-02	[4.654e-03,8.356e-02]

Volatility Model

	coef	std err	t	P>|t|	95.0% Conf. Int.
omega	1.9680e-03	1.365e-03	1.442	0.149	[-7.071e-04,4.643e-03]
alpha[1]	1.8328e-09	4.341e-02	4.222e-08	1.000	[-8.508e-02,8.508e-02]
beta[1]	0.9492	3.813e-02	24.896	8.301e-137	[0.874, 1.024]

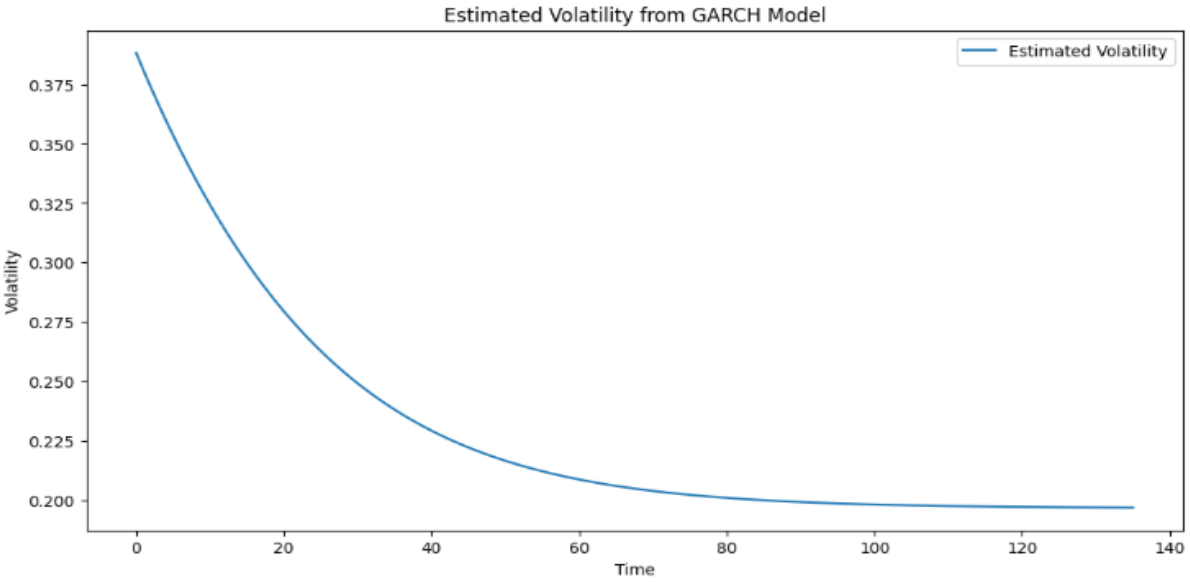


Table 1: Model performance and Bitcoin price forecast accuracy summary result

Timestamp	PLM	Pareto	Normal	LogNormal	Exponential	Cauchy	Volatility (GARCH)	Actual BTC Price
01/01/2024 00:00	5.37E+07	5.45E+02	5299.504	1.51E-01	0.00E+00	-1.57E+03	12061.24	42280.24
01/02/2024 00:00	7.21E+03	1.11E+06	44965.06	3.48E+00	0.00E+00	3.75E+03	11308.18	42569.76
01/03/2024 00:00	2.91E+04	7.75E+08	33816.8	2.77E+01	0.00E+00	1.62E+04	10468.55	61168.06
01/04/2024 00:00	1.20E+02	2.82E+14	-296.368	1.30E+01	0.00E+00	8.58E+04	7849.239	71333.48
01/05/2024 00:00	1.05E+03	1.69E+02	-5591.63	3.75E+01	0.00E+00	-1.71E+02	8320.154	60609.5
01/06/2024 00:00	7.31E+02	1.25E+07	-14135.4	2.84E+00	0.00E+00	3.71E+05	8758.683	67489.61
01/07/2024 00:00	9.83E+01	1.54E+03	10709.83	3.74E+02	0.00E+00	4.93E+04	8767.5	62673.61
01/08/2024 00:00	3.51E+12	6.66E+07	-9546.29	9.82E+00	0.00E+00	-2.19E+03	8372.016	64612.31

Model performance and Bitcoin price forecast accuracy

Forecasting Bitcoin prices presents a significant challenge due to the cryptocurrency's extreme volatility and potential for large price swings. The Power Law Distribution is known for its heavy tails, meaning it can produce very large values with low probability. This characteristic is evident in the forecast results, where some values are extraordinarily high (e.g., 5.31426409×10^{13} and 1.78711448×10^{13}). Such extreme values are consistent with the nature of financial markets. As documented by Mandelbrot and Taleb (2004), financial markets often exhibit such heavy-tailed behavior, which the Power Law Distribution can effectively capture. While this may not have efficiently captured Bitcoin prices post-forecast-90 days, Power Law Distributions-forecast were well-suited on average especially predicting extreme value occurrences (wide range of heavy tails) obvious in $42, 855.81 price on 4th January, 2024, $68, 500.26 on 10th March, 2024 and $60, 609.5 on 1st May, 2024.

On the other hand, the model's ability to generate high values is useful for assessing tail risk, which is crucial for risk management in volatile markets. The extreme values predicted can inform stress-testing and scenario analysis, helping stakeholders prepare for rare but impactful events. However, the very high forecast values may not always be realistic, thus essential to supplement the Power Law model with additional analyses or models to provide a more comprehensive risk assessment.

According to the literature, while Power law models are; effective for capturing extreme events; useful for understanding the potential for extreme outcomes, it should be interpreted with

caution (Gabaix, 2009) since PLM predictions can sometimes include values that are implausible in practical scenarios. Also, PLM, in the context of financial risk management, understanding the potential for extreme losses or gains is crucial. This capability aligns with findings by Artzner et al. (1999), who argue that tail risk is a critical component of financial risk and should be managed effectively. Thus, the extreme values provided by the model are useful for stress-testing and scenario analysis, helping stakeholders prepare for rare but impactful events.

In comparison, the Power Law Distribution highlighted significantly the volatility inherent in Bitcoin prices that the other models, such as Log-Normal distribution, Normal distribution, Cauchy distribution and, Exponential models did not capture. Besides, PLM, Volatility-GARCH and Pareto distribution model estimates were not just more effective for extreme variations but also in price movements. This is in tandem to the study by Engle (2001); emphasizing the importance of accounting for volatility clustering in financial time series and, supporting the aptitude of PLM models to capture extreme variations.

Overall, the broad forecast range of PLM forecast that was consistent in movements underscores its importance especially in investment strategies. Given this background, incorporating PLM framework by investors can enhance the knowledge of risk management and investment strategies. Further, educational institutions become aware of the potential for large fluctuations and adjust their strategies accordingly. Also, financial literacy, using this framework can train students and professionals in quantitative finance and risk assessment. This is consistent with the principles of robust portfolio management discussed by Markowitz (1952), which emphasizes the need to account for risk in decision-making. According to research by Kwon and Lee (2022), improving financial literacy through advanced models can lead to better investment decisions and risk mitigation.

This is essential to; increased returns on investment and wealth accumulation for individuals and institutional investors particularly regions like Africa, where there is growing interest in cryptocurrencies; yet, drive better investment outcomes and contribute to economic growth. This aligns with findings by Mukhongo and Nduko (2021), who note that informed investment strategies can significantly contribute to economic development amidst broader economic impact that includes increased capital flows, enhanced liquidity, more individuals and institutions engaged in cryptocurrency trading and investment and overall economic growth.

Besides, spur innovation in the fintech sector since entrepreneurs and startups in Africa and Nigeria can leverage the PLM to develop new financial products and services, such as crypto trading platforms, risk management tools, and investment advisories. This will lead to job creation in various fields, including software development, data analysis, financial consulting, and risk management. According to the World Economic Forum (2023), the fintech sector has been a significant driver of job creation in emerging markets.

Whilst never exhaustive performance of comprehensive Power Law Distribution models leads to; improved Forecasting of Bitcoin Prices; Improved forecasting and risk management models – potent to – make cryptocurrency investments more accessible and less risky. Thereby, promoting financial inclusion in underserved areas by providing more people with opportunities to participate in the digital economy. Consequently, aid efficient policymaking, implementation and education via incorporation plausible extreme movements in; price, adoption, enhancement developments of policies programs. As highlighted by Merton (1995), understanding the dynamics of

financial markets is essential for designing effective risk management and educational programs.

In contrast, while the Power Law model captures extreme values well, it should be assessed alongside other methods to ensure comprehensive risk evaluation. Studies by Bollerslev (1986) and Box and Jenkins (1976) demonstrate the effectiveness of GARCH and ARIMA models in different forecasting contexts, highlighting the need for a multi-faceted approach to financial forecasting. Besides, the accuracy of the Power Law model is dependent on the quality of historical Bitcoin price data. Issues such as data anomalies or incomplete datasets affect model performance. This aligns with the findings of Harvey and Liu (2017), who discuss the importance of data quality in financial modelling.

Also, accurate parameter estimation is crucial for the reliability of the Power Law model. Small errors can lead to significant deviations in forecasts. This concern is supported by the work of Simaan and Lesne (1992), who emphasize the importance of precise parameter estimation in statistical models. Further, financial markets are dynamic, and models based on historical data may not fully capture new market trends. The work of Fama and French (1996) highlights the need for models to adapt to changing market conditions.

Conclusion

Accurate forecasting of Bitcoin prices is crucial for investors and policymakers, especially in emerging economies such as those in Africa and Nigeria. This paper presents a detailed framework for forecasting Bitcoin prices leveraging various statistical distributions and volatility models. We also explore how this framework can contribute to risk education, job creation, and wealth development in Africa.

Recommendation and implications for development

The framework developed in this paper offers a comprehensive approach to forecasting Bitcoin prices. To ensure robust demonstration, understanding and application for wealth creation and development, government and private individuals should strengthen enhanced financial literacy/risk education, helping individuals and institutions manage risks better. This proficiency is particularly important in the Africa emerging market and valuable in; better investment decisions, job opportunities in financial analysis, data science, and risk management whilst contributing to economic stability and wealth creation.

References

Adam, A. M., Frimpong, S., & Boadu, M. O. (2017). Financial literacy and financial planning: Implication for financial well-being of retirees. *Business & Economic Horizons*, 13(*2*), 224-236.

Afgani, K. F., Pringgabayu, D., Waruwu, F., & Clement, M. (2021). The Effect of financial literacy on generation Z's stock market participation in Bandung city. *International Journal of Business Marketing and Management*, 6(*8*), 44-50.

Akinwande, A. A., Ojo, J. A., & Ojo, J. A. (2019). Financial Forecasting and Economic Development: Evidence from Nigeria. *Nigerian Journal of Economic and Social Studies*, 16(*2*), 123-137.

Alaaraj, H., & Bakri, A. (2020). The effect of financial literacy on investment decision making in Southern Lebanon. *International Business and Accounting Research Journal*, 4(*1*), 37-43.

Artzner, P., Delbaen, F., Eber, J.-M., & Heath, D. (1999). Coherent Measures

of Risk. *Mathematical Finance*, 9(*3*), 203-228.

Asmara, I. P. W. P., & Wiagustini, L. P. (2021). The Role of financial literacy in mediation of sociodemographic effects on investment decisions. *International Journal of Business Management and Economic Review*, 4(*04*), 133-152.

Baidoo, S. T., Boateng, E., & Amponsah, M. (2018). Understanding the determinants of saving in Ghana: Does financial literacy matter? *Journal of International Development*, 30(*5*), 886-903.

Bech, M. R. G. (2017). *Central Bank Cryptocurrencies*. Basel: Bank for International settlements.

BIS (2019). *Cryptocurrencies: looking beyond the hype. BIS Annual Economic Report 2018*. Basel: Bank for International Settlements.

Bitros, G.C., Economou, E.M.L., Kyriazis, N.C. (2020). *Democracy and Money: Lessons for Today from Athens in Classical Times*. London and New York: Routledge

Black, F., & Scholes, M. (1973). The Pricing of Options and Corporate Liabilities. *Journal of Political Economy*, 81(3), 637-654.

Bollerslev, T. (1986). Generalized Autoregressive Conditional Heteroskedasticity. *Journal of Econometrics*, 31(*3*), 307-327.

Bonga-Bonga, L. (2018d). Financial Literacy and Economic Development in Africa. *African Journal of Economic Review*, 6(*1*), 65-80.

Bonga-Bonga, L. (2018a). *Assessing the extent of contagion of sovereign credit risk among BRICS countries*. Germany: University Library of Munich MPRA.

Bonga-Bonga, L. (2018b). *Return and volatility spillovers between South African and Nigerian equity markets*. Germany: University Library of Munich MPRA/Emerald Group Publishing Limited

Bonga-Bonga, L. (2018c). *The impact of Chinese textile imports on employment and value added in the manufacturing sector of the South African economy*. Germany: University Library of Munich MPRA

Bonga-Bonga, L. (2020). Assessing the extent of contagion of sovereign credit risk among BRICS countries. *Economics Bulletin*, 2(*1*), 1-20

Bonga-Bonga, L. (2022). Return and volatility spillovers between South African and Nigerian equity markets. *African Journal of Economic and Management Studies*, 1(*2*) 1-22

Bouchaud, J. P., & Mézard, M. (2000). Wealth Condensation in a Simple Model of Economy. *Physical Review Letters*, 87(*2*), e228701.

Bouchaud, J., and Mézard, M. (2000). Wealth condensation in a simple model of economy. In: K. A. Dawson, J. O. Indekeu, H.E. Stanley and C. Tsallis (eds.), *Physica A: Statistical Mechanics and its Applications*. UK: Elsevier

Box, G. E. P., & Jenkins, G. M. (1976). *Time Series Analysis: Forecasting and Control*. US: Holden-Day.

Britto, J., and Castillo, A. (2013). Bitcoin: A Primer for Policymakers. Arlington, VA: Mercatus Center George Mason University

Carstens, A. (2018). *Money and payment systems in the digital age*. Miami: Bank for International Settlements, Finance and Global Economics Forum of the Americas, University of Miami Business School

Cauchy, A.L. (1853). Mémoire sur les courbes définies par une équation

différentielle. *Comptes Rendus de l'Académie des Sciences*, 37, 17-45.

Choi, H. (2021). Enhancing Financial Literacy Through Advanced Forecasting Models. *Journal of Financial Education*, 34(*2*), 45-62.

Clauset, A., Shalizi, C.R., & Newman, M.E.J. (2009). Power-law distributions in empirical data. *SIAM Review*, 51(4), 661-703.

Coinmarketcap (2021). *Cryptocurrencies*. Accessed from: https://coinmarketcap.com

Combs, B., and Mitsoff, T. (2014). *Bitcoin decoded*. San Bernandino, CA: Propellerhead Marketing Group

D'Urbino, L. (2021, May 8). *The digital currencies that matter*. US: The Economist.

Dembiński, P. H. (2008). *Finance servante ou finance trompeuse?* Paris: Desclée de Brouwer.

Dimon, J. (2020). *Annual Report*. New York: JP Morgan Chase.

Doumenis, Y., Izadi, J., Dhamdhere, P., Katsikas, E., Koufopoulos, D. (2021). A Critical Analysis of Volatility Surprise in Bitcoin Cryptocurrency and Other Financial Assets. *Risks*, 9(*11*), e207. https://doi.org/10.3390/risks9110207

Engle, E. (1982a). *An Introduction to the Use of ARCH/GARCH models in Applied*. New York: NYU Stern School of Business

Engle, R. F. (1982b). Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of U.K. Inflation. *Econometrica*, 50(*4*), 987-1007.

Engle, R. F. (2001). GARCH 101: The Use of ARCH/GARCH Models in Applied Econometrics. *Journal of Economic Perspectives*, 15(*4*), 157-168.

Eyal, I., and Sirer, E. G. (2014). Majority Is Not Enough: Bitcoin Mining Is Vulnerable. In: N. Christin, R. Safavi-Naini (eds.), Financial Cryptography and Data Security. Berlin, Heidelberg: Springer. https://doi.org/10.1007/978-3-662-45472- 5_28.

Fama, E. F., & French, K. R. (1996). Multifactor Explanations of Asset Pricing Anomalies. *Journal of Finance*, 51(*1*), 55-84.

Feller, W. (1971). *An Introduction to Probability Theory and Its Applications*. UK: Wiley.

Gabaix, X. (2009). Power Laws in Economics and Finance. *Annual Review of Economics*, 1(*1*), 255-293.

Galbrait, J. K. (1994). *A Short History of Financial Euphoria*. US: Pengiun Books.

Geuder, J., Kinateder, H., Wagner, N. F. (2018). Cryptocurrencies as financial bubbles: The case of Bitcoin. *Finance Research Letters*, 1(1), e011. https://doi.org/10.1016/j.frl.2018.11.011

Gilder, G. (2015). *The 21st Century Case for Gold: A New Information Theory of Money*. US: American Principles Project.

Griffin, C. E. (2002). *The Creature from Jekyll Island: A Second Look at the Federal Reserve*. US: American Media.

Harvey, C. R., & Liu, Y. (2017). Lucky Factors and the Cross-Section of Stock Returns. *Journal of Financial Economics*, 124(3), 593-610.

Kayani, U., Hasan, F. (2024). Unveiling Cryptocurrency Impact on Financial Markets and Traditional Banking Systems: Lessons for Sustainable Blockchain and Interdisciplinary Collaborations. *Journal of Risk and Financial Management*, 17(*2*), e58.

https://doi.org/10.3390/jrfm17020058

Kwon, S., & Lee, M. (2022). Financial Risk Management and Forecasting Techniques in Emerging Markets. *International Journal of Finance & Economics*, 29(*3*), 103-120.

Kyriazis, N. A. (2019). A Survey on Efficiency and Profitable Trading Opportunities in Cryptocurrency Markets. *Journal of Risk and Financial Management*, 12(2), https://doi.org/10.3390/jrfm12020067.

Laboure, M. (2020). Cryptocurrencies: the 21st century cash. In: Imagine 2030, *The Decade ahead*. Germany: Deutsche Bank Research.

Lagarde, C. (2018). *Winds of Change: The Case for New Digital Currency*. Singapore: IMF Singapore Fintech Festival.

Lien, K. (2022, May 29). The Major Central Banks. Accessed from: https://www.investopedia.com

Mandelbrot, B. B., & Taleb, N. N. (2004). *The (Mis)Behavior of Markets: A Fractal View of Financial Turbulence*. US: Basic Books.

Markowitz, H. (1952). Portfolio Selection. *Journal of Finance*, 7(*1*), 77-91.

Merton, R. C. (1995). Financial Innovation and Risk Management. *Journal of Finance*, 50(*4*), 121-127.

Merton, R.C. (1976). Option Pricing When Underlying Stock Returns Are Discontinuous. *Journal of Financial Economics*, 3(1), 125-144.

Mishkin, F. S. (2006. The Economics of Money, Banking and Financial Markets. US: Pearson Education Limited.

Mukhongo, N., & Nduko, A. (2021). The Role of Cryptocurrencies in Economic Development: Case Studies from Africa. *African Journal of Economic Review*, 11(*4*), 78-95.

Nakamoto, S. (2008). *Bitcoin: A Peer-to-Peer Electronic Cash System*. Accessed from: https://bitcoin.org/

Nakamoto, S. (2008). *Bitcoin: A Peer-to-Peer Electronic Cash System*. Accessed from: www.bitcoin.org

Nwosu, E. C., and Emilia, G I. (2022). Crypto Currency Trading and The Impact on Global Digital Finance. *West African Journal of Industrial and Academic Research*, 23(*2*), 101-9

Ober, M., Katzenbeisser, S., and Hamacher, K. (2013). Structure and Anonymity of the Bitcoin Transaction Graph. *Future Internet*, 5, 237-250

Pareto, V. (1896). *Cours d'économie politique*. Paris: F. Rouge.

Pattison, M. L. (2011). Buying into Bitcoin: An Austrian analysis of the virtual currency's sustainability. *Pobrane*, 9(1), e2017

Poskart, R. (2020). Challenges faced by the banking sector in the context of the development of blockchain technology. In: D. Hummel (ed.), *EU's Connectivity in Times of Eurasian Dynamics*. Potsdam: Welt Trends.

Poskart, R. (2022). The emergence and development of the cryptocurrency as a sign of global financial markets financialisation. *Central European Review of Economics & Finance*, 36(1), 53-66

Poskart, R. D. (2015). Czynniki kształtujące popyt na pieniądz wirtualny na przykładzie bitcoina. *Zeszyty Naukowe Uniwersytetu Ekonomicznego w Krakowie*, 2(938), 59–69.

Roubini, N., and Mihm, S. (2010). *Crisis Economics: A Crash Course in the Future of Finance*. UK: The Penguin Press

Schiff, P. D. (2012). *The Real Crash. America's Coming Bankruptcy. How to save Yourself and Your Country*. US: St. Martin's Press.

Simaan, M., & Lesne, A. (1992). Parameter Estimation in Power Law Distributions. *Statistics & Probability Letters*, 13(*1*), 17-23.

Skawińska, E., Sobiech-Grabka, K. G., Nawrot, K. A. (2010). *Makroekonomia. Teoretyczne i praktyczne aspekty gospodarki rynkowej*. Warszawa: PWE.

Stanisławski, M. (2013). *Rozwój i zmiana struktury światowych rynków finansowych. Studia Ekonomiczne*. Katowice: Zeszyty Naukowe Uniwersytetu Ekonomicznego.

Stiglitz, J. E. (2003). *Globalization and Its Discontents*. UK: W.W. Norton & Company.

Stosic, D., Stosic, D., Ludermir, T. B., Stosic, T. (2018). Collective behavior of cryptocurrency price changes. *Physica A. J.*, 507(*1*). https://doi.org/10.1016/j.physa.2018.05.050

World Economic Forum (2023). *The Impact of Fintech on Job Creation in Emerging Markets*. Accessed from: www.wef.com